GEOS-Chem Reference, Vol. 3: "Core" Modules and Routines

GEOS-Chem Support Team

24 July 2012

Contents

1 Routine/Function Prologues

1.1 Fortran: Module Interface GEOS-Chem include files

Here follows a list of include files used by the GEOS-Chem modules and subroutines.

1.1.1 Include File define.h

Include file "define.h" specifies C-preprocessor "switches" that are used to include or exclude certain sections of code.

REMARKS:

```
List of "Switches"
=========================================================================
GCAP        : Enables code for GCAP   met fields & chemistry
GEOS_4      : Enables code for GEOS-4 met fields & chemistry
GEOS_5      : Enables code for GEOS-5 met fields & chemistry
MERRA       : Enables code for MERRA  met fields & chemistry
GRIDREDUCED : Enables code for reduced stratosphere grids
GRID1x1     : Enables code for 1 x 1    GLOBAL        GRID
NESTED_CH   : Enables code for CHINA  NESTED GRID
NESTED_NA   : Enables code for N. AM. NESTED GRID
NESTED_EUR  : Enables code for EUROPE NESTED GRID
GRID1x125   : Enables code for 1 x 1.25 GLOBAL        GRID
GRID2x25    : Enables code for 2 x 2.5  GLOBAL        GRID
GRID4x5     : Enables code for 4 x 5    GLOBAL        GRID
IBM_AIX     : Enables code for IBM/AIX compiler
IBM_XLF     : Enables code for IBM/XLF compiler
LINUX_PGI   : Enables code for Linux w/ PGI compiler
LINUX_IFORT : Enables code for Linux v8 or v9 "IFORT" compiler
SPARC       : Enables code for Sun w/ SPARC or Sun Studio compiler
GTMM_Hg     : Enables code for Hg simulation with GTMM
                                                                        .
NOTES:
(1 ) "define.h" is #include'd at the top of CMN_SIZE.  All subroutines
      that normally reference CMN_SIZE will also reference "define.h".
(2 ) Only define the "switches" that are *absolutely* needed for a
      given implementation, as the criteria for code inclusion/exclusion
      is the #if defined() statement.  Undefined "switches" are "off".
(3 ) To turn off a switch, comment that line of code out.
```

REVISION HISTORY:

```
30 Nov 1999 - R. Yantosca - DO_MASSFLUX is obsolete, since the mass flux
                            arrays are now declared allocatable in
                           "diag_mod.f".
12 Apr 2000 - R. Yantosca - Eliminate DO_MASSB switch -- ND63 diagnostic
                            is now obsolete.
```

```
07 Jul 2000 - R. Yantosca - Add GEOS_3 and GRID1x1 switches for future use
03 Oct 2000 - R. Yantosca - Make sure that one of FULLCHEM, SMALLCHEM, or
                            LGEOSCO is turned on.  Also cosmetic changes.
03 Sep 2001 - R. Yantosca - Added new switches "DEC_COMPAQ" and "SGI"
16 Jul 2001 - R. Yantosca - Added new "LINUX" switch\
21 Nov 2001 - R. Yantosca - Added new "GEOS_4" switch for GEOS-4/fvDAS
                            met fields
20 Mar 2002 - R. Yantosca - Now enclose switch names in ' ', since the
                            PGI compiler chokes on barewords
25 Jun 2002 - R. Yantosca - Changed RCS ID tag comment character from "C"
                            to "!" to allow freeform compilation
23 Mar 2003 - R. Yantosca - Removed GEOS_2 switch; added GEOS_4 switch.
                            Also added SPARC switch to invoke Sun/Sparc
                            specific code.
27 Mar 2003 - R. Yantosca - Added IBM_AIX switch
21 Oct 2003 - R. Yantosca - Added INTEL_FC switch
31 Oct 2003 - R. Yantosca - GRID30LEV switch for 30L GEOS-3 or GEOS-4 grid
02 Dec 2003 - R. Yantosca - Renamed cpp switch "LINUX" to "LINUX_PGI".
                            Renamed cpp switch "INTEL_FC" to "LINUX_IFC".
                            Renamed cpp switch "SGI" to "SGI_MIPS".
                            Added cpp switch "LINUX_EFC".
                            Removed cpp switch SMALLCHEM.
22 Mar 2004 - R. Yantosca - Added "A_LLK_03" switch to denote GEOS-4
                            "a_llk_03" met fields.  This will be temporary
                            since "a_llk_03" met fields will be replaced by
                            a newer product.
01 Dec 2004 - R. Yantosca - Added NESTED_NA and NESTED_CH cpp switches.
                            Also add GRID1x125 cpp switch.
23 Jun 2005 - R. Yantosca - Removed obsolete A_LLK_03, LFASTJ, LSLOWJ,
                            FULLCHEM, LGEOSCO switches.  Also added extra
                            switches for GCAP and GEOS_5 met fields.
18 Oct 2005 - R. Yantosca - Added LINUX_IFORT switch to delineate Intel
                            compilers v8 or v9 from v7.
04 Aug 2006 - R. Yantosca - Removed obsolete GEOS_1, GEOS_STRAT, LINUX_IFC,
                            LINUX_EFC switches.
07 Feb 2007 - R. Yantosca - Renamed GRID30LEV to GRIDREDUCED
06 Nov 2008 - R. Yantosca - Added IN_CLOUD_OD flag for reprocessed GEOS-5
                            met.  Added GRID05x0666 flag for GEOS-5 nested
                            grids (cf. yxw, dan, bmy, hyl)
08 Jul 2009 - R. Yantosca - Deleted support for old COMPAQ and SGI_MIPS
                            compilers.  Added switch for IBM XLF compiler.
15 Oct 2009 - R. Yantosca - Remove IN_CLOUD_OD.  Added ProTex headers.
18 Dec 2009 - Aaron van D - Added NESTED_EU C-preprocessor switch
20 Jul 2010 - C. Carouge  - Added GTMM_Hg for mercury simulation.
12 Aug 2010 - R. Yantosca - Added MERRA switch for MERRA reanalysis met
01 Feb 2012 - R. Yantosca - Modify error trap to allow GEOS-5.7.x met
10 Feb 2012 - R. Yantosca - Added GRID025x03125 C-preprocessor switch
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

```
   23 Apr 2012 - R. Yantosca - Cosmetic changes
   29 May 2012 - S. Kim      - Added SEAC4RS C-preprocessor switch
   10 Jun 2012 - L. Murray   - GRIDREDUCED no longer required for GEOS5.
```

1.2 Fortran: Module Interface CMN_SIZE

CMN_SIZE contains size parameters for GEOS-Chem arrays.

INTERFACE:

```
      MODULE CMN_SIZE_MOD
```

USES:

```
      IMPLICIT NONE
      PUBLIC

#     include "define.h"
```

DEFINED PARAMETERS:

```
      !=================================================================
      ! DISIZE = size (in degrees) of a longitude grid box
      ! DJSIZE = size (in degrees) of a latitude  grid box
      !=================================================================
#if   defined( GRID4x5 )
      REAL*8, PARAMETER :: DISIZE = 5.0d0
      REAL*8, PARAMETER :: DJSIZE = 4.0d0
#elif defined( GRID2x25 )
      REAL*8, PARAMETER :: DISIZE = 2.5d0
      REAL*8, PARAMETER :: DJSIZE = 2.0d0
#elif defined( GRID1x125 )
      REAL*8, PARAMETER :: DISIZE = 1.25d0
      REAL*8, PARAMETER :: DJSIZE = 1.0d0
#elif defined( GRID1x1 )
      REAL*8, PARAMETER :: DISIZE = 1.0d0
      REAL*8, PARAMETER :: DJSIZE = 1.0d0
#elif defined( GRID05x0666 )
      REAL*8, PARAMETER :: DISIZE = 2d0/3d0
      REAL*8, PARAMETER :: DJSIZE = 0.5d0
#elif defined( GRID025x03125)
      REAL*8, PARAMETER :: DISIZE = 0.3125d0
      REAL*8, PARAMETER :: DJSIZE = 0.25d0
#elif defined( EXTERNAL_GRID )
      REAL*8            :: DISIZE
      REAL*8            :: DJSIZE
#endif
```

```
      !=================================================================
      ! GRID PARAMETERS
      ! IGLOB      = global longitude dimension
      ! JGLOB      = global latitude dimension
      ! LGLOB      = max number of sigma levels
      ! IIPAR      = window longitude dimension
      ! JJPAR      = window latitude dimension
      ! LLPAR      = window vertical dimension
      ! LLTROP     = maximum number of tropospheric levels for variable
      !              tropopause
      ! LLTROP_FIX = number of tropospheric levels for offline simulations
      ! PTOP       = model top pressure (mb)
      ! Most of the time, GEOS-CHEM is used for global simulations.
      ! In this case, then IIPAR=IGLOB, JJPAR=JGLOB, LLPAR=LGLOB.
      ! For nested grids, then IIPAR<IGLOB, JJPAR<JGLOB, LLPAR<LGLOB.
      !=================================================================
#if   defined( GCAP ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GCAP: 4 x 5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 72
      INTEGER            :: JGLOB      = 45
      INTEGER            :: LGLOB      = 23
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
      INTEGER            :: LLPAR
      INTEGER, PARAMETER :: LLTROP     = 12
      INTEGER, PARAMETER :: LLTROP_FIX = LLTROP
      REAL*8,  PARAMETER :: PTOP       = 0.002d0

#elif defined( GEOS_4 ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GEOS-4: 4 x 5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 72
      INTEGER            :: JGLOB      = 46
      INTEGER            :: LGLOB      = 55
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 30        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP     = 22        !  -- 30 levels
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP     = 23        !  -- 55 levels
#endif
```

```
      INTEGER, PARAMETER :: LLTROP_FIX = 17
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_4 ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! GEOS-4: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 144
      INTEGER            :: JGLOB      = 91
      INTEGER            :: LGLOB      = 55
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 30        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP     = 22        !  -- 30 levels
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP     = 23        !  -- 55 levels
#endif
      INTEGER, PARAMETER :: LLTROP_FIX = 17
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_4 ) && defined( GRID1x125 )

      !-----------------------------------------------------------------
      ! GEOS-4: 1 x 1.2.5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 288
      INTEGER            :: JGLOB      = 181
      INTEGER            :: LGLOB      = 55
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 30        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP     = 22        !  -- 30 levels
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP     = 23        !  -- 55 levels
#endif
      INTEGER, PARAMETER :: LLTROP_FIX = 17
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_5 ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GEOS-5: 4 x 5
      !-----------------------------------------------------------------
```

```
      INTEGER            :: IGLOB      = 72
      INTEGER            :: JGLOB      = 46
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_5 ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! GEOS-5: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 144
      INTEGER            :: JGLOB      = 91
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_5 ) && defined( GRID1x125 )

      !-----------------------------------------------------------------
      ! GEOS-5: 1 x 1.25
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 288
      INTEGER            :: JGLOB      = 181
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
```

```
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_5 ) && defined( GRID05x0666 )

      !-----------------------------------------------------------------
      ! GEOS-5: 0.5 x 0.666
      !-----------------------------------------------------------------
#if   defined( NESTED_CH )
      INTEGER            :: IGLOB      = 121       ! NESTED CHINA   0.5x0.666
      INTEGER            :: JGLOB      = 133
      INTEGER            :: LGLOB      = 72
#elif defined( NESTED_NA )
      INTEGER            :: IGLOB      = 151       ! NESTED N.AMER. 0.5x0.666
      INTEGER            :: JGLOB      = 121
      INTEGER            :: LGLOB      = 72
#elif defined( NESTED_EU )
      INTEGER            :: IGLOB      = 121       ! NESTED EUROPE  0.5x0.666
      INTEGER            :: JGLOB      = 81
      INTEGER            :: LGLOB      = 72
#endif
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( MERRA ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! MERRA: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 144
      INTEGER            :: JGLOB      = 91
```

```
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( MERRA ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! MERRA: 4 x 5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 72
      INTEGER            :: JGLOB      = 46
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_57 ) && defined( GRID025x03125 ) && defined( SEAC4RS )

      !-----------------------------------------------------------------
      ! GEOS-5.7.x: SEA4CRS Grid
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 177
      INTEGER            :: JGLOB      = 161
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
```

```
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_57 ) && defined( GRID025x03125 ) && defined( NESTED_CH )

      !-----------------------------------------------------------------
      ! GEOS-5.7.x: Nested China Grid
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 225
      INTEGER            :: JGLOB      = 161
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_57 ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! GEOS-5.7.x: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 144
      INTEGER            :: JGLOB      = 91
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
```

```
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_57 ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GEOS-5.7.x: 4 x 5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 72
      INTEGER            :: JGLOB      = 46
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined ( EXTERNAL_GRID )

      !-----------------------------------------------------------------
      ! EXTERNALLY INITIALIZED GRID
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB, JGLOB, LGLOB
      INTEGER            :: IIPAR, JJPAR, LLPAR

      INTEGER, PARAMETER :: LLTROP_FIX = 22
      INTEGER, PARAMETER :: LLTROP     = 22
      REAL*8,  PARAMETER :: PTOP       = 0.01d0
#endif

      !-----------------------------------------------------------------
      ! For GEOS 1x1 files
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: I1x1       = 360
      INTEGER, PARAMETER :: J1x1       = 181

      !-----------------------------------------------------------------
      ! For GEOS 05x0666 files
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: I05x0666   = 540
      INTEGER, PARAMETER :: J05x0666   = 361
```

```
      !-----------------------------------------------------------------
      ! For GFED3
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGFED3     = 720
      INTEGER, PARAMETER :: JGFED3     = 360

      !=================================================================
      ! TRACER & EMISSION SPECIES PARAMETERS
      ! NNPAR   = max number of tracers
      ! NEMPARA = max number of anthropogenic emission species
      ! NEMPARB = max number of biogenic      emission species
      !=================================================================
      ! increase NNPAR and NEMPARA an extra amount (hotp 7/31/09)
#if   defined( TOMAS )
      INTEGER, PARAMETER :: NNPAR   = 320   ! For TOMAS (win, bmy, 1/25/10)
#elif defined( APM )
      INTEGER, PARAMETER :: NNPAR   = 154   ! For APM (G. Luo, 3/8/11)
#else
 ------------------------------------------------------------------------------
  Prior to 12/27/11:
  Changed NNPAR from 75 to 85 to accommodate 10 bromine species added
  (J. Parrella, mpayer, 12/27/11)
       ! increase NNPAR to 100 (FP 8/2009)
       INTEGER, PARAMETER :: NNPAR   = 75    ! For non-TOMAS simulations
       !INTEGER, PARAMETER :: NNPAR   = 100
 ------------------------------------------------------------------------------
      INTEGER, PARAMETER :: NNPAR   = 85    ! For non-TOMAS simulations
#endif

      ! Nempara increased to 26. (fp, 2/8/10)
      ! new emissions HNO3 and O3 (phs)
      !  Add non-biogenic emission species:
      !  BENZ, TOLU, XYLE, C2H2, C2H4, GLYX, MGLY, GLYC, HAC. (tmf, 1/7/09)
      !INTEGER, PARAMETER :: NEMPARA = 21
      !  Add RCHO, HCOOH, ACTA
      !INTEGER, PARAMETER :: NEMPARA = 26
      INTEGER, PARAMETER :: NEMPARA = 29

 ------------------------------------------------------------------------------
  Prior to 12/27/11:
  Added 3 to NEMPARB, to allow for biogenic VSL emissions of CH2Br2 and CHBr3
  and seasalt emissions of Br2 (J. Parrella, mpayer, 12/27/11)
       ! Add biogenic emissions: MBO, MONX. (tmf, 1/7/09)
 !      INTEGER, PARAMETER :: NEMPARB = 3
       INTEGER, PARAMETER :: NEMPARB = 17
 ------------------------------------------------------------------------------
      INTEGER, PARAMETER :: NEMPARB = 20
```

```
!=================================================================
! OTHER PARAMETERS
!=================================================================

! NVEGTYPE - Maximum number of surface types: 74 olson
! NTYPE    - Maximum number of veg types in a CTM grid box
! NPOLY    - Number of coefficients for polynomial fits
INTEGER, PARAMETER :: NVEGTYPE = 74
INTEGER, PARAMETER :: NTYPE    = 25
INTEGER, PARAMETER :: NPOLY    = 20

! NNSTA = max number of time series stations (in inptr.ctm)
INTEGER, PARAMETER :: NNSTA = 800

! MAXIJ - Maximum number of 1st level grid boxes
INTEGER :: MAXIJ

! LLCONVM - Max number of layers for convection
INTEGER :: LLCONVM

! NOXLEVELS = Number of levels of anthro NOx emission
!             (e.g. surface and 100m)
! NOXEXTENT = Highest sigma level that receives anthro NOx emission
INTEGER, PARAMETER :: NOXLEVELS = 2
INTEGER, PARAMETER :: NOXEXTENT = 2

! MAXFAM -- Max number of families for prod and loss output
INTEGER, PARAMETER :: MAXFAM = 40

! MAXMEM is maximum number of families of prod and loss
! moved from input_mod and diag_pl_mod to here (hotp 7/31/09)
! MAXMEM also increased from 10 to 20 by FP
! MAXMEM increased from 20 to 22 for bromine (jpp, mpayer, 12/28/11)
INTEGER, PARAMETER :: MAXMEM = 22

! MAXPL increased from 100 to 500 and moved from diag_pl_mod
! to here by FP (hotp 7/31/09)
INTEGER, PARAMETER :: MAXPL = 500


! NDUST -- Number of FAST-J aerosol size bins (rvm, bmy, 11/15/01)
INTEGER, PARAMETER :: NDUST = 7

! NAER -- number of other aerosol categories (rvm, bmy, 2/27/02)
INTEGER, PARAMETER :: NAER = 5

! NRH -- number of relative humidity bins (rvm, bmy, 2/27/02)
INTEGER, PARAMETER :: NRH = 5
```

```
      !NBIOMAX -- biomass burning
      ! increase NBIOMAX to 20 (hotp 7/31/09)
      ! increase NBIOMAX to 24 for dicarbonyls (ccc, 2/02/10)
      ! increase NBIOMAX to 25 fpr CH4 (kjw)
      INTEGER, PARAMETER :: NBIOMAX = 25


#if   defined( TOMAS )

      ! NDSTBIN -- redimensioned for TOMAS (dwest, bmy, 2/1/10)
      INTEGER, PARAMETER :: NDSTBIN   = 30

      ! Number of TOMAS bins
      INTEGER, PARAMETER :: TOMASBIN  = 30
      INTEGER, PARAMETER :: TOMASSPEC = 8

#else

      ! NDSTBIN -- number of dust size bins for transport (tdf, bmy, 3/31/04)
      INTEGER, PARAMETER :: NDSTBIN   = 4

#endif
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%% NOTE: THIS WAS MADE INTO A MODULE IN ORDER TO REMOVE COMMON BLOCKS  %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
(1 ) Now set LLTROP = 20 for GEOS-3 (bmy, 4/12/01)
(2 ) Eliminated obsolete commented-out code (bmy, 4/20/01)
(3 ) Now set MAXFAM = 12 for more P-L families (bmy, 6/28/01)
(4 ) Comment out {IJL}GCMPAR -- these are obosolete (bmy, 9/24/01)
(5 ) Also set LLPAR = 30 for GEOS-3, will regrid online (bmy, 9/24/01)
(6 ) Removed obsolete code from 9/01 (bmy, 10/23/01)
(7 ) Removed NAIR, LAIREMS, these are now defined
      in "aircraft_nox_mod.f" (bmy, 2/14/02)
(8 ) Eliminated commented-out code from 2/14/02.  Also added NAER
      and NRH parameters for aerosols. (rvm, bmy, 2/27/02)
(9 ) Removed IM, JM, IMX, JMX to avoid namespace pollution.  This
      is needed to get the new TPCORE to work.  Also changed RCS
      ID tag comment character from "C" to "!" to allow freeform
      compilation. (bmy, 6/25/02)
(10) Removed obsolete code from 6/02 (bmy, 8/26/02)
(11) Added NUMDEP_SULF in a common block for sulfate dry deposition.
      Also set MAXDEP=31 and NNPAR=31 for coupled fullchem/sulfate
```

```
      simulations. (rjp, bdf, bmy, 11/15/02)
(12) Removed I0, J0; these are now superseded by "grid_mod.f"
      (bmy, 2/11/03)
(13) Added parameters for GEOS-4 (bmy, 6/18/03)
(14) Now defines both 55 level and 30 level GEOS-4 grids.  Also
      define LLTROP=19 for GEOS-4 grids.  Also remove obsolete
      GEOS-2 grid declarations. (bmy, 10/31/03)
(15) LLTROP should be 17 for GEOS-4...based on the ND55 diagnostic
      when computed for 2003 met fields (bmy, 2/18/04)
(16) Increase NNPAR from 31 to 39 for carbon & dust tracers.  Also
      declare NDSTBIN as # of dust bins. (rvm, tdf, bmy, 4/1/04)
(17) Increase NNPAR to 41 for seasalt tracers (rjp, bec, bmy, 4/20/04)
(18) Increase NNPAR to 50 for SOA tracers (rjp, bmy, 7/15/04)
(19) Now use NESTED_CH and NESTED_NA cpp switches to define
      parameters for 1x1 nested grids.  Also add parameters for
      the 1 x 1.25 global grid. (bmy, 12/1/04)
(20) Now add parameters for GCAP and GEOS-5 grids.  Remove references
      to obsolete LGEOSCO and FULLCHEM Cpp switches (bmy, 6/24/05)
(21) Now add I1x1 and J1x1 parameters for data on the 1x1 GEOS
      grid. (bmy, 10/24/05)
(22) Increase NNPAR to 52 (bmy, 12/6/05)
(23) Increase NNPAR to 54 (dkh, bmy, 5/22/06)
(24) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(25) Added variable tropopause case (bmy, phs, bdf, 8/21/06)
(26) Set LLTROP to level of first box entirely above 20km for GEOS-3
     and GEOS-4 (phS, 9/14/06)
(27) Bug fix: set LLTROP_FIX = LLPAR for GCAP (bmy, 11/29/06)
(28) Reset vertical coordinates for GEOS-5.  Also renamed GRID30LEV
      to GRIDREDUCED (bmy, 4/3/07)
(29) New parameters for GEOS-5 nested grid (yxw, dan, bmy, 11/6/08)
(30) NEMPARA set to 12 to emit O3 and HNO3 (phs, 4/3/08)
(31) Add tracers to NNPAR = 73. (tmf, 1/7/09)
(32) NEMPARA set to 21 to emit new tracers for GLYX chemistry
     (tmf, ccc, 3/2/09)
(33) NEMPARB set to 3 to emit MBO, MONX (tmf, ccc, 3/2/09)
(34) Added EUROPE grid parameters (amv, 10/19/09)
18 Dec 2009 - Aaron van D - Added NESTED_EU grid parameters
18 Dec 2009 - R. Yantosca - Added ProTeX headers
25 Jan 2010 - R. Yantosca - Set NNPAR=320 for TOMAS simulations
25 Jan 2010 - R. Yantosca - Define TOMASBIN and TOMASSPEC for TOMAS sims
08 Feb 2010 - F. Paulot   - Increase NNPAR, NEMPARA and NEMPARB
08 Feb 2010 - F. Paulot   - Move MAXMEM and MAXPL from diag_pl_mod.
30 Nov 2010 - R. Yantosca - Increase LLTROP (from 38 to 40) for GEOS-5 and
                            MERRA for the full 72-layer grids (i.e. when
                            the Cpp switch GRIDREDUCED is not set).
09 Mar 2011 - R. Yantosca - Updated NNPAR for APM (G. Luo)
23 Aug 2011 - M. Long     - Converted to Module from Header file
27 Dec 2011 - M. Payer    - Updated NNPAR, NEMPARB, MAXMEM for bromine
```

```
                              chemistry (J. Parrella)
   10 Feb 2012 - R. Yantosca - Added #if blocks for GEOS-5.7.x nested CH grid
   28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
   27 Mar 2012 - R. Yantosca - Increase NTYPE from 15 to 25 for Olson 2001 map
```

1.3 Fortran: Module Interface CMN_SIZE

CMN_SIZE contains size parameters for GEOS-Chem arrays.

INTERFACE:

```
      MODULE CMN_SIZE_MOD
```

USES:

```
      IMPLICIT NONE
      PUBLIC

#     include "define.h"
```

DEFINED PARAMETERS:

```
      !=================================================================
      ! DISIZE = size (in degrees) of a longitude grid box
      ! DJSIZE = size (in degrees) of a latitude  grid box
      !=================================================================
#if   defined( GRID4x5 )
      REAL*8, PARAMETER :: DISIZE = 5.0d0
      REAL*8, PARAMETER :: DJSIZE = 4.0d0
#elif defined( GRID2x25 )
      REAL*8, PARAMETER :: DISIZE = 2.5d0
      REAL*8, PARAMETER :: DJSIZE = 2.0d0
#elif defined( GRID1x125 )
      REAL*8, PARAMETER :: DISIZE = 1.25d0
      REAL*8, PARAMETER :: DJSIZE = 1.0d0
#elif defined( GRID1x1 )
      REAL*8, PARAMETER :: DISIZE = 1.0d0
      REAL*8, PARAMETER :: DJSIZE = 1.0d0
#elif defined( GRID05x0666 )
      REAL*8, PARAMETER :: DISIZE = 2d0/3d0
      REAL*8, PARAMETER :: DJSIZE = 0.5d0
#elif defined( GRID025x03125)
      REAL*8, PARAMETER :: DISIZE = 0.3125d0
      REAL*8, PARAMETER :: DJSIZE = 0.25d0
#endif

      !=================================================================
      ! GRID PARAMETERS
```

```
      ! IGLOB      = global longitude dimension
      ! JGLOB      = global latitude dimension
      ! LGLOB      = max number of sigma levels
      ! IIPAR      = window longitude dimension
      ! JJPAR      = window latitude dimension
      ! LLPAR      = window vertical dimension
      ! LLTROP     = maximum number of tropospheric levels for variable
      !              tropopause
      ! LLTROP_FIX = number of tropospheric levels for offline simulations
      ! PTOP       = model top pressure (mb)
      ! Most of the time, GEOS-CHEM is used for global simulations.
      ! In this case, then IIPAR=IGLOB, JJPAR=JGLOB, LLPAR=LGLOB.
      ! For nested grids, then IIPAR<IGLOB, JJPAR<JGLOB, LLPAR<LGLOB.
      !=================================================================
#if   defined( GCAP ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GCAP: 4 x 5
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 72
      INTEGER, PARAMETER :: JGLOB      = 45
      INTEGER, PARAMETER :: LGLOB      = 23
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
      INTEGER, PARAMETER :: LLPAR      = LGLOB
      INTEGER, PARAMETER :: LLTROP     = 12
      INTEGER, PARAMETER :: LLTROP_FIX = LLTROP
      REAL*8,  PARAMETER :: PTOP       = 0.002d0

#elif defined( GEOS_4 ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GEOS-4: 4 x 5
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 72
      INTEGER, PARAMETER :: JGLOB      = 46
      INTEGER, PARAMETER :: LGLOB      = 55
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 30        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP     = 22        !  -- 30 levels
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP     = 23        !  -- 55 levels
#endif
      INTEGER, PARAMETER :: LLTROP_FIX = 17
      REAL*8,  PARAMETER :: PTOP       = 0.01d0
```

```
#elif defined( GEOS_4 ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! GEOS-4: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 144
      INTEGER, PARAMETER :: JGLOB      = 91
      INTEGER, PARAMETER :: LGLOB      = 55
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 30        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP     = 22        !  -- 30 levels
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP     = 23        !  -- 55 levels
#endif
      INTEGER, PARAMETER :: LLTROP_FIX = 17
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_4 ) && defined( GRID1x125 )

      !-----------------------------------------------------------------
      ! GEOS-4: 1 x 1.2.5
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 288
      INTEGER, PARAMETER :: JGLOB      = 181
      INTEGER, PARAMETER :: LGLOB      = 55
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 30        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP     = 22        !  -- 30 levels
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP     = 23        !  -- 55 levels
#endif
      INTEGER, PARAMETER :: LLTROP_FIX = 17
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_5 ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GEOS-5: 4 x 5
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 72
      INTEGER, PARAMETER :: JGLOB      = 46
```

```
      INTEGER, PARAMETER :: LGLOB      = 72
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_5 ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! GEOS-5: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 144
      INTEGER, PARAMETER :: JGLOB      = 91
      INTEGER, PARAMETER :: LGLOB      = 72
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_5 ) && defined( GRID1x125 )

      !-----------------------------------------------------------------
      ! GEOS-5: 1 x 1.25
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 288
      INTEGER, PARAMETER :: JGLOB      = 181
      INTEGER, PARAMETER :: LGLOB      = 72
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
```

```
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_5 ) && defined( GRID05x0666 )

      !-----------------------------------------------------------------
      ! GEOS-5: 0.5 x 0.666
      !-----------------------------------------------------------------
#if   defined( NESTED_CH )
      INTEGER, PARAMETER :: IGLOB      = 121       ! NESTED CHINA   0.5x0.666
      INTEGER, PARAMETER :: JGLOB      = 133
      INTEGER, PARAMETER :: LGLOB      = 72
#elif defined( NESTED_NA )
      INTEGER, PARAMETER :: IGLOB      = 151       ! NESTED N.AMER. 0.5x0.666
      INTEGER, PARAMETER :: JGLOB      = 121
      INTEGER, PARAMETER :: LGLOB      = 72
#elif defined( NESTED_EU )
      INTEGER, PARAMETER :: IGLOB      = 121       ! NESTED EUROPE  0.5x0.666
      INTEGER, PARAMETER :: JGLOB      = 81
      INTEGER, PARAMETER :: LGLOB      = 72
#endif
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( MERRA ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! MERRA: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 144
      INTEGER, PARAMETER :: JGLOB      = 91
      INTEGER, PARAMETER :: LGLOB      = 72
      INTEGER, PARAMETER :: IIPAR      = IGLOB
```

```
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( MERRA ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! MERRA: 4 x 5
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 72
      INTEGER, PARAMETER :: JGLOB      = 46
      INTEGER, PARAMETER :: LGLOB      = 72
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_57 ) && defined( GRID025x03125 ) && defined( SEAC4RS )

      !-----------------------------------------------------------------
      ! GEOS-5.7.x: SEA4CRS Grid
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 177
      INTEGER, PARAMETER :: JGLOB      = 161
      INTEGER, PARAMETER :: LGLOB      = 72
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
```

```
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_57 ) && defined( GRID025x03125 ) && defined( NESTED_CH )

      !-----------------------------------------------------------------
      ! GEOS-5.7.x: Nested China Grid
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 225
      INTEGER, PARAMETER :: JGLOB      = 161
      INTEGER, PARAMETER :: LGLOB      = 72
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_57 ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! GEOS-5.7.x: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 144
      INTEGER, PARAMETER :: JGLOB      = 91
      INTEGER, PARAMETER :: LGLOB      = 72
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0
```

```
#elif defined( GEOS_57 ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GEOS-5.7.x: 4 x 5
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGLOB      = 72
      INTEGER, PARAMETER :: JGLOB      = 46
      INTEGER, PARAMETER :: LGLOB      = 72
      INTEGER, PARAMETER :: IIPAR      = IGLOB
      INTEGER, PARAMETER :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER, PARAMETER :: LLPAR      = LGLOB     ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#endif

      !-----------------------------------------------------------------
      ! For GEOS 1x1 files
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: I1x1       = 360
      INTEGER, PARAMETER :: J1x1       = 181

      !-----------------------------------------------------------------
      ! For GEOS 05x0666 files
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: I05x0666   = 540
      INTEGER, PARAMETER :: J05x0666   = 361

      !-----------------------------------------------------------------
      ! For GFED3
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGFED3     = 720
      INTEGER, PARAMETER :: JGFED3     = 360

      !=================================================================
      ! TRACER & EMISSION SPECIES PARAMETERS
      ! NNPAR   = max number of tracers
      ! NEMPARA = max number of anthropogenic emission species
      ! NEMPARB = max number of biogenic      emission species
      !=================================================================
      ! increase NNPAR and NEMPARA an extra amount (hotp 7/31/09)
```

```
#if   defined( TOMAS )
      INTEGER, PARAMETER :: NNPAR   = 320   ! For TOMAS (win, bmy, 1/25/10)
#elif defined( APM )
      INTEGER, PARAMETER :: NNPAR   = 154   ! For APM (G. Luo, 3/8/11)
#else
 ------------------------------------------------------------------------
  Prior to 12/27/11:
  Changed NNPAR from 75 to 85 to accommodate 10 bromine species added
  (J. Parrella, mpayer, 12/27/11)
       ! increase NNPAR to 100 (FP 8/2009)
       INTEGER, PARAMETER :: NNPAR   = 75    ! For non-TOMAS simulations
       !INTEGER, PARAMETER :: NNPAR   = 100
 ------------------------------------------------------------------------
      INTEGER, PARAMETER :: NNPAR   = 85    ! For non-TOMAS simulations
#endif

      ! Nempara increased to 26. (fp, 2/8/10)
      ! new emissions HNO3 and O3 (phs)
      !  Add non-biogenic emission species:
      !  BENZ, TOLU, XYLE, C2H2, C2H4, GLYX, MGLY, GLYC, HAC. (tmf, 1/7/09)
      !INTEGER, PARAMETER :: NEMPARA = 21
      !  Add RCHO, HCOOH, ACTA
      !INTEGER, PARAMETER :: NEMPARA = 26
      INTEGER, PARAMETER :: NEMPARA = 29

 ------------------------------------------------------------------------
  Prior to 12/27/11:
  Added 3 to NEMPARB, to allow for biogenic VSL emissions of CH2Br2 and CHBr3
  and seasalt emissions of Br2 (J. Parrella, mpayer, 12/27/11)
       ! Add biogenic emissions: MBO, MONX. (tmf, 1/7/09)
!       INTEGER, PARAMETER :: NEMPARB = 3
       INTEGER, PARAMETER :: NEMPARB = 17
 ------------------------------------------------------------------------
      INTEGER, PARAMETER :: NEMPARB = 20

      !=================================================================
      ! OTHER PARAMETERS
      !=================================================================

      ! NVEGTYPE - Maximum number of surface types: 74 olson
      ! NTYPE    - Maximum number of veg types in a CTM grid box
      ! NPOLY    - Number of coefficients for polynomial fits
      INTEGER, PARAMETER :: NVEGTYPE = 74
      INTEGER, PARAMETER :: NTYPE    = 25
      INTEGER, PARAMETER :: NPOLY    = 20

      ! NNSTA = max number of time series stations (in inptr.ctm)
      INTEGER, PARAMETER :: NNSTA = 800
```

```
      ! MAXIJ - Maximum number of 1st level grid boxes
      INTEGER, PARAMETER :: MAXIJ = IIPAR * JJPAR

      ! LLCONVM - Max number of layers for convection
      INTEGER, PARAMETER :: LLCONVM = LLPAR - 1

      ! NOXLEVELS = Number of levels of anthro NOx emission
      !             (e.g. surface and 100m)
      ! NOXEXTENT = Highest sigma level that receives anthro NOx emission
      INTEGER, PARAMETER :: NOXLEVELS = 2
      INTEGER, PARAMETER :: NOXEXTENT = 2

      ! MAXFAM -- Max number of families for prod and loss output
      INTEGER, PARAMETER :: MAXFAM = 40

      ! MAXMEM is maximum number of families of prod and loss
      ! moved from input_mod and diag_pl_mod to here (hotp 7/31/09)
      ! MAXMEM also increased from 10 to 20 by FP
      ! MAXMEM increased from 20 to 22 for bromine (jpp, mpayer, 12/28/11)
      INTEGER, PARAMETER :: MAXMEM = 22

      ! MAXPL increased from 100 to 500 and moved from diag_pl_mod
      ! to here by FP (hotp 7/31/09)
      INTEGER, PARAMETER :: MAXPL = 500


      ! NDUST -- Number of FAST-J aerosol size bins (rvm, bmy, 11/15/01)
      INTEGER, PARAMETER :: NDUST = 7

      ! NAER -- number of other aerosol categories (rvm, bmy, 2/27/02)
      INTEGER, PARAMETER :: NAER = 5

      ! NRH -- number of relative humidity bins (rvm, bmy, 2/27/02)
      INTEGER, PARAMETER :: NRH = 5

      !NBIOMAX -- biomass burning
      ! increase NBIOMAX to 20 (hotp 7/31/09)
      ! increase NBIOMAX to 24 for dicarbonyls (ccc, 2/02/10)
      ! increase NBIOMAX to 25 fpr CH4 (kjw)
      INTEGER, PARAMETER :: NBIOMAX = 25


#if   defined( TOMAS )

      ! NDSTBIN -- redimensioned for TOMAS (dwest, bmy, 2/1/10)
      INTEGER, PARAMETER :: NDSTBIN   = 30
```

```
      ! Number of TOMAS bins
      INTEGER, PARAMETER :: TOMASBIN  = 30
      INTEGER, PARAMETER :: TOMASSPEC = 8

#else

      ! NDSTBIN -- number of dust size bins for transport (tdf, bmy, 3/31/04)
      INTEGER, PARAMETER :: NDSTBIN   = 4

#endif
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%% NOTE: THIS WAS MADE INTO A MODULE IN ORDER TO REMOVE COMMON BLOCKS  %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
(1 ) Now set LLTROP = 20 for GEOS-3 (bmy, 4/12/01)
(2 ) Eliminated obsolete commented-out code (bmy, 4/20/01)
(3 ) Now set MAXFAM = 12 for more P-L families (bmy, 6/28/01)
(4 ) Comment out {IJL}GCMPAR -- these are obosolete (bmy, 9/24/01)
(5 ) Also set LLPAR = 30 for GEOS-3, will regrid online (bmy, 9/24/01)
(6 ) Removed obsolete code from 9/01 (bmy, 10/23/01)
(7 ) Removed NAIR, LAIREMS, these are now defined
      in "aircraft_nox_mod.f" (bmy, 2/14/02)
(8 ) Eliminated commented-out code from 2/14/02.  Also added NAER
      and NRH parameters for aerosols. (rvm, bmy, 2/27/02)
(9 ) Removed IM, JM, IMX, JMX to avoid namespace pollution.  This
      is needed to get the new TPCORE to work.  Also changed RCS
      ID tag comment character from "C" to "!" to allow freeform
      compilation. (bmy, 6/25/02)
(10) Removed obsolete code from 6/02 (bmy, 8/26/02)
(11) Added NUMDEP_SULF in a common block for sulfate dry deposition.
      Also set MAXDEP=31 and NNPAR=31 for coupled fullchem/sulfate
      simulations. (rjp, bdf, bmy, 11/15/02)
(12) Removed I0, J0; these are now superseded by "grid_mod.f"
      (bmy, 2/11/03)
(13) Added parameters for GEOS-4 (bmy, 6/18/03)
(14) Now defines both 55 level and 30 level GEOS-4 grids.  Also
      define LLTROP=19 for GEOS-4 grids.  Also remove obsolete
      GEOS-2 grid declarations. (bmy, 10/31/03)
(15) LLTROP should be 17 for GEOS-4...based on the ND55 diagnostic
      when computed for 2003 met fields (bmy, 2/18/04)
(16) Increase NNPAR from 31 to 39 for carbon & dust tracers.  Also
      declare NDSTBIN as # of dust bins. (rvm, tdf, bmy, 4/1/04)
(17) Increase NNPAR to 41 for seasalt tracers (rjp, bec, bmy, 4/20/04)
(18) Increase NNPAR to 50 for SOA tracers (rjp, bmy, 7/15/04)
```

```
(19) Now use NESTED_CH and NESTED_NA cpp switches to define
      parameters for 1x1 nested grids.  Also add parameters for
      the 1 x 1.25 global grid. (bmy, 12/1/04)
(20) Now add parameters for GCAP and GEOS-5 grids.  Remove references
      to obsolete LGEOSCO and FULLCHEM Cpp switches (bmy, 6/24/05)
(21) Now add I1x1 and J1x1 parameters for data on the 1x1 GEOS
      grid. (bmy, 10/24/05)
(22) Increase NNPAR to 52 (bmy, 12/6/05)
(23) Increase NNPAR to 54 (dkh, bmy, 5/22/06)
(24) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(25) Added variable tropopause case (bmy, phs, bdf, 8/21/06)
(26) Set LLTROP to level of first box entirely above 20km for GEOS-3
     and GEOS-4 (phS, 9/14/06)
(27) Bug fix: set LLTROP_FIX = LLPAR for GCAP (bmy, 11/29/06)
(28) Reset vertical coordinates for GEOS-5.  Also renamed GRID30LEV
      to GRIDREDUCED (bmy, 4/3/07)
(29) New parameters for GEOS-5 nested grid (yxw, dan, bmy, 11/6/08)
(30) NEMPARA set to 12 to emit O3 and HNO3 (phs, 4/3/08)
(31) Add tracers to NNPAR = 73. (tmf, 1/7/09)
(32) NEMPARA set to 21 to emit new tracers for GLYX chemistry
     (tmf, ccc, 3/2/09)
(33) NEMPARB set to 3 to emit MBO, MONX (tmf, ccc, 3/2/09)
(34) Added EUROPE grid parameters (amv, 10/19/09)
18 Dec 2009 - Aaron van D - Added NESTED_EU grid parameters
18 Dec 2009 - R. Yantosca - Added ProTeX headers
25 Jan 2010 - R. Yantosca - Set NNPAR=320 for TOMAS simulations
25 Jan 2010 - R. Yantosca - Define TOMASBIN and TOMASSPEC for TOMAS sims
08 Feb 2010 - F. Paulot   - Increase NNPAR, NEMPARA and NEMPARB
08 Feb 2010 - F. Paulot   - Move MAXMEM and MAXPL from diag_pl_mod.
30 Nov 2010 - R. Yantosca - Increase LLTROP (from 38 to 40) for GEOS-5 and
                            MERRA for the full 72-layer grids (i.e. when
                            the Cpp switch GRIDREDUCED is not set).
09 Mar 2011 - R. Yantosca - Updated NNPAR for APM (G. Luo)
23 Aug 2011 - M. Long     - Converted to Module from Header file
27 Dec 2011 - M. Payer    - Updated NNPAR, NEMPARB, MAXMEM for bromine
                            chemistry (J. Parrella)
10 Feb 2012 - R. Yantosca - Added #if blocks for GEOS-5.7.x nested CH grid
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
27 Mar 2012 - R. Yantosca - Increase NTYPE from 15 to 25 for Olson 2001 map
29 May 2012 - S. Kim      - Separate the SEAC4RS and Nested China Grids
```

1.4 Fortran: Module Interface CMN_DEP_mod

Common blocks for dry deposition.

INTERFACE:

```
MODULE CMN_DEP_MOD
```

USES:

```
USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR, NTYPE

IMPLICIT NONE
PUBLIC
```

PUBLIC DATA MEMBERS:

```
! IREG   - Number of landtypes in grid square (I,J)
INTEGER, ALLOCATABLE :: IREG(:,:)

! ILAND  - Land type ID in grid square (I,J) for IREG landtypes
INTEGER, ALLOCATABLE :: ILAND(:,:,:)

! IUSE   - Fraction ((per mil) of gridbox area occupied by land type
INTEGER, ALLOCATABLE :: IUSE(:,:,:)

! Fraction of land in grid box
REAL*8,  ALLOCATABLE :: FRCLND(:,:)

! XLAI    - Leaf Area Index of land type for current MONTH
REAL*8,  ALLOCATABLE :: XLAI(:,:,:)

! XLAI2   - Leaf Area Index of land type for following MONTH
REAL*8,  ALLOCATABLE :: XLAI2(:,:,:)
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: THIS MODULE IS DEPRECATED.  IT WILL BE REMOVED WHEN THE  %%%
%%%  GEIA BIOGENIC EMISSIONS ARE REMOVED FROM GEOS-CHEM (v9-01-03)  %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
23 Aug 2011 - M. Long     - Converted to Module from Header file
25 Aug 2011 - R. Yantosca - Change IGLOB,JGLOB to IIPAR,JJPAR
```

1.5 Fortran: Module Interface CMN_DEP_mod

Common blocks for dry deposition.

INTERFACE:

```
MODULE CMN_DEP_MOD
```

USES:

```
USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR, NTYPE

IMPLICIT NONE
PUBLIC
```

PUBLIC DATA MEMBERS:

```
! IREG   - Number of landtypes in grid square (I,J)
INTEGER :: IREG(IIPAR,JJPAR)

! ILAND  - Land type ID in grid square (I,J) for IREG landtypes
INTEGER :: ILAND(IIPAR,JJPAR,NTYPE)

! IUSE   - Fraction ((per mil) of gridbox area occupied by land type
INTEGER :: IUSE(IIPAR,JJPAR,NTYPE)

! Fraction of land in grid box
REAL*8  :: FRCLND(IIPAR,JJPAR)

! XLAI    - Leaf Area Index of land type for current MONTH
REAL*8  :: XLAI(IIPAR,JJPAR,NTYPE)

! XLAI2   - Leaf Area Index of land type for following MONTH
REAL*8  :: XLAI2(IIPAR,JJPAR,NTYPE)
```

REMARKS:

REVISION HISTORY:

```
23 Aug 2011 - M. Long     - Converted to Module from Header file
25 Aug 2011 - R. Yantosca - Change IGLOB,JGLOB to IIPAR,JJPAR
```

1.6 Fortran: Module Interface CMN_DIAG_mod

Module CMN_DIAG_mod contains size parameters and global variables for the GEOS-Chem diagnostic arrays. This is mostly historical baggage.

INTERFACE:

```
MODULE CMN_DIAG_MOD
```

USES:

```
USE CMN_SIZE_MOD

IMPLICIT NONE
PUBLIC
```

DEFINED PARAMETERS:

```
!=============================================================
! Maximum sizes of diagnostic arrays
! Changed PD66 to 6  (bmy, 9/8/00)
! Changed PD21 to 10 (bmy, 9/30/00)
! Changed PD67 to 18 (bmy, 10/11/00)
! Changed PD46 to 4  (bmy, 1/2/01)
! Changed PD29 to 5  (bmy, 1/2/01)
! Changed PD11 to 7  (bmy, 9/4/01)
! Changed PD32 to 0  (bmy, 2/14/02)
! Changed PD21 to 20 (bmy, 2/27/02)
! Changed PD43 to 4  (bmy, 3/4/02)
! Changed PD05 to 10 (bmy, 10/18/02)
! Changed PD44 to 30 (bmy, 11/19/02)
! Changed PD43 to 5
! Changed PD67 to 22 (bmy, 6/23/03)
! Changed PD66 to 5  (bmy, 6/23/03)
! Changed PD03 to 5  (bmy, 8/20/03)
! Changed PD37 to 10 (bmy, 1/21/04)
! Changed PD06 to NDSTBIN (bmy, 4/5/04)
! Changed PD07 to 7  (bmy, 4/5/04)
! Changed PD08 to 2  (bmy, 4/20/04)
! Changed PD07 to 12 (bmy, 7/15/04)
! Changed PD21 to 26 (bmy, 1/5/05)
! Removed PD03 -- now in "diag03_mod.f" (bmy, 1/21/05)
! Removed PD41 -- now in "diag41_mod.f" (bmy, 1/21/05)
! Now set PD09 to 6 (bmy, 6/27/05)
! Removed PD04 -- now in "diag04_mod.f" (bmy, 7/26/05)
! Now set PD30 to 1 (bmy, 8/18/05)
! Now set PD46 to 6 (tmf, 1/20/09)
! Now set PD10 to 20 (phs, 9/18/07)
! Changed PD17 to 8 (tmf, 1/7/09)
! Changed PD18 to 8 (tmf, 1/7/09)
! Changed PD22 to 8 (tmf, 1/7/09)
! Changed PD37 to 35 (tmf, 1/7/09)
! Changed PD38 to 35 (tmf, 1/7/09)
! Changed PD39 to 35 (tmf, 1/7/09)
! Changed PD44 to 41 (tmf, 1/7/09)
! Now set PD52 to 1 (jaegle 2/26/09)
! Increase PD46 from 6 to 13 (mpb, ccc, 11/19/09)
! increase PD21 from 20 to 27 (clh, 05/06/10)
! changed PD44 (drydep) to 53 (jpp, 6/13/09)
! changed PD39 (wetdep) to 38 (jpp, 7/08/09)
! Now set PD46 to 16 (jpp, 6/7/09)
! Changed PD11 from 7 to 5 (efischer, mpayer, 3/19/12)
!=============================================================
INTEGER, PARAMETER :: PD01=3
INTEGER, PARAMETER :: PD02=3
INTEGER, PARAMETER :: PD05=10
```

```
INTEGER, PARAMETER :: PD06=NDSTBIN
INTEGER, PARAMETER :: PD07=12
INTEGER, PARAMETER :: PD08=2
INTEGER, PARAMETER :: PD09=6
INTEGER, PARAMETER :: PD10=20
INTEGER, PARAMETER :: PD11=5
INTEGER, PARAMETER :: PD12=0
INTEGER, PARAMETER :: PD13=1
INTEGER, PARAMETER :: PD14=NNPAR
INTEGER, PARAMETER :: PD15=NNPAR
INTEGER, PARAMETER :: PD16=2
INTEGER, PARAMETER :: PD17=8
INTEGER, PARAMETER :: PD18=8
INTEGER, PARAMETER :: PD19=0
INTEGER, PARAMETER :: PD20=0
INTEGER, PARAMETER :: PD21=27
INTEGER, PARAMETER :: PD22=14      !jpp replaced 8, 4/24/2011... for Br.
INTEGER, PARAMETER :: PD23=0
INTEGER, PARAMETER :: PD24=NNPAR
INTEGER, PARAMETER :: PD25=NNPAR
INTEGER, PARAMETER :: PD26=NNPAR
INTEGER, PARAMETER :: PD27=1
INTEGER, PARAMETER :: PD28=0
INTEGER, PARAMETER :: PD29=5
INTEGER, PARAMETER :: PD30=1
INTEGER, PARAMETER :: PD31=1
INTEGER, PARAMETER :: PD32=1
INTEGER, PARAMETER :: PD33=NNPAR
INTEGER, PARAMETER :: PD34=2
INTEGER, PARAMETER :: PD35=NNPAR
INTEGER, PARAMETER :: PD36=NNPAR
INTEGER, PARAMETER :: PD37=35
INTEGER, PARAMETER :: PD38=35
INTEGER, PARAMETER :: PD39=38      !jpp replaced 35
INTEGER, PARAMETER :: PD40=4
INTEGER, PARAMETER :: PD43=5
INTEGER, PARAMETER :: PD44=53      !jpp replaced 41
INTEGER, PARAMETER :: PD45=NNPAR+1
INTEGER, PARAMETER :: PD46=16      !jpp replaced 13
INTEGER, PARAMETER :: PD47=NNPAR+1
INTEGER, PARAMETER :: PD48=2
INTEGER, PARAMETER :: PD49=0
INTEGER, PARAMETER :: PD50=0
INTEGER, PARAMETER :: PD51=0
INTEGER, PARAMETER :: PD52=1
INTEGER, PARAMETER :: PD53=0
INTEGER, PARAMETER :: PD54=0
INTEGER, PARAMETER :: PD55=3
```

```
      ! Potential temperature diagnostic (hotp 7/31/09)
      INTEGER, PARAMETER :: PD57=1
      INTEGER, PARAMETER :: PD58=12
#if   defined( TOMAS )
      ! Special settings for TOMAS aerosol microphysics (win, bmy, 1/22/10)
      INTEGER, PARAMETER :: PD59=TOMASBIN*TOMASSPEC
      INTEGER, PARAMETER :: PD60=TOMASBIN*TOMASSPEC
      INTEGER, PARAMETER :: PD61=2
#else
      ! Normal settings for non-TOMAS simulations
      INTEGER, PARAMETER :: PD59=0
      INTEGER, PARAMETER :: PD60=1
      INTEGER, PARAMETER :: PD61=0
#endif
      INTEGER, PARAMETER :: PD62=NNPAR
      INTEGER, PARAMETER :: PD63=0
      INTEGER, PARAMETER :: PD64=0
#if defined( DEVEL )
      INTEGER            :: PD65
#else
      INTEGER, PARAMETER :: PD65=LLPAR*MAXFAM
#endif
      INTEGER, PARAMETER :: PD66=6
      INTEGER, PARAMETER :: PD67=23 ! (Lin, 31/03/09)
      INTEGER, PARAMETER :: PD68=4
      INTEGER, PARAMETER :: PD69=1
      INTEGER, PARAMETER :: PD70=0

      !=================================================================
      ! Variables for printing out selected tracers in diagnostic output
      !=================================================================
      INTEGER, PARAMETER :: MAX_DIAG   = 70
#if   defined( TOMAS )
      INTEGER, PARAMETER :: MAX_TRACER = NNPAR+1   ! For TOMAS (win, 1/25/10)
#elif defined( APM )
      INTEGER, PARAMETER :: MAX_TRACER = NNPAR+100 ! For APM (G. Luo 3/8/11)
#else
      INTEGER, PARAMETER :: MAX_TRACER = NNPAR+6   ! For non-TOMAS simulations
#endif
```

PUBLIC DATA MEMBERS:

```
      !=================================================================
      ! Diagnostic counters & time variables
      !=================================================================
      INTEGER :: KDA48, NJDAY(366)

      !=================================================================
```

```
! Variables for the number of levels in multi-level diagnostics
! Removed LD03 -- this is now in diag03_mod.f (bmy, 1/21/05)
! Added LD09 (bmy, 6/27/05)
! Added LD54 (phs, 9/22/06)
! Added LD10 (phs, 9/18/07)
! Added LD31 (bmy, 5/8/07)
! Added LD52 (jaegle, 02/26/09)
! Added LD59, LD60, LD61 (bmy, 1/22/10)
! Added LD57 (hotp 7/31/09)
!=================================================================
INTEGER :: LD12, LD13, LD14, LD15, LD16, LD17, LD18, LD21, LD22
INTEGER :: LD24, LD25, LD26, LD37, LD38, LD39, LD43, LD45, LD47
INTEGER :: LD54, LD64, LD65, LD66, LD68, LD01, LD02, LD05, LD07
INTEGER :: LD09, LD10, LD31, LD52, LD19, LD57, LD58, LD59, LD60
INTEGER :: LD61, LD62

!=================================================================
! NDxx diagnostic flags
!=================================================================
INTEGER :: ND01, ND02, ND05, ND06, ND07, ND08, ND09, ND10, ND11
INTEGER :: ND12, ND13, ND14, ND15, ND16, ND17, ND18, ND19, ND20
INTEGER :: ND21, ND22, ND23, ND24, ND25, ND26, ND27, ND28, ND29
INTEGER :: ND30, ND31, ND32, ND33, ND34, ND35, ND36, ND37, ND38
INTEGER :: ND39, ND40, ND43, ND44, ND45, ND46, ND47, ND48, ND49
INTEGER :: ND50, ND51, ND52, ND53, ND54, ND55, ND57, ND58, ND59
INTEGER :: ND60, ND61, ND62, ND63, ND64, ND65, ND66, ND67, ND68
INTEGER :: ND69, ND70, ND71, ND72, ND73, ND74, ND75

!=================================================================
! Variables for printing out selected tracers in diagnostic output
!=================================================================
INTEGER :: TINDEX(MAX_DIAG,MAX_TRACER)
INTEGER :: TCOUNT(MAX_DIAG)
INTEGER :: TMAX(MAX_DIAG)

!=================================================================
! NO, J-Value, and 2-PM diagnostic arrays (bmy, 9/25/98)
! Move this here for now (bmy, 7/20/04)
!=================================================================
REAL*8  :: HR1_NO, HR2_NO, HR1_JV,  HR2_JV
REAL*8  :: HR1_OH, HR2_OH, HR1_OTH, HR2_OTH
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: THIS MODULE IS DEPRECATED.  AT SOME POINT WE NEED TO DO A  %%%
%%%  TOTAL REWRITE OF THE GEOS-CHEM DIAGNOSTICS.  MANY OF THESE FLAGS %%%
%%%  CAN BE BUNDLED INTO A DERIVED TYPE FOR THE DIAGNOSTICS, THUS     %%%
%%%  SIMPLIFYING THE CODE.  FOR NOW, LEAVE AS-IS.                     %%%
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
(1 ) Changed RCS ID tag comment character from "C" to "!" to allow freeform
      compilation.  Also added & continuation characters in column 73
      to allow header files to be included in F90 freeform files.
      Also converted PARAMETER statements to F90 syntax. (bmy, 6/25/02)
(2 ) Add LD05 for sulfate prod/loss (rjp, bdf, bmy, 9/20/02)
(3 )  Removed obsolete variables NTAU0, IDAY0, JDATE0, JYEAR0, KDACC,
       KDADYN, KDACONV, KDASRCE, KDACHEM, KDA3FLDS, KDA6FLDS, KDI6FLDS,
       KDKZZFLDS (bmy, 2/11/03)
(4 ) Fix for LINUX - remove & from column 73 (bmy, 6/27/03)
(5 ) Added LD03 for Kr85 Prod/loss diagnostic (bmy, 8/20/03)
(6 ) Removed obsolete arrays (bmy, 1/21/05)
(7 ) Rename MAXDIAG to MAX_DIAG and MAXTRACER to MAX_TRACER in order to
      avoid name conflicts with "gamap_mod.f" (bmy, 5/3/05)
(8 ) Remove reference to TRCOFFSET (bmy, 5/16/06)
(9 ) Added multi level LD54 to common CDIAG1 (phs, 9/22/06)
(10) Added multi level LD10 to common CDIAG1. Set PD10 to 20.  Set
      PD66 to 6. (phs, 9/18/07)
(11) Added LD52 to common CDIAG1 (jaegle, 02/26/09)
(12) Add GLYX, MGLY, SOAG, SOAM, and a few other tracers to AD17, AD18
      for archiving rainout and washout fraction. (tmf, 1/7/09)
(13) Add GLYX, MGLY J value archive. (tmf, 1/7/09)
(14) Add GLYX, MGLY, SOAG, SOAM, and a few other tracers to AD37, AD38,
      AD39
      for archiving rainout and washout flux. (tmf, 1/7/09)
(15) Add GLYX, MGLY, GLYC, 6 PANs, SOAG, SOAM dry dep,
      PD44 = 41.(tmf, 1/7/09)
(16) Add biogenic C2H4 emission, PD46 = 6. (tmf, 1/20/09)
(17) Add one met field to ND67 (EFLUX). (ccc, 5/14/09)
(18) Add declarations for PD58 and PD60, LD19, LD58. (kjw,8/18/09)
(19) Redimension PD59, PD60, PD61 for TOMAS microphysics.  Added LD59, LD60,
      LD61 to common block.  Reset MAX_TRACER to NNPAR+1 for TOMAS.
      (win, bmy, 1/22/10)
(20) Add LD57 and PD57 (potential temperature) (hotp, 3/15/10)
03 Aug 2010 - R. Yantosca - Added ProTeX headers
03 Aug 2010 - P. Kasibhatla & R. Yantosca - Now set MAX_TRACER to NNPAR+6
                                            to match ND09 diagnostic
09 Mar 2011 - R. Yantosca - Updated MAX_TRACER for APM (G. Luo)
03 Aug 2011 - M. Long     - Converted from Header file to Module
```

1.7 Fortran: Module Interface CMN_GCTM_mod

CMN_GCTM_mod contains GEOS-Chem specific PHYSICAL CONSTANTS and DERIVED QUANTITIES.

INTERFACE:

```
MODULE CMN_GCTM_MOD
```

USES:

```
IMPLICIT NONE
PUBLIC
```

DEFINED PARAMETERS:

```
! AIRMW : Molecular weight of air [28.97 g/mole]
REAL*8, PARAMETER :: AIRMW  =  28.97d0

! g0    : Gravity at Surface of Earth [9.8 m/s^2]
REAL*8, PARAMETER :: g0     =   9.8d0

! PI    : Double-Precision value of PI
REAL*8, PARAMETER :: PI     =   3.14159265358979323d0

! Re    : Radius of Earth [m]
REAL*8, PARAMETER :: Re     =   6.375d6

! Rd    : Gas Constant (R) in Dry Air [287 J/K/kg]
REAL*8, PARAMETER :: Rd     = 287.0d0

! g0_100 = 100.0 / g0
REAL*8, PARAMETER :: g0_100 = 100d0 / g0

! PI_180 = PI    / 180.0
REAL*8, PARAMETER :: PI_180 =    PI / 180d0

! Rdg0   = Rd    / g0
REAL*8, PARAMETER :: Rdg0   =    Rd / g0

! Scale height of atmosphere (7.6 km = 7600m)
REAL*8, PARAMETER :: SCALE_HEIGHT = 7600d0
```

REVISION HISTORY:

```
25 Jun 2002 - R. Yantosca - Initial version
23 Aug 2011 - M. Long     - Converted to Module from Header file
```

1.8 Fortran: Module Interface CMN_NOX_mod

CMN_NOX_mod is the module file for containing NOx from soils.

INTERFACE:

```
      MODULE CMN_NOX_MOD
```

USES:

```
      USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR

      IMPLICIT NONE
      PUBLIC
```

PUBLIC DATA MEMBERS:

```
      ! NOTE: Keep this for backwards compatibility for now (bmy, 10/2/07)
      ! GEMISNOX2 = Soil Nox [molec NOx/cm3/s]
#if defined( DEVEL )
      REAL*8, ALLOCATABLE :: GEMISNOX2(:,:)
#else
      REAL*8 :: GEMISNOX2(IIPAR,JJPAR)
#endif
```

REMARKS:

```
   !%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
   !%%%  NOTE: THIS MODULE IS DEPRECATED.  IT CAN BE REMOVED WHEN THE  %%%
   !%%%  UPDATED SOIL NOX EMISSIONS ARE FINALLY ADDED TO GEOS-CHEM.    %%%
   !%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
   05 Mar 1998 - M. Schultz - Initial version
   (1 ) Changed RCS ID tags from "C" to "!" to allow
        freeform compilation.  (bmy, 6/25/02)
   (2 ) Moved BXHEIGHT to "dao_mod.f".  The fact that BXHEIGHT
        was in "CMN_NOX" is historical baggage. (bmy, 9/18/02)
   (3 ) Now everything except GEMISNOX, GEMISNOX2 is in
        "lightning_mod.f" (bmy, 4/14/04)
   (4 ) Remove GEMISNOX from common block (ltm, bmy, 10/2/07)
   23 Aug 2011 - M. Long    - Converted to Module from Header file
  -----------------------------------------------------------------------------
  BOC
#if defined( DEVEL )
      CONTAINS

      SUBROUTINE SET_CMN_NOX_MOD

      IMPLICIT NONE

      INTEGER AS

      ALLOCATE(
     &     GEMISNOX2(IIPAR,JJPAR),
```

```
      &     STAT=AS)

       END SUBROUTINE SET_CMN_NOX_MOD
 #endif

       END MODULE CMN_NOX_MOD
  EOC
\markboth{Left}{Source File: CMN\_O3\_mod.F,  Date: Tue Jul 24 15:01:12 EDT 2012
}


  ------------------------------------------------------------------------------
           Harvard University Atmospheric Chemistry Modeling Group            !
  ------------------------------------------------------------------------------
%//////////////////////////////////////////////////////////

\mbox{}\hrulefill\


  \subsection{Fortran:  Module Interface CMN\_O3\_mod }


  Common blocks for anthro emissions (via SMVGEAR!)

  \\
  \\{\bf INTERFACE:}
\begin{verbatim}       MODULE CMN_O3_MOD
```

USES:

```
       USE CMN_SIZE_MOD, ONLY : IIPAR,     JJPAR,     LLPAR
       USE CMN_SIZE_MOD, ONLY : NEMPARA,   NEMPARB
       USE CMN_SIZE_MOD, ONLY : NOXLEVELS, NOXEXTENT

       IMPLICIT NONE
       PUBLIC
```

PUBLIC DATA MEMBERS:

```
       ! Rural Emissions: EMISRN = NOx (1:NOXLEVELS), EMISR = all other tracers
       ! Total Emissions: EMISTN = NOx (1:NOXLEVELS), EMIST = all other tracers
 #if defined( DEVEL )
       REAL*8, ALLOCATABLE  :: EMISR(:,:,:)
       REAL*8, ALLOCATABLE  :: EMISRN(:,:,:)
       REAL*8, ALLOCATABLE  :: EMIST(:,:,:)
       REAL*8, ALLOCATABLE  :: EMISTN(:,:,:)
 #else
       REAL*8  :: EMISR(IIPAR,JJPAR,NEMPARA)
       REAL*8  :: EMISRN(IIPAR,JJPAR,NOXLEVELS)
```

```
      REAL*8  :: EMIST(IIPAR,JJPAR,NEMPARA)
      REAL*8  :: EMISTN(IIPAR,JJPAR,NOXLEVELS)
#endif

      ! Rural Emissions:
      ! EMISRRN = NOx emissions into sigma levels L=1,NOXEXTENT
      ! EMISRR  = All other tracer emissions into sigma level L=1
#if defined( DEVEL )
      REAL*8, ALLOCATABLE  :: EMISRR (:,:,:)
      REAL*8, ALLOCATABLE  :: EMISRRN(:,:,:)
#else
      REAL*8  :: EMISRR (IIPAR,JJPAR,NEMPARA+NEMPARB)
      REAL*8  :: EMISRRN(IIPAR,JJPAR,NOXEXTENT      )
#endif

      !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      ! New biogenic VOC emissions (mpb,2009)
      !     ---------------------------
      !     Species            | Order
      !     ---------------------------
      !     Isoprene           = 1
      !     Total Monoterpenes = 2
      !     MBO                = 3
      !     Alpha-Pinene       = 4
      !     Beta-Pinene        = 5
      !     Limonene           = 6
      !     Sabinene           = 7
      !     Mycrene            = 8
      !     3-Carene           = 9
      !     Ocimene            = 10
      !     ---------------------------

      ! Define common block
#if defined( DEVEL )
      REAL*8, ALLOCATABLE  :: EMISS_BVOC(:,:,:)
#else
      REAL*8  :: EMISS_BVOC(IIPAR,JJPAR,10)
#endif


      !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      ! Arrays to read emissions from updated merge file :
      !        NOx, CO, PRPE, C3H8, ALK4, C2H6, ACET, MEK
      ! NOTE: ALD2 is not emitted in GEIA so we don't need an array for
      !       it below...but it is emitted in EMEP.  It will be saved
      !       into the EMISRR array for SMVGEAR. (bdf, bmy, 11/1/05)
      !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      ! Arrays to read emissions from updated merge file :
```

```
      !        NOx, CO, PRPE, C3H8, ALK4, C2H6, ACET, MEK
      ! NOTE: ALD2 is not emitted in GEIA so we don't need an array for
      !       it below...but it is emitted in EMEP.  It will be saved

#if defined( DEVEL )
      REAL*4, ALLOCATABLE  :: EMISTNOX (:,:,:,:)
      REAL*4, ALLOCATABLE  :: EMISTETHE(:,:)
      REAL*4, ALLOCATABLE  :: EMISTCO  (:,:)
      REAL*4, ALLOCATABLE  :: EMISTPRPE(:,:)
      REAL*4, ALLOCATABLE  :: EMISTC3H8(:,:)
      REAL*4, ALLOCATABLE  :: EMISTALK4(:,:)
      REAL*4, ALLOCATABLE  :: EMISTC2H6(:,:)
      REAL*4, ALLOCATABLE  :: EMISTSOX (:,:,:,:)
      REAL*4, ALLOCATABLE  :: EMISTACET(:,:)
      REAL*4, ALLOCATABLE  :: EMISTMEK (:,:)
      REAL*4, ALLOCATABLE  :: EMISTBENZ(:,:)
      REAL*4, ALLOCATABLE  :: EMISTTOLU(:,:)
      REAL*4, ALLOCATABLE  :: EMISTXYLE(:,:)
      REAL*4, ALLOCATABLE  :: EMISTC2H4(:,:)
      REAL*4, ALLOCATABLE  :: EMISTC2H2(:,:)
#else
      REAL*4  :: EMISTNOX (IIPAR,JJPAR,4,2)
      REAL*4  :: EMISTETHE(IIPAR,JJPAR    )
      REAL*4  :: EMISTCO  (IIPAR,JJPAR    )
      REAL*4  :: EMISTPRPE(IIPAR,JJPAR    )
      REAL*4  :: EMISTC3H8(IIPAR,JJPAR    )
      REAL*4  :: EMISTALK4(IIPAR,JJPAR    )
      REAL*4  :: EMISTC2H6(IIPAR,JJPAR    )
      REAL*4  :: EMISTSOX (IIPAR,JJPAR,4,2)
      REAL*4  :: EMISTACET(IIPAR,JJPAR    )
      REAL*4  :: EMISTMEK (IIPAR,JJPAR    )
      REAL*4  :: EMISTBENZ(IIPAR,JJPAR    )
      REAL*4  :: EMISTTOLU(IIPAR,JJPAR    )
      REAL*4  :: EMISTXYLE(IIPAR,JJPAR    )
      REAL*4  :: EMISTC2H4(IIPAR,JJPAR    )
      REAL*4  :: EMISTC2H2(IIPAR,JJPAR    )
#endif

      ! Time of day and weekday/weekend scale factors
      ! NOTE: Now SCNR89 is (3,3) because of the weekday scale factor!!!
      REAL*8  :: TODH(6)
      REAL*8  :: TODN(6)
      REAL*8  :: TODB(6)
      REAL*8  :: SCNR89(3,3)


      ! IFSCLYR = Year to use for scaling fossil fuel emissions
      ! (1985 = no scaling        !)
```

```
      INTEGER :: FSCALYR


      ! FTOTCO2 = yearly scale factors based on Total  Fuel CO2 emissions
      ! FLIQCO2 = yearly scale factors based on Liquid Fuel CO2 emissions
#if defined( DEVEL )
      REAL*4, ALLOCATABLE  :: FTOTCO2(:,:)
      REAL*4, ALLOCATABLE  :: FLIQCO2(:,:)
#else
      REAL*4  :: FTOTCO2(IIPAR,JJPAR)
      REAL*4  :: FLIQCO2(IIPAR,JJPAR)
#endif

      ! FRACO3, FRACNO          = fractions of O3, NO
      ! SAVEOH, SAVENO, SAVENO3 = array to save OH, NO, & NO3 fields
      ! SAVENO2                 = array to save NO2 fields (rvm, 5/9/00)
      ! FRACNO2                 = fraction of NO2 (rvm, bmy, 2/27/02)
      ! SAVEHO2                 = array to save HO2 fields (rvm, bmy, 2/27/02)
      ! fracnox                 = look up table for fraction of NOx remaining
      !                           for ship emissions (gvinken, 6/6/10)
      ! intope                  = look up table for integrated Ozone Production
      !                           Efficiency for ship emiss (gvinken, 6/6/10)
#if defined( DEVEL )
      REAL*8, ALLOCATABLE ::   FRACO3(:,:,:)
      REAL*8, ALLOCATABLE ::   SAVEOH(:,:,:)
      REAL*8, ALLOCATABLE ::   FRACNO(:,:,:)
      REAL*8, ALLOCATABLE ::   SAVENO(:,:,:)
      REAL*8, ALLOCATABLE ::   SAVENO2(:,:,:)
      REAL*8, ALLOCATABLE ::   SAVENO3(:,:,:)
      REAL*8, ALLOCATABLE ::   FRACNO2(:,:,:)
      REAL*8, ALLOCATABLE ::   SAVEHO2(:,:,:)
      REAL  , ALLOCATABLE ::   jvalues(:,:,:)
#else
      REAL*8 ::   FRACO3(IIPAR,JJPAR,LLPAR)
      REAL*8 ::   SAVEOH(IIPAR,JJPAR,LLPAR)
      REAL*8 ::   FRACNO(IIPAR,JJPAR,LLPAR)
      REAL*8 ::   SAVENO(IIPAR,JJPAR,LLPAR)
      REAL*8 ::   SAVENO2(IIPAR,JJPAR,LLPAR)
      REAL*8 ::   SAVENO3(IIPAR,JJPAR,LLPAR)
      REAL*8 ::   FRACNO2(IIPAR,JJPAR,LLPAR)
      REAL*8 ::   SAVEHO2(IIPAR,JJPAR,LLPAR)
      REAL   ::   jvalues(IIPAR,JJPAR,2)
#endif
      REAL*4 ::   fracnox(4,4,4,12,12,4,5)
      REAL*4 ::   intope(4,4,4,12,12,4,5)
```

REMARKS:

```
   NOTE: Now NEMPARA = max no. of anthropogenic emissions
```

```
            NEMPARB = max no. of biogenic emissions

   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
   %%%  NOTE: THIS MODULE IS NOW DEPRECATED.  IT WILL BE REMOVED WHEN  %%%
   %%%  THE GEOS-CHEM EMISSIONS MODULE IS UPDATED (SOMETIME SOON)      %%%
   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
   23 Aug 2011 - M. Long   - Converted to Module from Header file
```

1.9 Fortran: Module Interface CMN_mod.F

Module CMN is the remnant of header file "CMN", which once held many global variables, but now is reduced to only a couple.

INTERFACE:

```
      MODULE CMN_MOD
```

USES:

```
      USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR

      IMPLICIT NONE
      PUBLIC
```

PUBLIC DATA MEMBERS:

```
      ! LPAUSE  stores the annual mean tropopause (bmy, 12/6/99)
#if defined( DEVEL )
      INTEGER, ALLOCATABLE :: LPAUSE(:,:)
#else
      INTEGER :: LPAUSE(IIPAR,JJPAR)
#endif

      ! IFLX stores the flags for ND27 diagnostic (bmy, 12/6/99)
      ! This is mostly obsolete by now (bmy, 8/24/11)
#if defined( DEVEL )
      INTEGER, ALLOCATABLE :: IFLX(:,:)
#else
      INTEGER :: IFLX(IIPAR,JJPAR)
#endif
```

REMARKS:

```
   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
   %%% NOTE: THIS MODULE IS DEPRECATED.  IT WILL BE REMOVED IN THE FUTURE  %%%
   %%% COMBINE THESE ARRAYS INTO ANOTHER MODULE FILE.  FOR NOW, KEEP IT.   %%%
   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
23 Aug 2011 - M. Long   - Converted to Module from Header file
```

1.10 Fortran: Module Interface cmn_fj_mod

Module cmn_fj_mod contains parameters and global variables used to interface between Harvard chemistry and UC-Irvine Fast-J photolysis programs.

INTERFACE:

```
      MODULE CMN_FJ_MOD
```

USES:

```
      USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR, LLPAR

      IMPLICIT NONE
      PUBLIC
```

DEFINED PARAMETERS:

```
      ! Global array sizes in longitude, latitude, altitude
#if defined( DEVEL )
       INTEGER :: IPAR
       INTEGER :: JPAR
       INTEGER :: LPAR
#else
      INTEGER, PARAMETER :: IPAR = IIPAR
      INTEGER, PARAMETER :: JPAR = JJPAR
      INTEGER, PARAMETER :: LPAR = LLPAR
#endif

      ! max # of photolysis rxns = 4 + IPHOT (see comode.h)
      ! FP increased JPMAX since IPHOT was increased (hotp 7/31/09)
      !INTEGER, PARAMETER :: JPMAX = 79
      INTEGER, PARAMETER :: JPMAX = 89
```

PUBLIC DATA MEMBERS:

```
      ! Variables for number of layers and number of photolysis rxns
      INTEGER            :: JPNL, JPPJ

      ! Branches for photolysis species
      INTEGER            :: BRANCH(JPMAX)

      ! Names of photolysis species
      ! FP increased length of RNAMES for species indistinguishable
      ! with only 4 characters (hotp 7/31/09)
```

```
      ! used in jv_index and rd_js.f
      !CHARACTER (LEN=4)  :: RNAMES
      CHARACTER (LEN=7)  :: RNAMES(JPMAX)

      ! Mapping array from Harvard species names to UCI species names
      INTEGER            :: RINDEX(JPMAX)

      ! Output J-values
#if defined( DEVEL )
      REAL*8, ALLOCATABLE :: ZPJ(:,:,:,:)
#else
      REAL*8             :: ZPJ(LPAR,JPMAX,IPAR,JPAR)
#endif
```

REMARKS:

```
Based on code from Oliver Wild (9 Jul 1999)
```

REVISION HISTORY:

```
(1 ) Uses Fortran 90 declarations for parameters and variables
(2 ) Pass CTM size parameters and preprocessor switches via CMN_SIZE.
(3 ) Update JPMAX for new chemistry mechanism (amf, bmy, 4/20/00)
(4 ) Return JPMAX to original setting (bmy, 9/25/00)
(5 ) Return JPMAX to 55 for peroxy recycling (again) (bmy, 12/20/00)
(6 ) Now need to use the window parameters IIPAR,JJPAR,LLPAR (bmy, 9/25/01)
(7 ) Changed RCS ID tag comment character from "C" to "!" to allow freeform
      compilation. (bmy, 6/25/02)
(8 ) Replaced ESIG array with ETAA and ETAB arrays for the hybrid
      pressure formulation.  Also deleted PREST, since we don't need that
      anymore. (bmy, 8/23/02)
(9 ) Removed ETAA and ETAB arrays.  We now compute PJ directly from the
      GET_PEDGE routine. (bmy, 10/30/07)
(10) Increase photolysis rxns JPMAX = 79 (tmf, 1/7/09)
(11) Increase photolysis rxns JPMAX = 89 for Isoprene (fp, 2/2/10)
(12) Increase species name length. (fp, 2/2/10)
23 Aug 2011 - M. Long   - Converted to Module from Header file
```

1.11 Fortran: Module Interface commsoil_mod

Module commsoil_mod contains global variables for the soil NOx emissions routines.

INTERFACE:

```
      MODULE COMMSOIL_MOD
```

USES:

```
      USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR, MAXIJ, NTYPE, NVEGTYPE

      IMPLICIT NONE
      PUBLIC

#     include "define.h"
```

DEFINED PARAMETERS:

```
      ! The defined soil types
      INTEGER, PARAMETER :: NSOIL = 11

      ! Number of soil pulsing types
      INTEGER, PARAMETER :: NPULSE = 3

#if   defined( GRID4x5  )

      ! There are 1118 land boxes for the 4 x 5 GLOBAL GRID
      INTEGER, PARAMETER :: NLAND = 1118

#elif defined( GRID2x25 )

      ! There are 3920 land boxes for the 2 x 2.5 GLOBAL GRID
      INTEGER, PARAMETER :: NLAND = 3920

#elif defined( GRID1x125 )

      !%%% NOTE: still to be determined
      INTEGER, PARAMETER :: NLAND = 9999

#elif defined( GRID1x1 ) && defined( NESTED_CH )

      ! There are 2861 land points for the 1x1 CHINA nested grid
      INTEGER, PARAMETER :: NLAND = 2861

#elif defined( GRID1x1 ) && defined( NESTED_NA )

      ! There are 2118  land points for the 1x1 N. AMERICA nested grid
      INTEGER, PARAMETER :: NLAND = 2118

#elif defined( GRID1x1 )

      ! There are 17174 land points for the 1x1 GLOBAL grid
      INTEGER, PARAMETER :: NLAND=17174

#elif defined( GRID05x0666 ) && defined( NESTED_CH )

      ! There are 8261 land points for the 0.5 x 0.666 CHINA nested grid
      INTEGER, PARAMETER :: NLAND = 8261
```

```
#elif defined( GRID05x0666 ) && defined( NESTED_NA )

      !%%% NOTE: still to be determined
      INTEGER, PARAMETER :: NLAND = 8568

#elif defined( GRID05x0666 ) && defined( NESTED_EU )

      !%%% NOTE: still to be determined
      INTEGER, PARAMETER :: NLAND = 5536

#elif defined( GRID025x03125 ) && defined( NESTED_CH )

      !%%% NOTE: still to be determined, use fudge factor for now
      INTEGER, PARAMETER :: NLAND = 5536

#elif defined( GRID025x03125 ) && defined( SEAC4RS )

      !%%% NOTE: still to be determined, use fudge factor for now
      INTEGER, PARAMETER :: NLAND = 5536

#if defined( DEVEL )
#elif defined( EXTERNAL_GRID )

      !%%% NOTE: still to be determined!!!
      INTEGER, PARAMETER :: NLAND = 5536
#endif
#endif
```

PUBLIC DATA MEMBERS:

```
      ! Land types:
      ! water/desert/ice//Trop. Rain. Forst.//conifers//dry deciduous//
      ! other deciduous//woodland//grassland//agriculture (other than rice)
      ! rice paddies//wetland/tundra

      ! i,j of the grid
      INTEGER :: INDEXSOIL(2,NLAND)

      ! Tracking of wet/dry & three types of pulsing (Y&L, 94)
      REAL*8  :: SOILPULS(NPULSE+1,NLAND)

      ! Two month observed precip
      REAL*8  :: SOILPREP(2,NLAND)

      ! Fertilizers
      REAL*8  :: SOILFERT(NLAND)

      ! Pulsing factors
```

```
      REAL*8  :: PULSFACT(NPULSE)

      ! Pulsing decay per timestep
      REAL*8  :: PULSDECAY(NPULSE)

      ! Stores output
#if defined( DEVEL )
      REAL*8, ALLOCATABLE  :: SOILNOX(:,:)
#else
      REAL*8  :: SOILNOX(IIPAR,JJPAR)
#endif

      ! Olson->soil type,nvegtype in commbio.h
      INTEGER :: NCONSOIL(NVEGTYPE)

      ! Track NOx within canopy dry dep.
#if defined( DEVEL )
      REAL*8, ALLOCATABLE  :: CANOPYNOX(:,:)
#else
      REAL*8  :: CANOPYNOX(MAXIJ,NTYPE)
#endif

      ! Canopy wind extinction coeff from Y&L
      REAL*8  :: SOILTA(NSOIL)
      REAL*8  :: SOILTB(NSOIL)
      REAL*8  :: SOILAW(NSOIL)
      REAL*8  :: SOILAD(NSOIL)
      REAL*8  :: SOILEXC(NSOIL)

      ! The correct sequence of PULSFACT is 5, 10, 15
      DATA PULSFACT  / 5.D0,    10.D0,   15.D0   /

      ! PULSDECAY now contains the correct decay factors from Yienger & Levy
      DATA PULSDECAY / 0.805D0, 0.384D0, 0.208D0 /

      ! SOILTA = Coefficient used to convert from surface temperture to
      !          soil temperature
      DATA SOILTA /0.D0,   0.84D0, 0.84D0, 0.84D0, 0.84D0,
     &             0.66D0, 0.66D0, 1.03D0, 1.03D0, 0.92D0,
     &             0.66D0/

      ! SOILTB = Coefficient used to convert from surface temperture to
      !          soil temperature
      DATA SOILTB /0.D0,   3.6D0,  3.6D0,  3.6D0,  3.6D0,
     &             8.8D0,  8.8D0,  2.9D0,  2.9D0,  4.4D0,
     &             8.8D0/

      ! SOILAW = Wet biome coefficient
```

```
      DATA SOILAW /0.D0,   2.6D0,  0.03D0, 0.06D0, 0.03D0,
     &             0.17D0, 0.36D0, 0.36D0, 0.36D0, 0.003D0,
     &             0.05D0/

      ! SOILAD = Dry biome coefficient
      DATA SOILAD /0.D0,   8.6D0,  0.22D0, 0.40D0, 0.22D0,
     &             1.44D0, 2.65D0, 2.65D0, 2.65D0, 0.003D0,
     &             0.37D0/

      ! SOILEXC = Canopy wind extinction coeff.
      DATA SOILEXC /0.1D0, 4.D0,   4.D0,   4.D0,   4.D0,
     &              2.D0,  1.D0,   2.D0,   2.D0,   0.5D0,
     &              0.1D0/
```

REMARKS:

```
Original code from:
  HARVARD ATMOSPHERIC CHEMISTRY MODELING GROUP
  MODULE FOR SOIL NOx EMISSIONS
  by Yuhang Wang, Gerry Gardner and Prof. Daniel Jacob
  (Release V2.1)

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: THIS MODULE IS DEPRECATED!  IT WILL BE REMOVED WHEN WE  %%%
%%%  REPLACE THE SOIL NOX EMISSIONS ALGORITHM (IN THE NEAR FUTURE  %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
!
```

REVISION HISTORY:

```
(1 ) Be sure to force double precision with the DBLE function
     and the "D" exponent, wherever necessary (bmy, 10/6/99)
(2 ) Changed RCS ID tag comment character from "C" to "!" to allow
     freeform compilation.  Also added & continuation characters in
     column 73 to allow header files to be included in F90 freeform
     files. Updated comments, cosmetic changes. (bmy, 6/25/02)
(3 ) Now use cpp switches to define 1x1 parameters.  Also added
     space in the #ifdef block for the 1x125 grid (bmy, 12/1/04)
(4 ) Bug fix: 2681 should be 2861 in NLAND (bmy, 9/22/06)
(5 ) Set # of land boxes for GEOS-5 nested grids (yxw, dan, bmy, 11/6/08)
(6 ) Set # of land boxes for GEOS-5 EUROPE nested grid (amv, 10/19/09)
23 Aug 2011 - M. Long   - Converted to Module from Header file
```

1.12 Fortran: Module Interface comode_loop_mod

Module file COMODE contains common blocks and variables for SMVGEAR II.

INTERFACE:

```
      MODULE COMODE_LOOP_MOD
```

USES:

```
      USE CMN_SIZE_MOD

      IMPLICIT NONE
      PUBLIC
```

REMARKS:

```
          CCCCCCC  OOOOOOO  M     M  OOOOOOO  DDDDDD   EEEEEEE
          C        O     O  M M M M  O     O  D     D  E
          C        O     O  M  M  M  O     O  D     D  EEEEEEE
          C        O     O  M     M  O     O  D     D  E
          CCCCCCC  OOOOOOO  M     M  OOOOOOO  DDDDDD   EEEEEEE
```

```
C=======================================================================
C THIS IS THE COMMON BLOCK FOR "SMVGEAR" AND "MIE," TWO ORDINARY    C
C DIFFERENTIAL EQUATION SOLVERS. THE REFERENCE FOR THE CODES IS     C
C                                                                   C
C   JACOBSON M. Z. AND TURCO R. P. (1993) SMVGEAER: A SPARSE-       C
C    MATRIX, VECTORIZED GEAR CODE FOR ATMOSPHERIC MODELS.           C
C    SUBMITTED TO ATMOSPHERIC ENVIRONMENT, PART A. MAY 20, 1993     C
C                                                                   C
C COMODE.H SETS PARAMETER VALUES AND SERVES AS A COMMON BLOCK FOR   C
C ALL DIMENSIONED AND NON-DIMENSIONED VARIABLES. COMODE.H ALSO      C
C DEFINES EACH PARAMETER, BUT DATA FILE DEFINE.DAT EXPLAINS NON-    C
C DIMENSIONED VARIABLES. INDIVIDUAL SUBROUTINES DEFINE DIMENSIONED  C
C VARIABLES.                                                        C
C=======================================================================

C=======================================================================
C                       SET PARAMETERS                              C
C=======================================================================

C****************** COORDINATE-SYSTEM PARAMETERS *********************
C ILAT     = MAXIMUM NUMBER OF LATITUDE(ILAT)   GRID POINTS
C ILONG    = MAXIMUM NUMBER OF LONGITUDE(ILONG) GRID POINTS
C IMLOOP   = ILAT * ILONG - USED FOR MORE EFFICIENT ARRAYS
C IVERT    = MAXIMUM NUMBER OF LAYERS
C ILAYER   = MAXIMUM OF LAYER BOUNDARIES
C KBLOOP   = MAXIMUM NUMBER OF GRID POINTS IN A VECTORIZED BLOCK
C            SHOULD RANGE FROM 512 (BELOW WHICH VECTORIZATION DECREASES)
C            TO 1024 (ABOVE WHICH, ARRAY SPACE IS LIMITED)
C MXBLOCK  = MAXIMUM NUMBER OF GRID POINT BLOCKS
C MAXDAYS  = MAXIMUM NUMBER OF DAYS FOR THE MODEL TO RUN
```

REVISION HISTORY:

```
(M. Jacobson 1997; bdf, bmy, 4/23/03, 6/1/06)
(1 ) Removed many commented-out common blocks not needed for GEOS-CHEM.
     Also updated comments.  Also make sure that MAXGL3 is dimensioned
     for at least NNPAR tracers.  Add NNADDG and NKSPECG for DMS+OH+O2
     rxn.  COEF12 and QRM2 are now obsolete for SMVGEAR II. (bmy, 4/23/03)
(2 ) Added ICH4 to the /SPECIE2/ common block for interannual-varying
     CH4 concentration.  Added variables for latitude distribution of
     CH4 to the /SPECIE3/ common block. (bmy, 7/1/03)
(3 ) Added ITS_NOT_A_ND65_FAMILY to the /LPL/ common block for the ND65
     production/loss diagnostic.   Comment out counter variables, you can
     get the same info w/ a profiling run.  Updated comments, cosmetic
     changes. (bmy, 7/9/03)
(4 ) Removed the following variables from common blocks which are not needed
     for GEOS-CHEM: COLENG, AERSURF, VHMET1, VHMET, VMET3, CINIT, RHO3,
     GRIDVH, CSUMA1, XELRAT, T1BEG, T2BEG, T1FIN, T2FIN, DECLIN, RAGSUT,
     SINDEC, COSDEC, SIGMAL, PRESSL, RHOA, DSIG_SMV, TEMPL, VMET, SIGDIF,
     TMORN, PRESSC, XLAT, XLON, DMERIDUT, GRIDAREA, DSX, XLONUT, DSY,
     SINXLAT, COSXLAT, HMETT, HMET1, HMET2, RSET, RRIS, TZDIF, ZENRAT0,
     ZENRAT1, MLOPJ, REORDER_SAVE, RHO3K, GRIDVH3K, FIELDXY, FIELDYZ,
     FIELDXZ, RATMIX, GQSCHEM, C, QPRODA, QPRODB, QPRODC, QPRODD, QPROD,
     CINP, NUMSDT, NKSDT, PRATE.  MONTHP, KYEAR, LDMONTH, ININT, ICLO,
     JCLO, FIELD1, MZLO, MZLO2, MZHI0, MZHI1, KZLO1, KZLO2, KZHI0, KZHI1,
     IHIZ1, IHIZ2, IHIZ3, PRESS5KM, KGRP, IABOVK, MROTAT1, MINROT1,
     NUMSUBS, LSPECEMIS, MROTAT2, MINROT2, MAXPOS, NOGAINR, NOLOSSR,
     MAXSTEPS, YLOW, HMAXDAY, KPHT, KRDD, KMIX, KINS, KGCO, ABHSUMK, DX0,
     DY0, XU0, DTOUT, CONPSUR, DXLONG, DYLAT, SWLONDC, CONSTIM, SWLATDC,
     UTSECY, TOTSEC, FINHOUR, FINMIN, FINSEC, TFROMID, ZENFIXED, ZENITH,
     DENCONS, HALFDAY, GRAVC, FOURPI, TWOPI, REARTH, RPRIMB, AVOG1,
     HALF, THIRD, THRPI2, PID180, PID2, SCTWOPI, AMRGAS, TWPISC.
     This should free up more memory for runs. (bmy, 7/16/03)
(5 ) Split off NOCC into the /CHEM3B/ common block, since it doesn't need
     to be held THREADPRIVATE.  Removed /DKBLOOP/ and /DKBLOOP5/, since
     these contain variables which are used locally within either
     "calcrate.f" or "smvgear.f".  Cosmetic changes. (bmy, 7/28/03)
(6 ) Add NKN2O5 to /CHEM4/ common block to flag N2O5 hydrolysis rxn.
      (mje, bmy, 8/7/03)
(7 ) Eliminated SMALLCHEM cpp switch (bmy, 12/2/03)
(8 ) Now set MAXGL3 = NNPAR for new # of tracers (bmy, 4/6/04)
(9 ) Remove obsolete LGEOSCO and FULLCHEM Cpp switches (bmy, 6/24/05)
(10) For COMPAQ, put IRMA, IRMB in /INMTRATE2/ common block.  For COMPAQ,
     also declare /INMTRATE2/ THREADPRIVATE. (Q. Liang, bmy, 10/17/05)
(11) Now remove AVG, BOLTG, RGAS, SCDAY, BK, EIGHTDPI, RSTARG, WTAIR,
     ONEPI, CONSVAP, SMAL1, SMAL2, SMAL3 from common blocks and declare
     these as parameters. (bec, bmy, 3/29/06)
(12) Added ILISOPOH, the index of ISOP lost to OH (dkh, bmy, 6/1/06)
(13) Added NKHO2 to /CHEM4/ common block to flag HO2 aerosol uptake
     (jaegle 02/26/09)
(14) Add NNADDF and NNADDH to /CHEM4/ for HOC2H4O rxns
```

```
        Add NKHOROI and NKHOROJ to /CHEM4/ for HOC2H4O rxns in EP photolysis
        (tmf, 3/6/09)
   (15) Added NKSPECF, NKSPECH to /IDICS/ for C2H4 chemistry (tmf, 3/6/09)
   (16) Increase IGAS, MAXGL, MAXGL2, NMRATE, IPHOT (tmf, 3/6/09)
   (17) Add RRATE_FOR_KPP variable to DKBLOOP2 common block (phs,ks,dhk, 09/15/09)
   (18) PINP(20) increased to PINP(IMISC) (FP 2/10)
```

REVISION HISTORY:

```
   23 Aug 2011 - M. Long   - Converted to Module from Header file
```

1.13 Fortran: Module Interface jv_cmn_mod

Module jv_cmn_mod contains global variables (formerly in common blocks) for the FAST-J code (cf. Wild/Prather 7/99).

INTERFACE:

```
      MODULE JV_CMN_MOD
```

USES:

```
#if defined( DEVEL )
      USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR, LLPAR
#else
      USE CMN_FJ_MOD,   ONLY : LPAR, IPAR, JPAR
#endif
      USE CMN_SIZE_MOD, ONLY : NDUST, NAER, NRH
      USE CMN_FJ_MOD,   ONLY : JPMAX
      USE SMV_DIMENSION_MOD, ONLY : MAX_COLUMN

      IMPLICIT NONE
      PUBLIC
  !DEFINED PARAMETERS
      ! NB  Number of levels in CTM plus one for above model top
      ! NC  Number of levels in the fundamental Fast-J grid
      ! NS  Maximum number of species which require J-values calculating
      ! NW  Maximum number of wavelength bins that can be used
      ! NP  Maximum number of aerosol/cloud types that can be used
      ! MX  Number of aerosol/cloud types supplied from CTM
#if defined( DEVEL )
      INTEGER, PARAMETER :: NB      = MAX_COLUMN+1
#else
      INTEGER, PARAMETER :: NB      = LPAR+1
#endif
      INTEGER, PARAMETER :: NC      = 2*NB
      INTEGER, PARAMETER :: NS      = 51
      INTEGER, PARAMETER :: NW      = 15
```

```
      INTEGER, PARAMETER :: NP      = 56
      INTEGER, PARAMETER :: MX      = 35

      REAL*8,  PARAMETER :: RAD     = 6375.d5
      REAL*8,  PARAMETER :: ZZHT    = 5.d5
      REAL*8,  PARAMETER :: dtaumax = 1.d0
      REAL*8,  PARAMETER :: dtausub = 1.d0
      REAL*8,  PARAMETER :: dsubdiv = 10.d0
      REAL*8,  PARAMETER :: szamax  = 98.0d0
```

PUBLIC DATA MEMBERS:

```
      ! Character variables
      CHARACTER*20 TITLEA(NP)
      CHARACTER*78 TITLE0
      CHARACTER*7  TITLEJ(3,NS), jlabel(JPMAX)

      !-----------------------------------------------------------------------
      ! These common blocks MUST NOT be held local (bmy, 5/2/00)

      REAL*8  :: WBIN(NW+1),WL(NW),FL(NW),QO2(NW,3),QO3(NW,3)
      REAL*8  :: Q1D(NW,3),QQQ(NW,2,NS-3),QRAYL(NW),TQQ(3,NS)
      REAL*8  :: WAA(4,NP),QAA(4,NP)
      REAL*8  :: PAA(8,4,NP),RAA(4,NP),SSA(4,NP),QBC(NW)

      INTEGER :: NJVAL,NW1,NW2,NAA,NLBATM

      REAL*8  :: WAA_AOD(NP),QAA_AOD(NP),PAA_AOD(8,NP)
      REAL*8  :: RAA_AOD(NP),SSA_AOD(NP)

      REAL*8  :: TREF(51,18,12),OREF(51,18,12),BREF(51)
#if defined( DEVEL )
      REAL*8, ALLOCATABLE  :: ODMDUST(:,:,:,:)
      REAL*8, ALLOCATABLE  :: ODAER(:,:,:,:)
#else
      REAL*8  :: ODMDUST(IPAR,JPAR,LPAR,NDUST)
      REAL*8  :: ODAER(IPAR,JPAR,LPAR,NAER*NRH)
#endif

      REAL*8  :: jfacta(JPMAX),zpdep(NW,7)
      INTEGER :: npdep,jpdep(NS),jind(JPMAX)

      INTEGER :: MIEDX(MX)

      !-----------------------------------------------------------------------
      ! Split off GLYX-chemistry specific arrays into separate common blocks
      ! (ccarouge, bmy, 8/20/09)
      INTEGER :: PDEPF(7)
```

```
      REAL*8  :: MGLYPDEP(NW, 3)

      !-----------------------------------------------------------------------
      ! These common blocks MUST be held local for the parallelization
      ! (bmy, 5/2/00)
      REAL*8   :: TJ(NB),PJ(NB+1),DM(NB),DO3(NB),DBC(NB),Z(NB)
      REAL*8   :: AER(MX,NB),AMF(NB,NB),RFLECT,SZA,U0,TANHT
      REAL*8   :: zj(NB,JPMAX)
      REAL*8   :: FFF(NW,NB),VALJ(NS)
      INTEGER  :: jadsub(NC)

$OMP THREADPRIVATE( TJ, PJ, DM, DO3, DBC, Z)
$OMP THREADPRIVATE( AER, AMF, RFLECT, SZA, U0, TANHT)
$OMP THREADPRIVATE( zj )
$OMP THREADPRIVATE( FFF, VALJ )
$OMP THREADPRIVATE( jadsub )
```

REMARKS:

```
    NOTES for CTM Interface (bmy, 10/27/99, 3/23/03)
    ================================================================
    (1) Change JPNL and JPPJ from parameters to variables, which are
        set in "inphot.f".  This allows the user to switch the number
        of levels at run-time via the CTM inputs.

                                                                      .
    (2) Now make RAD, ZZHT, DTAUMAX, DTAUSUB, DSUBDIV, SZAMAX into
        parameters instead of holding them in common blocks.

                                                                      .
    (3) Create new common blocks /WLLOC/ and /JVLOC/ to hold certain
        quantities -Xlocal for parallel code (ppm, 4/98, bmy, 9/21/99)

                                                                      .
    (4) The common blocks that must be held -Xlocal are:
           /ATMOS/, /JVSUB/, /WLLOC/, /JVLOC/

                                                                      .
    (4a) Declare the above commons THREADPRIVATE for the Compaq
         Alpha platform (bmy, 7/10/01)

                                                                      .
    (5) Break MIEDX off from the WLLOC common block, since it must
        not be declared LOCAL for the parallelization. (bmy, 5/2/00)

                                                                      .
    (6) For including aerosol optical depths: (rvm, bmy, 9/30/00)
        (a) Increase MX from 3 to 10 .
        (c) Add ODMDUST(IIPAR,JJPAR,LLPAR,NDUST) to common block /CLIM/

                                                                      .
    (7) Move NDUST to CMN_SIZE to avoid conflicts (bmy, 11/15/01)

                                                                      .
    (8) For updating aerosol optical depths again (rvm, bmy, 2/27/02):
        (a) Change NP from 21 to 56
```

```
      (b) Change MX from 10 to 35
      (c) Add ODAER(IIPAR,JJPAR,LLPAR,NAER*NRH) to common block /CLIM/
                                                                             .
  (9) Changed RCS ID tag comment character from "C" to "!" to allow freeform
       compilation.  Also added & continuation characters in column 73
       to allow header files to be included in F90 freeform files.
       Also changed comment character from "C" to "!" to allow this
       file to be inlined into freeform source code. (bmy, 6/25/02)
                                                                             .
  (10) Renamed cpp switch from DEC_COMPAQ to COMPAQ.  Also declare common
        blocks ATMOS, JVLOC, WLLOC, JVSUB as !$OMP THREADPRIVATE for
        all platforms. (bmy, 3/23/03)
                                                                             .
  (11) Added new pressure denpendencies algorithm parameters
         for MGLY. (tmf, 1/7/09)
                                                                             .
  (12) Added 'pdepf' as pressure dependancy function selector. (tmf, 1/31/06)
                                                                             .
  (13) Split off PDEPF and MGLYPDEP into separate common blocks to avoid
        warnings on IFORT 9 (ccarouge, bmy, 8/20/09)
                                                                             .
  (14) Add new optical variables for AOD calculation (clh, 05/06/10)
```

REVISION HISTORY:

```
  23 Aug 2011 - M. Long   - Converted to Module from Header file
```

1.14 Fortran: Module Interface jv_cmn_mod

Module jv_cmn_mod contains global variables (formerly in common blocks) for the FAST-J code (cf. Wild/Prather 7/99).

INTERFACE:

```
      MODULE JV_CMN_MOD
```

USES:

```
      USE CMN_SIZE_MOD, ONLY : NDUST, NAER, NRH
      USE CMN_FJ_MOD,   ONLY : JPMAX, LPAR, IPAR, JPAR

      IMPLICIT NONE
      PUBLIC
  !DEFINED PARAMETERS
      ! NB  Number of levels in CTM plus one for above model top
      ! NC  Number of levels in the fundamental Fast-J grid
      ! NS  Maximum number of species which require J-values calculating
      ! NW  Maximum number of wavelength bins that can be used
```

```
! NP  Maximum number of aerosol/cloud types that can be used
! MX  Number of aerosol/cloud types supplied from CTM
INTEGER, PARAMETER :: NB      = LPAR+1
INTEGER, PARAMETER :: NC      = 2*NB
INTEGER, PARAMETER :: NS      = 51
INTEGER, PARAMETER :: NW      = 15
INTEGER, PARAMETER :: NP      = 56
INTEGER, PARAMETER :: MX      = 35

REAL*8,  PARAMETER :: RAD     = 6375.d5
REAL*8,  PARAMETER :: ZZHT    = 5.d5
REAL*8,  PARAMETER :: dtaumax = 1.d0
REAL*8,  PARAMETER :: dtausub = 1.d0
REAL*8,  PARAMETER :: dsubdiv = 10.d0
REAL*8,  PARAMETER :: szamax  = 98.0d0
```

PUBLIC DATA MEMBERS:

```
! Character variables
CHARACTER*20 TITLEA(NP)
CHARACTER*78 TITLE0
CHARACTER*7  TITLEJ(3,NS), jlabel(JPMAX)

!-----------------------------------------------------------------------
! These common blocks MUST NOT be held local (bmy, 5/2/00)

REAL*8  :: WBIN(NW+1),WL(NW),FL(NW),QO2(NW,3),QO3(NW,3)
REAL*8  :: Q1D(NW,3),QQQ(NW,2,NS-3),QRAYL(NW),TQQ(3,NS)
REAL*8  :: WAA(4,NP),QAA(4,NP)
REAL*8  :: PAA(8,4,NP),RAA(4,NP),SSA(4,NP),QBC(NW)

INTEGER :: NJVAL,NW1,NW2,NAA,NLBATM

REAL*8  :: WAA_AOD(NP),QAA_AOD(NP),PAA_AOD(8,NP)
REAL*8  :: RAA_AOD(NP),SSA_AOD(NP)

REAL*8  :: TREF(51,18,12),OREF(51,18,12),BREF(51)
REAL*8  :: ODMDUST(IPAR,JPAR,LPAR,NDUST)
REAL*8  :: ODAER(IPAR,JPAR,LPAR,NAER*NRH)

REAL*8  :: jfacta(JPMAX),zpdep(NW,7)
INTEGER :: npdep,jpdep(NS),jind(JPMAX)

INTEGER :: MIEDX(MX)

!-----------------------------------------------------------------------
! Split off GLYX-chemistry specific arrays into separate common blocks
! (ccarouge, bmy, 8/20/09)
INTEGER :: PDEPF(7)
```

```
      REAL*8  :: MGLYPDEP(NW, 3)

      !-----------------------------------------------------------------------
      ! These common blocks MUST be held local for the parallelization
      ! (bmy, 5/2/00)
      REAL*8   :: TJ(NB),PJ(NB+1),DM(NB),DO3(NB),DBC(NB),Z(NB)
      REAL*8   :: AER(MX,NB),AMF(NB,NB),RFLECT,SZA,U0,TANHT
      REAL*8   :: zj(LPAR,JPMAX)
      REAL*8   :: FFF(NW,lpar),VALJ(NS)
      INTEGER  :: jadsub(NC)

$OMP THREADPRIVATE( TJ, PJ, DM, DO3, DBC, Z)
$OMP THREADPRIVATE( AER, AMF, RFLECT, SZA, U0, TANHT)
$OMP THREADPRIVATE( zj )
$OMP THREADPRIVATE( FFF, VALJ )
$OMP THREADPRIVATE( jadsub )
```

REMARKS:

```
    NOTES for CTM Interface (bmy, 10/27/99, 3/23/03)
    ================================================================
    (1) Change JPNL and JPPJ from parameters to variables, which are
        set in "inphot.f".  This allows the user to switch the number
        of levels at run-time via the CTM inputs.

                                                                      .
    (2) Now make RAD, ZZHT, DTAUMAX, DTAUSUB, DSUBDIV, SZAMAX into
        parameters instead of holding them in common blocks.

                                                                      .
    (3) Create new common blocks /WLLOC/ and /JVLOC/ to hold certain
        quantities -Xlocal for parallel code (ppm, 4/98, bmy, 9/21/99)

                                                                      .
    (4) The common blocks that must be held -Xlocal are:
           /ATMOS/, /JVSUB/, /WLLOC/, /JVLOC/

                                                                      .
    (4a) Declare the above commons THREADPRIVATE for the Compaq
         Alpha platform (bmy, 7/10/01)

                                                                      .
    (5) Break MIEDX off from the WLLOC common block, since it must
        not be declared LOCAL for the parallelization. (bmy, 5/2/00)

                                                                      .
    (6) For including aerosol optical depths: (rvm, bmy, 9/30/00)
        (a) Increase MX from 3 to 10 .
        (c) Add ODMDUST(IPAR,JPAR,LPAR,NDUST) to common block /CLIM/

                                                                      .
    (7) Move NDUST to CMN_SIZE to avoid conflicts (bmy, 11/15/01)

                                                                      .
    (8) For updating aerosol optical depths again (rvm, bmy, 2/27/02):
```

```
        (a) Change NP from 21 to 56
        (b) Change MX from 10 to 35
        (c) Add ODAER(IPAR,JPAR,LPAR,NAER*NRH) to common block /CLIM/
                                                                             .
    (9) Changed RCS ID tag comment character from "C" to "!" to allow freeform
        compilation.  Also added & continuation characters in column 73
        to allow header files to be included in F90 freeform files.
        Also changed comment character from "C" to "!" to allow this
        file to be inlined into freeform source code. (bmy, 6/25/02)
                                                                             .
    (10) Renamed cpp switch from DEC_COMPAQ to COMPAQ.  Also declare common
         blocks ATMOS, JVLOC, WLLOC, JVSUB as !$OMP THREADPRIVATE for
         all platforms. (bmy, 3/23/03)
                                                                             .
    (11) Added new pressure denpendencies algorithm parameters
          for MGLY. (tmf, 1/7/09)
                                                                             .
    (12) Added 'pdepf' as pressure dependancy function selector. (tmf, 1/31/06)
                                                                             .
    (13) Split off PDEPF and MGLYPDEP into separate common blocks to avoid
         warnings on IFORT 9 (ccarouge, bmy, 8/20/09)
                                                                             .
    (14) Add new optical variables for AOD calculation (clh, 05/06/10)
```

REVISION HISTORY:

```
    23 Aug 2011 - M. Long   - Converted to Module from Header file
```

1.15 Fortran: Module Interface jv_mie_mod.F

This include file contains physical constants for the GEOS-Chem column chemistry code.

INTERFACE:

```
      MODULE JV_MIE_MOD
```

USES:

```
      IMPLICIT NONE
      PUBLIC
```

DEFINED PARAMETERS:

```
      ! NL    Maximum number of levels after insertion of extra Mie levels
      ! N__   Number of levels in Mie grid: 2*(2*lpar+2+jaddto(1))+3
      ! M__   Number of Gauss points used
  ------------------------------------------------------------------------
      NL=1500 was too small for dicarbonyls, so we upped it to 2000.
      Uncomment this line to restore the previous definition (phs, 10/9/09)
```

```
       INTEGER, PARAMETER :: NL  = 1500
 -----------------------------------------------------------------------
      INTEGER, PARAMETER :: NL  = 2000
      INTEGER, PARAMETER :: N__ = 2*NL
      INTEGER, PARAMETER :: M__ = 4
```

PUBLIC DATA MEMBERS:

```
      ! Arrays
      REAL*8  :: A(M__),           B(M__,M__),   C1(M__)
      REAL*8  :: H(M__),           AA(M__,M__),  CC(M__,M__)
      REAL*8  :: S(M__,M__),       W(M__,M__),   U1(M__,M__)
      REAL*8  :: V1(M__),          WT(M__),      EMU(M__)
      REAL*8  :: PM(M__,2*M__),    PM0(2*M__),   POMEGA(2*M__,N__)
      REAL*8  :: ZTAU(N__),        FZ(N__),      FJ(N__)
      REAL*8  :: DD(M__,M__,N__),  RR(M__,N__)
      REAL*8  :: ZREFL,            ZFLUX

      ! Scalars
      REAL*8  :: RADIUS,           ZU0
      INTEGER :: ND,               N
      INTEGER :: M,                MFIT

      !=================================================================
      ! Declare the following global variables as THREADPRIVATE for the
      ! OpenMP parallelization on all platforms (bmy, 3/23/03)
      !=================================================================
$OMP THREADPRIVATE( A,B,C1,H,AA,CC,S,W,U1,V1,WT,EMU,PM,PM0,POMEGA )
$OMP THREADPRIVATE( ZTAU,FZ,FJ,DD,RR,ZREFL,ZFLUX,RADIUS,ZU0 )
$OMP THREADPRIVATE( ND,N,M,MFIT )
```

REMARKS:

```
   Keep increasing NL if necessary.  This will avoid the "too many levels
   in photolysis" error.
```

REVISION HISTORY:

```
   (1 ) Changed RCS ID tags to by adding a ! comment character to allow
        freeform compilation.  Also added & continuation characters in
        column 73 to allow header files to be included in F90 freeform files.
        Also changed comment character from "C" to "!", to allow this
        file to be inlined into freeform source code. (bmy, 6/25/02)
   (2 ) Now declare common blocks /MIEBLK/ and /MINDEX/ as THREADPRIVATE for
        all platforms (bmy, 3/23/03)
   (3 ) Set NL to 1000 to avoid SMVGEAR crash with GEOS-5.2.0 on Sept 1st 2008
   03 Aug 2011 - M. Long     - Converted from Header file to Module
```

1.16 Fortran: Module Interface smv_dimension_mod.F

This include file contains the various placeholder parameters that are required to replace references to GEOS-Chem grid parameters. This is necessary because several quantities in the FAST-J and SMVGEAR codes are contained in common blocks, and we need to have these parameters for sizing those arrays properly.

INTERFACE:

```
MODULE SMV_DIMENSION_MOD
```

USES:

```
IMPLICIT NONE
PUBLIC
```

DEFINED PARAMETERS:

```
! Locally defined replacement for GEOS-Chem parameter "LLPAR"
!INTEGER, PARAMETER :: MAX_COLUMN  = 72    ! Full GEOS-5 vertical grid
INTEGER, PARAMETER :: MAX_COLUMN  = 47    ! Reduced GEOS-5 vertical grid

! Locally defined replacement for GEOS-Chem parameter "NNPAR"
INTEGER, PARAMETER :: MAX_TRACERS = 100

! Locally defined replacement for "comode.h" parameter "IGAS"
INTEGER, PARAMETER :: MAX_SPECIES = 125
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: THIS MODULE WAS ORIGINALLY DEVELOPED FOR THE COLUMN CODE.  %%%
%%%  THE PARAMETERS HERE CAN BE COMBINED INTO A SINGLE MODULE WITH    %%%
%%%  DECLARED SIZE PARAMETERS (IN THE NEAR FUTURE).                   %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
24 Mar 2009 - R. Yantosca - Initial version
16 Apr 2010 - R. Yantosca - Added MAX_SPECIES = 125
03 Aug 2011 - M. Long     - Converted from Header file to Module
```

1.17 Fortran: Module Interface smv_errcode_mod.F

This include file contains the various success or failure parameters for the GEOS-Chem column chemistry code.

INTERFACE:

```
MODULE SMV_ERRCODE_MOD
```

USES:

```
IMPLICIT NONE
PUBLIC
```

DEFINED PARAMETERS:

```
! Return w/ success
INTEGER, PARAMETER :: SMV_SUCCESS =  0

! Return w/ failure
INTEGER, PARAMETER :: SMV_FAILURE = -1
```

REVISION HISTORY:

```
20 Mar 2009 - R. Yantosca - Initial version
15 Jul 2009 - R. Yantosca - Updated w/ error codes for drydep,
                            wetdep, and PBL mixing routines
03 Nov 2009 - R. Yantosca - Added error codes for column & interface
14 Dec 2009 - R. Yantosca - Added error code for unit conversion
01 Feb 2010 - R. Yantosca - Added error code for ISORROPIA ATE code
06 May 2010 - R. Yantosca - Deleted redundant error codes
03 Jun 2010 - R. Yantosca - Deleted error codes for SCHEM routines
03 Aug 2011 - M. Long     - Converted from Header file to Module
```

1.18 Fortran: Module Interface smv_physconst_mod.F

This include file contains physical constants for the GEOS-Chem column chemistry code.

INTERFACE:

```
MODULE SMV_PHYSCONST_MOD
```

USES:

```
IMPLICIT NONE
PUBLIC
```

DEFINED PARAMETERS:

```
! Molecular weight of air [28.97e-3 kg/mol]
REAL*8, PARAMETER :: MW_AIR       = 28.97d-3

! Avogadro's # [#/mol]
REAL*8, PARAMETER :: AVO          = 6.022d23

! g0    : Gravity at Surface of Earth [9.8 m/s^2]
REAL*8, PARAMETER :: g0           = 9.8d0

! PI    : Double-Precision value of PI
```

```
      REAL*8, PARAMETER :: PI           = 3.14159265358979323d0

      ! Re    : Radius of Earth [m]
      REAL*8, PARAMETER :: Re           = 6.375d6

      ! Rd    : Gas Constant (R) in Dry Air [287 J/K/kg]
      REAL*8, PARAMETER :: Rd           = 287.0d0

      ! g0_100 = 100.0 / g0
      REAL*8, PARAMETER :: g0_100       = 100d0 / g0

      ! PI_180 = PI    / 180.0
      REAL*8, PARAMETER :: PI_180       = PI / 180d0

      ! Rdg0   = Rd    / g0
      REAL*8, PARAMETER :: Rdg0         = Rd / g0

      ! Scale height of atmosphere (7.6 km = 7600m)
      REAL*8, PARAMETER :: SCALE_HEIGHT = 7600d0

      ! Cp = 1000 J / kg / K = specific heat of air at constant P
      REAL*8, PARAMETER :: Cp           = 1000.0d0

      ! Von Karman's constant
      REAL*8, PARAMETER :: VON_KARMAN   = 0.4d0
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: THIS MODULE WAS ORIGINALLY DEVELOPED FOR THE COLUMN CODE.  %%%
%%%  THE PARAMETERS HERE CAN BE COMBINED INTO A SINGLE MODULE WITH    %%%
%%%  DECLARED PHYSICAL CONSTANTS (IN THE NEAR FUTURE).                %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

In older sections of code, AIRMW may be replaced by (MW_AIR*1d3).
```

REVISION HISTORY:

```
14 Dec 2009 - R. Yantosca - Initial version, adapted from CMN_GCTM
03 Aug 2011 - M. Long     - Converted from Header file to Module
```

1.19 Fortran: Module Interface geos_chem

Program GEOS_CHEM is the main level driver program for the GEOS-Chem model of atmospheric chemistry and composition.

INTERFACE:

```
      PROGRAM GEOS_CHEM
```

USES:

```
!-------------------------------------------------------------------
! Basic GEOS-Chem modules
!-------------------------------------------------------------------
USE CMN_SIZE_MOD          ! Size parameters
USE CMN_GCTM_MOD          ! Physical constants
USE ERROR_MOD             ! For error checking
USE FILE_MOD              ! For file I/O
USE INPUT_MOD             ! For reading settings from "input.geos"
USE LOGICAL_MOD           ! Logical flags to toggle G-C options
USE MAPPING_MOD           ! For regridding MODIS LAI
USE OLSON_LANDMAP_MOD     ! Computes IREG, ILAND, IUSE from Olson map
USE PRESSURE_MOD          ! For computing pressure at grid boxes
USE RESTART_MOD           ! For restart file I/O
USE TIME_MOD              ! For computing date & time
USE TRACER_MOD            ! Tracer array (STT) + related functions
USE TRACERID_MOD          ! Flags for G-C tracers & chemical species

!-------------------------------------------------------------------
! GEOS-Chem chemistry modules
!-------------------------------------------------------------------
USE CHEMISTRY_MOD         ! Driver routines for chemistry
USE COMODE_MOD            ! Allocatable arrays for SMVGEAR solver
USE COMODE_LOOP_MOD       ! Formerly common-block arrays for SMVGEAR
USE GCKPP_COMODE_MOD      ! For the KPP chemical solver
USE GLOBAL_CH4_MOD        ! For offline CH4 simulation
USE MERCURY_MOD           ! For offline Hg simulation (driver)
USE OCEAN_MERCURY_MOD     ! For offline Hg simulation (ocean model)
USE SOAPROD_MOD           ! For SOA simulation
USE STRAT_CHEM_MOD        ! For linearized stratospheric chemistry
USE TOMS_MOD              ! For overhead O3 columns (for FAST-J)
USE UVALBEDO_MOD          ! For reading UV albedoes (for FAST-J)

!-------------------------------------------------------------------
! GEOS-Chem deposition modules
!-------------------------------------------------------------------
USE DEPO_MERCURY_MOD      ! Deposition for offline Hg simulation
USE DRYDEP_MOD            ! For dry deposition
USE WETSCAV_MOD           ! For wet deposition (rainout & washout)

!-------------------------------------------------------------------
! GEOS-Chem diagnostics modules
!-------------------------------------------------------------------
USE BENCHMARK_MOD         ! For the 1-month benchmark simulations
USE CMN_DIAG_MOD          ! Logical switches for G-C diagnostics
USE DIAG_MOD              ! G-C diagnostic arrays & counters
USE DIAG41_MOD            ! For ND41  (afternoon PBL       ) diag
```

```
      USE DIAG42_MOD            ! For ND42  (SOA products        ) diag
      USE DIAG48_MOD            ! For ND48  (station timeseries  ) diag
      USE DIAG49_MOD            ! For ND49  (inst. timeseries    ) diag
      USE DIAG50_MOD            ! For ND50  (24h avg timeseries  ) diag
      USE DIAG51_MOD            ! For ND51  (satellite timeseries) diag
      USE DIAG51b_MOD           ! For ND51b (satellite timeseries) diag
      USE DIAG63_MOD            ! For ND63  (PARANOX timeseries  ) diag
      USE DIAG_OH_MOD           ! For ND43  (OH,NO2,etc. prod    ) diag
      USE PLANEFLIGHT_MOD       ! For ND40  (plane flight track  ) diag

      !-----------------------------------------------------------------
      ! GEOS-Chem dynamics modules
      !-----------------------------------------------------------------
      USE CONVECTION_MOD        ! For deep cloud convection
      USE LINOZ_MOD             ! For LINOX linear strat chemistry
      USE PBL_MIX_MOD           ! For full PBL mixing (TURBDAY)
      USE TPCORE_BC_MOD         ! For nested-grid boundary conditions
      USE TRANSPORT_MOD         ! Driver routines for advection
      USE TROPOPAUSE_MOD        ! For the dynamic tropopause
      USE VDIFF_MOD             ! For non-local PBL mixing (J. Lin)

      !-----------------------------------------------------------------
      ! GEOS-Chem emissions modules
      !-----------------------------------------------------------------
      USE EMISSIONS_MOD         ! Driver routines for emissions
      USE MODIS_LAI_MOD         ! For MODIS leaf area indices (replacement)
      USE LIGHTNING_NOX_MOD     ! For lightning NOx emissions
      USE MEGAN_MOD             ! For biogenic emissions
      USE BROMOCARB_MOD         ! For setting CH3Br concentrations in PBL, jpp

      !-----------------------------------------------------------------
      ! GEOS-Chem met field I/O modules
      !-----------------------------------------------------------------
      USE DAO_MOD               ! Met field definitions
      USE GCAP_READ_MOD         ! For reading GCAP met data
      USE GEOS57_READ_MOD       ! For reading GEOS-5.7.x data
      USE MERRA_A1_MOD          ! For reading MERRA A1 data
      USE MERRA_A3_MOD          ! For reading MERRA A3 data
      USE MERRA_CN_MOD          ! For reading MERRA CN data
      USE MERRA_I6_MOD          ! For reading MERRA I6 data
      USE A3_READ_MOD           ! For reading A3 data (all other met)
      USE A6_READ_MOD           ! For reading A6 data (all other met)
      USE I6_READ_MOD           ! For reading I6 data (all other met)

#if defined( DEVEL )
      USE LOGICAL_MOD,        ONLY : DO_DIAG_WRITE
      USE GC_ENVIRONMENT_MOD, ONLY : ALLOCATE_ALL, INIT_ALL
      USE GC_TYPE2_MOD,       ONLY : CHEMSTATE
```

```
      USE GC_TYPE_MOD,        ONLY : GC_MET_LOCAL
#endif

      IMPLICIT NONE

#     include "define.h"
```

REMARKS:

```
.
      GGGGGG  EEEEEEE  OOOOO  SSSSSSS       CCCCCC H     H EEEEEEE M     M
     G        E       O     O S           C       H     H E       M M M M
     G   GGG  EEEEEE  O     O SSSSSSS     C       HHHHHHH EEEEEE  M  M  M
     G     G  E       O     O       S     C       H     H E       M     M
      GGGGGG  EEEEEEE  OOOOO  SSSSSSS       CCCCCC H     H EEEEEEE M     M
.
.
              (formerly known as the Harvard-GEOS model)
          for 4 x 5, 2 x 2.5 global grids and hi-res nested grids
.
       Contact: GEOS-Chem Support Team (geos-chem-support@as.harvard.edu)

.
   See the GEOS-Chem Web Site:
.
      http://acmg.seas.harvard.edu/geos/
.
   and the GEOS-Chem User's Guide:
.
      http://acmg.seas.harvard.edu/geos/doc/man/
.
   and the GEOS-Chem wiki:
.
      http://wiki.seas.harvard.edu/geos-chem/
.
   for the most up-to-date GEOS-Chem documentation on the following topics:
.
      - installation, compilation, and execution
      - coding practice and style
      - input files and met field data files
      - horizontal and vertical resolution
      - modification history
```

REVISION HISTORY:

```
   13 Aug 2010 - R. Yantosca - Added ProTeX headers
   13 Aug 2010 - R. Yantosca - Add modifications for MERRA (treat like GEOS-5)
   19 Aug 2010 - R. Yantosca - Now call MERRA met field reader routines
   02 Feb 2011 - S. Kim      - Call Compute_OD after wet deposition
```

```
05 Oct 2011 - R. Yantosca - Now get SUNCOS30 array from routine COSSZA
07 Oct 2011 - R. Yantosca - Rename SUNCOS30 to SUNCOS_MID, which is the
                            cos(SZA) at the midpt of the chemistry timestep
02 Feb 2012 - R. Yantosca - Added modifications for GEOS-5.7.x met fields
06 Feb 2012 - R. Yantosca - Reorganize USE statements for clarity
06 Feb 2012 - R. Yantosca - Renamed NN to NNN to avoid name confusion
07 Feb 2012 - R. Yantosca - Split off met field I/O into internal routines
                            READ_INITIAL_MET_FIELDS and READ_MET_FIELDS
07 Feb 2012 - M. Payer    - Replace call to COSSZA with GET_COSINE_SZA
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
06 Mar 2012 - R. Yantosca - Now call READ_TOMS every month (this was
                            formerly done within routine "fast_j.F")
06 Mar 2012 - R. Yantosca - Add subroutine GET_OVERHEAD_O3_FOR_FASTJ
                            which calls COMPUTE_OVERHEAD_O3 (in toms_mod.F)
                            to pre-compute the overhead O3 columsn for
                            FAST-J photolysis.  This removes code from
                            "set_prof.F" to facilitate the GI model.
19 Mar 2012 - R. Yantosca - Now call routines from olson_landmap_mod.F90
                            to read the Olson land map data
04 Apr 2012 - R. Yantosca - Now call updated LAI routines from new module
                            modis_lai_mod.F90.  Retire routine RDLAI.
05 Apr 2012 - R. Yantosca - Removed reference to LXTRA, it's obsolete
11 Apr 2012 - R. Yantosca - Replace lai_mod.F with modis_lai_mod.F90
11 Apr 2012 - R. Yantosca - Now call INIT_MODIS_LAI (in modis_lai_mod.F90)
                            here so that we don't have to call it from
                            megan_mod.F and mercury_mod.F separately.
17 Apr 2012 - R. Yantosca - Need to set the mapping variable to NULL()
10 Jun 2012 - L. Murray   - Remove references to UPBDFLX_MOD.F
```

1.19.1 display_grid_and_model

Internal Subroutine DISPLAY_GRID_AND_MODEL displays the appropriate messages for the given model grid and machine type. It also prints the starting time and date (local time) of the GEOS-Chem simulation.

INTERFACE:

```
SUBROUTINE DISPLAY_GRID_AND_MODEL
```

REVISION HISTORY:

```
02 Dec 2003 - R. Yantosca - Initial version
13 Aug 2010 - R. Yantosca - Added ProTeX headers
13 Aug 2010 - R. Yantosca - Added extra output
02 Feb 2012 - R. Yantosca - Added output for GEOS-5.7.x met fields
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
19 Mar 2012 - R. Yantosca - Now echo info for 0.25 x 0.3125 runs
```

```
19 Mar 2012 - R. Yantosca - Now echo info if ISORROPIA is turned off
```

1.19.2 ctm_flush

Internal subroutine CTM_FLUSH flushes certain diagnostic file buffers to disk.

CTM_FLUSH should normally be called after each diagnostic output, so that in case the run dies, the output files from the last diagnostic timestep will not be lost.

FLUSH is an intrinsic FORTRAN subroutine and takes as input the unit number of the file to be flushed to disk.

INTERFACE:

```
SUBROUTINE CTM_FLUSH
```

REVISION HISTORY:

```
31 Aug 2000 - R. Yantosca - Initial version
13 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.19.3 display_end_time

Internal subroutine DISPLAY_END_TIME prints the ending time of the GEOS-Chem simulation.

INTERFACE:

```
SUBROUTINE DISPLAY_END_TIME
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
13 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.19.4 read_initial_met_fields

Internal subroutine READ_INITIAL_MET_FIELDS calls the various routines to read met fields at the beginning of a GEOS-Chem simulation. This code was moved out of the main routine for clarity, due to the many #if defined() blocks that are required.

INTERFACE:

```
SUBROUTINE READ_INITIAL_MET_FIELDS()
```

REMARKS:

```
All variables used in this routine are declared above in the main
program, and as such, are visible here.

Also calls the following routines:
(1) AVGPOLE   (average pressure @ poles) when I3 or I6 fields are read
(2) LIGHTNING (lightning NOx emissions)  when A3 or A6 fields are read
```

REVISION HISTORY:

```
07 Feb 2012 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.19.5 read_met_fields

Internal subroutine READ_MET_FIELDS calls the various routines to read met fields in the main GEOS-Chem timestepping loop. This code was moved out of the main routine for clarity, due to the many #if defined() blocks that are required.

INTERFACE:

```
SUBROUTINE READ_MET_FIELDS()
```

REMARKS:

```
All variables used in this routine are declared above in the main
program, and as such, are visible here.

Also calls the following routines:
(1) AVGPOLE   (average pressure @ poles) when I3 or I6 fields are read
(2) LIGHTNING (lightning NOx emissions)  when A3 or A6 fields are read
```

REVISION HISTORY:

```
07 Feb 2012 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.19.6 get_overhead_o3_for_fastj

Internal subroutine GET_OVERHEAD_O3_FOR_FASTJ

INTERFACE:

```
SUBROUTINE GET_OVERHEAD_O3_FOR_FASTJ()
```

REMARKS:

```
This routine makes use of variables declared in above in the main program
(which are visible in all sub-programs below the CONTAINS statement).

The original code was done in FAST-J routine "set_prof.F", but has been
split off to facilitate development of the grid-independent model.
```

REVISION HISTORY:

```
 7 Mar 2012 - R. Yantosca - Initial version
```

1.20 Fortran: Module Interface acetone_mod

Module ACETONE_MOD contains subroutines to emit the biogenic flux of acetone into the full chemistry simulation.

INTERFACE:

```
      MODULE ACETONE_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_ACETONE
      PUBLIC :: EMISS_BIOACET
      PUBLIC :: OCEAN_SOURCE_ACET
      PUBLIC :: OCEAN_SINK_ACET
```

REMARKS:

```
References:
============================================================================
(1 ) Jacob, D.J., B.D. Field, E. Jin, I. Bey, Q. Li, J.A. Logan, and
      R.M. Yantosca, "Atmospheric budget of acetone", Geophys. Res. Lett.,
      107(D11), 4100, 2002.
(2 ) Nightingale et al [2000a], J. Geophys. Res, 14, 373-387
(3 ) Nightingale et al [2000b], Geophys. Res. Lett, 27, 2117-2120
```

REVISION HISTORY:

```
NOTES:
18 Sep 2001 - B. Field, R. Yantosca - Initial version
(1 ) Added changes from bdf and updated comments (bmy, 9/5/01)
(2 ) Updated comments (bmy, 9/12/01)
(3 ) Removed VERBOSE flag and all "print-to-log-file" diagnostics.  The
      ND11 diagnostic produces the same totals. (bdf, bmy, 9/18/01)
(4 ) Now cal GET_TAU0 w/ 3 arguments instead of 2.  Also minor bug
```

```
      fix in READ_RESP (bmy, 11/15/01)
(5 ) Implemented fix for ocean source/sink from Mat Evans.  Also deleted
      obsolete code from 11/01. (bmy, 11/26/01)
(6 ) Eliminated more obsolete code from 11/01 (bmy, 2/27/02)
(7 ) Removed duplicate variable definitions (bmy, 3/20/02)
(8 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
      MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(9 ) Bug fix: Now apply true exponential loss in OCEAN_SINK_ACET, instead
      of just the 1st order approximation. (bdf, bmy, 7/11/02)
(10) Scale the ocean source of acetone for GEOS-3 meteorology in order to
      match the total listed in Jacob et al 2002. (bdf, bmy, 9/16/02)
(11) Now references "error_mod.f" (bmy, 10/15/02)
(12) Minor modifications to READ_JO1D, READ_RESP (bmy, 3/14/03)
(13) Add surface area scale factor for ocean source for 1x1 nested
      grids.  (yxw, bmy, 5/16/03)
(14) Scale ACET ocean source to Jacob et al 2002 for GEOS-4, and now
      account for surface area ratio for all GEOS grids. (bmy, 3/15/04)
(15) Now references "directory_mod.f" (bmy, 7/19/04)
(16) Now can read data from GEOS and GCAP grids.  Also now use Nightingale
      et al 2000b formulation for piston velocity KL. (swu, bmy, 8/16/05)
(17) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(18) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(19) Updates for nested EU and NA grids (amv, bmy, 12/18/09)
(20) Updates for GEOS-4 1 x 1.25 grid (lok, bmy, 1/13/10)
13 Aug 2010 - R. Yantosca - Add modifications for MERRA (treat like GEOS-5)
04 Nov 2010 - R. Yantosca - Added ProTeX headers
06 Dec 2011 - E. Fischer  - Updated Ocean exchange, MEGAN biogenic emiss.
                            Removed obsolete code.
19 Mar 2012 - M. Payer    - Removed obsolete subroutines READ_JO1D and
                            READ_RESP (E. Fischer)
```

1.20.1 ocean_source_acet

Subroutine OCEAN_SOURCE_ACET specifies the ocean source of acetone.

INTERFACE:

```
SUBROUTINE OCEAN_SOURCE_ACET( I, J, ACETONE )
```

USES:

```
USE ERROR_MOD, ONLY : CHECK_VALUE
USE DAO_MOD,   ONLY : ALBD, TS
USE DIAG_MOD,  ONLY : AD11
USE GRID_MOD,  ONLY : GET_AREA_CM2
USE TIME_MOD,  ONLY : GET_TS_EMIS

USE CMN_SIZE_MOD                 ! Size parameters
```

```
      USE CMN_DIAG_MOD                  ! ND11
      USE CMN_DEP_MOD                   ! FRCLND
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: I         ! GEOS-Chem longitude index
      INTEGER, INTENT(IN)    :: J         ! GEOS-Chem latitude index
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: ACETONE   ! Acetone emission [atoms C/s]
```

REMARKS:

REVISION HISTORY:

```
    14 Sep 2001 - B. Field    - Initial version
    (1 ) Now compute u = SQRT( U10M^2 + V10M^2 ) as SQRT( SFCWINDSQR(I,J) ).
         This is necessary since U10M and V10M are missing for 1996, and
         need to be computed from UWND and VWND.  (bmy, 9/5/01)
    (2 ) Bug fixes: multiply kg by 360000 and use exponent to the -0.5 power
         in the expression for Kl.  Also update value of the OCEAN_SCALE
         factor to 3.63e11.  Also updated comments. (bdf, bmy, 9/5/01)
    (3 ) Bug fix: ACETONE has units of [atoms C/box/s], to match those of
         EMISRR.  This involves an extra division by DTSRCE. (bmy, 9/14/01)
    (4 ) Removed diagnostic variable OCEAN_SOURCE (bmy, 9/18/01)
    (5 ) JO1D(IREF,JREF) is now JO1D(I,J).  Bug fix: Zero the ocean source
         of acetone in grid boxes that are covered by less than 50% ocean.
         Bug fix: make sure -5 <= TC <= 30, in order to prevent the power
         series for Schmidt # from going negative.  Also eliminate IREF,
         JREF, we don't need them anymore. (mje, rvm, bmy, 11/26/01)
    (6 ) Eliminated obsolete code from 11/01 (bmy, 2/27/02)
    (7 ) Scale the ocean source of acetone for GEOS-3 meteorology in order to
         match the total listed in Jacob et al 2002. (bdf, bmy, 9/16/02)
    (8 ) Now use function GET_AREA_CM2 of "grid_mod.f" to return the
         grid box area in cm2.  Use function GET_TS_EMIS from "time_mod.f".
         Remove reference to CMN header file. (bmy, 2/11/03)
    (9 ) Apply surface area scale factor for 1x1 nested grids, in order to
         make the total ocean source the same as for 4x5. (yxw, bmy, 5/16/03)
    (10) Scale the ocean source to Jacob et al 2002 for GEOS-4.  Also account
         for surface area ratio for all GEOS grids. (bmy, 3/15/04)
    (11) Added space in #ifdef block for GEOS-4 x 1x125 grid (bmy, 12/1/04)
    (12) Now use Nightingale et al 2000b formulation for piston velocity KL.
         (swu, bmy, 8/16/05)
    (13) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
    (14) Adjust SCALE_FACTOR for 0.5 x 0.667 grid (dan, bmy, 11/6/08)
    (15) Additional scale factors for NESTED_NA and NESTED_EU calculated and
         included (amv, bmy, 12/18/09)
    (16) Added scale factor for GEOS-4 1 x 1.25 grid (lok, bmy, 1/13/10)
```

```
13 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
04 Nov 2010 - R. Yantosca - Added ProTeX headers
04 Nov 2010 - R. Yantosca - Cleaned up #if statements for clarity
06 Dec 2011 - E. Fischer  - Updated ocean source and sink terms to be
                            different than Jacob et al. [2002]. Ocean mixed
                            layer is now set to a constant concentration of
                            acetone (15 nM). Fluxes are now calculated
                            using a direct application of the standard
                            two-film model described by Liss and Slater
                            [1974]. The fluxes are calculated using an
                            updated Henry's law coefficient and transfer
                            velocities have been updated following Johnson
                            [2010]. The model now reproduces aircraft
                            measurements over the remote oceans well.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.20.2 ocean_sink_acet

Subroutine OCEAN_SINK_ACET applies the ocean sink to global acetone concentrations.

INTERFACE:

```
SUBROUTINE OCEAN_SINK_ACET( ACETONE )
```

USES:

```
USE DAO_MOD,  ONLY : ALBD
USE DAO_MOD,  ONLY : TS
USE DIAG_MOD, ONLY : AD11
USE GRID_MOD, ONLY : GET_AREA_CM2
USE TIME_MOD, ONLY : GET_TS_CHEM

USE CMN_SIZE_MOD                              ! Size parameters
USE CMN_DIAG_MOD                              ! ND11
USE CMN_DEP_MOD                               ! FRCLND
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8, INTENT(INOUT) :: ACETONE(IIPAR,JJPAR)   ! Acetone mass [kg C]
```

REVISION HISTORY:

```
14 Sep 2001 - B. Field    - Initial version
(1 ) Remove references to CMN_UV10M and CMN_LWI -- these are now
      obsolete in GEOS-CHEM versions 4.18 and higher (bmy, 9/5/01)
(2 ) Now compute u = SQRT( U10M^2 + V10M^2 ) as SQRT( SFCWINDSQR(I,J) ).
      This is necessary since U10M and V10M are missing for 1996, and
      need to be computed from UWND and VWND.  (bmy, 8/2/01)
```

```
(3 ) Now declare OCEANSINK_SCALE = 0.15 as a parameter.  This is the
     optimized value of BETA from Emily Jin's analysis.  Also updated
     comments. (bdf, bmy, 9/5/01)
(4 ) Updated comments.  Also parallellized DO loops. (bmy, 9/14/01)
(5 ) Removed diagnostic variable OCEAN_LOSS (bmy, 9/18/01)
(6 ) Bug fix: Zero the ocean sink of acetone in grid boxes where there
     is less than 50% of ocean, and where there is ice on the surface.
     Bug fix: Make sure -5 <= TC <= 30, in order to prevent the power
     series for Schmidt # from going negative.  Also eliminate IREF,
     JREF, we don't need them. (mje, rvm, bmy, 11/26/01)
(7 ) Eliminated obsolete code from 11/01 (bmy, 2/27/02)
(8 ) Bug fix: now use true exponential for loss instead of just 1st
     order term.  Also added PRE_ACET variable to save previous acetone
     mass for diagnostic, before applying loss.  (bdf, bmy, 7/11/02)
(9 ) Now use function GET_AREA_CM2 of "grid_mod.f" to return the
     grid box area in cm2.  Now use function GET_TS_CHEM from
     "time_mod.f".  Remove reference to CMN header file. (bmy, 2/11/03)
(12) Now use Nightingale et al 2000b formulation for piston velocity KL.
     (swu, bmy, 8/16/05)
04 Nov 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

1.20.3 emiss_bioacet

Subroutine EMISS_BIOACET computes the biogenic emissions of ACETONE from monoterpenes, isoprene, methyl butenol, dry leaf matter, and grasslands.

INTERFACE:

```
evf, edits to use MEGAN biogenic acetone emissions (5/25/2011)
     SUBROUTINE EMISS_BIOACET( I,    J,    TMMP,  EMMO, SUNCOS, Q_DIR,
    &                          Q_DIFF, XNUMOL_C, EMIS, EMMB, GRASS,
    &                          ACETONE )
```

USES:

```
      USE DIAG_MOD, ONLY : AD11
      USE GRID_MOD, ONLY : GET_AREA_M2
      USE GRID_MOD, ONLY : GET_XMID
      USE GRID_MOD, ONLY : GET_YMID
      USE TIME_MOD, ONLY : GET_TS_EMIS
!(evf, 5/25/2011)
      USE MEGAN_MOD, ONLY : GET_EMACET_MEGAN

      USE CMN_SIZE_MOD                 ! Size parameters
      USE CMN_DIAG_MOD                 ! ND11
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: I         ! Grid box longitude index
      INTEGER, INTENT(IN)    :: J         ! Grid box latitude index
      REAL*8,  INTENT(IN)    :: TMMP      ! Local Surface Air temperature [K]
      REAL*8,  INTENT(IN)    :: EMMO      ! Monoterpene emission [atoms C]
      REAL*8,  INTENT(IN)    :: EMIS      ! Isoprene emission [atoms C]
      REAL*8,  INTENT(IN)    :: EMMB      ! Methylbutenol emission  [atoms C]
      REAL*8,  INTENT(IN)    :: GRASS     ! Isoprene from grasslands [atoms C]
  evf, edits to use MEGAN biogenic acetone emissions (5/25/2011)
      REAL*8,  INTENT(IN)    :: SUNCOS    ! Cosine of Solar Zenith Angle
      REAL*8,  INTENT(IN)    :: Q_DIR     ! Flux of direct PAR above canopy
      REAL*8,  INTENT(IN)    :: Q_DIFF    ! Flux of diffuse PAR above canopy
      REAL*8,  INTENT(IN)    :: XNUMOL_C  ! Number of atoms C / kg C
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: ACETONE   ! Biogenic acetone [atoms C/s]
```

REVISION HISTORY:

```
    18 Sep 2001 - B. Field    - Initial version
    (1 ) Now pass acetone array (e.g. from STT) thru the argument list, since
         this avoids dependence on IDTACET in this program (bmy, 8/1/01)
    (2 ) Updated scale factors (bdf, bmy, 9/5/01)
    (3 ) Updated comments (bmy, 9/14/01)
    (4 ) Removed diagnostic variables: MONOTERPENES, ISOPRENE, ISOP_TOTAL,
         MONO_TOTAL, NA_TOT, RESP_TOT, GRASS_TOT.  These have now been
         supplanted by the ND11 acetone source diagnostic. (bdf, bmy, 9/18/01)
    (5 ) XRESP(I+I0,J+J0) is now XRESP(I,J) (bmy, 11/26/01)
    (6 ) Eliminated obsolete code from 11/01 (bmy, 2/27/02)
    (7 ) Removed duplicate definitions of EMMB and GRASS (bmy, 3/20/02)
    (8 ) Now use functions from "grid_mod.f" to get surface area, lon, and
         lat of grid box (I,J).   Use function GET_AREA_M2 to get the grid
         box surface area in m2, then convert to cm2.   Now use function
         GET_TS_EMIS from "time_mod.f".  Remove reference to CMN header
         file. (bmy, 2/11/03)
    04 Nov 2010 - R. Yantosca - Added ProTeX headers
    06 Dec 2011 - E. Fischer  - Direct biogenic emissions of acetone from
                                metabolism and decay are now calculated using
                                the MEGAN biogenic emission model [Guenther et
                                al., 2006]. The code assumes the fraction of
                                emissions that are light-independent is 0.20,
                                and the temperature response factor (beta) is
                                0.10 as recommended by Alex Guenther. The
                                dependency on GEIA has been removed.
    08 Dec 2011 - M. Payer    - Remove use of obsolete CMN_MONOT_MOD
    01 Mar 2012 - R. Yantosca - Use new grid routines from grid_mod.F90
```

1.20.4 cleanup_acetone

Subroutine CLEANUP_ACETONE deallocates module arrays

INTERFACE:

```
SUBROUTINE CLEANUP_ACETONE
```

REVISION HISTORY:

```
14 Sep 2001 - R. Yantosca - Initial version
04 Nov 2010 - R. Yantosca - Added ProTeX headers
19 Mar 2012 - M. Payer    - Removed deallocation of JO1D and XRESP. They
                            are obsolete after removal of READ_JO1D and
                            READ_RESP routines.
```

1.21 Fortran: Module Interface aerosol_mod

Module AEROSOL_MOD contains variables and routines for computing optical properties for aerosols which are needed for both the FAST-J photolysis and ND21 optical depth diagnostics. (bmy, 7/20/04, 2/10/09)

INTERFACE:

```
MODULE AEROSOL_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: AEROSOL_CONC
      PUBLIC :: AEROSOL_RURALBOX
      PUBLIC :: RDAER
      PUBLIC :: CLEANUP_AEROSOL
```

PUBLIC DATA MEMBERS:

```
      PUBLIC :: SOILDUST
```

REVISION HISTORY:

```
(1 ) Added AEROSOL_RURALBOX routine (bmy, 9/28/04)
(2 ) Now convert ABSHUM from absolute humidity to relative humidity in
       AEROSOL_RURALBOX, using the same algorithm as in "gasconc.f".
       (bmy, 1/27/05)
(3 ) Now references "tropopause_mod.f" (bmy, 8/22/05)
```

```
(4 ) Now add contribution of SOA4 into Hydrophilic OC (dkh, bmy, 5/18/06)
(5 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(6 ) Add support for variable tropopause (bdf, phs, 9/14/06)
(7 ) Now set OCF=2.1 in AEROSOL_CONC for consistency w/ carbon_mod.f
     (tmf, 2/10/09)
(8 ) Add WTAREA and WERADIUS for dicarbonyl SOA production.
     WTAREA is the same as TAREA, but excludes dry dust, BCPO and OCPO;
     use same units as TAREA.
     WERADIUS is same as ERADIUS, but excludes dry dust, BCPO and OCPO;
     use same units as ERADIUS. (tmf, 3/2/09)
(9 ) Add SOAG and SOAM species. (tmf, ccc, 3/2/09)
(10) Modify AOD output to wavelength specified in jv_spec_aod.dat
     (clh, 05/07/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.21.1 aerosol_ruralbox

! DESCRIPTION: Subroutine AEROSOL_RURALBOX computes quantities that are needed by RDAER. This mimics the call to RURALBOX, which is only done for fullchem runs. (bmy, 9/28/04, 9/14/06)

INTERFACE:

```
SUBROUTINE AEROSOL_RURALBOX( N_TROP )
```

USES:

```
USE COMODE_MOD,     ONLY : ABSHUM, AIRDENS, IXSAVE
USE COMODE_MOD,     ONLY : IYSAVE, IZSAVE,  JLOP
USE DAO_MOD,        ONLY : AD,     AVGW,    MAKE_AVGW, T
USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_TROP
USE LOGICAL_MOD,    ONLY : LVARTROP

USE CMN_SIZE_MOD         ! Size parameters
USE COMODE_LOOP_MOD      ! AD, AVG, WTAIR, other SMVGEAR variables
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: N_TROP  ! Number of tropospheric boxes
```

REVISION HISTORY:

```
(1 ) Now convert ABSHUM from absolute humidity to relative humidity in
     AEROSOL_RURALBOX, using the same algorithm as in "gasconc.f".
     (bmy, 1/27/05)
(2 ) Now references ITS_IN_THE_TROP from "tropopause_mod.f" to diagnose
     boxes w/in the troposphere. (bmy, 8/22/05)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Modified for variable tropopause (phs, bdf, 9/14/06)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.21.2 aerosol_conc

Subroutine AEROSOL_CONC computes aerosol concentrations in kg/m3 from the tracer mass in kg in the STT array. These are needed to compute optical properties for photolysis and for the optical depth diagnostics. (bmy, 7/20/04, 2/10/09)

INTERFACE:

```
SUBROUTINE AEROSOL_CONC
```

USES:

```
USE DAO_MOD,      ONLY : AIRVOL
USE LOGICAL_MOD,  ONLY : LCARB,   LDUST,   LSOA,    LSSALT, LSULF
USE TRACER_MOD,   ONLY : STT
USE TRACERID_MOD, ONLY : IDTBCPI, IDTBCPO, IDTDST1, IDTDST2
USE TRACERID_MOD, ONLY : IDTDST3, IDTDST4, IDTNH4,  IDTNIT
USE TRACERID_MOD, ONLY : IDTOCPO, IDTOCPI, IDTSALA, IDTSALC
USE TRACERID_MOD, ONLY : IDTSOA1, IDTSOA2, IDTSOA3, IDTSOA4
USE TRACERID_MOD, ONLY : IDTSO4,  IDTSOA5
USE TRACERID_MOD, ONLY : IDTSOAG, IDTSOAM

USE CMN_SIZE_MOD       ! Size parameters
```

REMARKS:

```
This code was originally included in "chemdr.f", but the same computation
also needs to be done for offline aerosol simulations.  Therefore, we have
split this code off into a separate subroutine which can be called by both
fullchem and offline aerosol simulations.
```

REVISION HISTORY:

```
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) Now add contribution from SOA4 into Hydrophilic OC (dkh, bmy, 5/18/06)
(3 ) Now set OCF=2.1 to be consistent w/ "carbon_mod.f" (tmf, 2/10/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.21.3 rdaer

Subroutine RDAER reads global aerosol concentrations as determined by Mian Chin. Calculates optical depth at each level for "set_prof.f". Also calculates surface area for heterogeneous chemistry. It uses aerosol parameters in FAST-J input file "jv_spec.dat" for these calculations. (rvm, rjp, tdf, bmy, 11/04/01, 7/20/04)

INTERFACE:

```
SUBROUTINE RDAER( MONTH, YEAR, WAVELENGTH )
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
      USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
      USE COMODE_MOD,    ONLY : ABSHUM,       ERADIUS,    IXSAVE
      USE COMODE_MOD,    ONLY : IYSAVE,       IZSAVE,     TAREA
      USE COMODE_MOD,    ONLY : WTAREA,       WERADIUS
      USE DAO_MOD,       ONLY : BXHEIGHT
      USE DIAG_MOD,      ONLY : AD21
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE ERROR_MOD,     ONLY : ERROR_STOP
      USE LOGICAL_MOD,   ONLY : LSULF,        LCARB,      LSSALT
      USE TIME_MOD,      ONLY : ITS_A_NEW_MONTH
      USE TRACER_MOD,    ONLY : ITS_A_FULLCHEM_SIM
      USE TRANSFER_MOD,  ONLY : TRANSFER_3D

      USE CMN_SIZE_MOD,  ONLY : NNPAR, NDSTBIN, IIPAR,   JJPAR,   LLTROP
      USE CMN_SIZE_MOD,  ONLY : LLPAR, MAXFAM,  NEMPARA, NEMPARB, LGLOB
      USE JV_CMN_MOD          ! ODAER, QAA, RAA, QAA_AOD (clh)
      USE COMODE_LOOP_MOD     ! NTLOOP
      USE CMN_DIAG_MOD        ! ND21, LD21

#if defined( DEVEL )
      USE CMN_FJ_MOD,    ONLY : JPMAX, JPPJ   ! LPAR, F77_CMN_SIZE
#else
      USE CMN_FJ_MOD,    ONLY : IPAR, JPAR, LPAR, JPMAX, JPPJ   ! LPAR, F77_CMN_SIZE
#endif
      USE JV_CMN_MOD   ! ODAER, QAA, RAA, QAA_AOD (clh)
      USE COMODE_LOOP_MOD   ! NTLOOP
      USE CMN_DIAG_MOD   ! ND21, LD21

      IMPLICIT NONE
#     include "define.h"
```

INPUT PARAMETERS:

```
      ! Arguments
      INTEGER, INTENT(IN), OPTIONAL :: MONTH      ! # of current month (1-12)
      INTEGER, INTENT(IN), OPTIONAL :: YEAR       ! 4-digit year (e.g. 2002)
      INTEGER, INTENT(IN), OPTIONAL :: WAVELENGTH ! Logical indicator
                                                  ! = 0 AOD computed at 999 nm
                                                  ! = 1 AOD computed at
                                                  !   wavelength in jv_spec_aod
```

REVISION HISTORY:

```
   (1 ) At the point in which "rdaer.f" is called, ABSHUM is actually
        absolute humidity and not relative humidity (rvm, bmy, 2/28/02)
   (2 ) Now force double-precision arithmetic by using the "D" exponent.
        (bmy, 2/28/02)
```

```
(3 ) At present aerosol growth is capped at 90% RH.  The data
     in jv_spec.dat could be used to allow a particle to grow to
     99% RH if desired. (rvm, 3/15/02)
(4 ) Bug fix: TEMP2 needs to be sized (IIPAR,JJPAR,LLPAR) (bmy, 5/30/02)
(5 ) Now reference BXHEIGHT from "dao_mod.f".  Also references ERROR_STOP
     from "error_mod.f".  Delete local declaration of TIME, since that
     is also declared w/in comode.h -- this causes compile-time errors
     on the ALPHA platform. (gcc, bmy, 11/6/02)
(6 ) Now use the online SO4, NH4, NIT aerosol, taken from the STT array,
     and passed via SO4_NH4_NIT argument if sulfate chemistry is turned on.
     Otherwise, read monthly mean sulfate from disk.  (rjp, bmy, 3/23/03)
(7 ) Now call READ_BPCH2 with QUIET=.TRUE., which prevents info from being
     printed to stdout.  Also made cosmetic changes. (bmy, 3/27/03)
(8 ) Add BCPI, BCPO, OCPI, OCPO to the arg list.  Bug fix: for online
     sulfate & carbon aerosol tracers, now make sure these get updated
     every timestep.  Now references "time_mod.f".  Now echo info about
     which online/offline aerosols we are using.  Updated comments.
     (bmy, 4/9/04)
(9 ) Add SALA, SALC to the arg list (rjp, bec, bmy, 4/20/04)
(10) Now references DATA_DIR from "directory_mod.f".  Now references LSULF,
     LCARB, LSSALT from "logical_mod.f".  Added minor bug fix for
     conducting the appropriate scaling for optical depth for ND21
     diagnostic.  Now make MONTH and YEAR optional arguments.  Now bundled
     into "aerosol_mod.f".  (rvm, aad, clh, bmy, 7/20/04)
(11) Now remove FWET from extinction efficiency computation (avd, 8/3/10)
(12) Include third input argument to determine the wavelength at which
     the AOD should be computed. This will set the optical properties
     that are used for the calculation of the AOD. The ND21 diagnostic
     should only be updated when WAVELENGTH = 1. (skim, 02/03/11)
09 Mar 2011 - R. Yantosca - Set MSDENS(2) = 1800 for APM (G. Luo)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.21.4 init_aerosol

Subroutine INIT_AEROSOL allocates and zeroes module arrays (bmy, 7/20/04)

INTERFACE:

```
SUBROUTINE INIT_AEROSOL
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
    22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.21.5 cleanup_aerosol

Subroutine CLEANUP_AEROSOL deallocates all module arrays (bmy, 7/20/04)

INTERFACE:

```
      SUBROUTINE CLEANUP_AEROSOL
```

REVISION HISTORY:

```
    22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.22 Fortran: Module Interface arctas_ship_emiss_mod

Module ARCTAS_SHIP_EMISS_MOD contains variables and routines to read the Arctas Ship emissions.

INTERFACE:

```
      MODULE ARCTAS_SHIP_EMISS_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_ARCTAS_SHIP
      PUBLIC  :: EMISS_ARCTAS_SHIP
      PUBLIC  :: GET_ARCTAS_SHIP
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: INIT_ARCTAS_SHIP
      PRIVATE :: READ_ARCTAS_SHIP
      PRIVATE :: TOTAL_EMISS_TG
```

REVISION HISTORY:

```
    28 Jan 2009 - P. Le Sager - Initial Version
    31 Aug 2010 - R. Yantosca - Updated comments
    01 Mar 2012 - R. Yantosca - Remove A_CM2 array, use the new function
                                GET_AREA_CM2( I, J, L ) from grid_mod.F90
```

REMARKS:

```
(1) Part of the ARCTAS pre-campaign composite inventory distributed by
     David Streets.
(2) Only SO2 differs from existing EDGAR inventory. All other
     species are disregarded for now, except CO2 that we did not have
     before.
(3) The ship emission is based on the work by Eyring et al., JGR 2005,
    which estimates the total international ship emissions for 1985, 1990,
    2001, and 2020 (projection). The ship emission for each individual year
    is interpreted based on the above years, and the spatial pattern
    (gridded) is mapped based on the EDGAR gridded ship emission for 2000
    (total amount from EDGAR is scaled to Eyring-based number).
    If you want to reference the work on publication or website, you may
    either mention "Diehl et al., manuscript in preparation, 2009" or
    refer to the AeroCom readme document for hindcast emissions for ship
    (prepared by Diehl):
    http://www-lscedods.cea.fr/aerocom/AEROCOM_HC/readme_ship/.
    If you have further questions, please contact Thomas directly
    (thomas.diehl@nasa.gov).
```

1.22.1 get_arctas_ship

Function GET_ARCTAS_SHIP returns the ARCTAS_SHIP emission for GEOS-Chem grid box (I,J) and tracer N. Emissions can be returned in units of [kg/s] or [molec/cm2/s].

INTERFACE:

```
      FUNCTION GET_ARCTAS_SHIP( I, J, N, MOLEC_CM2_S, KG_S )
     &     RESULT( VALUE )
```

USES:

```
      USE GRID_MOD,     ONLY : GET_AREA_CM2
      USE TRACER_MOD,   ONLY : ITS_A_CO2_SIM
      USE TRACER_MOD,   ONLY : XNUMOL
      USE TRACERID_MOD, ONLY : IDTSO2
```

INPUT PARAMETERS:

```
      ! Longitude, latitude, and tracer indices
      INTEGER, INTENT(IN)           :: I, J, N

      ! OPTIONAL -- return emissions in [molec/cm2/s]
      LOGICAL, INTENT(IN), OPTIONAL :: MOLEC_CM2_S

      ! OPTIONAL -- return emissions in [kg/s]
      LOGICAL, INTENT(IN), OPTIONAL :: KG_S
```

RETURN VALUE:

```
      ! Emissions output
      REAL*8                        :: VALUE
```

REVISION HISTORY:

```
   28 Jan 2009 - P. Le Sager - Initial Version
```

1.22.2 emiss_arctas_ship

Subroutine EMISS_ARCTAS_SHIP reads the ARCTAS_SHIP emissions from disk.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISS_ARCTAS_SHIP( YEAR, EMISSIONS )
#else
      SUBROUTINE EMISS_ARCTAS_SHIP( YEAR )
#endif
```

USES:

```
      USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
      USE TRACER_MOD,     ONLY : ITS_A_CO2_SIM, N_TRACERS

      USE CMN_SIZE_MOD       ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)     :: YEAR   ! Year of data to read

#if defined( DEVEL )
      REAL*8,  INTENT(INOUT)  :: EMISSIONS(IIPAR,JJPAR)
#endif
```

REVISION HISTORY:

```
   28 Jan 2009 - P. Le Sager - Initial Version
```

1.22.3 read_arctas_ship

Subroutine READ_ARCTAS_SHIP reads data from one ARCTAS_SHIP data file from disk, at GENERIC 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
      SUBROUTINE READ_ARCTAS_SHIP( FILENAME, CATEGORY,
     &                             TRACERN,  ARR,      YEAR )
```

USES:

```
USE BPCH2_MOD,         ONLY : GET_TAU0,      READ_BPCH2
USE REGRID_A2A_MOD,    ONLY : DO_REGRID_A2A
USE DIRECTORY_MOD,     ONLY : DATA_DIR_1x1
USE SCALE_ANTHRO_MOD, ONLY : GET_ANNUAL_SCALAR

USE CMN_SIZE_MOD           ! Size parameters
```

INPUT PARAMETERS:

```
! Year of data to read
INTEGER,          INTENT(IN)    :: YEAR

! Tracer number
INTEGER,          INTENT(IN)    :: TRACERN

! Filename & category under which data is stored in bpch file
CHARACTER(LEN=*), INTENT(IN)    :: FILENAME, CATEGORY
```

INPUT/OUTPUT PARAMETERS:

```
! Array containing output data
REAL*8,           INTENT(INOUT) :: ARR(IIPAR,JJPAR)
```

REMARKS:

```
(1) Even though the inventory was prepared for Arctas 2008 campaign, CO2
    base year is 2000, and SO2 base year is 2006. Input YEAR is used to
    scale SO2 into 1985-2005
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
14 May 2012 - R. Yantosca - Bug fix: SC should be defined w/ IIPAR,JJPAR
24 May 2012 - R. Yantosca - Fix minor bugs in map_a2a implementation
```

1.22.4 TOTAL_EMISS_TG

Subroutine TOTAL_EMISS_TG prints the totals for the anthropogenic or biomass emissions.

INTERFACE:

```
SUBROUTINE TOTAL_EMISS_TG
```

USES:

```
USE TRACER_MOD, ONLY : ITS_A_CO2_SIM

USE CMN_SIZE_MOD   ! Size parameters
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
```

1.22.5 INIT_ARCTAS_SHIP

Subroutine INIT_ARCTAS_SHIP allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_ARCTAS_SHIP
```

USES:

```
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE LOGICAL_MOD, ONLY : LARCSHIP
USE TRACER_MOD,  ONLY : ITS_A_CO2_SIM

USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
01 Mar 2012 - R. Yantosca - Remove A_CM2 array
```

1.22.6 CLEANUP_ARCTAS_SHIP

Subroutine CLEANUP_ARCTAS_SHIP deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_ARCTAS_SHIP
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
```

1.23 Fortran: Module Interface bravo_mod

Overview

Module BRAVO_MOD contains variables and routines to read the BRAVO Mexican anthropogenic emission inventory for NOx, CO, and SO2. (rjp, kfb, bmy, 6/22/06, 1/30/09)

References

1. Kuhns, H., M. Green, and Etyemezian, V, *Big Bend Regional Aerosol and Visibility Observational (BRAVO) Study Emissions Inventory*, Desert Research Institute, 2003.

INTERFACE:

```
      MODULE BRAVO_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_BRAVO
      PUBLIC  :: EMISS_BRAVO
      PUBLIC  :: GET_BRAVO_MASK
      PUBLIC  :: GET_BRAVO_ANTHRO
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: BRAVO_SCALE_FUTURE
      PRIVATE :: INIT_BRAVO
      PRIVATE :: READ_BRAVO_MASK
```

REVISION HISTORY:

```
    (1 ) Now pass the unit string to DO_REGRID_G2G_1x1 (bmy, 8/9/06)
    (2 ) Now scale emissions using int-annual scale factors (amv, 08/24/07)
    (3 ) Now accounts for FSCLYR (phs, 3/17/08)
    (4 ) Added ProTeX headers (bmy, 1/30/09)
    31 Aug 2010 - R. Yantosca - Updated comments
```

1.23.1 get_bravo_mask

Function GET_BRAVO_MASK returns the value of the Mexico mask for BRAVO emissions at grid box (I,J). MASK=1 if (I,J) is in the BRAVO Mexican region, or MASK=0 otherwise.

INTERFACE:

```
      FUNCTION GET_BRAVO_MASK( I, J ) RESULT( MASK )
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I        ! Longitude index
      INTEGER, INTENT(IN) :: J        ! Latitude  index
```

RETURN VALUE:

```
      REAL*8              :: MASK     ! Returns the mask value @ (I,J)
```

REVISION HISTORY:

```
    22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
```

1.23.2 get_bravo_anthro

Function GET_BRAVO_ANTHRO returns the BRAVO emission for GEOS-Chem grid box (I,J) and tracer N. Units are [molec/cm2/s].

INTERFACE:

```
      FUNCTION GET_BRAVO_ANTHRO( I, J, N ) RESULT( BRAVO )
```

USES:

```
      USE TRACERID_MOD, ONLY : IDTNOX, IDTCO, IDTSO2
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I       ! Longitude index
      INTEGER, INTENT(IN) :: J       ! Latitude index
      INTEGER, INTENT(IN) :: N       ! Tracer number
  RETURN VALUE:

      REAL*8              :: BRAVO   ! Returns emissions at (I,J)
```

REVISION HISTORY:

```
   22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
   (1 ) added SOx, SOx ship and NH3 emissions, plus optional kg/s output
        (amv, 06/2008)
   (2 ) Now returns ship emissions if requested (phs, 6/08)
   (3 ) Added checks to avoid calling unavailable ship emissions (phs, 6/08)
```

1.23.3 emiss_bravo

Subroutine EMISS_BRAVO reads the BRAVO emission fields at 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISS_BRAVO(EMISSIONS)
#else
      SUBROUTINE EMISS_BRAVO
#endif
```

USES:

```
      USE BPCH2_MOD,         ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,     ONLY : DATA_DIR_1x1
      USE LOGICAL_MOD,       ONLY : LFUTURE
      USE SCALE_ANTHRO_MOD, ONLY : GET_ANNUAL_SCALAR
      USE TIME_MOD,          ONLY : GET_YEAR
      USE REGRID_A2A_MOD,    ONLY : DO_REGRID_A2A
```

```
      USE CMN_SIZE_MOD           ! Size parameters
      USE CMN_O3_MOD             !

#if defined( DEVEL )
      USE TRACER_MOD,   ONLY : N_TRACERS
      USE TRACERID_MOD, ONLY : IDTNOX, IDTCO, IDTSO2
#endif
```

REVISION HISTORY:

```
   22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
   (1 ) Now pass the unit string to DO_REGRID_G2G_1x1 (bmy, 8/9/06)
   13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
   24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.23.4 bravo_scale_future

Subroutine BRAVO_SCALE_FUTURE applies the IPCC future scale factors to the BRAVO anthropogenic emissions.

INTERFACE:

```
      SUBROUTINE BRAVO_SCALE_FUTURE
```

USES:

```
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_COff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff

      USE CMN_SIZE_MOD             ! Size parameters
```

REVISION HISTORY:

```
   30 May 2006 - S. Wu & R. Yantosca - Initial version
```

1.23.5 total_anthro_Tg

Subroutine TOTAL_ANTHRO_TG prints the amount of BRAVO anthropogenic emissions that are emitted each year.

INTERFACE:

```
      SUBROUTINE TOTAL_ANTHRO_TG( YEAR )
```

USES:

```
! References to F90 modules
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TRACERID_MOD, ONLY : IDTNOX, IDTCO, IDTSO2

USE CMN_SIZE_MOD     ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)   :: YEAR
```

REVISION HISTORY:

```
22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
(1 ) Now YEAR is input to reflect scaling factors applied (phs, 3/17/08)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.23.6 read_bravo_mask

Subroutine READ_BRAVO_MASK reads the Mexico mask from disk. The Mexico mask is the fraction of the grid box (I,J) which lies w/in the BRAVO Mexican emissions region.

INTERFACE:

```
SUBROUTINE READ_BRAVO_MASK
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE TRANSFER_MOD,   ONLY : TRANSFER_2D

USE CMN_SIZE_MOD         ! Size parameters
```

REVISION HISTORY:

```
22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
(1 ) Now pass UNIT to DO_REGRID_G2G_1x1 (bmy, 8/9/06)
06 Apr 2012 - M. Payer    - Changed regrid algorithm to map_a2a (M. Cooper)
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.23.7 init_bravo

Subroutine INIT_BRAVO allocates and zeroes BRAVO module arrays, and also creates the mask which defines the Mexico region

INTERFACE:

```
      SUBROUTINE INIT_BRAVO
```

USES:

```
      USE ERROR_MOD,   ONLY : ALLOC_ERR
      USE GRID_MOD,    ONLY : GET_XMID, GET_YMID
      USE LOGICAL_MOD, ONLY : LBRAVO

      USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
    22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
```

1.23.8 CLEANUP_BRAVO

Subroutine CLEANUP_BRAVO deallocates all BRAVO module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_BRAVO
```

REVISION HISTORY:

```
    22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
```

1.24 Fortran: Module Interface bromocarb_mod

Module BROMOCARB_MOD contains variables and routines for the GEOS-CHEM bromocarbon simulation.

INTERFACE:

```
      MODULE BROMOCARB_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: EMIS_CHBr3
      PUBLIC :: EMIS_CH2Br2
      PUBLIC :: SET_CH3Br
      PUBLIC :: SET_BrO
      PUBLIC :: SEA_SURFACE
      PUBLIC :: INIT_BROMOCARB
      PUBLIC :: CLEANUP_BROMOCARB
```

PUBLIC DATA MEMBERS:

```
! For scaling bromine emissions (mpayer, 5/15/12)
REAL*8, PUBLIC :: Br_SCALING
```

REVISION HISTORY:

```
13 Aug 2007 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
```

1.24.1 emiss_ch3br

Function EMIS_CHBr3 is the emissions driver for very short lived bromocarbon (VSLB) species and the one long-lived compound, methyl bromide (CH3Br).

INTERFACE:

```
FUNCTION EMIS_CHBr3( I, J ) RESULT( E_R_CHBr3 )
```

USES:

```
USE LOGICAL_MOD,  ONLY : LWARWICK_VSLS
USE TIME_MOD,     ONLY : GET_MONTH
USE GRID_MOD,     ONLY : GET_YMID

USE CMN_SIZE_MOD       ! Size parameters
USE CMN_DIAG_MOD       ! ND57 -- diagnostics
USE COMODE_LOOP_MOD    ! Avogadro's #, called 'AVG' = 6.02252d+23
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: I        ! Longitude index
INTEGER, INTENT(IN)    :: J        ! Latitude  index
```

RETURN VALUE:

```
REAL*8                 :: E_R_CHBr3
```

REMARKS:

```
only ocean emissions for all bromocarbons
plan: (1) Bromoform: 400 Gg CHBr3/yr emitted from ocean, broken into
             latitudinal bands: 75% between 20deg south and 20deg north
                25% between 20deg and 50deg north and south
             - This emission scheme follows the work of
               Warwick et al. (2006) Global Modeling of Bromocarbons
                  --> scheme A (eventually, should try B as well,
                      with coastal and shelf emissions...)
               & Yang et al. (2005) Tropospheric Bromine Chemistry
      (2) Dibromomethane:
```

```
              - Warwick et al. use same spatial scheme as used for
                bromoform in scenario 3 (lat bands above...)
                   --> schemes A & B: 113 Gg CH2Br2/yr global flux
              - they say they require higher emissions than some previous
                lit probably because they center emissions in the tropics,
                yielding shorter lifetimes for bromocarbons...
```

REVISION HISTORY:

```
  23 Aug 2007 - J. Parrella - Initial version
  22 May 2012 - M. Payer    - Added ProTeX headers
```

1.24.2 emis_ch2br2

Function EMIS_CH2Br2 is the emissions driver for very short lived bromocarbon (VSLB) species and the one long-lived compound, dibromomethane (CH2Br2)

INTERFACE:

```
      FUNCTION EMIS_CH2Br2( I, J ) RESULT( E_R_CH2Br2 )
```

USES:

```
      USE LOGICAL_MOD,   ONLY : LWARWICK_VSLS

      USE CMN_SIZE_MOD        ! Size parameters
      USE CMN_DIAG_MOD        ! ND57 -- diagnostics
      USE COMODE_LOOP_MOD     ! Avogadro's #, called 'AVG' = 6.02252d+23
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: I        ! Longitude index
      INTEGER, INTENT(IN)    :: J        ! Latitude  index
```

RETURN VALUE:

```
      REAL*8                 :: E_R_CH2Br2
```

REMARKS:

```
  only ocean emissions for all bromocarbons
  plan: (1) Bromoform: 400 Gg CHBr3/yr emitted from ocean, broken into
              latitudinal bands: 75% between 20deg south and 20deg north
                 25% between 20deg and 50deg north and south
              - This emission scheme follows the work of
                Warwick et al. (2006) Global Modeling of Bromocarbons
                   --> scheme A (eventually, should try B as well,
                       with coastal and shelf emissions...)
                & Yang et al. (2005) Tropospheric Bromine Chemistry
        (2) Dibromomethane:
```

```
- Warwick et al. use same spatial scheme as used for
  bromoform in scenario 3 (lat bands above...)
     --> schemes A & B: 113 Gg CH2Br2/yr global flux
- they say they require higher emissions than some previous
  lit probably because they center emissions in the tropics,
  yielding shorter lifetimes for bromocarbons...
```

REVISION HISTORY:

```
23 Aug 2007 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
```

1.24.3 sea_surface

Subroutine SEA_SURFACE calculates the total sea surface area within two specified regions: (1) total area between 20S and 20N (2) total area between 20 and 50 degrees, North + South These surface area values are used to set the emission fluxes for each of the aforementioned regions.

INTERFACE:

```
SUBROUTINE SEA_SURFACE
```

USES:

```
USE GRID_MOD,    ONLY : GET_AREA_M2, GET_YEDGE

USE CMN_SIZE_MOD      ! Size parameters
USE CMN_DEP_MOD       ! FRCLND = returns land-fraction of given box
```

REVISION HISTORY:

```
16 Aug 2007 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
```

1.24.4 set_ch3br

Subroutine SET_CH3Br set CH3Br Concentrations in the planetary boundary layer. Based on latitude bands (1) 90-55N, (2) 55N-0, (3) 0-55S, (4) 55-90S. Values for setting pbl flux were determined by surface measurements from NOAA 2006 data.

INTERFACE:

```
SUBROUTINE SET_CH3Br( N_TRACERS, TCVV, AD, STT, unit_flag )
```

USES:

```
USE GRID_MOD,      ONLY : GET_YMID
USE PBL_MIX_MOD,   ONLY : GET_FRAC_UNDER_PBLTOP
USE TRACER_MOD,    ONLY : TRACER_NAME
USE LOGICAL_MOD,   ONLY : LWARWICK_VSLS

USE CMN_SIZE_MOD        ! Size parameters
USE CMN_DEP_MOD         ! FRCLND = returns land-fraction of given box
```

INPUT PARAMETERS:

```
!=================================================================
! Arguments:
! TCVV : Array containing [Air MW / Tracer MW] for tracers
! AD   : Array containing grid box air masses
! STT  : Array containing tracer conc. [kg] in this case
!=================================================================
LOGICAL, INTENT(IN)    :: unit_flag
INTEGER, INTENT(IN)    :: N_TRACERS
REAL*8,  INTENT(IN)    :: TCVV(N_TRACERS)
REAL*8,  INTENT(IN)    :: AD(IIPAR,JJPAR,LLPAR)
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,  INTENT(INOUT) :: STT(IIPAR,JJPAR,LLPAR,N_TRACERS)
```

REMARKS:

```
1) STT is converted back and forth between units of [kg] and
   [v/v]. Placement of the call to SET_CH3Br in main.f (it's
   with the emissions) means that it should be in [kg].
```

REVISION HISTORY:

```
12 Feb 2008 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
```

1.24.5 set_bro

Subroutine SET_BRO sets BrO concentrations in the planetary boundary layer. Based on latitude bands (1) 90-55N, (2) 55N-0, (3) 0-55S, (4) 55-90S. Values for setting pbl flux were determined by surface measurements from NOAA 2006 data.

INTERFACE:

```
SUBROUTINE SET_BRO( N_TRACERS, TCVV, AD, SUNCOS, STT, unit_flag )
```

USES:

```
USE PBL_MIX_MOD,   ONLY : GET_FRAC_UNDER_PBLTOP
USE TRACER_MOD,    ONLY : TRACER_NAME
USE LOGICAL_MOD,   ONLY : LFIX_PBL_BRO
USE DAO_MOD,       ONLY : IS_WATER

USE CMN_SIZE_MOD        ! Size parameters
USE CMN_DEP_MOD         ! FRCLND = returns land-fraction of given box
```

INPUT PARAMETERS:

```
!=================================================================
! Arguments:
! TCVV : Array containing [Air MW / Tracer MW] for tracers
! AD   : Array containing grid box air masses
! STT  : Array containing tracer conc. [kg] in this case
!=================================================================
LOGICAL, INTENT(IN)    :: unit_flag
INTEGER, INTENT(IN)    :: N_TRACERS
REAL*8,  INTENT(IN)    :: TCVV(N_TRACERS)
REAL*8,  INTENT(IN)    :: SUNCOS(MAXIJ)
REAL*8,  INTENT(IN)    :: AD(IIPAR,JJPAR,LLPAR)
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,  INTENT(INOUT) :: STT(IIPAR,JJPAR,LLPAR,N_TRACERS)
```

REMARKS:

```
1) STT is converted back and forth between units of [kg] and
   [v/v]. Placement of the call to SET_Bro in main.f (it's
   with the emissions) means that it should be in [kg].
```

REVISION HISTORY:

```
12 Feb 2008 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
```

1.24.6 init_bromocarb

Subroutine INIT_BROMOCARB allocates and zeroes BROMOCARB module arrays.

INTERFACE:

```
SUBROUTINE INIT_BROMOCARB
```

USES:

```
USE ERROR_MOD,      ONLY : ALLOC_ERR, DEBUG_MSG
USE LOGICAL_MOD,    ONLY : LPRT,      LWARWICK_VSLS
USE GRID_MOD,       ONLY : GET_AREA_M2
USE DIRECTORY_MOD,  ONLY : DATA_DIR, DATA_DIR_1x1
```

```
      USE REGRID_A2A_MOD

      USE CMN_SIZE_MOD         ! Size parameters
      USE COMODE_LOOP_MOD      ! Avogadro's #, called 'AVG' = 6.02252d+23

      USE m_netcdf_io_open
      USE m_netcdf_io_read
      USE m_netcdf_io_close
```

REVISION HISTORY:

```
   13 Aug 2007 - J. Parrella - Initial version
   22 May 2012 - M. Payer    - Added ProTeX headers
    3 Jul 2012 - R. Yantosca -
```

1.24.7 cleanup_bromocarb

Subroutine CLEANUP_BROMOCARB deallocates all BROMOCARB module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_BROMOCARB
```

REVISION HISTORY:

```
   13 Aug 2007 - J. Parrella - Initial version
   22 May 2012 - M. Payer    - Added ProTeX headers
```

1.25 Fortran: Module Interface c2h6_mod

Module C2H6_MOD contains variables and routines used for the tagged C2H6 (ethane) simulation. (xyp, qli, bmy, 7/28/01, 4/5/06)

INTERFACE:

```
      MODULE C2H6_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: GET_C2H6_ANTHRO
      PUBLIC  :: EMISSC2H6
      PUBLIC  :: CHEMC2H6
      PUBLIC  :: CLEANUP_C2H6
  PRIVATE DATA MEMBERS:
      PRIVATE :: NGASC2H6
      PRIVATE :: FMOL_C2H6
      PRIVATE :: XNUMOL_C2H6
```

REMARKS:

```
   Setting LSPLIT = T in "input.geos" will run with the following tracers:
      (1) Total C2H6
      (2) C2H6 from biomass burning
      (3) C2H6 from biofuel burning
      (4) C2H6 from natural gas leaking/venting (e.g. "anthro" C2H6)

   Setting LSPLIT = F in "input.geos" will run w/ the following tracers:
      (1) Total C2H6
```

REVISION HISTORY:

```
   (1 ) Eliminated obsolete code from 1/02 (bmy, 2/27/02)
   (2 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
        MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
   (3 ) Now reference BXHEIGHT and T from "dao_mod.f".  Also references
        "error_mod.f".  Removed obsolete code.  Now references F90 module
         tracerid_mod.f". (bmy, 11/15/02)
   (4 ) Now references "grid_mod.f" and the new "time_mod.f" (bmy, 2/11/03)
   (5 ) Now references "directory_mod.f", "logical_mod.f", and "tracer_mod.f".
        (bmy, 7/20/04)
   (6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (7 ) Now modified
   22 Mar 2012 - M. Payer    - Add function GET_C2H6_ANTHRO
   22 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.25.1 emissc2h6

Subroutine EMISSC2H6 reads in C2H6 emissions for the Tagged C2H6 run. (xyp, qli, bmy, 7/21/00, 4/5/06)

INTERFACE:

```
 #if defined( DEVEL )
       SUBROUTINE EMISSC2H6(EMISS, BIO_EMISS)
 #else
       SUBROUTINE EMISSC2H6
 #endif
```

USES:

```
      USE BIOMASS_MOD,   ONLY : BIOMASS
      USE TRACERID_MOD,  ONLY : IDBC2H6
      USE BIOFUEL_MOD,   ONLY : BIOFUEL, BIOFUEL_BURN
      USE DIAG_MOD,      ONLY : AD36
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE GEIA_MOD,      ONLY : READ_C3H8_C2H6_NGAS, TOTAL_FOSSIL_TG
      USE GRID_MOD,      ONLY : GET_AREA_CM2
      USE LOGICAL_MOD,   ONLY : LSPLIT, LBIOMASS, LBIOFUEL, LANTHRO
      USE TIME_MOD,      ONLY : GET_MONTH, GET_TS_EMIS
      USE TRACER_MOD,    ONLY : STT
      USE TRACER_MOD,    ONLY : ITS_A_C2H6_SIM
      USE TRACERID_MOD,  ONLY : IDBFC2H6, IDEC2H6, IDTC2H6
      USE TRANSFER_MOD,  ONLY : TRANSFER_2D

      USE CMN_SIZE_MOD        ! Size parameters
      USE CMN_O3_MOD          ! EMISTC2H6
      USE CMN_DIAG_MOD        ! Diagnostic arrays & switches
      USE CMN_MOD             ! STT, etc.
```

INPUT/OUTPUT PARAMETERS:

```
#if defined( DEVEL )
      REAL*8, INTENT(INOUT)  :: EMISS(IIPAR,JJPAR)
      REAL*8, INTENT(INOUT)  :: BIO_EMISS(:,:,:)
#endif
```

REVISION HISTORY:

(1) BURNEMIS and BIOFUEL are now dimensioned with IIPAR,JJPAR instead of IIPAR,JJPAR. Remove BXHEIGHT from the arg list, since ND28 and ND36 diags are archived in BIOBURN and BIOFUEL_BURN. Now use routine TRANSFER_2D from "transfer_mod.f" to cast from REAL*4 to REAL*8. Now print emission totals for C2H6 emissions to stdout. (bmy, 1/25/02)

(2) Eliminated obsolete code from 1/02 (bmy, 2/27/02)

(3) Now references IDBC2H6 etc from "tracerid_mod.f". Now make FIRSTEMISS a local SAVEd variable instead of an argument. (bmy, 11/15/02)

(4) Now use GET_AREA_CM2 from "grid_mod.f" to get grid box surface area in cm2. Remove references to DXYP. Use routines GET_MONTH and GET_TS_EMIS from "time_mod.f". Remove MONTH from call to BIOBURN. (bmy, 2/11/03)

(5) Now replace CMN_SETUP w/ references from "logical_mod.f" and "directory_mod.f". Now references STT from "tracer_mod.f". Replace LFOSSIL with LANTHRO (bmy, 7/20/04)

(6) Now make sure all USE statements are USE, ONLY. Also eliminate reference to BPCH2_MOD, it's obsolete. (bmy, 10/3/05)

(7) Now modified for new "biomass_mod.f" (bmy, 4/5/06)

(8) BIOMASS(:,:,IDBCO) from "biomass_mod.f" is now in units of [atoms C/cm2/s]. Adjust unit conversion accordingly. (bmy, 9/27/06)

```
(9 ) Now IDBC2H6 is defined in TRACERID_MOD. (fp, hotp , 7/31/09)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
22 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.25.2 chemc2h6

Subroutine CHEMC2H6 performs C2H6 chemistry. Loss of C2H6 is via reaction with OH. (xyp, qli, bmy, 10/19/99, 7/20/04)

INTERFACE:

```
SUBROUTINE CHEMC2H6
```

USES:

```
USE DAO_MOD,       ONLY : AIRVOL,    T
USE GLOBAL_OH_MOD, ONLY : OH,        GET_GLOBAL_OH
USE LOGICAL_MOD,   ONLY : LSPLIT
USE TIME_MOD,      ONLY : GET_MONTH, GET_TS_CHEM
USE TRACER_MOD,    ONLY : N_TRACERS, STT

USE CMN_SIZE_MOD        ! Size parameters
```

REVISION HISTORY:

```
(1 ) Now do chemistry all the way to the model top.
(2 ) Use monthly mean OH fields for oxidation -- reference the monthly
     mean OH array and the routine which reads it from disk in
    "global_oh_mod.f" (bmy, 1/25/02)
(3 ) Now reference T from "dao_mod.f".  Also make FIRSTCHEM a local SAVEd
     variable. (bmy, 11/15/02)
(4 ) Now use functions GET_MONTH and GET_TS_CHEM from "time_mod.f".
(5 ) Now reference STT & N_TRACERS from "tracer_mod.f".  Now reference
     LSPLIT from "logical_mod.f" (bmy, 7/20/04)
22 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.25.3 get_c2h6_anthro

Function GET_C2H6_ANTHRO returns the monthly average anthropogenic C2H6 emissions at GEOS-Chem grid box (I,J). Data will be returned in units of [atoms C/cm2/s].

INTERFACE:

```
FUNCTION GET_C2H6_ANTHRO( I, J, N ) RESULT( C2H6_ANTHRO )
```

USES:

```
      USE TRACERID_MOD, ONLY : IDTC2H6
      USE CMN_SIZE_MOD       ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: I   ! GEOS-Chem longitude index
      INTEGER, INTENT(IN)   :: J   ! GEOS-Chem latitude index
      INTEGER, INTENT(IN)   :: N   ! GEOS-Chem tracer index
```

RETURN VALUE:

```
      REAL*8                :: C2H6_ANTHRO
```

REVISION HISTORY:

```
    22 Mar 2012 - M. Payer    - Initial version adapted from GET_RETRO_ANTHRO
```

1.25.4 init_c2h6

Subroutine INIT_C2H6 allocates and zeroes the NGASC2H6 array, which holds global monthly mean natural gas C2H6 emissions. (qli, bmy, 1/1/01, 10/15/02)

INTERFACE:

```
      SUBROUTINE INIT_C2H6
```

USES:

```
      USE ERROR_MOD, ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
    (1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
    22 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.25.5 cleanup_c2h6

Subroutine CLEANUP_C2H6 deallocates the natural gas C2H6 emission array.

INTERFACE:

```
      SUBROUTINE CLEANUP_C2H6
```

REVISION HISTORY:

```
    22 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.26 Fortran: Module Interface cac_anthro_mod

Module CAC_ANTHRO_MOD contains variables and routines to read the Criteria Air Contaminant Canadian anthropogenic emissions (amv, phs, 1/28/2009)

INTERFACE:

```
      MODULE CAC_ANTHRO_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_CAC_ANTHRO
      PUBLIC :: EMISS_CAC_ANTHRO
      PUBLIC :: EMISS_CAC_ANTHRO_05x0666
      PUBLIC :: GET_CANADA_MASK
      PUBLIC :: GET_CAC_ANTHRO
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: CAC_SCALE_FUTURE
      PRIVATE :: READ_CANADA_MASK
      PRIVATE :: READ_CANADA_MASK_05x0666
      PRIVATE :: INIT_CAC_ANTHRO
      PRIVATE :: TOTAL_ANTHRO_TG
```

REVISION HISTORY:

```
   28 Jan 2009 - P. Le Sager - Initial Version
   18 Dec 2009 - Aaron van D - Added EMISS_CAC_ANTHRO_05x0666 routine
   18 Dec 2009 - Aaron van D - Added READ_CANADA_MASK_05x0666 routine
   01 Mar 2012 - R. Yantosca - Remove A_CM2 array, use the new function
                               GET_AREA_CM2( I, J, L ) from grid_mod.F90
```

1.26.1 get_canada_mask

Function GET_CANADA_MASK returns the value of the Canadian geographic mask at grid box (I,J). MASK=1 if (I,J) is within Canada, MASK=0 otherwise. (amv, phs, 1/28/09)

INTERFACE:

```
      FUNCTION GET_CANADA_MASK( I, J ) RESULT( THISMASK )
```

INPUT PARAMETERS:

```
! Longitude and latitude indices
INTEGER, INTENT(IN) :: I, J
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
```

1.26.2 get_cac_anthro

Function GET_CAC_ANTHRO returns the Critical Air Contaminants emission for GEOS-Chem grid box (I,J) and tracer N. Emissions can be returned in units of [kg/s] or [molec/cm2/s]. (amv, phs, 1/28/09)

INTERFACE:

```
FUNCTION GET_CAC_ANTHRO( I,    J,     N,
&                        MOLEC_CM2_S, KG_S ) RESULT( VALUE )
```

USES:

```
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TRACER_MOD,   ONLY : XNUMOL
USE TRACERID_MOD, ONLY : IDTNOx, IDTCO, IDTSO2, IDTNH3
```

INPUT PARAMETERS:

```
! Longitude, latitude, and tracer indices
INTEGER, INTENT(IN)           :: I, J, N

! OPTIONAL -- return emissions in [molec/cm2/s]
LOGICAL, INTENT(IN), OPTIONAL :: MOLEC_CM2_S

! OPTIONAL -- return emissions in [kg/s]
LOGICAL, INTENT(IN), OPTIONAL :: KG_S
```

RETURN VALUE:

```
! Emissions output
REAL*8                        :: VALUE
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
```

1.26.3 emiss_cac_anthro

Subroutine EMISS_CAC_ANTHRO reads the Critical Air Contaminants emission fields at 1x1 resolution and regrids them to the current model resolution. (amv, phs, 1/28/2009)

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISS_CAC_ANTHRO(EMISSIONS)
#else
      SUBROUTINE EMISS_CAC_ANTHRO
#endif
```

USES:

```
      USE BPCH2_MOD,         ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,     ONLY : DATA_DIR_1x1
      USE LOGICAL_MOD,       ONLY : LFUTURE
      USE TIME_MOD,          ONLY : GET_YEAR
      USE SCALE_ANTHRO_MOD,  ONLY : GET_ANNUAL_SCALAR_1x1
      USE REGRID_A2A_MOD,    ONLY : DO_REGRID_A2A
      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_O3_MOD               ! FSCALYR

#if defined( DEVEL )
      USE TRACERID_MOD, ONLY : IDTNOx, IDTCO, IDTSO2, IDTNH3
      USE TRACER_MOD, ONLY   : N_TRACERS
#endif
```

REVISION HISTORY:

```
   28 Jan 2009 - P. Le Sager - Initial Version
```

REMARKS:

```
   (1 ) Emissions are read for a year b/w 2002-2005, and scaled
        (except NH3) between 1985-2003 if needed (phs, 3/10/08)
   (2 ) Now accounts for FSCALYR (phs, 3/17/08)
   18 Dec 2009 - Aaron van D - Use 2005 scale factors for years beyond 2005
   13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
   24 May 2012 - R. Yantosca - Fixed minor bug in map_a2a implementation
```

1.26.4 emiss_cac_anthro_05x0666

Subroutine EMISS_CAC_ANTHRO_05x0666 reads the Critical Air Contaminants emission fields at nested NA resolution (1/2 x 2/3) (amv, phs, 11/03/2009)

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISS_CAC_ANTHRO_05x0666(EMISSIONS)
#else
      SUBROUTINE EMISS_CAC_ANTHRO_05x0666
#endif
```

USES:

```
      USE BPCH2_MOD,         ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,     ONLY : DATA_DIR
      USE LOGICAL_MOD,       ONLY : LFUTURE
      USE TIME_MOD,          ONLY : GET_YEAR
      USE SCALE_ANTHRO_MOD,  ONLY : GET_ANNUAL_SCALAR_05x0666_NESTED

      USE CMN_SIZE_MOD          ! Size parameters
      USE CMN_O3_MOD            ! FSCALYR
#if defined( DEVEL )
      USE TRACERID_MOD, ONLY : IDTNOx, IDTCO, IDTSO2, IDTNH3
      USE TRACER_MOD,   ONLY : N_TRACERS
#endif
```

REVISION HISTORY:

```
   03 Nov 2009 - A. van Donkelaar - Initial Version
```

REMARKS:

```
   (1 ) Emissions are read for a year b/w 2002-2005, and scaled
        (except NH3) between 1985-2003 if needed (phs, 3/10/08)
   (2 ) Now accounts for FSCALYR (phs, 3/17/08)
```

1.26.5 cac_scale_future

Subroutine CAC_SCALE_FUTURE applies the IPCC future scale factors to the Criteria Air Contaminant anthropogenic emissions. (amv, phs, 1/28/09)

INTERFACE:

```
      SUBROUTINE CAC_SCALE_FUTURE
```

USES:

```
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_COff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NH3an
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff

      USE CMN_SIZE_MOD             ! Size parameters
```

REVISION HISTORY:

```
   28 Jan 2009 - P. Le Sager - Initial Version
```

1.26.6 total_anthro_tg

Subroutine TOTAL_ANTHRO_TG prints the totals for the anthropogenic emissions of NOx, CO, SO2 and NH3. (amv, phs, 1/28/09)

INTERFACE:

```
SUBROUTINE TOTAL_ANTHRO_TG( YEAR )
```

USES:

```
USE CMN_SIZE_MOD            ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: YEAR   ! Year of data to compute totals
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
```

1.26.7 read_canada_mask

Subroutine READ_CANADA_MASK reads and regrids the Canadian geographic mask from disk. (amv, phs, 1/28/09)

INTERFACE:

```
SUBROUTINE READ_CANADA_MASK
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_TAU0, READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

USE CMN_SIZE_MOD         ! Size parameters
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
07 Jun 2012 - M. Payer    - Fixed minor bugs in map_a2a implementation
```

1.26.8 read_canada_mask_05x0666

Subroutine READ_CANADA_MASK_05x0666 reads the Canadian geographic mask from disk. (amv, phs, 1/28/09)

INTERFACE:

```
SUBROUTINE READ_CANADA_MASK_05x0666
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_TAU0, READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR


USE CMN_SIZE_MOD       ! Size parameters
```

REVISION HISTORY:

```
11 Nov 2009 - A. van Donkelaar - Initial Version
```

1.26.9 init_cac_anthro

Subroutine INIT_CAC_ANTHRO allocates and zeroes all module arrays. (phs, 1/28/09)

INTERFACE:

```
SUBROUTINE INIT_CAC_ANTHRO
```

USES:

```
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE LOGICAL_MOD, ONLY : LCAC

USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
01 Mar 2012 - R. Yantosca - Delete the A_CM2 array, we will now just
                            use the function directly
```

1.26.10 cleanup_cac_anthro

Subroutine CLEANUP_CAC_ANTHRO deallocates all module arrays. (phs, 1/28/09)

INTERFACE:

```
SUBROUTINE CLEANUP_CAC_ANTHRO
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
```

1.27 Fortran: Module Interface chemistry_mod

Module CHEMISTRY_MOD is used to call the proper chemistry subroutine for the various GEOS-Chem simulations.

INTERFACE:

```
MODULE CHEMISTRY_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: DO_CHEMISTRY
      PUBLIC :: GCKPP_DRIVER
      PUBLIC :: RECOMPUTE_OD
```

REVISION HISTORY:

```
(1 ) Bug fix in DO_CHEMISTRY (bnd, bmy, 4/14/03)
(2 ) Now references DEBUG_MSG from "error_mod.f" (bmy, 8/7/03)
(3 ) Now references "tagged_ox_mod.f"(bmy, 8/18/03)
(4 ) Now references "Kr85_mod.f" (jsw, bmy, 8/20/03)
(5 ) Bug fix: Now also call OPTDEPTH for GEOS-4 (bmy, 1/27/04)
(6 ) Now references "carbon_mod.f" and "dust_mod.f" (rjp, tdf, bmy, 4/5/04)
(7 ) Now references "seasalt_mod.f" (rjp, bec, bmy, 4/20/04)
(8 ) Now references "logical_mod.f", "tracer_mod.f", "diag20_mod.f", and
      "diag65_mod.f", and "aerosol_mod." (bmy, 7/20/04)
(9 ) Now references "mercury_mod.f" (bmy, 12/7/04)
(10) Updated for SO4s, NITs chemistry (bec, bmy, 4/13/05)
(11) Now call CHEM_HCN_CH3CN from "hcn_ch3cn_mod.f".  Also remove all
      references to the obsolete CO-OH param simulation. (xyp, bmy, 6/24/05)
(12) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(13) Now call MAKE_RH from "main.f" (bmy, 3/16/06)
(14) Updated for SOA from isoprene (dkh, bmy, 6/1/06)
(15) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(16) For now, replace use RPMARES instead of ISORROPIA. (bmy, 4/2/08)
(17) Added KPP chemistry driver subroutine (phs,ks,dhk, 09/15/09)
(18) Added public member function recompute_OD (skim, 02/03/11)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
28 Jan 2010 - C. Carouge, R. Yantosca - Modified for ISORROPIA II
```

1.27.1 do_chemistry

Subroutine DO_CHEMISTRY is the driver routine which calls the appropriate chemistry subroutine for the various GEOS-Chem simulations.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE DO_CHEMISTRY(CHEM_STATE)
#else
      SUBROUTINE DO_CHEMISTRY
#endif
```

USES:

```
      USE ACETONE_MOD,     ONLY : OCEAN_SINK_ACET
      USE AEROSOL_MOD,     ONLY : AEROSOL_CONC, AEROSOL_RURALBOX
      USE AEROSOL_MOD,     ONLY : RDAER,        SOILDUST
      USE C2H6_MOD,        ONLY : CHEMC2H6
      USE CARBON_MOD,      ONLY : CHEMCARBON
      USE CH3I_MOD,        ONLY : CHEMCH3I
      USE DAO_MOD,         ONLY : CLDF,    DELP
      USE DAO_MOD,         ONLY : OPTDEP,  OPTD,   T
      USE DRYDEP_MOD,      ONLY : DRYFLX, DRYFLXRnPbBe, DRYFLXH2HD
      USE DUST_MOD,        ONLY : CHEMDUST, RDUST_ONLINE
      USE ERROR_MOD,       ONLY : DEBUG_MSG
      USE GLOBAL_CH4_MOD,  ONLY : CHEMCH4
      USE H2_HD_MOD,       ONLY : CHEM_H2_HD
      USE HCN_CH3CN_MOD,   ONLY : CHEM_HCN_CH3CN
      USE ISOROPIAII_MOD,  ONLY : DO_ISOROPIAII
      USE LOGICAL_MOD,     ONLY : LCARB, LCHEM,  LCRYST, LDUST, LSCHEM
      USE LOGICAL_MOD,     ONLY : LPRT,  LSSALT, LSULF,  LSOA
      USE MERCURY_MOD,     ONLY : CHEMMERCURY
      USE OPTDEPTH_MOD,    ONLY : OPTDEPTH
      USE RnPbBe_MOD,      ONLY : CHEMRnPbBe
      USE RPMARES_MOD,     ONLY : DO_RPMARES
      USE SEASALT_MOD,     ONLY : CHEMSEASALT
      USE SULFATE_MOD,     ONLY : CHEMSULFATE
      USE STRAT_CHEM_MOD,  ONLY : DO_STRAT_CHEM
      USE TAGGED_CO_MOD,   ONLY : CHEM_TAGGED_CO
      USE TAGGED_OX_MOD,   ONLY : CHEM_TAGGED_OX
      USE TIME_MOD,        ONLY : GET_ELAPSED_MIN, GET_TS_CHEM
      USE TRACER_MOD,      ONLY : N_TRACERS,       STT
      USE TRACER_MOD,      ONLY : ITS_A_C2H6_SIM
      USE TRACER_MOD,      ONLY : ITS_A_CH3I_SIM
      USE TRACER_MOD,      ONLY : ITS_A_CH4_SIM
      USE TRACER_MOD,      ONLY : ITS_A_FULLCHEM_SIM
      USE TRACER_MOD,      ONLY : ITS_A_H2HD_SIM
      USE TRACER_MOD,      ONLY : ITS_A_HCN_SIM
      USE TRACER_MOD,      ONLY : ITS_A_MERCURY_SIM
      USE TRACER_MOD,      ONLY : ITS_A_RnPbBe_SIM
      USE TRACER_MOD,      ONLY : ITS_A_TAGCO_SIM
      USE TRACER_MOD,      ONLY : ITS_A_TAGOX_SIM
      USE TRACER_MOD,      ONLY : ITS_AN_AEROSOL_SIM
      USE TRACER_MOD,      ONLY : ITS_NOT_COPARAM_OR_CH4
      USE TRACERID_MOD,    ONLY : IDTACET, IDTISOP
      USE LOGICAL_MOD,     ONLY : LNLPBL ! (Lin, 03/31/09)

      USE CMN_SIZE_MOD           ! Size parameters
      USE COMODE_LOOP_MOD        ! NPHOT
      USE CMN_DIAG_MOD           ! NDxx flags

#if defined( DEVEL )
```

```
      USE GC_TYPE2_MOD,           ONLY : CHEMSTATE, NULL
#endif
```

REVISION HISTORY:

```
(1 ) Now reference DELP, T from "dao_mod.f" since we need to pass this
     to OPTDEPTH for GEOS-1 or GEOS-STRAT met fields (bnd, bmy, 4/14/03)
(2 ) Now references DEBUG_MSG from "error_mod.f" (bmy, 8/7/03)
(3 ) Removed call to CHEMO3, it's obsolete.  Now calls CHEM_TAGGED_OX !
     from "tagged_ox_mod.f" when NSRCX==6.  Now calls Kr85 chemistry if
     NSRCX == 12 (jsw, bmy, 8/20/03)
(4 ) Bug fix: added GEOS-4 to the #if block in the call to OPTDEPTH.
     (bmy, 1/27/04)
(5 ) Now calls CHEMCARBON and CHEMDUST to do carbon aerosol & dust
     aerosol chemistry (rjp, tdf, bmy, 4/2/04)
(6 ) Now calls CHEMSEASALT to do seasalt aerosol chemistry
     (rjp, bec, bmy, 4/20/04)
(7 ) Now references "logical_mod.f" & "tracer_mod.f".  Now references
     AEROSOL_CONC, AEROSOL_RURALBOX, and RDAER from "aerosol_mod.f".
     Now includes "CMN_DIAG" and "comode.h".  Also call READER, READCHEM,
     and INPHOT to initialize the FAST-J arrays so that we can save out !
     AOD's to the ND21 diagnostic for offline runs. (bmy, 7/20/04)
(8 ) Now call routine CHEMMERCURY from "mercury_mod.f" for an offline
     Hg0/Hg2/HgP simulation. (eck, bmy, 12/7/04)
(9 ) Now do not call DO_RPMARES if we are doing an offline aerosol run
     with crystalline sulfur & aqueous tracers (cas, bmy, 1/7/05)
(10) Now use ISOROPIA for aer thermodyn equilibrium if we have seasalt
     tracers defined, or RPMARES if not.  Now call CHEMSEASALT before
     CHEMSULFATE.  Now do aerosol thermodynamic equilibrium before
     aerosol chemistry for offline aerosol runs.  Now also reference
     CLDF from "dao_mod.f" (bec, bmy, 4/20/05)
(11) Now modified for GCAP met fields.  Now call CHEM_HCN_CH3CN from
     "hcn_ch3cn_mod.f".  Also remove allreferences to the obsolete
      CO-OH param simulation. (xyp, bmy, 6/23/05)
(12) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(13) Now call MAKE_RH from "main.f" (bmy, 3/16/06)
(14) Removed ISOP_PRIOR as a local variable (dkh, bmy, 6/1/06)
(15) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(16) Now use DRYFLXH2HD and CHEM_H2_HD for H2/HD sim (lyj, phs, 9/18/07)
(17) Bug fix: now hardwired to use RPMARES since ISORROPIA can return very
     unphysical values at low RH.  Wait for ISORROPIA II. (bmy, 4/2/08)
(18) The dry deposition diagnostic (ND44) is done in vdiff_mod if using non-
     local PBL (lin, ccc, 5/29/09)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
28 Jan 2010 - C. Carouge, R. Yantosca - Modified for ISORROPIA II
19 Mar 2012 - R. Yantosca - Add C-preprocessor switch to shut off
                            ISORROPIA to facilitate debugging
```

1.27.2 gckpp_driver

Subroutine GCKPP_DRIVER is the driver routine to perform integration with the full KPP chemistry mechanism.

INTERFACE:

```
SUBROUTINE GCKPP_DRIVER( KTLOOP, JLOOPLO, R_KPP, NSPEC_GC )
```

USES:

```
USE COMODE_MOD,           ONLY : JLOP,   CSPEC
USE COMODE_MOD,           ONLY : IXSAVE, IYSAVE,    IZSAVE
USE GCKPP_COMODE_MOD,     ONLY : HSAVE_KPP
USE TIME_MOD,             ONLY : GET_TS_CHEM
USE GCKPP_UTIL,           ONLY : SHUFFLE_KPP2USER
USE GCKPP_INITIALIZE,     ONLY : INITIALIZE
USE GCKPP_MODEL
USE GCKPP_GLOBAL
USE GCKPP_RATES,          ONLY : UPDATE_RCONST
USE GCKPP_MONITOR,        ONLY : SPC_NAMES
USE GCKPP_FUNCTION
USE ERROR_MOD,            ONLY : ERROR_STOP
USE GCKPP_INTEGRATOR,     ONLY : NHNEW, NHEXIT, INTEGRATE
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: KTLOOP       ! Local loop index
INTEGER, INTENT(IN) :: JLOOPLO      ! JLOOPLO + KLOOP = JLOOP
REAL*8,  INTENT(IN) :: R_KPP(:,:)   ! Array of reaction rates
INTEGER, INTENT(IN) :: NSPEC_GC     ! # of active chemical species
```

REMARKS:

```
Variables used to pass the last/first step size b/w call
                                                                        .
For Rosenbrock:
----------------
    Nhexit=2, Nhnew = 3
OUT
    RSTATUS(2)  -> Hexit, last accepted step before exit
    RSTATUS(3)  -> Hnew, last predicted step (not yet taken)
    For multiple restarts, use Hnew as Hstart in the subsequent run
IN
    RCNTRL(3)   -> Hstart, starting value for the integration step size
                                                                        .
                                                                        .
For LSODE:
------------
OUT
    RSTATUS(1)  -> Texit, the time corresponding to the
```

```
                    computed Y upon return
     RSTATUS(2)  -> Hexit, last predicted step before exit
     For multiple restarts, use Hexit as Hstart in the following run
 IN
     RCNTRL(3)  -> Hstart, starting value for the integration step size
                                                                          .
                                                                          .
 For RADAU5:
 ------------
 OUT
     RSTATUS(1)  -> final time
 IN
     RCNTRL(3)   -> not used
                                                                          .
                                                                          .
For RUNGE-KUTTA
---------------
OUT
    same as Rosenbrock
```

REVISION HISTORY:

```
 24 Jan 2008 - Kumaresh    - Based on Daven Henze's GCKPP_DRIVER.
 16 Sep 2009 - R. Yantosca - Commented, and updated to call various
 03 Dec 2009 - C. Carouge  - Use CSPEC instead of CSPEC_FOR_KPP
                             to save memory space
 17 Dec 2009 - R. Yantosca - Added ProTeX headers
 20 Jan 2010 - C. Carouge  - Now call GCKPP_DRIVER from physproc.f to save
                             memory.
 20 Jan 2010 - C. Carouge  - Now use the # of active species from GC to
                             update CSPEC and not the of variable species
                             from KPP.
```

1.27.3 recompute_od

Subroutine RECOMPUTE_OD will update the optical depth values before accumulating or writing the diagnostics.

INTERFACE:

```
      SUBROUTINE RECOMPUTE_OD
```

USES:

```
      ! References to F90 modules
      USE AEROSOL_MOD,     ONLY : AEROSOL_CONC
      USE AEROSOL_MOD,     ONLY : RDAER, SOILDUST
```

```
      USE DUST_MOD,         ONLY : RDUST_ONLINE, RDUST_OFFLINE
      USE ERROR_MOD,        ONLY : DEBUG_MSG
      USE LOGICAL_MOD,      ONLY : LCARB, LCHEM, LCRYST, LDUST
      USE LOGICAL_MOD,      ONLY : LPRT, LSSALT, LSULF,  LSOA
      USE TIME_MOD,         ONLY : GET_MONTH, GET_YEAR
      USE TRACER_MOD,       ONLY : ITS_A_FULLCHEM_SIM
      USE TRACER_MOD,       ONLY : ITS_AN_AEROSOL_SIM
```

REVISION HISTORY:

```
    03 Fev 2011 - Adapted from chemdr.f by skim
```

1.28 Fortran: Module Interface co2_mod

Module CO2_MOD contains variables and routines used for the CO2 simulation. A tagged CO2 simulation capability has now been added.

References:

- Andres, R.J, G. Marland, I. Fung, and E. Matthews, *A 1x1 distribution of carbon dioxide emissions from fossil fuel consumption and cement manufacture*, Glob. Biogeochem. Cycles, **10**, 419-429, 1996.
- Corbett and Koehler (2003) *Updated emissions from ocean shipping*, J. Geophys. Res., **108**, D20, 4650.
- Corbett and Koehler (2004) *Considering alternative input parameters in an activity-based ship fuel consumption and emissions model: Reply ...* J. Geophys. Res., D23303.
- Endresen et al. (2007) *A historical reconstruction of ships fuel consumption and emissions*, J. Geophys. Res. **112**, D12301.
- Kim et al. (2005) *System for assessing Aviation's Global Emissions (SAGE) Version 1.5 global Aviation Emissions Inventories for 2000-2004*
- Kim et al. (2007) *System for assessing Aviation's Global Emissions (SAGE) Part 1: Model description and inventory results*
- LeQuere et al. (2009) *Trends in the sources and sinks of carbon dioxide*, Nature Geoscience, doi:10.1038/ngeo689.
- Olsen and Randerson (2004), *Differences between surface and column atmospheric CO2 and implications for carbon cycle research*, J. Geophys. Res., **109**, D02301,
- Potter et al. (1993), *Terrestrial Ecosystem Production: A process model based on global satellite and surface data*, Glob. Biogeochem. Cycles, **7**(4), 811-841.
- Randerson, J.T, M.V. Thompson, T.J.Conway, I.Y. Fung, and C.B. Field, *The contribution of terrestrial sources and sinks to trends in the seasonal cycle of atmospheric carbon dioxide*, Glob. Biogeochem. Cycles,**11**, 535-560, 1997.

- Suntharalingam et al. (2005) *Infulence of reduced carbon emissions and oxidation on the distribution of atmospheric CO2: Implications for inversion analysis*, BGC, 19, GB4003.
- Takahashi, T, R. Feely, R. Weiss, R. Wanninkof, D. Chipman, S. Sutherland, and T. Takahashi (1997), *Global air-sea flux of CO2: An estimate based on measurements of sea-air pCO2 difference*, Proceedings of the National Academy of Sciences, **94**, 8292-8299.
- Takahashi, T, et al. (2009), *Climatological mean and decadal change in surface ocean pCO2, and net sea-air CO2 flux over the global oceans*, **Deep-Sea Research II**, doi:10.1016/jdsr2/2008.12.009.
- Yevich, R. and J. A. Logan, *An assesment of biofuel use and burning of agricultural waste in the developing world*, Glob. Biogeochem. Cycles, **17**, 1095, doi:10.1029/2002GB001952, 2003.
- Sausen, R. and Schumann, U. "Estimates of the Climate Response to Aircraft CO2 and NOx Emissions Scenarios", Climate Change, 44: 27-58, 2000
- Wilkersen, J.T. et al. *Analysis of emission data from global commercial Aviation: 2004 and 2006*, Atmos. chem. Phys. Disc., **10**, 2945-2983, 2010.

INTERFACE:

```
      MODULE CO2_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_CO2
      PUBLIC  :: EMISSCO2
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: READ_CHEMCO2
      PRIVATE :: READ_FOSSILCO2
      PRIVATE :: CHEM_SURF
      PRIVATE :: AVIATION_DOM_CORR
      PRIVATE :: READ_OCEANCO2
      PRIVATE :: READ_ANNUAL_BIOFUELCO2
      PRIVATE :: READ_SHIPCO2_EDGAR
      PRIVATE :: READ_SHIPCO2_ICOADS
      PRIVATE :: READ_AVIATION_CO2
```

```
PRIVATE :: READ_ANNUAL_BIONET_CO2
PRIVATE :: READ_BBIO_DAILYAVERAGE
PRIVATE :: READ_BBIO_DIURNALCYCLE
PRIVATE :: TOTAL_BIOMASS_TG
PRIVATE :: DEF_BIOSPH_CO2_REGIONS_F
PRIVATE :: DEF_OCEAN_CO2_REGIONS_F
PRIVATE :: DEF_FOSSIL_CO2_REGIONS_F
PRIVATE :: INIT_CO2
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%   BUYER BEWARE! Tagged CO2 tracers only work for 2 x 2.5 grid!   %%%
%%%   Someone will have to make this more general later on...        %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

.

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam - Initial version
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) Now references biomass_mod.f (bmy, 9/27/06)
(3 ) Tagged CO2 capability developed (dbj)
(4 ) Implemented monthly and annual fossil fuel inventories
      (R.Nassar 2009-03-10)
(5 ) Implemented CO2 emissions from shipping and aviation (R.Nassar 2010)
(6 ) Implemented monthly CO2 chemical production and surface correction
      (R.Nassar 2010)
25 Feb 2011 - R. Nassar  - Now read updated CDIAC CO2 emissions data
07 Sep 2011 - P. Kasibhatla - Modified to include GFED3
```

1.28.1 emissco2

Subroutine EMISSCO2 is the driver routine for CO2 emissions.

INTERFACE:

```
SUBROUTINE EMISSCO2
```

USES:

```
USE BIOMASS_MOD,  ONLY : BIOMASS
USE DIAG04_MOD,   ONLY : AD04, ND04
USE DIAG04_MOD,   ONLY : AD04_plane,    AD04_chem
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TIME_MOD,     ONLY : GET_DAY,       GET_DAY_OF_YEAR
USE TIME_MOD,     ONLY : GET_HOUR,      GET_MONTH
USE TIME_MOD,     ONLY : GET_YEAR,      GET_TS_CHEM, GET_TS_EMIS
USE TIME_MOD,     ONLY : ITS_A_NEW_DAY, ITS_A_NEW_MONTH
```

```
      USE TRACER_MOD,   ONLY : N_TRACERS,     STT
      USE TRACERID_MOD, ONLY : IDBCO2
      USE LOGICAL_MOD,  ONLY : LGENFF,      LANNFF,   LMONFF, LSTREETS
      USE LOGICAL_MOD,  ONLY : LSEASBB,     LGFED2BB, L8DAYBB, LBIOFUEL
      USE LOGICAL_MOD,  ONLY : LGFED3BB
      USE LOGICAL_MOD,  ONLY : LBIODAILY,   LBIODIURNAL
      USE LOGICAL_MOD,  ONLY : LBIONETORIG, LBIONETCLIM
      USE LOGICAL_MOD,  ONLY : LOCN1997,    LOCN2009ANN, LOCN2009MON
      USE LOGICAL_MOD,  ONLY : LSHIPEDG,    LSHIPICO,    LPLANE
      USE LOGICAL_MOD,  ONLY : LBIOSPHTAG,  LFOSSILTAG,  LFFBKGRD
      USE LOGICAL_MOD,  ONLY : LSHIPTAG,    LPLANETAG
      USE LOGICAL_MOD,  ONLY : LSHIPSCALE,  LPLANESCALE
      USE LOGICAL_MOD,  ONLY : LCHEMCO2

      USE CMN_SIZE_MOD    ! Size parameters
```

REMARKS:

```
The initial condition for CO2 has to be at least 50 ppm or higher or else
the balanced biosphere fluxes will make STT negative. (pns, bmy, 8/16/05)
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam - Initial version
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) We now get CO2 biomass emissions from biomass_mod.f.  This allows us
     to use either GFED2 or default Duncan et al biomass emissions.
     (bmy, 9/27/06)
(3 ) Tagged tracer capability added. This requires the editable region
     files Regions_land.dat and Regions_ocean.dat in the run directory
     (rnassar,dbj, 2009)
(4 ) New tracers for emissions from international and domestic shipping,
     international and domestic aviation, and the chemical CO2 source
     from the oxidation of CO, CH4, and other organics (rnassar,dbj, 2009)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.28.2 read_chemco2

Reads the chemical source of CO2 [molec/cm3/s] from disk.

INTERFACE:

```
      SUBROUTINE READ_CHEMCO2
```

USES:

```
      USE DIRECTORY_MOD, ONLY : DATA_DIR
```

```
      USE BPCH2_MOD,     ONLY : GET_MODELNAME, GET_RES_EXT
      USE BPCH2_MOD,     ONLY : GET_TAU0,   READ_BPCH2
      USE TIME_MOD,      ONLY : GET_MONTH,  GET_YEAR

      USE CMN_SIZE_MOD      ! Size parameters
```

REMARKS:

REVISION HISTORY:

```
    18 May 2010 - R. Nassar, D. Jones - Initial version
```

1.28.3 read_fossilco2

Subroutine READ_FOSSILCO2 reads in fossil fuel CO2 emissions from a bpch file.

INTERFACE:

```
      SUBROUTINE READ_FOSSILCO2
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
      USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE TRANSFER_MOD,  ONLY : TRANSFER_2D
      USE TIME_MOD,      ONLY : GET_YEAR, GET_MONTH
      USE LOGICAL_MOD,   ONLY : LGENFF, LANNFF, LMONFF, LCHEMCO2, LPLANE

      USE CMN_SIZE_MOD      ! Size parameters
```

REMARKS:

```
    Original data provided by Robert Andres (CDIAC), personal communication
                                                                             .
    If GENFF=T, then annual data for 1995 are read (but tau is for 1985)
    If ANNFF=T, then annual data for a given year (1985-2006) are read
    If MONFF=T, then annual data for a given month (198501-200612) are read
                                                                             .
    ANNFF and MONFF for 2007-2009 were developed based on scaling using
    preliminary data on the CDIAC website for 2007-2008 and LeQuere et al.
    (2009) for 2009
                                                                             .
        -- Ray Nassar 2010-03-10
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
25 Feb 2011 - R. Nassar           - Now point to annual_v2010 and
                                    monthly_v2010 directories, which
                                    contain updated CO2 data from CDIAC
```

1.28.4 chem_surf

This subroutine reads the fossil fuel distribution from file to be used for part of the spatial distribution of the CO2 surface correction, based on a value of 4.89Suntharalingam et al. (2005).

INTERFACE:

```
SUBROUTINE CHEM_SURF
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_TAU0,   READ_BPCH2
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE DIRECTORY_MOD,  ONLY : DATA_DIR
USE LOGICAL_MOD,    ONLY : LGENFF, LANNFF, LMONFF
USE TRANSFER_MOD,   ONLY : TRANSFER_2D
USE TIME_MOD,       ONLY : GET_YEAR,GET_MONTH
USE GRID_MOD,       ONLY : GET_AREA_CM2

USE CMN_SIZE_MOD       ! Size parameters
```

REMARKS:

```
Methane source distribution are read for the same purpose from 2004 data
provided by Kevin Wecht.

Monoterpenes and Isoprene are read and treated as representative NMVOCs.

   -- Ray Nassar 2010-03-27
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
25 Feb 2011 - R. Nassar           - Now point to annual_v2010 and
                                    monthly_v2010 directories, which
                                    contain updated CO2 data from CDIAC
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.28.5 aviation_dom_corr

This subroutine downscales national fossil fuels emissions for the CO2 which is atttibuted to domestic aviation based on Kim et al. (2005,2007). It should only be used when the aviation emissions are turned on since these emissions will instead be emitted throughout the troposphere.

INTERFACE:

```
SUBROUTINE AVIATION_DOM_CORR( EMFOSS )
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE DIRECTORY_MOD,  ONLY : DATA_DIR,        DATA_DIR_1x1  !(lmw,05/16/11)
USE LOGICAL_MOD,    ONLY : LGENFF
USE TRANSFER_MOD,   ONLY : TRANSFER_2D
USE TIME_MOD,       ONLY : GET_YEAR,        ITS_A_LEAPYEAR
USE GRID_MOD,       ONLY : GET_AREA_CM2
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
REAL*8, INTENT(INOUT)   :: EMFOSS(IIPAR,JJPAR)  ! Fuel to be scaled
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
25 Feb 2011 - R. Nassar           - Now point to annual_v2010 and
                                    monthly_v2010 directories, which
                                    contain updated CO2 data from CDIAC
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
05 Mar 2012 - M. Payer    - Add modifications for nested-grid CO2
                            (Yuxuan Wang, lmw)
06 Apr 2012 - M. Payer    - Changed regrid algorithm to map_a2a (M. Cooper)
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.28.6 read_oceanco2

Subroutine READ_OCEANCO2 reads in either

- Annual mean oceanic CO2 exchange from Takahashi 1997
- Annual mean oceanic CO2 exchange from Takahashi 2009
- Aonthly mean oceanic CO2 exchange from Takahashi 2009

from a binary punch file.

INTERFACE:

```
SUBROUTINE READ_OCEANCO2
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TIME_MOD,      ONLY : GET_MONTH
USE TRANSFER_MOD,  ONLY : TRANSFER_2D
USE LOGICAL_MOD,   ONLY : LOCN1997, LOCN2009ANN, LOCN2009MON

USE CMN_SIZE_MOD      ! Size parameters
```

REMARKS:

```
See References Above
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
25 Feb 2011 - R. Nassar           - Now point to annual_v2010 and
                                    monthly_v2010 directories, which
                                    contain updated CO2 data from CDIAC
```

1.28.7 read_annual_biofuelco2

Subroutine READ_ANNUAL_BIOFUELCO2 reads in annual mean biofuel CO2 emissions from a binary punch file.

INTERFACE:

```
SUBROUTINE READ_ANNUAL_BIOFUELCO2
```

USES:

```
! References to F90 modules
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR,        DATA_DIR_1x1  !(lmw,05/16/11)
USE TRANSFER_MOD,   ONLY : TRANSFER_2D
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

USE CMN_SIZE_MOD         ! Size parameters
```

REMARKS:

```
References:
(1 ) Yevich and Logan 2001 gridded (1x1) dataset in combination with
      emission factors for CO2 per kg drymatter burned
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
05 Mar 2012 - M. Payer            - Add modifications for nested-grid CO2
                                    (Yuxuan Wang, lmw)
06 Apr 2012 - M. Payer            - Changed regrid algorithm to map_a2a
                                    (M. Cooper)
24 May 2012 - R. Yantosca         - Fixed minor bugs in map_a2a calls
```

1.28.8 read_shipco2_edgar

Subroutine READ_SHIPCO2_EDGAR reads in annual mean ship CO2 emissions from a binary punch file. Scaling is based on Endresen et al. (2007).

INTERFACE:

```
SUBROUTINE READ_SHIPCO2_EDGAR
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR, DATA_DIR_1x1
USE TRANSFER_MOD,   ONLY : TRANSFER_2D
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE GRID_MOD,       ONLY : GET_AREA_CM2
USE TIME_MOD,       ONLY : GET_YEAR

USE CMN_SIZE_MOD         ! Size parameters
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a impelementation
```

1.28.9 read_shipco2_icoads

Subroutine READ_SHIPCO2_ICOADS reads in ICOADS monthly ship CO2 emissions

INTERFACE:

```
SUBROUTINE READ_SHIPCO2_ICOADS
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR, DATA_DIR_1x1
USE TRANSFER_MOD,   ONLY : TRANSFER_2D
USE FILE_MOD,       ONLY : IU_FILE, IOERROR
USE TIME_MOD,       ONLY : GET_YEAR, GET_MONTH
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

USE CMN_SIZE_MOD         ! Size parameters
```

REMARKS:

```
This subroutine reads from bpch files at GEOS 1x1 (half-polar) resolution
although the original data are provided as 0.1 deg x 0.1 deg. Regridding to
the current resolution is carried out in the code.
                                                                             .
References:
(1) Corbett and Koehler (2003) "Updated emissions from ocean shipping",
     JGR 108, D20, 4650.
(2) Corbett and Koehler (2004) "Considering alternative input parameters in
     an activity-based ship fuel consumption and emissions model: Reply ..."
     JGR, 109, D23303.
(3) Endresen et al. (2007) "A historical reconstruction of ships fuel
     consumption and emissions", JGR, 112, D12301.
                                                                             .
NOTE: The Corbett website values do not sum to the values in any Corbett
et al. or Wang (2008) papers. It is not clear if this relates to the
ongoing dispute between Corbett et al.(2003,2004) and Endresen et al.
(2003,2004,2007)
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.28.10 read_aviation_co2

Subroutine READ_AVIATION_CO2 reads monthly mean aircraft fuel emissions and converts them to CO2 emissions.

INTERFACE:

```
SUBROUTINE READ_AVIATION_CO2
```

USES:

```
! Reference to F90 modules
USE BPCH2_MOD,     ONLY : GET_RES_EXT, GET_TAU0, READ_BPCH2
USE DAO_MOD,       ONLY : BXHEIGHT
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IU_FILE, IOERROR
USE TIME_MOD,      ONLY : GET_MONTH, GET_YEAR

USE CMN_SIZE_MOD      ! Size parameters
```

REMARKS:

```
This is a modified version of READ_AIRCRAFT_SO2 from:
                                          rjp, bdf, bmy, 9/18/02, 10/3/05
                                                                          .
The sulfate data are based on an inventory by the Atmospheric Effects of
Aviation Project (AEAP) for the year 1992.
                                                                          .
CO2 emission factor of 3155 g/kg fuel was taken from
(1) Kim et al. (2005) System for assessing Aviation's Global Emissions
     (SAGE) Federal Aviation Administration Office of Environment and
     Energy Version 1.5 (FAA-EE-2005-02), Global Aviation Emissions
     Inventories for 2000 through 2004.
(2) Kim et al. (2007) System for assessing Aviation's Global Emissions
     (SAGE) Part 1: Model description and inventory results
```

REVISION HISTORY:

```
(1 ) Extracted from old module routine SULFATE_READMON (bmy, 9/18/02)
(2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(3 ) Now read files from "sulfate_sim_200508/".  Now read data for both
      GCAP and GEOS grids (bmy, 8/16/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Reading of GlobPTot values from input.geos has not yet been implemented
18 May 2010 - R. Nassar, D. Jones - Initial version
```

1.28.11 read_annual_bionet_co2

Subroutine READ_ANNUAL_BIONET_CO2 reads in annual mean values of for Net Terrestrial exchange from a binary punch file.

INTERFACE:

```
SUBROUTINE READ_ANNUAL_BIONET_CO2
```

USES:

```
! References to F90 modules
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D,   GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,          READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR,          DATA_DIR_1x1
USE FILE_MOD,       ONLY : IU_FILE,           IOERROR
USE TRANSFER_MOD,   ONLY : TRANSFER_2D
USE LOGICAL_MOD,    ONLY : LBIONETORIG,       LBIONETCLIM
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

USE CMN_SIZE_MOD         ! Size parameters
```

REMARKS:

```
The two choices are:
(1 ) Old Net Terrestrial Exchange for Year 2000 from David Baker
      (pers. comm.) from undocumented Transcom 3 inversion results
(2 ) New Baker et al [2006] Transcom 3 climatology 1991-2000 minus
     GFEDv2 climatology 1997-2007.

References:
(1 ) Baker et al. (2006), Transcom3 inversion intercomparison: Impact of
      Transport model errors on the interannual vaiability of regional CO2
      fluxes, 1988-2003, Glob. Biogeochem. Cycles, 20, GB1002.
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
05 Mar 2012 - M. Payer            - Add modifications for nested-grid CO2
                                    (Yuxuan Wang, lmw)
06 Apr 2012 - M. Payer            - Changed regrid algorithm to map_a2a
                                    (M. Cooper)
24 May 2012 - R. Yantosca         - Fix minor bugs in map_a2a calls
```

1.28.12 read_bbio_dailyaverage

Subroutine READ_DAILY_BBIO_CO2 reads in daily values for balanced biospheric exchange from a binary punch file.

INTERFACE:

```
SUBROUTINE READ_BBIO_DAILYAVERAGE( MONTH, DAY, DOY )
```

USES:

```
! References to F90 modules
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
```

```
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D
USE TIME_MOD,      ONLY : GET_YEAR,        ITS_A_LEAPYEAR

USE CMN_SIZE_MOD      ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: MONTH   ! Current month (1-12)
INTEGER, INTENT(IN) :: DAY     ! Current day (1-31)
INTEGER, INTENT(IN) :: DOY     ! Current day of year (0-366)
```

REMARKS:

```
Data Source: CASA gridded (1x1) dataset for from M. Thompson
Monthly values interpolated to daily values : 365 daily files
NB : These files DO NOT have the diurnal cycle in daily emissions
See routine ' ' to read in files with diurnal cycle imposed
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Added fixes for leapyears
```

1.28.13 read_bbio_diurnalcycle

Subroutine READ_BBIO_DIURNALCYCLE reads CASA daily Net Ecosystem Production (NEP) fluxes but with a diurnal cycle imposed.

INTERFACE:

```
SUBROUTINE READ_BBIO_DIURNALCYCLE( MONTH, DAY, HOUR, DOY )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D
USE TIME_MOD,      ONLY : GET_YEAR, ITS_A_LEAPYEAR

USE CMN_SIZE_MOD      ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: MONTH   ! Current month (1-12)
INTEGER, INTENT(IN) :: DAY     ! Current day (1-31)
INTEGER, INTENT(IN) :: HOUR    ! Current hour (0-23)
INTEGER, INTENT(IN) :: DOY     ! Current day of year (0-365)
```

REMARKS:

```
References
(1 ) Olsen and Randerson (2004), Differences between surface and column
      atmospheric CO2 and implications for carbon cycle research, J.
      Geophys. Res., 109, D02301,
(2 ) Potter et al. (1993), terrestrial Ecosystem Production: A process
      model based on global satellite and surface data, Glob. Biogeochem.
      Cycles, 7(4), 811-841.
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Added fixes for leapyears
```

1.28.14 total_biomass_tg

Subroutine TOTAL_BIOMASS_Tg prints the amount of biomass burning emissions that are emitted each month in Tg or Tg

INTERFACE:

```
SUBROUTINE TOTAL_BIOMASS_Tg( BBARRAY, MOLWT, NAME )
```

USES:

```
USE GRID_MOD, ONLY : GET_AREA_CM2

USE CMN_SIZE_MOD  ! Size parameters
```

INPUT PARAMETERS:

```
REAL*8,           INTENT(IN) :: MOLWT                 ! Mol wt [kg/mole]
CHARACTER(LEN=*), INTENT(IN) :: NAME                  ! Species name
REAL*8,           INTENT(IN) :: BBARRAY(IIPAR,JJPAR)  ! BB Emissions
                                                      ! [molec/cm2/month]
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Updated
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.28.15 def_biosph_co2_regions_f

Subroutine DEF_BIOSPH_CO2_REGIONS defines the land biospheric and ocean CO2 exchange regions.

INTERFACE:

```
SUBROUTINE DEF_BIOSPH_CO2_REGIONS_F( REGION )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IU_FILE, IOERROR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD      ! Size parameters
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT)   :: REGION(IIPAR,JJPAR)
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%   BUYER BEWARE! Tagged CO2 tracers only work for 2 x 2.5 grid!   %%%
%%%   Someone will have to make this more general later on...        %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%!
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
```

1.28.16 def_ocean_co2_regions_f

Subroutine DEF_OCEAN_CO2_REGIONS defines CO2 regions for ocean exchange.

INTERFACE:

```
SUBROUTINE DEF_OCEAN_CO2_REGIONS_F( REGION )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IU_FILE, IOERROR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD      ! Size parameters
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT)  :: REGION(IIPAR,JJPAR)
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%   BUYER BEWARE! Tagged CO2 tracers only work for 2 x 2.5 grid!   %%%
%%%   Someone will have to make this more general later on...        %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%!
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
```

1.28.17 def_fossil_co2_regions_f

Subroutine DEF_FOSSIL_CO2_REGIONS defines CO2 regions for anthropogenic emissions

INTERFACE:

```
SUBROUTINE DEF_FOSSIL_CO2_REGIONS_F( REGION )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IU_FILE, IOERROR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD      ! Size parameters
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT)   :: REGION(IIPAR,JJPAR)
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%   BUYER BEWARE! Tagged CO2 tracers only work for 2 x 2.5 grid!   %%%
%%%   Someone will have to make this more general later on...        %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%!
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
```

1.28.18 init_co2

Subroutine INIT_CO2 allocates memory to module arrays and reads in annual mean emissions.

INTERFACE:

```
SUBROUTINE INIT_CO2
```

USES:

```
      ! References to F90 modules
      USE ERROR_MOD,   ONLY : ALLOC_ERR
      USE LOGICAL_MOD, ONLY : LGENFF,  LANNFF,   LMONFF, LSTREETS
      USE LOGICAL_MOD, ONLY : LSEASBB, LGFED2BB, L8DAYBB, LBIOFUEL
      USE LOGICAL_MOD, ONLY : LGFED3BB
      USE LOGICAL_MOD, ONLY : LBIODAILY,   LBIODIURNAL
      USE LOGICAL_MOD, ONLY : LBIONETORIG, LBIONETCLIM
      USE LOGICAL_MOD, ONLY : LOCN1997,    LOCN2009ANN, LOCN2009MON
      USE LOGICAL_MOD, ONLY : LFFBKGRD
      USE LOGICAL_MOD, ONLY : LSHIPEDG,    LSHIPICO,    LPLANE
      USE LOGICAL_MOD, ONLY : LBIOSPHTAG,  LFOSSILTAG
      USE LOGICAL_MOD, ONLY : LSHIPTAG,    LPLANETAG
      USE TRACER_MOD,  ONLY : N_TRACERS

      USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
```

1.28.19 cleanup_co2

Subroutine CLEANUP_CO2 deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_CO2
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
```

1.29 Fortran: Module Interface comode_mod

Module COMODE_MOD contains allocatable arrays for SMVGEAR that were previously contained in common blocks in header file "comode.h".

INTERFACE:

```
      MODULE COMODE_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
!=========================================================================
! ABSHUM    : array for absolute humidity [H2O molec/cm3]
! AIRDENS   : array for air density [molec/cm3]
! CSPEC     : array of chemical species concentration [molec/cm3]
! CSPEC_FULL: array of chemical species for full potential troposphere
! CSUMA     : array for time of sunrise/sunset, from midnight [s]
! CSUMC     : array for temporary storage
! ERADIUS   : array for aerosol or dust radii [cm]
! ERRMX2    : array for storing stiffness values
! IXSAVE    : array of grid box longitude indices
! IYSAVE    : array of grid box latitude indices
! IZSAVE    : array of grid box altitude indices
! JLOP      : array of 1-D grid box indices
! PRESS3    : array for grid box pressure [mb]
! REMIS     : array for emissions from GEOS-CHEM [molec/cm3]
! T3        : array for grid box temperature [K]
! TAREA     : array for surface area of aerosol or dust [cm2/cm3]
! VOLUME    : array for grid box volume [cm3]
!=========================================================================
REAL*8,  ALLOCATABLE, PUBLIC :: ABSHUM(:)
REAL*8,  ALLOCATABLE, PUBLIC :: AIRDENS(:)
REAL*8,  ALLOCATABLE, PUBLIC :: CSPEC(:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: CSPEC_FULL(:,:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: CSUMA(:)
REAL*8,  ALLOCATABLE, PUBLIC :: CSUMC(:)
REAL*8,  ALLOCATABLE, PUBLIC :: ERADIUS(:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: ERRMX2(:)
INTEGER, ALLOCATABLE, PUBLIC :: IXSAVE(:)
INTEGER, ALLOCATABLE, PUBLIC :: IYSAVE(:)
INTEGER, ALLOCATABLE, PUBLIC :: IZSAVE(:)
INTEGER, ALLOCATABLE, PUBLIC :: JLOP(:,:,:)
INTEGER, ALLOCATABLE, PUBLIC :: JLOP_PREVIOUS(:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: PRESS3(:)
REAL*8,  ALLOCATABLE, PUBLIC :: REMIS(:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: T3(:)
REAL*8,  ALLOCATABLE, PUBLIC :: TAREA(:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: VOLUME(:)
REAL*8,  ALLOCATABLE, PUBLIC :: WTAREA(:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: WERADIUS(:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: CLEANUP_COMODE
PUBLIC :: INIT_COMODE
```

REMARKS:

```
In case you were wondering, "comode" stands for:
   "COMmon blocks: Ordinary Differential Equations"
```

REVISION HISTORY:

```
31 Aug 2000 - R. Yantosca - Initial version
(1 ) Now zero CSPEC after allocating memory (bmy, 9/8/00)
(2 ) Now declare more SMVGEAR arrays allocatable (bmy, 10/19/00)
(3 ) Updated comments (bmy, 9/4/01)
(4 ) Now make ERADIUS, TAREA 2-D arrays, for het chem (bmy, 11/15/01)
(5 ) DARSFCA is now obsolete, remove it.  Now allocate ERADIUS and
      TAREA arrays to be of size (ITLOOP,NDUST+NAER).  (rvm, bmy, 2/27/02)
(5 ) Removed obsolete code from 2/02 (bmy, 4/15/02)
(6 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
      MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(7 ) Now references "error_mod.f" (bmy, 10/15/02)
(8 ) Now add CSUMA, CSUMC, ERRMX2 arrays for SMVGEAR II (bmy, 7/18/03)
(9 ) Now also references "tracer_mod.f" (bmy, 9/28/04)
(10) Add WTAREA and WERADIUS variables.
     For SOA production from reactive uptake of dicarbonyls,
     archived WTAREA and WERADIUS should include dusts,
     but excludes BCPO and OCPO (tmf, ccc, 1/7/09)
(11) Added 3 *_KPP arrays (phs,ks,dhk, 09/15/09)
(12) Removed 3 *_KPP arrays (phs, 09/16/09)
21 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.29.1 init_comode

Subroutine INIT_COMODE allocates memory for allocatable arrays that were previously contained in common blocks in "comode.h".

INTERFACE:

```
SUBROUTINE INIT_COMODE
```

USES:

```
USE ERROR_MOD,  ONLY : ALLOC_ERR
USE TRACER_MOD, ONLY : ITS_AN_AEROSOL_SIM
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM

USE CMN_SIZE_MOD
USE COMODE_LOOP_MOD
```

REVISION HISTORY:

```
31 Aug 2000 - R. Yantosca - Initial version
(1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
(2 ) Cosmetic chagnes (bmy, 2/27/03)
(3 ) Now allocate CSUMA, CSUMC, ERRMX2; cosmetic changes (bmy, 7/18/03)
(4 ) Now allocate certain arrays for offline aerosol sim (bmy, 9/28/04)
21 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.29.2 cleanup_comode

Subroutine CLEANUP_COMODE deallocates memory from allocatable arrays that were previously contained in common blocks in "comode.h"

INTERFACE:

```
      SUBROUTINE CLEANUP_COMODE
```

REVISION HISTORY:

```
   31 Aug 2000 - R. Yantosca - Initial version
   (1 ) Now deallocate CSPEC, CSUMA, ERRMX2; cosmetic changes (bmy, 7/18/03)
   21 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.30 Fortran: Module Interface convection_mod

Module CONVECTION_MOD contains routines which select the proper convection code for GEOS-3, GEOS-4, GEOS-5, MERRA, or GCAP met field data sets.

INTERFACE:

```
      MODULE CONVECTION_MOD
```

USES:

```
      USE GC_TYPE_MOD
      USE SMV_ERRCODE_MOD
      USE SMV_PHYSCONST_MOD

      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: DO_CONVECTION
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: DO_GEOS4_CONVECT
      PRIVATE :: DO_GCAP_CONVECT
      PRIVATE :: NFCLDMX
      PRIVATE :: DO_MERRA_CONVECTION
```

REVISION HISTORY:

```
27 Jan 2004 - R. Yantosca - Initial version
(1 ) Contains new updates for GEOS-4/fvDAS convection.  Also now references
     "error_mod.f".  Now make F in routine NFCLDMX a 4-D array to avoid
     memory problems on the Altix. (bmy, 1/27/04)
(2 ) Bug fix: Now pass NTRACE elements of TCVV to FVDAS_CONVECT in routine
     DO_CONVECTION (bmy, 2/23/04)
(3 ) Now references "logical_mod.f" and "tracer_mod.f" (bmy, 7/20/04)
(4 ) Now also references "ocean_mercury_mod.f" and "tracerid_mod.f"
     (sas, bmy, 1/19/05)
(5 ) Now added routines DO_GEOS4_CONVECT and DO_GCAP_CONVECT by breaking
     off code from DO_CONVECTION, in order to implement GCAP convection
     in a much cleaner way. (swu, bmy, 5/25/05)
(6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(7 ) Shut off scavenging in shallow convection for GCAP (swu, bmy, 11/1/05)
(8 ) Modified for tagged Hg simulation (cdh, bmy, 1/6/06)
(9 ) Bug fix: now only call ADD_Hg2_WD if LDYNOCEAN=T (phs, 2/8/07)
(10) Fix for GEOS-5 met fields in routine NFCLDMX (swu, 8/15/07)
(11) Resize DTCSUM array in NFCLDMX to save memory (bmy, 1/31/08)
13 Aug 2010 - R. Yantosca - Added ProTeX headers
13 Aug 2010 - R. Yantosca - Treat MERRA in the same way as for GEOS-5
29 Sep 2010 - R. Yantosca - Added modifications for MERRA
05 Oct 2010 - R. Yantosca - Added ND14 and ND38 diagnostics to
                            DO_MERRA_CONVECTION routine
16 Aug 2011 - J. Fisher   - Minor bug fixes in DO_MERRA_CONVECTION
15 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
02 Mar 2012 - R. Yantosca - Now reference the new grid_mod.F90
```

1.30.1 do_convection

Subroutine DO_CONVECTION calls the appropriate convection driver program for different met field data sets.

INTERFACE:

```
SUBROUTINE DO_CONVECTION
```

USES:

```
USE DAO_MOD,      ONLY : AD
USE DAO_MOD,      ONLY : BXHEIGHT
USE DAO_MOD,      ONLY : T
USE DAO_MOD,      ONLY : CLDMAS
USE DAO_MOD,      ONLY : CMFMC
USE DAO_MOD,      ONLY : DQRCU
USE DAO_MOD,      ONLY : DTRAIN
USE DAO_MOD,      ONLY : PFICU
USE DAO_MOD,      ONLY : PFLCU
```

```
      USE DAO_MOD,      ONLY : REEVAPCN
      USE DIAG_MOD,     ONLY : CONVFLUP
      USE DIAG_MOD,     ONLY : AD38
      USE ERROR_MOD,    ONLY : GEOS_CHEM_STOP
      USE GRID_MOD,     ONLY : GET_AREA_M2
      USE LOGICAL_MOD,  ONLY : LDYNOCEAN
      USE PRESSURE_MOD, ONLY : GET_PEDGE
      USE TRACER_MOD,   ONLY : ITS_A_MERCURY_SIM
      USE TRACER_MOD,   ONLY : N_TRACERS
      USE TRACER_MOD,   ONLY : TCVV
      USE TRACER_MOD,   ONLY : TRACER_MW_KG
      USE TRACER_MOD,   ONLY : STT
      USE TRACERID_MOD, ONLY : IDTHg2
      USE TRACERID_MOD, ONLY : IDTHgP
      USE TIME_MOD,     ONLY : GET_TS_DYN
      USE WETSCAV_MOD,  ONLY : COMPUTE_F
      USE WETSCAV_MOD,  ONLY : H2O2s
      USE WETSCAV_MOD,  ONLY : SO2s
#if   defined( APM )
      USE TRACER_MOD,   ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD     ! Size parameters
      USE CMN_DIAG_MOD     ! Diagnostic flags
```

REVISION HISTORY:

```
   25 May 2005 - S. Wu       - Initial version
   08 Feb 2007 - R. Yantosca - Now reference "CMN_SIZE".  Now references
                               CLDMAS, CMFMC, DTRAIN from "dao_mod.f" so that
                               we can pass either GEOS-5 or GEOS-3 meteorology
                               to NFCLDMX.
   13 Aug 2010 - R. Yantosca - Added ProTeX headers
   13 Aug 2010 - R. Yantosca - Treat MERRA in the same way as for GEOS-5
   29 Sep 2010 - R. Yantosca - Now call DO_MERRA_CONVECTION for MERRA met
   05 Oct 2010 - R. Yantosca - Now attach diagnostics to MERRA conv routine
   06 Oct 2010 - R. Yantosca - Parallelized call to DO_MERRA_CONVECTION
   15 Oct 2010 - H. Amos     - Now get BXHEIGHT, T from dao_mod.f
   15 Oct 2010 - R. Yantosca - Now get LDYNOCEAN from logical_mod.f
   15 Oct 2010 - R. Yantosca - Now get ITS_A_MERCURY_SIM from tracer_mod.f
   15 Oct 2010 - R. Yantosca - Now get IDTHg2, IDTHgP from tracerid_mod.f
   15 Oct 2010 - R. Yantosca - Now get H2O2s, SO2s from wetscav_mod.f
   15 Oct 2010 - H. Amos     - Now pass BXHEIGHT, T, to DO_MERRA_CONVECTION
   15 Oct 2010 - R. Yantosca - Now pass H2O2s, SO2s to DO_MERRA_CONVECTION
   15 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
   29 Aug 2011 - R. Yantosca - Bug fix: reposition #if defined(APM) statement
   09 Feb 2012 - R. Yantosca - For GEOS-5.7, PFICU and PFLCU fields are
                               defined on level edges.  Pass the top edge
```

```
                              of each level to DO_MERRA_CONVECTION
   28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
   01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
   21 Jun 2012 - R. Yantosca - Now use poiners to pass array slices to routines
```

1.30.2 do_geos4_convect

Subroutine DO_GEOS4_CONVECT is a wrapper for the GEOS-4/fvDAS convection code. This was broken off from the old DO_CONVECTION routine above.

INTERFACE:

```
      SUBROUTINE DO_GEOS4_CONVECT
```

USES:

```
      USE DAO_MOD,           ONLY : HKETA, HKBETA, ZMEU, ZMMU, ZMMD
      USE DIAG_MOD,          ONLY : AD37
      USE ERROR_MOD,         ONLY : DEBUG_MSG
      USE FVDAS_CONVECT_MOD, ONLY : INIT_FVDAS_CONVECT, FVDAS_CONVECT
      USE LOGICAL_MOD,       ONLY : LPRT
      USE TIME_MOD,          ONLY : GET_TS_CONV
      USE TRACER_MOD,        ONLY : N_TRACERS, STT, TCVV
      USE PRESSURE_MOD,      ONLY : GET_PEDGE
      USE WETSCAV_MOD,       ONLY : COMPUTE_F
#if   defined( APM )
      USE TRACER_MOD,        ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD          ! Size parameters
      USE CMN_DIAG_MOD          ! ND37, LD37
```

REVISION HISTORY:

```
   25 May 2005 - S. Wu       - Initial version
   (1 ) Now use array masks to flip arrays vertically in call to FVDAS_CONVECT
        (bmy, 5/25/05)
   (2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (3 ) Add a check to set negative values in STT to TINY (ccc, 4/15/09)
   13 Aug 2010 - R. Yantosca - Added ProTeX headers
   15 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
```

1.30.3 do_gcap_convect

Subroutine DO_GCAP_CONVECT is a wrapper for the GCAP convection code. This was broken off from the old DO_CONVECTION routine above.

INTERFACE:

```
      SUBROUTINE DO_GCAP_CONVECT
```

USES:

```
      USE DAO_MOD,          ONLY : DETRAINE, DETRAINN, DNDE
      USE DAO_MOD,          ONLY : DNDN,     ENTRAIN,  UPDN, UPDE
      USE DIAG_MOD,         ONLY : AD37
      USE ERROR_MOD,        ONLY : DEBUG_MSG
      USE GCAP_CONVECT_MOD, ONLY : GCAP_CONVECT
      USE LOGICAL_MOD,      ONLY : LPRT
      USE TIME_MOD,         ONLY : GET_TS_CONV
      USE TRACER_MOD,       ONLY : N_TRACERS, STT, TCVV
      USE PRESSURE_MOD,     ONLY : GET_PEDGE, GET_PCENTER
      USE WETSCAV_MOD,      ONLY : COMPUTE_F
#if   defined( APM )
      USE TRACER_MOD,       ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD         ! Size parameters
      USE CMN_DIAG_MOD         ! ND37, LD37
```

REVISION HISTORY:

```
   25 May 2005 - S. Wu       - Initial version
   (1 ) Now use array masks to flip arrays vertically in call to GCAP_CONVECT
        (bmy, 5/25/05)
   (2 ) Shut off scavenging in shallow convection for GCAP below 700 hPa
        (swu, bmy, 11/1/05)
   (3 ) Add a check to set negative values in STT to TINY (ccc, 4/15/09)
   13 Aug 2010 - R. Yantosca - Added ProTeX headers
   15 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
```

1.30.4 nfcldmx

Subroutine NFCLDMX is S-J Lin's cumulus transport module for 3D GSFC-CTM, modified for the GEOS-Chem model. The "NF" stands for "no flipping", and denotes that you don't have to flip the tracer array Q in the main program before passing it to NFCLDMX.

NOTE: NFCLDMX can be used with GEOS-1, GEOS-STRAT, and GEOS-3 met fields. For GEOS-4/fVDAS, you must use the routines in "fvdas_convect_mod.f"

INTERFACE:

```
      SUBROUTINE NFCLDMX( NC, TCVV, CLDMAS, DTRN, Q )
```

USES:

```
      USE DAO_MOD,          ONLY : AD  !,   CLDMAS, DTRN=>DTRAIN
```

```
      USE DIAG_MOD,         ONLY : AD37, AD38,   CONVFLUP
      USE GRID_MOD,         ONLY : GET_AREA_M2
      USE LOGICAL_MOD,      ONLY : LDYNOCEAN, LGTMM
      USE DEPO_MERCURY_MOD, ONLY : ADD_Hg2_WD, ADD_HgP_WD
      USE PRESSURE_MOD,     ONLY : GET_BP, GET_PEDGE
      USE TIME_MOD,         ONLY : GET_TS_CONV
      USE TRACER_MOD,       ONLY : ITS_A_MERCURY_SIM
      USE TRACERID_MOD,     ONLY : IS_Hg2, IS_HgP
      USE WETSCAV_MOD,      ONLY : COMPUTE_F
      USE DEPO_MERCURY_MOD, ONLY : ADD_Hg2_SNOWPACK !CDH
      USE DAO_MOD,          ONLY : SNOMAS, SNOW  !,   CLDMAS, DTRN=>DTRAIN

      USE CMN_SIZE_MOD     ! Size parameters
      USE CMN_DIAG_MOD     ! Diagnostic switches & arrays
#if defined( DEVEL )
      USE ERROR_MOD,        ONLY : ALLOC_ERR
#endif

      IMPLICIT NONE
#     include "define.h"
```

INPUT PARAMETERS:

```
      ! TOTAL number of tracers (soluble + insoluble)  [unitless]
      INTEGER, INTENT(IN)    :: NC

      ! CLDMAS : Cloud mass flux (at upper edges of each level) [kg/m2/s]
      REAL*8,  INTENT(IN)    :: CLDMAS(IIPAR,JJPAR,LLPAR)

      ! Detrainment mass flux [kg/m2/s]
      REAL*8,  INTENT(IN)    :: DTRN(IIPAR,JJPAR,LLPAR)

      ! MW air (g/mol) / MW of tracer (g/mol) [unitless]
      REAL*8,  INTENT(IN)    :: TCVV(NC)
```

INPUT/OUTPUT PARAMETERS:

```
      ! Tracer concentration [v/v]
      REAL*8,  INTENT(INOUT) :: Q(IIPAR,JJPAR,LLPAR,NC)
```

REMARKS:

```
    (1) The "NF" stands for "no flipping", and denotes that you don't have to
    flip the tracer array Q in the main program before passing it to NFCLDMX.
    (bmy, 2/12/97, 1/31/08)
    (2) This version has been customized to work with GEOS-5 met fields.
    Reference:
    ============================================================================
    Lin, SJ.  "Description of the parameterization of cumulus transport
```

```
   in the 3D Goddard Chemistry Transport Model, NASA/GSFC, 1996.
Vertical indexing:
================================================================================
The indexing of the vertical sigma levels has been changed from
SJ-Lin's original code:
              Old Method          New Method
               (SJ Lin)
             ------------------------------------ Top of Atm.
                k = 1               k = NLAY
             ==================================== Max Extent
                k = 2               k = NLAY-1      of Clouds
             ------------------------------------

                 ...                 ...
             ------------------------------------
                k = NLAY-3          k = 4
             ------------------------------------
                k = NLAY-2          k = 3
             ------------------------------------ Cloud base
                k = NLAY-1          k = 2
             -    -    -    -    -    -    -    -
                k = NLAY            k = 1
             ==================================== Ground
    which means that:
                Old Method                      New Method
                 (SJ Lin)
          k-1      ^                    k+1      ^
          ---------|---------            ---------|---------
                   |                              |
                CMFMC(k)                        CMFMC(k)

                                 becomes
          k     DTRAIN(k),                k     DTRAIN(k),
                QC(k), Q(k)                     QC(k), Q(k)

                   ^                              ^
          ---------|---------            ---------|---------
                   |                              |
          k+1   CMFMC(k+1)                k-1   CMFMC(k-1)
    i.e., the lowest level    used to be  NLAY  but is now  1
          the level below k   used to be  k+1   but is now  k-1.
          the level above k   used to be  k-1   but is now  k+1
          the top of the atm. used to be  1     but is now  NLAY.
The old method required that the vertical dimensions of the CMFMC, DTRAIN,
and Q arrays had to be flipped before and after calling CLDMX.  Also,
diagnostic arrays generated within CLDMX also had to be flipped.  The new
indexing eliminates this requirement (and also saves on array operations).
Major Modifications:
```

```
=============================================================================
Original Author:   Shian-Jiann Lin, Code 910.3, NASA/GSFC
Original Release:  12 February 1997
                   Version 3, Detrainment and Entrainment are considered.
                   The algorithm reduces to that of version 2 if Dtrn = 0.
                                                                            .
Modified By:       Bob Yantosca, for Harvard Atmospheric Sciences
Modified Release:  27 January 1998
                   Version 3.11, contains features of V.3 but also
                   scavenges soluble tracer in wet convective updrafts.
                                                                            .
                   28 April 1998
                   Version 3.12, now includes mass flux diagnostic
                                                                            .
                   11 November 1999
                   Added mass-flux diagnostics
                                                                            .
                   04 January 2000
                   Updated scavenging constant AS2
                                                                            .
                   14 March 2000
                   Added new wet scavenging code and diagnostics
                   based on the GMI algorithm
                                                                            .
                   02 May 2000
                   Added parallel loop over tracers!
```

REVISION HISTORY:

```
12 Feb 1997 - M. Prather  - Initial version
(1 ) NFCLDMX is written in Fixed-Form Fortran 90.
(2 ) Added TCVV to the argument list.  Also cleaned up argument
      and local variable declarations. (bey, bmy, 11/10/99)
(3 ) AD38 and CONVFLUP are now declared allocatable in "diag_mod.f".
      (bmy, 11/29/99)
(4 ) Bug fix for tagged CO tracer run (bey, bmy, 1/4/00)
(5 ) Add new routines for computing scavenging coefficients,
      as well as adding the AD37 diagnostic array. (bmy, 3/14/00)
(6 ) Updated comments (bmy, 10/2/01)
(7 ) Now print a header to stdout on the first call, to confirm that
      NFCLDMX has been called (bmy, 4/15/02)
(8 ) Remove PZ from the arg list -- it isn't used! (bmy, 8/22/02)
(9 ) Fixed ND38 diagnostic so that it now reports correctly (must divide
      by DNS).  Updatec comments, cosmetic changes. (bmy, 1/27/03)
(10) Bug fix: remove duplicate K from PRIVATE declaration (bmy, 3/23/03)
(11) Now removed all arguments except NC, TCVV, Q from the arg list -- the
      other arguments can be supplied via F90 modules.  Now references
      "dao_mod.f", "grid_mod.f", "pressure_mod.f", and "time_mod.f".
```

```
      (bmy, 3/27/03)
(12) Bundled into "convection_mod.f" (bmy, 6/26/03)
(13) Make sure K does not go out of bounds in ND38 diagnostic.  Now make
      F a 4-D array in order to avoid memory problems on the Altix.
      (bmy, 1/27/04)
(14) Now references both "ocean_mercury_mod.f" and "tracerid_mod.f".
      Now call ADD_Hg2_WD from "ocean_mercury_mod.f" to pass the amt of Hg2
      lost by wet scavenging (sas, bmy, 1/19/05)
(15) Now references IS_Hg2 from "tracerid_mod.f".  Now pass tracer # IC
      to ADD_Hg2_WD. (cdh, bmy, 1/6/06)
(16) Bug fix: now only call ADD_Hg2_WD if LDYNOCEAN=T (phs, 2/8/07)
(17) Now make CLDMAS, DTRN as arguments, so that we can pass either
      GEOS-3 or GEOS-3 met data.  Redimension DTCSUM with NC instead of
      NNPAR.  In many cases, NC is less than NNPAR and this will help to
      save memory especially when running at 2x25 or greater resolution
      (bmy, 1/31/08)
(18) Add a check to set negative values in Q to TINY (ccc, 4/15/09)
(19) Updates for mercury simulation (ccc, 5/17/10)
13 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

1.30.5 do_merra_convection

Subroutine DO_MERRA_CONVECTION (formerly called NFCLDMX) is S-J Lin's cumulus transport module for 3D GSFC-CTM, modified for the GEOS-Chem model.

INTERFACE:

```
 SUBROUTINE DO_MERRA_CONVECTION( IDENT,    DIMINFO,  COEF,
&                                IDT,      OPTIONS,  AD,
&                                AREA_M2,  BXHEIGHT, CMFMC,
&                                DQRCU,    DTRAIN,   F,
&                                PEDGE,    PFICU,    PFLCU,
&                                REEVAPCN, T,        TS_DYN,
&                                Q,        DIAG14,   DIAG38,
&                                H2O2s,    SO2s,     I,
&                                J,        RC )
```

USES:

```
 USE ERROR_MOD,        ONLY : IT_IS_NAN, IT_IS_FINITE
 USE ERROR_MOD,        ONLY : GEOS_CHEM_STOP  ! hma Nov 3, debug
 USE DEPO_MERCURY_MOD, ONLY : ADD_Hg2_SNOWPACK
 USE DEPO_MERCURY_MOD, ONLY : ADD_Hg2_WD
 USE DEPO_MERCURY_MOD, ONLY : ADD_HgP_WD
 USE MERCURY_MOD,      ONLY : PARTITIONHg
 USE TRACERID_MOD,     ONLY : IS_Hg2
 USE TRACERID_MOD,     ONLY : IS_HgP
```

```
      USE WETSCAV_MOD,      ONLY : WASHOUT
      USE WETSCAV_MOD,      ONLY : LS_K_RAIN
      USE WETSCAV_MOD,      ONLY : LS_F_PRIME
```

INPUT PARAMETERS:

```
      TYPE(SPEC_2_TRAC), INTENT(IN) :: COEF        ! Obj w/ spec <-> trac map
      TYPE(GC_DIMS),     INTENT(IN) :: DIMINFO     ! Obj w/ array dimensions
      TYPE(ID_TRAC),     INTENT(IN) :: IDT         ! Obj w/ tracer ID flags
      TYPE(GC_OPTIONS),  INTENT(IN) :: OPTIONS     ! Obj w/ logical switches
      REAL*8,            INTENT(IN) :: AD(:)       ! Air mass [kg]
      REAL*8,            INTENT(IN) :: AREA_M2     ! Surface area [m2]
      REAL*8,            INTENT(IN) :: BXHEIGHT(:) ! Box height [m]
      REAL*8,            INTENT(IN) :: CMFMC(:)    ! Cloud mass flux [kg/m2/s]
      REAL*8,            INTENT(IN) :: DQRCU(:)    ! Precip production rate:
                                                   !  convective [kg/kg/s]
      REAL*8,            INTENT(IN) :: DTRAIN(:)   ! Detrainment flux [kg/m2/s]
      REAL*8,            INTENT(IN) :: F(:,:)      ! Fraction of soluble tracer
                                                   !  for updraft scavenging
                                                   !  [unitless].  ! This is
                                                   !  computed by routine
                                                   !  COMPUTE_UPDRAFT_FSOL
      REAL*8,            INTENT(IN) :: PEDGE(:)    ! P @ level box edges [hPa]
      REAL*8,            INTENT(IN) :: PFICU(:)    ! Dwnwd flux of convective
                                                   !  ice precip [kg/m2/s]
      REAL*8,            INTENT(IN) :: PFLCU(:)    ! Dwnwd flux of convective
                                                   !  liquid precip [kg/m2/s]
      REAL*8,            INTENT(IN) :: REEVAPCN(:) ! Evap of precip'ing conv.
                                                   !  condensate [kg/kg/s]
      REAL*8,            INTENT(IN) :: T(:)        ! air temperature [K]
      REAL*8,            INTENT(IN) :: TS_DYN      ! Dynamic timestep [min]
      INTEGER,           INTENT(IN) :: I, J        ! Lon & lat indices
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(GC_IDENT), INTENT(INOUT) :: IDENT       ! Obj w/ info from ESMF etc.
      REAL*8,         INTENT(INOUT) :: H2O2s(:)
      REAL*8,         INTENT(INOUT) :: SO2s(:)
      REAL*8,         INTENT(INOUT) :: Q(:,:)      ! Tracer conc. [mol/mol]
```

OUTPUT PARAMETERS:

```
      REAL*8,           INTENT(OUT) :: DIAG14(:,:) ! Array for ND14 diagnostic
      REAL*8,           INTENT(OUT) :: DIAG38(:,:) ! Array for ND38 diagnostic
      INTEGER,          INTENT(OUT) :: RC          ! Return code
```

REMARKS:

```
    Reference:
```

```
=============================================================================
Lin, SJ.  "Description of the parameterization of cumulus transport
   in the 3D Goddard Chemistry Transport Model, NASA/GSFC, 1996.

                                                                             .
Unit conversion for BMASS:
    Ps - Pt (mb)| P2 - P1 | 100 Pa |  s^2  | 1  |  1 kg        kg
   -------------+--------+--------+-------+----+--------  =  -----
                | Ps - Pt |   mb   | 9.8 m | Pa | m^2 s^2      m^2

                                                                             .
NOTE: We are passing I & J down to this routine so that it can call the
proper code from "mercury_mod.f".  Normally, we wouldn't pass I & J as
arguments to columnized code.  This prevents rewriting the mercury_mod.f
routines ADD_Hg2_
```

REVISION HISTORY:

```
15 Jul 2009 - R. Yantosca - Columnized and cleaned up.
                          - CLDMAS renamed to CMFMC and DTRN renamed
                            to DTRAIN for consistency w/ GEOS-5.
17 Jul 2009 - R. Yantosca - Now do unit conversion of Q array from
                            [kg] --> [v/v] and vice versa internally
14 Dec 2009 - R. Yantosca - Now remove internal unit conversion, since
                            Q now comes in as [mol/mol] (=[v/v]) from the
                            calling routine.
14 Dec 2009 - R. Yantosca - Remove COEF from the argument list
06 May 2010 - R. Yantosca - Now add IDENT via the argument list
29 Sep 2010 - R. Yantosca - Modified for MERRA met fields
05 Oct 2010 - R. Yantosca - Now pass COEF via the argument list
05 Oct 2010 - R. Yantosca - Attach ND14 and ND38 diagnostics
15 Oct 2010 - H. Amos     - Added BXHEIGHT and T as arguments
15 Oct 2010 - R. Yantosca - Added I, J, H2O2s and SO2s as arguments
15 Oct 2010 - H. Amos     - Added scavenging below cloud base
06 Apr 2011 - M.Fu, H.Amos- Bug fix: make sure washout adheres to the same
                            algorithm as in the wet deposition code.
27 Jul 2011 - R. Yantosca - Declare CLDBASE as INTEGER to avoid PGI errors
16 Aug 2011 - J. Fisher   - Bug fix: use IS_Hg2() and IS_HgP to test if
                            a tracer is Hg2 or HgP (for tagged species)
16 Aug 2011 - J. Fisher   - Now use WETLOSS instead of TO_SUM in the ND38
                            diagnostic below the cloud.  Using TO_SUM leads
                            us to over-count the tracer scavenged out of
                            the column.
```

1.31 Fortran: Module Interface dao_mod

Module DAO_MOD contains both arrays that hold DAO met fields, as well as subroutines that compute, interpolate, or otherwise process DAO met field data.

INTERFACE:

```
      MODULE DAO_MOD
```

USES:

```
      USE CMN_SIZE_MOD          ! Size parameters
      USE CMN_GCTM_MOD          ! Physical constants

      IMPLICIT NONE
      PRIVATE

#     include "define.h"
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: INIT_DAO_GCAP
      PRIVATE :: INIT_DAO_GEOS4
      PRIVATE :: INIT_DAO_GEOS5
      PRIVATE :: INIT_DAO_GEOS57
      PRIVATE :: INIT_DAO_MERRA
      PRIVATE :: INIT_DAO_DERIVED
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: AVGPOLE
      PUBLIC  :: AIRQNT
      PUBLIC  :: AIRQNT_FULLGRID
      PUBLIC  :: CLEANUP_DAO
      PUBLIC  :: CONVERT_UNITS
      PUBLIC  :: COPY_I3_I6_FIELDS
      PUBLIC  :: GET_COSINE_SZA
      PUBLIC  :: GET_OBK
      PUBLIC  :: INIT_DAO
      PUBLIC  :: INTERP
      PUBLIC  :: IS_LAND
      PUBLIC  :: IS_WATER
      PUBLIC  :: IS_ICE
      PUBLIC  :: IS_NEAR
      PUBLIC  :: MAKE_AVGW
      PUBLIC  :: MAKE_RH
```

PUBLIC DATA MEMBERS:

```
      ! 2-D data fields
      REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: ALBD1          (:,:  )
      REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: ALBD2          (:,:  )
      REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: ALBD           (:,:  )
      INTEGER, ALLOCATABLE, PUBLIC, TARGET :: CLDTOPS        (:,:  )
      REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: CLDFRC         (:,:  )
      REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: EFLUX          (:,:  )
      REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: EVAP           (:,:  )
      REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: FRLAKE         (:,:  )
```

```
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: FRLAND         (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: FROCEAN        (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: FRLANDIC       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: FRSEAICE       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: FRSNO          (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: GRN            (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: GWETROOT       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: GWETTOP        (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: HFLUX          (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: LAI            (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: LWI_GISS       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: LWI            (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: MOLENGTH       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: OICE           (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PARDF          (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PARDR          (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PBL            (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PHIS           (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PREACC         (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PREANV         (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PRECON         (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PRELSC         (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PRECSNO        (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PS1            (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PS2            (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PSC2           (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: RADLWG         (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: RADSWG         (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SEAICE00       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SEAICE10       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SEAICE20       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SEAICE30       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SEAICE40       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SEAICE50       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SEAICE60       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SEAICE70       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SEAICE80       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SEAICE90       (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SLP            (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SNICE          (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SNODP          (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SNOMAS         (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SNOW           (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SUNCOS         (:    )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SUNCOS_MID     (:    )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SUNCOS_MID_5hr (:    )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TO31           (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TO32           (:,:  )
```

```
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TO3           (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TTO3          (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TROPP1        (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TROPP2        (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TROPP         (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TS            (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TSKIN         (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: U10M          (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: USTAR         (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: V10M          (:,:  )
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: Z0            (:,:  )

! 3-D data fields
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: AD            (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: AIRDEN        (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: AIRVOL        (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: AVGW          (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: BXHEIGHT      (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DQRCU         (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DQRLSAN       (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: CLDF          (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: CLDMAS        (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: CMFMC         (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DELP          (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DETRAINE      (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DETRAINN      (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DNDE          (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DNDN          (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DQIDTMST      (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DQLDTMST      (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DQRCON        (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DQRLSC        (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DQVDTMST      (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: DTRAIN        (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: ENTRAIN       (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: HKBETA        (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: HKETA         (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: MFXC          (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: MFYC          (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: MFZ           (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: MOISTQ        (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: OPTDEP        (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: OPTD          (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PFICU         (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PFILSAN       (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PFLCU         (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PFLLSAN       (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: PV            (:,:,:)
```

```
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: QI             (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: QL             (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: REEVAPCN       (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: REEVAPLS       (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: RH1            (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: RH2            (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: RH             (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SPHU1          (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SPHU2          (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: SPHU           (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: T              (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TAUCLI         (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TAUCLW         (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TMPU1          (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: TMPU2          (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: UPDE           (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: UPDN           (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: UWND1          (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: UWND2          (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: UWND           (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: VWND1          (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: VWND2          (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: VWND           (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: ZMEU           (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: ZMMD           (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: ZMMU           (:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: AIRDEN_FULLGRID(:,:,:)
  REAL*8,  ALLOCATABLE, PUBLIC, TARGET :: T_FULLGRID     (:,:,:)
```

REVISION HISTORY:

```
26 Jun 2010 - R. Yantosca - Initial version
(1 ) Added sea level pressure (SLP) met field for GEOS-3 (bmy, 10/10/00)
(2 ) Moved MAKE_QQ to "wetscav_mod.f" (bmy, 10/12/00)
(3 ) Now get LWI from ALBEDO for GEOS-3 in routines IS_LAND and
     IS_WATER (bmy, 4/4/01)
(4 ) Define OPTDEP allocatable array for GEOS-3 -- this is the grid
     box optical depth and is now stored as a met field (bmy, 8/15/01)
(5 ) Updated comments (bmy, 9/4/01)
(6 ) Now make AVGW an allocatable module array.  Also replace obsolete
     parameters {IJL}GCMPAR with IIPAR,JJPAR,LLPAR. (bmy, 9/27/01)
(7 ) Remove arguments LMAKEPW, PW, and LM from AIRQNT (bmy, 10/3/01)
(8 ) Remove obsolete code from 9/01 (bmy, 10/23/01)
(9 ) Bug fixes in IS_LAND and IS_WATER.  Also cosmetic changes and
     updated some comments. (mje, bmy, 1/9/02)
(10) Now add additional array PSC2 in order to pass to TPCORE, which will
     fix the mixing ratio bug.  Compute PSC2 in subroutine INTERP.
     Now bundle "convert_units.f" into "dao_mod.f".  Updated comments.
     (bmy, 3/27/02)
```

```
(11) Updated comments (bmy, 5/28/02)
(12) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(13) Eliminated PS, PSC arrays.  Now reference "pressure_mod.f".  Also
     updated AIRQNT for hybrid grid.  Added routine MAKE_RH to this
     module. (dsa, bdf, bmy, 8/27/02)
(14) Added arrays AD, BXHEIGHT, and T to "dao_mod.f".  Also removed
     obsolete code from 8/02 from several module routines.  Now
     references "error_mod.f".  Remove all references to QQ, it is now
     declared in "wetscav_mod.f".  (bmy, 11/8/02)
(15) Now references "grid_mod.f".  Also added PHIS field, which was
     formerly stored as PALTD in "CMN".  Added bug fix in routine
     AVGPOLE for 1x1 nested grid. (bmy, 3/11/03)
(16) Added SUNCOSB array for SMVGEAR II.  Also removed KZZ array, since
     that is now obsolete. (bmy, 4/28/03)
(17) Now moved MAKE_CLDFRC into "a6_read_mod.f".  Added HKBETA, HKETA,
     TSKIN, GWETTOP, ZMEU, ZMMD, ZMMU, PARDF, PARDR fields for
     GEOS-4/fvDAS. (bmy, 6/25/03)
(18) Added CLDFRC, RADSWG, RADLWG, SNOW arrays (bmy, 12/9/03)
(19) Added routine COPY_I6_FIELDS w/ parallel DO-loops (bmy, 4/13/04)
(20) Now also allocate AVGW for offline aerosol simulation (bmy, 9/28/04)
(21) AVGPOLE now uses NESTED_CH and NESTED_NA cpp switches (bmy, 12/1/04)
(22) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(23) Now allocate SNOW and GWET for GCAP (bmy, 8/17/05)
(24) Now also add TSKIN for GEOS-3 (tmf, bmy, 10/20/05)
(25) Modifications for near-land formulation (ltm, bmy, 5/16/06)
(26) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(27) Modified for variable tropopause (phs, bdf, 9/14/06)
(28) Add in extra fields for GEOS-5.  Updated COSSZA.  Now cap var trop
     at 200hPa near poles in INTERP (bmy, phs, 9/18/07)
(29) Bug fix in INIT_DAO for CMFMC array (bmy, jaf, 6/11/08)
(30) Add heat flux EFLUX for GEOS5. (lin, ccc, 5/29/09)
(31) Add fractions of land and water, FRLAND, FROCEAN, FRLANDIC, FRLAKE
     for methane (kjw, 8/18/09)
(32) Bug fix in AVGPOLE (bmy, 12/18/09)
(33) Remove obsolete SUNCOSB array (bmy, 4/28/10)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
18 Aug 2010 - R. Yantosca - Added modifications for MERRA data
18 Aug 2010 - R. Yantosca - Move CMN_SIZE, CMN_DIAG to top of module
25 Aug 2010 - R. Yantosca - Now read LWI (land/water/ice) for MERRA met
05 Oct 2011 - R. Yantosca - Add SUNCOS_30 array to hold the cos(SZA)
                            computed @ 30 mins after each GMT hour.
07 Oct 2011 - R. Yantosca - Rename SUNCOS30 to SUNCOS_MID, which is the
                            cos(SZA) at the midpt of the chemistry timestep
06 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met fields
06 Feb 2012 - R. Yantosca - Split up INIT_DAO into several routines
07 Feb 2012 - M. Payer    - Add subroutine GET_COSINE_SZA to compute sun
                            angles at the current time and 5 hours prior to
```

```
                              the current time (for the PARANOX ship emissions
                              plume model) (R. Yantosca)
    28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
    01 Mar 2012 - R. Yantosca - Now references the new grid_mod.F90
    06 Mar 2012 - R. Yantosca - Now allocate TO3 for all met fields
```

1.31.1 avgpole

Subroutine AVGPOLE computes average quantity near polar caps, defined by (J = 1, 2) and (J = JJPAR-1, JJPAR).

INTERFACE:

```
      SUBROUTINE AVGPOLE( Z )
```

USES:

```
      USE GRID_MOD, ONLY : GET_AREA_M2
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8, INTENT(INOUT) :: Z(IIPAR,JJPAR)   ! Quantity to be averaged
                                                !  over the pole (usually PS)
```

REVISION HISTORY:

```
    30 Jan 1998 - R. Yantosca - Initial version
    (1 ) AVGPOLE is written in Fixed-Form Fortran 90.  Use F90 syntax
         for declarations, etc (bmy, 4/14/99)
    (2 ) MAIN now passes the Harvard CTM variable for surface area of
         a gridbox, DXYP(JJPAR), to AVGPOLE.  Use window offset
         J+J0 when accessing DXYP.  Add JJPAR to the parameter list.
    (3 ) Added this routine to "dao_mod.f" (bmy, 6/27/00)
    (4 ) Updated comments (bmy, 4/4/01)
    (5 ) Now replaced DXYP(J) with routine GET_AREA_M2 of "grid_mod.f"
         Now also return immediately if GRID1x1 is selected. (bmy, 3/11/03)
    (6 ) Now use cpp switches NESTED_CH and NESTED_NA to denote nested
         grids...GRID1x1 can now also denote a global grid (bmy, 12/1/04)
    (7 ) Also need to RETURN for 0.5 x 0.666 nested grid simulations
         (mpb, bmy, 12/18/09)
    16 Aug 2010 - R. Yantosca - Added ProTeX headers
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

1.31.2 airqnt

Subroutine AIRQNT calculates the volume [m$\hat{3}$ and cm$\hat{3}$], mass [kg], density, [kg/m$\hat{3}$], and pressure thickness [hPa] of air for each grid box (I,J,L). The quantity (surface pressure -

PTOP) [hPa] at each surface grid box (I,J) is also computed.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE AIRQNT(LOCAL_MET)
#else
      SUBROUTINE AIRQNT
#endif
```

USES:

```
      USE GRID_MOD,     ONLY : GET_AREA_M2
      USE PRESSURE_MOD, ONLY : GET_BP, GET_PEDGE
#if defined( DEVEL )
      USE GC_TYPE_MOD,  ONLY : GC_MET_LOCAL
#endif
```

REMARKS:

```
DAO met fields updated by AIRQNT:
============================================================================
(1 ) BXHEIGHT (REAL*8 ) : Vertical extent of a grid box   [m       ]
(2 ) DELP     (REAL*8 ) : Delta-P extent  of a grid box   [mb      ]
(3 ) AIRVOL   (REAL*8 ) : Volume  of air  in a grid box   [m^3     ]
(4 ) AD       (REAL*8 ) : Mass    of air  in a grid box   [kg      ]
(5 ) AIRDEN   (REAL*8 ) : Density of air  in a grid box   [kg/m^3  ]
```

REVISION HISTORY:

```
30 Jan 1998 - R. Yantosca - Initial version
(1 ) AIRQNT is written in Fixed-Form Fortran 90.  Use F90 syntax
      for declarations etc. (bmy, 4/14/99)
(2 ) AIRQNT can now compute PW from PS (if LMAKEPW=T) or PS from PW.
(3 ) AIRQNT should also be called after TPCORE, since TPCORE changes
      the PW values.  AIRQNT must then be called to compute the post-TPCORE
      values of AD, BXHEIGHT, AIRVOL, and AIRDEN.
(4 ) The AIRDEN and DELP arrays are now dimensioned as (LLPAR,IIPAR,JJPAR)
      for better efficiency when processing a whole (I,J) column layer by
      layer.  In FORTRAN, the best efficiency is obtained when the leftmost
      array index corresponds to the innermost loop.
(5 ) Remove PTOP from the arg list.  PTOP is now a parameter in
    "CMN_SIZE".  Also updated comments. (bmy, 2/22/00)
(6 ) Replace IM, JM, LM with IIPAR, JJPAR, LLPAR as loop boundaries.
      This ensures that all quantities get defined up to the top of
      the atmosphere. (bmy, 6/15/00)
(7 ) Added to "dao_mod.f" (bmy, 6/26/00)
(8 ) Updated comments (bmy, 4/4/01)
(9 ) P(IREF,JREF) is now P(I,J).  T(IREF,JREF,L) is now T(I,J,L).  Also
      removed LM from the arg list, it is obsolete.  Also updated
```

```
      comments. (bmy, 9/26/01)
(10) Remove PW -- it is now obsolete.  Also make PW a local variable,
      we need to preserve the way it computes P so as to avoid numerical
      drift. (bmy, 10/4/01)
(11) Removed obsolete code from 9/01 and 10/01 (bmy, 10/23/01)
(12) Removed LMAKEPW from arg list.  Added parallel DO loops (bmy, 11/15/01)
(13) Removed obsolete code from 11/01 (bmy, 1/9/02)
(14) Now rename G_SIGE to SIGE, and dimension it (1:LLPAR+1).  Updated
      comments, cosmetic changes. (bmy, 4/4/02)
(15) Removed obsolete, commented-out code (bmy, 6/25/02)
(16) Removed PS, P, SIGE from the arg list for hybrid grid.  Now reference
      routines GET_PEDGE and GET_BP from "pressure_mod.f".  Removed
      obsolete, commented-out code. (dsa, bdf, bmy, 8/27/02)
(17) Now only pass DXYP via the arg list -- the other arguments are actually
      are already contained within "dao_mod.f" (bmy, 11/15/02)
(18) Now replace DXYP(JREF) with routine GET_AREA_M2 of "grid_mod.f".
      (bmy, 3/11/03)
(19) Now move computation of DELP into main loop.  Also remove P, LOGP,
      JREF, DSIG variables -- these are obsolete for fvDAS.  (bmy, 6/19/03)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

1.31.3 airqnt_fullgrid

Subroutine AIRQNT_FULLGRID calculates the same quantities as AIRQNT, but for the full, unlumped vertical grid of the GEOS GCM.

INTERFACE:

```
      SUBROUTINE AIRQNT_FULLGRID
```

USES:

```
      USE GRID_MOD,     ONLY : GET_AREA_M2
      USE PRESSURE_MOD, ONLY : GET_PEDGE_FULLGRID
```

REMARKS:

```
    DAO met fields updated by AIRQNT_FULLGRID:
    ============================================================================
    (1 ) AIRDEN_FULLGRID (REAL*8 ) : Density of air  in a grid box   [kg/m^3  ]
```

REVISION HISTORY:

```
    (1 ) Modified from AIRQNT in DAO_MOD (cdh, 1/22/09)
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

1.31.4 interp

Subroutine INTERP linearly interpolates GEOS-Chem I6 fields (winds, surface pressure, temperature, surface albedo, specific humidity etc.) to the current dynamic timestep.

INTERFACE:

```
SUBROUTINE INTERP( NTIME0, NTIME1, NTDT )
```

USES:

```
USE GRID_MOD,    ONLY : GET_YEDGE
USE LOGICAL_MOD, ONLY : LVARTROP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: NTIME0   ! Elapsed time [s] at start of 6hr step
INTEGER, INTENT(IN)  :: NTIME1   ! Elapsed time [s] at current time
INTEGER, INTENT(IN)  :: NTDT     ! Length of dynamic timestep [s]
```

REMARKS:

```
Different met fields are archived at I6 (instantaneous 6-hr) time
resolution depending on the specific product.  For example, relative
humidity is an instantaneous 6hr field in MERRA and a 6-hr time averaged
field in GEOS-5.
```

REVISION HISTORY:

```
30 Jan 1998 - R. Yantosca - Initial version
(1 ) INTERP is written in Fixed-Form Fortran 90.
(2 ) Subtract PINT from PSC since the only subroutine that uses PSC
     is TPCORE.  This prevents having to subtract and add PINT to PSC
     before and after each call of TPCORE.
(3 ) Pass the Harvard CTM temperature variable T(IGCMPAR,JGCMPAR,LGCMPAR)
     to INTERP via the argument list (instead of including file CMN).
     It is computationally inefficient to keep two large arrays for
     the same quantity.  Use the proper window offsets with T.
(4 ) Added to "dao_mod.f" (bmy, 6/26/00)
(5 ) Updated comments (bmy, 4/4/01)
(6 ) Replaced {IJL}GCMPAR w/ IIPAR,JJPAR,LLPAR.  Also now use parallel
     DO-loop for interpolation.  Updated comments. (bmy, 9/26/01)
(7 ) Removed obsolete code from 9/01 (bmy, 10/23/01)
(8 ) Add PSC2 as the surface pressure at the end of the dynamic timestep.
     This needs to be passed to TPCORE and AIRQNT so that the mixing ratio
     can be converted to mass properly.  Removed PINT from the arg list,
     since we don't need it anymore.  Also updated comments and made
     some cosmetic changes.  (bmy, 3/27/02)
(9 ) Removed obsolete, commented-out code (bmy, 6/25/02)
(10) Eliminated PS, PSC from the arg list, for floating-pressure fix.
     (dsa, bdf, bmy, 8/27/02)
```

```
(11) Met field arrays are module variables, so we don't need to pass them
     as arguments. (bmy, 11/20/02)
(12) Removed NDT from the arg list since that is always 21600.  For GEOS-4
     met fields, only interpolate PSC2; the other fields are 6-h averages.
     Eliminate TC variable, it's obsolete.  Now use double precision to
     compute TM and TC2 values.  Renamed NTIME to NTIME1 and NTIME1 to
     NTIME0.  Updated comments. (bmy, 6/19/03)
(13) Now modified for GEOS-5 and GCAP met fields. (swu, bmy, 5/25/05)
(14) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(15) Now interpolate TROPP, only if variable tropopause is used
     (phs, 9/12/06)
(16) Don't interpolate TROPP for GEOS-5 (bmy, 1/17/07)
(17) Now limit tropopause pressure to 200 mbar at latitudes above 60deg
     (phs, 9/18/07)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
18 Aug 2010 - R. Yantosca - Rewrite #if block logic for clarity
06 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met fields
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use GET_YEDGE(I,J,L) from new grid_mod.F90
```

1.31.5 is_land

Function IS_LAND returns TRUE if surface grid box (I,J) is a land box.

INTERFACE:

```
FUNCTION IS_LAND( I, J ) RESULT ( LAND )
```

USES:

```
USE TIME_MOD, ONLY : GET_YEAR
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: I           ! Longitude index of grid box
INTEGER, INTENT(IN)  :: J           ! Latitude  index of grid box
```

RETURN VALUE:

```
LOGICAL              :: LAND        ! =T if it is a land box
```

REVISION HISTORY:

```
26 Jun 2000 - R. Yantosca - Initial version
(1 ) Now use ALBEDO field to determine land or land ice boxes for GEOS-3.
     (bmy, 4/4/01)
(2 ) For 4x5 data, regridded albedo field can cause small inaccuracies
     near the poles (bmy, 4/4/01)
(3 ) Add references to CMN_SIZE and CMN, so that we can use the JYEAR
```

```
      variable to get the current year.  Also, for 1998, we need to compute
      if is a land box or not from the surface albedo, since for this
      year the LWI/SURFTYPE field is not given.  For other years than 1998,
      we use LWI(I,J) < 50 as our land box criterion.  Deleted obsolete
      code and updated comments.(mje, bmy, 1/9/02)
(4 ) Deleted GEOS-2 #ifdef statement.  GEOS-2 met fields never really
      materialized, we use GEOS-3 instead. (bmy, 9/18/02)
(5 ) Now uses function GET_YEAR from "time_mod.f".  Removed reference
      to CMN header file. (bmy, 3/11/03)
(6 ) Added code to determine land boxes for GEOS-4 (bmy, 6/18/03)
(7 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(8 ) Now return TRUE only for land boxes (w/ no ice) (bmy, 8/10/05)
(9 ) Now use NINT to round LWI for GEOS-4/GEOS-5 (ltm, bmy, 5/9/06)
(10) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
06 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA/GEOS-5
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.31.6 is_water

Function IS_WATER returns TRUE if surface grid box (I,J) is an ocean or an ocean-ice box.

INTERFACE:

```
FUNCTION IS_WATER( I, J ) RESULT ( WATER )
```

USES:

```
USE TIME_MOD, ONLY : GET_YEAR
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: I           ! Longitude index of grid box
INTEGER, INTENT(IN)  :: J           ! Latitude  index of grid box
```

RETURN VALUE:

```
LOGICAL              :: WATER       ! =T if this is a water box
```

REVISION HISTORY:

```
30 Jan 1998 - R. Yantosca - Initial version
(1 ) Now use ALBEDO field to determine water or water ice boxes for GEOS-3.
      (bmy, 4/4/01)
(2 ) For 4x5 data, regridded albedo field can cause small inaccuracies
      near the poles (bmy, 4/4/01)
(3 ) Add references to CMN_SIZE and CMN, so that we can use the JYEAR
      variable to get the current year.  Also, for 1998, we need to compute
```

```
      if is an ocean box or not from the surface albedo, since for this
      year the LWI/SURFTYPE field is not given.  For other years than 1998,
      we use LWI(I,J) >= 50 as our ocean box criterion.  Deleted obsolete
      code and updated comments. (mje, bmy, 1/9/02)
(4 ) Deleted GEOS-2 #ifdef statement.  GEOS-2 met fields never really
      materialized, we use GEOS-3 instead. (bmy, 9/18/02)
(5 ) Now uses function GET_YEAR from "time_mod.f".  Removed reference
      to CMN header file. (bmy, 3/11/03)
(6 ) Added code to determine water boxes for GEOS-4 (bmy, 6/18/03)
(7 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(8 ) Now remove test for sea ice (bmy, 8/10/05)
(9 ) Now use NINT to round LWI for GEOS-4/GEOS-5 (ltm, bmy, 5/9/06)
(10) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06
16 Aug 2010 - R. Yantosca - Added ProTeX headers
25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
06 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA/GEOS-5
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.31.7 is_ice

Function IS_ICE returns TRUE if surface grid box (I,J) contains either land-ice or sea-ice.

INTERFACE:

```
FUNCTION IS_ICE( I, J ) RESULT ( ICE )
```

USES:

```
USE TIME_MOD, ONLY : GET_YEAR
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: I           ! Longitude index of grid box
INTEGER, INTENT(IN)  :: J           ! Latitude  index of grid box
```

RETURN VALUE:

```
LOGICAL              :: ICE         ! =T if this is an ice box
```

REVISION HISTORY:

```
09 Aug 2005 - R. Yantosca - Initial version
(1 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
06 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA/GEOS-5
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.31.8 is_near

Function IS_NEAR returns TRUE if surface grid box (I,J) contains any land above a certain threshold (THRESH) or any of the adjacent boxes up to NEIGHBOR boxes away contain land.

INTERFACE:

```
FUNCTION IS_NEAR( I, J, THRESH, NEIGHBOR ) RESULT ( NEAR )
```

INPUT PARAMETERS:

```
! Arguments
INTEGER, INTENT(IN) :: I, J        ! Lon & lat grid box indices
INTEGER, INTENT(IN) :: NEIGHBOR    ! # of neighbor boxes to consider
REAL*8,  INTENT(IN) :: THRESH      ! LWI threshold for near-land
```

RETURN VALUE:

```
LOGICAL             :: NEAR        ! # of near land boxes
```

REMARKS:

```
Typical values for:
   GCAP   : THRESH =  0.2, NEIGHBOR = 1
   GEOS-3 : THRESH = 80.0, NEIGHBOR = 1
   GEOS-4 : THRESH =  0.2, NEIGHBOR = 1
   GEOS-5 : THRESH =  0.2, NEIGHBOR = 1

NOTE: This routine is mostly obsolete now.
```

REVISION HISTORY:

```
09 May 2006 - R. Yantosca - Initial version
(1 ) Modified for GCAP and GEOS-3 met fields (bmy, 5/16/06)
(2 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
19 Aug 2010 - R. Yantosca - Rewrote logic of #if block for clarity
25 Aug 2010 - R. Yantosca - Treat MERRA in same way as GEOS-5
06 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA/GEOS-5
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.31.9 make_avgw

Subroutine MAKE_AVGW converts DAO specific humidity SPHU to AVGW, which is the mixing ratio of water vapor.

INTERFACE:

```
SUBROUTINE MAKE_AVGW
```

REVISION HISTORY:

```
30 Jan 1998 - R. Yantosca - Initial version
(1 ) AVGW was originally indexed by (L,I,J).  Reorder the indexing to
      (I,J,L) to take advantage of the way FORTRAN stores by columns.
      An (L,I,J) ordering can lead to excessive disk swapping.
(2 ) Now dimension AVGW as (IIPAR,JJPAR,LLPAR).  Also use parallel
      DO-loop to compute AVGW.  Updated comments. (bmy, 9/24/01)
(3 ) Removed obsolete code from 9/01 (bmy, 10/23/01)
(4 ) SPHU and AVGW are declared w/in "dao_mod.f", so we don't need to pass
      these as arguments anymore (bmy, 11/15/02)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.31.10 make_rh

Subroutine MAKE_RH computes relative humidity from specific humidity and temperature.

INTERFACE:

```
SUBROUTINE MAKE_RH
```

USES:

```
USE PRESSURE_MOD, ONLY : GET_PCENTER
```

REMARKS:

```
Module variables used:
============================================================================
(1 ) SPHU (REAL*8) : Array containing 3-D specific humidity [g H2O/kg air]
(2 ) TMPU (REAL*8) : Array containing 3-D temperature field [K]
(3 ) RH   (REAL*8) : Output array for relative humidity     [%]
```

REVISION HISTORY:

```
13 Oct 1999 - R. Yantosca - Initial version
(1 ) Use F90 syntax for declarations, etc.
(2 ) Cosmetic changes (bmy, 10/12/99)
(3 ) Now use GET_PCENTER from "pressure_mod.f" to compute the pressure
      at the midpoint of grid box (I,J,L).  Updated comments, cosmetic
      changes.  Added parallel DO-loops.  Remove reference to "CMN"
      header file.  Added to "dao_mod.f" (dsa, bdf, bmy, 8/27/02)
(4 ) Removed obsolete code from 8/02 (bmy, 9/18/02)
(5 ) Now remove SPHU, TMPU, RH from the arg list, since these are now
      all contained w/in this dao_mod.f as module variables. (bmy, 9/23/02)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.31.11 get_obk

Function GET_OBK returns the Monin-Obhukov length at a grid box (I,J).

INTERFACE:

```
FUNCTION GET_OBK( I, J ) RESULT( OBK )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I     ! Longitude index
INTEGER, INTENT(IN) :: J     ! Latitude  index
```

RETURN VALUE:

```
REAL*8              :: OBK   ! Monin-Obhukhov length
```

REMARKS:

REVISION HISTORY:

```
25 May 2005 - R. Yantosca - Initial version
16 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.31.12 get_cosine_sza

Routine GET_COSINE_SZA is a driver for calling the COSSZA routine from dao_mod.F. This routine calls COSSZA twice. The first call computes the sun angles at the current time and midpoint of the current chemistry time step. The second call computes the sun angles 5 hours prior to the current time (for the PARANOX ship emissions plume model).

INTERFACE:

```
    SUBROUTINE GET_COSINE_SZA( SUNCOS, SUNCOS_MID, SUNCOS_MID_5hr )
USES:
    USE JULDAY_MOD, ONLY : JULDAY
    USE TIME_MOD,   ONLY : GET_DAY_OF_YEAR
    USE TIME_MOD,   ONLY : GET_DAY
    USE TIME_MOD,   ONLY : GET_GMT
    USE TIME_MOD,   ONLY : GET_HOUR
    USE TIME_MOD,   ONLY : GET_MINUTE
    USE TIME_MOD,   ONLY : GET_MONTH
    USE TIME_MOD,   ONLY : GET_YEAR
```

INPUT PARAMETERS:

```
! Cosine(SZA) at current time
REAL*8,  INTENT(OUT) :: SUNCOS(MAXIJ)

! Cosine(SZA) at midpoint of current chemistry  timestep
```

```
      REAL*8,  INTENT(OUT) :: SUNCOS_MID(MAXIJ)

      ! Cosine(SZA) at midpoint of the chemistry timestep 5hrs ago
      REAL*8,  INTENT(OUT) :: SUNCOS_MID_5hr(MAXIJ)
```

REVISION HISTORY:

```
07 Feb 2012 - R. Yantosca - Initial version
```

1.31.13 cossza

COSSZA computes the cosine of the solar zenith angle, given the day of the year and GMT hour. The cosine of the solar zenith angle is returned at both the current time and at the midpoint of the chemistry timestep (i.e. for the centralized chemistry timestep option).

INTERFACE:

```
      SUBROUTINE COSSZA( DOY, GMT_HOUR, SUNCOS, SUNCOS_MID )
```

USES:

```
      USE GRID_MOD, ONLY : GET_YMID_R
      USE TIME_MOD, ONLY : GET_MINUTE
      USE TIME_MOD, ONLY : GET_LOCALTIME
      USE TIME_MOD, ONLY : GET_TS_CHEM
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: DOY                 ! Day of the year
      INTEGER, INTENT(IN)  :: GMT_HOUR            ! Hour of day
```

OUTPUT PARAMETERS:

```
      ! Cosine of the solar zenith angle at:
      REAL*8,  INTENT(OUT) :: SUNCOS    (MAXIJ)   ! the current time
      REAL*8,  INTENT(OUT) :: SUNCOS_MID(MAXIJ)   ! midpt of chem timestep
```

REMARKS:

```
Hour angle (AHR) is a function of longitude.  AHR is zero at solar noon,
and increases by 15 deg for every hour before or after solar noon.  Hour
angle can be thought of as the time in hours since the sun last passed
the meridian (i.e. the time since the last local noon).

.

The cosine of the solar zenith angle (SZA) is given by:

.

   cos(SZA) = sin(LAT)*sin(DEC) + cos(LAT)*cos(DEC)*cos(AHR)

.

where LAT = the latitude angle,
      DEC = the solar declination angle,
      AHR = the hour angle, all in radians.

.

If SUNCOS < 0, then the sun is below the horizon, and therefore does not
contribute to any solar heating.
```

REVISION HISTORY:

```
21 Jan 1998 - R. Yantosca - Initial version
(1 ) COSSZA is written in Fixed-Form Fortran 90.
(2 ) Use IMPLICIT NONE
(3 ) Use C-preprocessor #include statement to include CMN_SIZE, which
     has IIPAR, JJPAR, LLPAR, IIPAR, JJPAR, LGLOB.
(4 ) Use IM and JM (in CMN_SIZE) as loop limits.
(5 ) Include Harvard CTM common blocks and rename variables where needed.
(6 ) Use SUNCOS(MAXIJ) instead of a 2D array, in order for compatibility
     with the Harvard CTM subroutines.  SUNCOS loops over J, then I.
(7 ) Added DO WHILE loops to reduce TIMLOC into the range 0h - 24h.
(8 ) Cosmetic changes.  Also use F90 declaration statements (bmy, 6/5/00)
(9 ) Added to "dao_mod.f".  Also updated comments. (bmy, 9/27/01)
(10) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(11) Deleted obsolete code from 6/02 (bmy, 8/21/02)
(12) Removed RLAT and XLON from the arg list.  Now compute these using
     functions from "grid_mod.f" (bmy, 2/3/03)
(13) Now uses GET_LOCALTIME from "time_mod.f" to get the local time.
     Added parallel DO loop. Removed NHMSb, NSEC arguments. (bmy, 2/13/07)
(14) Now compute SUNCOS at the midpoint of the relevant time interval
     (i.e. the chemistry timestep).   Also make the A and B coefficients
     parameters instead of variables. (bmy, 4/27/10)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
05 Oct 2011 - R. Yantosca - Now also return the cosine of the solar
                            zenith angle at 30m after the GMT hour.
07 Oct 2011 - R. Yantosca - Now return SUNCOS_MID, the cos(SZA) at the
                            midpt of the chem step (not always at 00:30).
07 Feb 2012 - R. Yantosca - Now add GMT_HOUR as a new argument, which !
                            will facilitate computing sun angles 5h ago
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_LOCALTIME(I,J,L) from time_mod.F90
```

1.31.14 convert_units

Subroutine CONVERT_UNITS converts the units of STT from [kg] to [v/v] mixing ratio, or vice versa.

INTERFACE:

```
SUBROUTINE CONVERT_UNITS( IFLAG, N_TRACERS, TCVV, AD, STT )
```

USES:

```
USE ERROR_MOD,  ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
! =1 then convert from [kg ] --> [v/v]
! =2 then convert from [v/v] --> [kg ]
INTEGER, INTENT(IN)    :: IFLAG

! Number of tracers
INTEGER, INTENT(IN)    :: N_TRACERS

! Array containing [Air MW / Tracer MW] for tracers
REAL*8,  INTENT(IN)    :: TCVV(N_TRACERS)

! Array containing grid box air masses
REAL*8,  INTENT(IN)    :: AD(IIPAR,JJPAR,LLPAR)
```

OUTPUT PARAMETERS:

```
!  Array containing tracer conc. [kg] or [v/v]
REAL*8,  INTENT(INOUT) :: STT(IIPAR,JJPAR,LLPAR,N_TRACERS)
```

REVISION HISTORY:

```
15 Jun 1998 - R. Yantosca - Initial version
(1 ) CONVERT_UNITS is written in Fixed-Form Fortran 90.
(2 ) Cosmetic changes, updated comments (bmy, 4/19/00)
(3 ) Now use SELECT CASE statement.  Also added parallel DO-loops
     with the new Open-MP compiler directives. (bmy, 4/27/00)
(4 ) Bundled into "dao_mod.f".  Now pass NTRACE, TCVV, AD, STT as args.
     Now use explicit DO-loops for I-J-L w/in parallel loops.  Updated
     comments, cosmetic changes. (bmy, 3/29/02)
(5 ) Removed obsolete, commented-out code.  Also now use F90 intrinsic
     REPEAT to write a line of "="'s to the screen. (bmy, 6/25/02)
(6 ) Updated comments.  Now reference ERROR_STOP from "error_mod.f"
     (bmy, 10/15/02)
(7 ) Renamed NTRACE to N_TRACERS for consistency (bmy, 7/19/04)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.31.15 copy_i3_i6_fields

Subroutine COPY_I3_I6_FIELDS copies the I-6 fields at the end of a 6-hr timestep. The I-6 fields at the end of a given 6-hr timestep become the fields at the beginning of the next 6-hr timestep.

INTERFACE:

```
SUBROUTINE COPY_I3_I6_FIELDS
```

REVISION HISTORY:

```
13 Apr 2004 - R. Yantosca - Initial version
```

```
(1 ) Added parallel DO-loops (bmy, 4/13/04)
(2 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(3 ) Added TROPP (phs 11/10/06)
(4 ) Don't copy TROPP2 to TROPP1 for GEOS-5 (bmy, 1/17/07)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
20 Aug 2010 - R. Yantosca - Rewrite #if block for clarity
20 Aug 2010 - R. Yantosca - Added #if block for MERRA met fields
06 Feb 2012 - R. Yantosca - Added #if block for GEOS-5.7.x met fields
07 Feb 2012 - R. Yantosca - Renamed to COPY_I3_I6_FIELDS
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.31.16 init_dao_gcap

Subroutine INIT_DAO allocates memory for all allocatable module arrays required when using the GCAP met fields.

INTERFACE:

```
SUBROUTINE INIT_DAO_GCAP
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR
```

REVISION HISTORY:

```
06 Feb 2012 - R. Yantosca - Split off GCAP array init from routine INIT_DAO
```

1.31.17 init_dao_geos4

Subroutine INIT_DAO_GEOS4 allocates memory for all allocatable module arrays required when using the GEOS-4 met fields

INTERFACE:

```
SUBROUTINE INIT_DAO_GEOS4
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR
```

REVISION HISTORY:

```
06 Feb 2012 - R. Yantosca - Split off GEOS-4 init from routine INIT_DAO
```

1.31.18 init_dao_geos5

Subroutine INIT_DAO_GEOS5 allocates memory for all allocatable module arrays required when using GEOS-5.2.0 met fields.

INTERFACE:

```
SUBROUTINE INIT_DAO_GEOS5
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR
```

REVISION HISTORY:

```
06 Feb 2012 - R. Yantosca - Split off GEOS-5 init from routine INIT_DAO
06 Mar 2012 - R. Yantosca - Move TO3 to INIT_GEOS3_DERIVED
```

1.31.19 init_dao_geos57

Subroutine INIT_DAO_GEOS57 allocates memory for all allocatable module arrays required when using the GEOS-5.7.x met fields.

INTERFACE:

```
SUBROUTINE INIT_DAO_GEOS57
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR
```

REVISION HISTORY:

```
06 Feb 2012 - R. Yantosca - Split off GEOS-5.7.x init from routine INIT_DAO
```

1.31.20 init_dao_merra

Subroutine INIT_DAO allocates memory for all allocatable module arrays required when using the MERRA met fields.

INTERFACE:

```
SUBROUTINE INIT_DAO_MERRA
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR
```

REVISION HISTORY:

```
06 Feb 2012 - R. Yantosca - Split off MERRA init from routine INIT_DAO
17 Apr 2012 - R. Yantosca - Bug fix: allocate ALBD array (it was omitted)
```

1.31.21 init_dao_derived

Subroutine INIT_DAO_DERIVED allocates memory for "derived" fields (i.e. met quantities that are computed from the fields that are read in from disk.

INTERFACE:

```
SUBROUTINE INIT_DAO_DERIVED
```

USES:

```
USE ERROR_MOD,  ONLY : ALLOC_ERR
USE TRACER_MOD, ONLY : ITS_AN_AEROSOL_SIM, ITS_A_FULLCHEM_SIM
```

REVISION HISTORY:

```
06 Feb 2012 - R. Yantosca - Split off init from routine INIT_DAO
24 Feb 2012 - M. Payer    - Add SUNCOS_MID_5hr for PARANOX
```

1.31.22 init_dao

Subroutine INIT_DAO allocates memory for all allocatable module arrays.

INTERFACE:

```
SUBROUTINE INIT_DAO
```

REVISION HISTORY:

```
26 Jun 2000 - R. Yantosca - Initial version
(1 ) Now allocate AVGW for either NSRCX == 3 or NSRCX == 5 (bmy, 9/24/01)
(2 ) Removed obsolete code from 9/01 (bmy, 10/23/01)
(3 ) Add PSC2 array for TPCORE mixing ratio fix.   (bmy, 3/27/02)
(4 ) Elimintated PS, PSC arrays for floating-pressure fix.
      (dsa, bdf, bmy, 8/20/02)
(5 ) Added AD, BXHEIGHT, T to "dao_mod.f" as allocatable arrays, to remove
      historical baggage and centralize variables.  Also remove GEOS_2
      flag from C-preprocessor statements.  Also allocate RH array
      but only if we are doing a sulfate simulation.  Now references
      ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
(6 ) Now allocate PHIS array (bmy, 3/11/03)
(7 ) Now allocate SUNCOSB array for SMVGEAR II.  Also removed KZZ array,
      that is now obsolete. (bdf, bmy, 4/28/03)
(8 ) Now order all arrays in alphabetical order.  Also added new fields
      for GEOS-4/fvDAS: HKBETA, HKETA, ZMEU, ZMMD, ZMMU, TSKIN, PARDF,
      and PARDR. (bmy, 6/25/03)
(9 ) Now allocate CLDFRC, RADLWG, RADSWG, SNOW arrays.  USTAR, CLDFRC,
      and Z0 and RADSWG are now 2-D arrays. (bmy, 12/9/03)
(10) Allocate RADLWG and SNOW for both GEOS-3 & GEOS-4 (bmy, 4/2/04)
(11) Now reference inquiry functions from "tracer_mod.f".  Now reference
```

```
      LWETD, LDRYD, LCHEM from "logical_mod.f".  Now allocate RH regardless
      of simulation. (bmy, 7/20/04)
(12) Now also allocate AVGW for offline aerosol simulations (bmy, 9/27/04)
(13) Now modified for GCAP met fields.  Removed references to CO-OH param
      simulation.  Now allocate AVGW only for fullchem or offline aerosol
      simulations. (bmy, 6/24/05)
(14) Now allocate SNOW and GWETTOP for GCAP (bmy, 8/17/05)
(15) Now also add TSKIN for GEOS-3 (bmy, 10/20/05)
(16) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(17) Reorganized for GEOS-5 met fields (bmy, 1/17/07)
(18) Bug fix: should be CMFMC=0 after allocating CMFMC (jaf, bmy, 6/11/08)
(19) Remove obsolete SUNCOSB array (bmy, 4/28/10)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
18 Aug 2010 - R. Yantosca - Now allocate met fields for MERRA
20 Aug 2010 - R. Yantosca - Bug fix, now allocate REEVAPCN
01 Feb 2012 - R. Yantosca - Now allocate met field arrays for GEOS-5.7.x
06 Feb 2012 - R. Yantosca - Now split off array initializations into
                            separate routines, for clarity
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.31.23 cleanup_dao

Subroutine CLEANUP_DAO deallocates all met field arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DAO
```

REVISION HISTORY:

```
26 Jun 2000 - R. Yantosca - Initial version
(1 ) Now deallocate SLP met field for GEOS-3 (bmy, 10/10/00)
(2 ) Now deallocate OPTDEP met field for GEOS-3 (bmy, 8/15/01)
(3 ) Now deallocate AVGW (bmy, 9/24/01)
(4 ) Remove TAUCLD deallocation -- it's obsolete (bmy, 10/23/01)
(5 ) Add call to deallocate PSC2 array (bmy, 3/27/02)
(6 ) Elimintated PS, PSC arrays for floating-pressure fix.
      (dsa, bdf, bmy, 8/20/02)
(7 ) Now deallocate AD, BXHEIGHT, and T arrays (bmy, 9/18/02)
(8 ) Now deallocate PHIS array (bmy, 3/11/03)
(9 ) Now deallocate SUNCOSB array.  Remove reference to KZZ, since
      that is now obsolete. (bmy, 4/28/03)
(10) Now list all arrays in order.  Now also deallocate new arrays
      for GEOS-4/fvDAS. (bmy, 6/25/03)
(11) Now deallocate CLDFRC, RADLWG, RADSWG, SNOW arrays (bmy, 12/9/03)
(12) Now deallocate GCAP met fields (bmy, 5/25/05)
(13) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
```

```
(14) Deallocate additional arrays for GEOS-5 (bmy, 1/17/07)
(15) Remove obsolete SUNCOSB (bmy, 4/28/10)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
18 Aug 2010 - R. Yantosca - Now deallocate MERRA met field arrays
05 Oct 2011 - R. Yantosca - Now deallocate SUNCOS_MID
06 Feb 2012 - R. Yantosca - Cosmetic changes
24 Feb 2012 - R. Yantosca - Now deallocate SUNCOS_MID_5hr; cosmetic changes
```

1.32 Fortran: Module Interface depo_mercury_mod

Module DEPO_MERCURY_MOD contains routines to handle deposition fluxes for mercury.
INTERFACE:

```
      MODULE DEPO_MERCURY_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: ADD_Hg2_DD
      PUBLIC :: ADD_Hg2_WD
      PUBLIC :: ADD_HgP_DD
      PUBLIC :: ADD_HgP_WD
      PUBLIC :: ADD_HG2_SNOWPACK
      PUBLIC :: RESET_HG_DEP_ARRAYS
      PUBLIC :: CHECK_DIMENSIONS
      PUBLIC :: READ_GTMM_RESTART
      PUBLIC :: MAKE_GTMM_RESTART
      PUBLIC :: UPDATE_DEP
      PUBLIC :: INIT_DEPO_MERCURY
      PUBLIC :: CLEANUP_DEPO_MERCURY
```

PUBLIC DATA MEMBERS:

```
      PUBLIC :: DD_HG2, DD_HGP, WD_HG2, WD_HGP
      PUBLIC :: HG2mth_wd, HG0mth_dd, HG2mth_dd
      PUBLIC :: SNOW_HG
      PUBLIC :: LHGSNOW
      REAL*8,  ALLOCATABLE :: DD_Hg2(:,:,:)
      REAL*8,  ALLOCATABLE :: DD_HgP(:,:,:)
      REAL*8,  ALLOCATABLE :: WD_Hg2(:,:,:)
      REAL*8,  ALLOCATABLE :: WD_HgP(:,:,:)
      REAL*8,  ALLOCATABLE :: HG0mth_dd(:,:)
      REAL*8,  ALLOCATABLE :: HG2mth_dd(:,:)
      REAL*8,  ALLOCATABLE :: HG2mth_wd(:,:)
```

```
      REAL*8,  ALLOCATABLE :: SNOW_HG(:,:,:) !CDH Hg stored in snow+ice
      REAL*8,  ALLOCATABLE :: Hg0dryGEOS(:,:), HgIIdryGEOS(:,:),
     &                        HgIIwetGEOS(:,:)
!PRIVATE DATA MEMBERS:
      CHARACTER(LEN=255)   :: GTMM_RST_FILE
      LOGICAL              :: LHGSNOW
```

REVISION HISTORY:

```
 23 Apr 2010 - C. Carouge  - Initial version
 12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
 08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met
```

1.32.1 add_Hg2_dd

Subroutine ADD_Hg2_DD computes the amount of Hg(II) dry deposited out of the atmosphere into the column array DD_Hg2.

INTERFACE:

```
      SUBROUTINE ADD_Hg2_DD( I, J, N, DRY_Hg2)
!USES
      USE TRACERID_MOD, ONLY : GET_Hg2_CAT
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: I, J, N   ! GEOS-Chem long, lat and tracer index
      REAL*8,  INTENT(IN)   :: DRY_Hg2   ! Hg(II) dry deposited out of the
                                         ! atmosphere [kg]
```

REVISION HISTORY:

```
 19 Jan 2005 - S. Strode, C. Holmes - Initial version
 (1 ) DD_Hg2 is now a 3-D array.  Also pass N via the argument list. Now
       call GET_Hg2_CAT to return the Hg category #. (cdh, bmy, 3/28/06)
 23 Apr 2010 - C. Carouge  - Moved from ocean_mercury_mod.f to
                             depo_mercury_mod.f
```

1.32.2 add_Hg2_wd

Subroutine ADD_Hg2_WD computes the amount of Hg(II) wet scavenged out of the atmosphere into the column array WD_Hg2.

INTERFACE:

```
      SUBROUTINE ADD_Hg2_WD( I, J, N, WET_Hg2 )
!USES
      USE TRACERID_MOD, ONLY : GET_Hg2_CAT
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: I, J, N   ! GEOS-Chem long, lat and tracer index
      REAL*8,  INTENT(IN)   :: WET_Hg2   ! Hg(II) scavenged out of the
                                         ! atmosphere [kg]
```

REVISION HISTORY:

```
    19 Jan 2005 - S. Strode, C. Holmes - Initial version
    (1 ) WD_Hg2 is now a 3-D array.  Also pass N via the argument list. Now
          call GET_Hg2_CAT to return the Hg category #. (cdh, bmy, 3/28/06)
    23 Apr 2010 - C. Carouge  - Moved from ocean_mercury_mod.f to
                                depo_mercury_mod.f
```

1.32.3 add_HgP_dd

Subroutine ADD_HgP_DD computes the amount of HgP dry deposited out of the atmosphere into the column array DD_HgP.

INTERFACE:

```
      SUBROUTINE ADD_HgP_DD( I, J, N, DRY_HgP )
   !USES
      USE TRACERID_MOD, ONLY : GET_HgP_CAT
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: I, J, N   ! GEOS-Chem long, lat and tracer index
      REAL*8,  INTENT(IN)   :: DRY_HgP   ! HgP dry deposited out of the
                                         ! atmosphere [kg]
```

REVISION HISTORY:

```
    19 Jan 2005 - S. Strode, C. Holmes - Initial version
    (1 ) DD_HgP is now a 3-D array.  Also pass N via the argument list. Now
          call GET_HgP_CAT to return the Hg category #. (cdh, bmy, 3/28/06)
    23 Apr 2010 - C. Carouge  - Moved from ocean_mercury_mod.f to
                                depo_mercury_mod.f
```

1.32.4 add_HgP_wd

Subroutine ADD_HgP_WD computes the amount of HgP wet scavenged out of the atmosphere into the column array WD_HgP.

INTERFACE:

```
      SUBROUTINE ADD_HgP_WD( I, J, N, WET_HgP )
   !USES
      USE TRACERID_MOD, ONLY : GET_HgP_CAT
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: I, J, N   ! GEOS-Chem long, lat and tracer index
      REAL*8,  INTENT(IN)   :: WET_HgP   ! HgP scavenged out of the
                                         ! atmosphere [kg]
```

REVISION HISTORY:

```
   19 Jan 2005 - S. Strode, C. Holmes - Initial version
   (1 ) WD_HgP is now a 3-D array.  Also pass N via the argument list. Now
         call GET_HgP_CAT to return the Hg category #. (cdh, bmy, 3/28/06)
   23 Apr 2010 - C. Carouge  - Moved from ocean_mercury_mod.f to
                               depo_mercury_mod.f
```

1.32.5 add_hg2_snowpack

Subroutine ADD_Hg2_SNOWPACKS adds Hg2 deposition to snowpack.

INTERFACE:

```
      SUBROUTINE ADD_HG2_SNOWPACK( I, J, N, DEP_Hg2 )
```

USES:

```
      USE DAO_MOD,           ONLY : SNOW, SNOMAS
      USE DAO_MOD,           ONLY : IS_ICE, IS_LAND
      USE DAO_MOD,           ONLY : FRSNO, FRSEAICE, FRLANDIC
      USE TRACERID_MOD,      ONLY : GET_Hg2_CAT, GET_HgP_CAT
      USE TRACERID_MOD,      ONLY : IS_Hg2,      IS_HgP

#     include "define.h"
```

INPUT PARAMETERS:

```
      ! Arguments as input
      INTEGER, INTENT(IN)   :: I, J, N
      REAL*8,  INTENT(IN)   :: Dep_Hg2
```

REVISION HISTORY:

```
   02 Sep 2008 - C. Holmes   - Initial version
   23 Apr 2010 - C. Carouge  - Moved from mercury_mod.f to depo_mercury_mod.f
   25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
   26 Apr 2011 - J. Fisher   - Use MERRA land fraction information
   12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
   13 Apr 2011 - R. Yantosca - Bug fix: reference IS_LAND from dao_mod.f
    8 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
```

1.32.6 reset_hg_dep_arrays

Subroutine RESET_Hg_DEP_ARRAYS resets the wet and dry deposition arrays for Hg(II) and Hg(p) to zero. This allows us to call OCEAN_MERCURY_FLUX and LAND_MERCURY_FLUX in any order in MERCURY_MOD.

INTERFACE:

```
SUBROUTINE RESET_HG_DEP_ARRAYS
```

REVISION HISTORY:

```
02 Sep 2008 - C. Holmes   - Initial version
23 Apr 2010 - C. Carouge  - Moved from ocean_mercury_mod.f to
                            depo_mercury_mod.f
```

1.32.7 make_gtmm_restart

MAKE_GTMM_RESTART writes a GTMM restart file with deposition fluxes and store deposition fluxes for continuous runs.

INTERFACE:

```
SUBROUTINE MAKE_GTMM_RESTART( NYMD, NHMS, TAU )
```

USES:

```
USE BPCH2_MOD
USE DIAG_MOD,      ONLY : AD39, AD44, AD38
USE DIRECTORY_MOD, ONLY : RUN_DIR
USE FILE_MOD,      ONLY : IU_FILE
USE GRID_MOD,      ONLY : GET_XOFFSET, GET_YOFFSET
USE TIME_MOD,      ONLY : EXPAND_DATE
USE TRACERID_MOD,  ONLY : ID_Hg0, ID_Hg2, ID_Hg_tot
USE TIME_MOD,      ONLY : GET_CT_DYN, GET_CT_CHEM

USE CMN_SIZE_MOD          ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)   :: NYMD    ! Year-Month-Date
INTEGER, INTENT(IN)   :: NHMS    ! and Hour-Min-Sec for which to create
                                 ! a restart file
REAL*8,  INTENT(IN)   :: TAU     ! GEOS-CHEM TAU value corresponding to
                                 ! NYMD, NHMS
```

REVISION HISTORY:

```
15 Sep 2009 - C. Carouge - Initial version
```

1.32.8 read_gtmm_restart

Subroutine READ_GTMM_RESTART reads dry and wet deposition for mercury from GTMM restart.

INTERFACE:

```
SUBROUTINE READ_GTMM_RESTART( YYYYMMDD, HHMMSS,
&                             Hg0dryGEOS, HgIIdryGEOS, HgIIwetGEOS )
```

USES:

```
USE BPCH2_MOD,     ONLY : OPEN_BPCH2_FOR_READ
USE DIRECTORY_MOD, ONLY : RUN_DIR
USE ERROR_MOD,     ONLY : DEBUG_MSG
USE FILE_MOD,      ONLY : IU_FILE,     IOERROR
USE TIME_MOD,      ONLY : EXPAND_DATE
USE TRACER_MOD,    ONLY : STT,         TRACER_NAME, TRACER_MW_G
USE TRACERID_MOD,  ONLY : GET_Hg0_CAT, GET_Hg2_CAT, N_Hg_CATS
USE TRACERID_MOD,  ONLY : ID_Hg0,      ID_Hg2

USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)   :: YYYYMMDD, HHMMSS
```

OUTPUT PARAMETERS:

```
REAL*8, DIMENSION(IIPAR, JJPAR)   :: Hg0dryGEOS
REAL*8, DIMENSION(IIPAR, JJPAR)   :: HgIIdryGEOS
REAL*8, DIMENSION(IIPAR, JJPAR)   :: HgIIwetGEOS
```

REVISION HISTORY:

```
15 Sep 2009 - C. Carouge - Initial version
```

1.32.9 update_dep

Subroutine UPDATE_DEP update the monthly average for wet and dry deposition of Hg0 and Hg2 for mercury from GTMM restart.

INTERFACE:

```
SUBROUTINE UPDATE_DEP( NN )
```

USES:

```
USE DIAG_MOD,     ONLY : AD38,   AD39,   AD44
USE LOGICAL_MOD,  ONLY : LGTMM
USE TIME_MOD,     ONLY : GET_CT_DYN,  GET_CT_CHEM
USE TRACERID_MOD, ONLY : IDTHg0, IDTHg2
```

INPUT PARAMETERS:

```
INTEGER :: NN    ! Hg2 ID for wet deposition
```

REVISION HISTORY:

```
04 June 2010  - C. Carouge  - Initial version
```

1.32.10 check_dimensions

Subroutine CHECK_DIMENSIONS makes sure that the dimensions of the Hg restart file extend to cover the entire grid.

INTERFACE:

```
SUBROUTINE CHECK_DIMENSIONS( NI, NJ, NL )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NI, NJ, NL
```

REVISION HISTORY:

```
30 Aug 2010 - S. Strode, C. Holmes - Initial version
```

1.32.11 init_depo_mercury

Subroutine INIT_DEPO_MERCURY initialize deposition arrays for mercury.

INTERFACE:

```
    SUBROUTINE INIT_DEPO_MERCURY( THIS_Hg_RST_FILE )
!USES
    USE ERROR_MOD,    ONLY : ALLOC_ERR
    USE LOGICAL_MOD,  ONLY : LGTMM
    USE TRACERID_MOD, ONLY : N_Hg_CATS

    USE CMN_SIZE_MOD     ! Size parameters
```

INPUT PARAMETERS:

```
! Name of the GTMM restart file
CHARACTER(LEN=*), INTENT(IN) :: THIS_Hg_RST_FILE
```

REVISION HISTORY:

```
23 Apr 2010 - C. Carouge   - Moved arrays allocation from
                             ocean_mercury_mod.f
```

1.32.12 cleanup_depo_mercury

Subroutine CLEANUP_DEPO_MERCURY deallocate all arrays

INTERFACE:

```
SUBROUTINE CLEANUP_DEPO_MERCURY
```

REVISION HISTORY:

```
23 Apr 2010 - C. Carouge - Moved from ocean_mercury_mod.f
```

1.33 Fortran: Module Interface diag03_mod

Module DIAG03_MOD contains arrays and routines for archiving the ND03 diagnostic – Hg emissions, mass, and production.

INTERFACE:

```
MODULE DIAG03_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

DEFINED PARAMETERS:

```
      INTEGER, PUBLIC, PARAMETER   :: PD03    = 18         ! Dim of AD03 array
      INTEGER, PUBLIC, PARAMETER   :: PD03_PL = 10         ! # of PL-HG2 diags
```

PUBLIC DATA MEMBERS:

```
      ! Scalars
      INTEGER, PUBLIC              :: ND03                 ! ND03 on/off flag
      INTEGER, PUBLIC              :: LD03                 ! # of levels

      ! Arrays
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03(:,:,:)          ! Diagnostic arrays
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_Hg0(:,:,:)  !  for the prod/loss
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_Br(:,:,:)   !  and mass of
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_OH(:,:,:)   !  various Hg
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_O3(:,:,:)   !  species
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_SS(:,:,:)   !
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_nat(:,:,:)      !
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_SSR(:,:)    !
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Br(:,:,:,:)     !
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_RGM(:,:,:)      !
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_PBM(:,:,:)      !
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: ZERO_DIAG03
PUBLIC :: WRITE_DIAG03
PUBLIC :: INIT_DIAG03
PUBLIC :: CLEANUP_DIAG03
```

REMARKS:

```
Nomenclature:
============================================================================
(1 ) Hg(0)  a.k.a. Hg0     : Elemental   mercury
(2 ) Hg(II) a.k.a. Hg2     : Divalent    mercury
(3 ) RGM a.k.a. Hg(II)gas  : Reactive (oxidized) gaseous mercury
(4 ) PBM a.k.a. Hg(II)P    : Reactive (oxidized) particulate mercury
```

REVISION HISTORY:

```
21 Jan 2005 - R. Yantosca - Initial version
(1 ) Updated for GCAP grid (bmy, 6/28/05)
(2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(3 ) Add 2 extra diagnostics to ND03. Set PD03=15.  (cdh, bmy, 12/15/05)
(4 ) Add loss of Hg2 by sea salt (eck, bmy, 4/6/06)
(5 ) Replace TINY(1d0) w/ 1d-32 to avoid problems on SUN 4100 platform
     (bmy, 9/5/06)
(6 ) Updates to mercury simulation (ccc, 5/17/10)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.33.1 zero_diag03

Subroutine ZERO_DIAG03 zeroes all module arrays.

INTERFACE:

```
SUBROUTINE ZERO_DIAG03
```

USES:

```
! References to F90 modules
USE TRACERID_MOD, ONLY : N_Hg_CATS

USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
21 Jan 2005 - R. Yantosca - Initial version
(1 ) Now references N_Hg_CATS from "tracerid_mod.f".  Now zero AD03_Hg2_SS
     array. (bmy, 4/6/06)
(2 ) Now use broadcast assignment and double precision 0D0 to zero arrays,
     rather than nested DO loops and single precision 0E0. (cdh, 8/14/08)
(3 ) Now zeros RGM and PBM diagnostics. (hma 20100219)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.33.2 write_diag03

Subroutine WRITE_DIAG03 writes the ND03 diagnostic arrays to the binary punch file at the proper time.

INTERFACE:

```
SUBROUTINE WRITE_DIAG03
```

USES:

```
USE BPCH2_MOD,    ONLY : BPCH2
USE BPCH2_MOD,    ONLY : GET_MODELNAME
USE BPCH2_MOD,    ONLY : GET_HALFPOLAR
USE FILE_MOD,     ONLY : IU_BPCH
USE GRID_MOD,     ONLY : GET_XOFFSET
USE GRID_MOD,     ONLY : GET_YOFFSET
USE TIME_MOD,     ONLY : GET_CT_EMIS
USE TIME_MOD,     ONLY : GET_DIAGb
USE TIME_MOD,     ONLY : GET_DIAGe
USE TIME_MOD,     ONLY : GET_CT_CHEM
USE TRACERID_MOD, ONLY : N_Hg_CATS
USE TIME_MOD,     ONLY : GET_CT_DIAG, GET_Hg2_DIAG !H Amos, 20100218

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! TINDEX
```

REMARKS:

```
 # : Field    : Description                     : Units    : Scale factor
-----------------------------------------------------------------------------
The following list is outdated and not reliable (cdh, 7/5/11)
(1 ) HG-SRCE  : Anthropogenic HG0 emission      : kg       : 1
(2 ) HG-SRCE  : Total mass of oceanic Hg0       : kg       : 1
(3 ) HG-SRCE  : Oceanic Hg0 emission            : kg       : 1
(4 ) HG-SRCE  : Land reemission                 : kg       : 1
(5 ) HG-SRCE  : Land natural emission           : kg       : 1
(6 ) HG-SRCE  : Anthropogenic Hg2 emission      : kg       : 1
(7 ) HG-SRCE  : Total mass of oceanic Hg2       : kg       : 1
(8 ) HG-SRCE  : Mass of Hg2 sunk in the ocean   : kg       : 1
(9 ) HG-SRCE  : Anthropogenic HgP emission      : kg       : 1
(10) HG-SRCE  : Henry's law piston velocity Kw  : cm/h     : em timesteps  (anls, redo)
(11) HG-SRCE  : Mass of Hg(P)                   : kg       : 1
(12) HG-SRCE  : Converted to Particulate        : kg       : 1
(13) HG-SRCE  : Biomass burning emissions       : kg       : 1
(14) HG-SRCE  : Emissions from vegetation       : kg       : 1
(15) HG-SRCE  : Emissions from soils            : kg       : 1
(16) HG-SRCE  : Flux-up Hg0 volat from ocean    : kg       : 1
```

```
(17) HG-SRCE  : Flux-down Hg0 dry dep to ocean  : kg       : 1
(18) PL-HG2-$ : Production of Hg2 from Hg0      : kg       : 1
(19) PL-HG2-$ : Production of Hg2 from rxn w/OH : kg       : 1
(20) PL-HG2-$ : Production of Hg2 from rxn w/O3 : kg       : 1
(21) PL-HG2-$ : Loss of Hg2 from rxn w/ seasalt : kg       : 1
(22) PL-HG2-$ : Prod of Hg2 form rxn w/ Br      : kg       : 1
(23) PL-HG2-$ : Br concentration                : molec/cm3: 1
(24) PL-HG2-$ : Br concentration                : molec/cm3: 1
(27) PL-HG2-$ : Reactive gaseous mercury        : pptv     : 1
(28) PL-HG2-$ : Reactice particule mercury      : pptv     : 1
NOTES:
```

REVISION HISTORY:

```
21 Jan 2005 - R. Yantosca - Initial version
(1 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
     value for GEOS or GCAP grids. (bmy, 6/28/05)
(2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(3 ) Add HgC ocean mass and converted to colloidal to ND03 diagnostic.
     The units of the Kw and conversion terms in ND03 should be kg
     and not divided by the scale factor. (cdh, sas, bmy, 2/26/02)
(4 ) Replace TINY(1d0) w/ 1d-32 to avoid problems on SUN 4100 platform
     (bmy, 9/5/06)
(5 ) Fixed tracer numbers (NN) for 'PL-HG2-$' diagnostic quantities.
     (cdh, 8/13/08)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.33.3 init_diag03

Subroutine INIT_DIAG03 allocates all module arrays.

INTERFACE:

```
SUBROUTINE INIT_DIAG03
```

USES:

```
USE ERROR_MOD,    ONLY : ALLOC_ERR
USE TRACERID_MOD, ONLY : N_Hg_CATS

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
21 Jan 2005 - R. Yantosca - Initial version
(1 ) Now allocates AD03_Hg2_SS (eck, bmy, 4/6/06)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.33.4 cleanup_diag03

Subroutine CLEANUP_DIAG03 deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG03
```

REVISION HISTORY:

```
21 Jan 2005 - R. Yantosca - Initial version
(1 ) Now deallocates AD03_Hg2_SS (eck, bmy, 4/6/06)
(2 ) Now deallocates AD03_PBM, AD03_RGM (hma 20100216)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.34 Fortran: Module Interface diag04_mod

Module DIAG04_MOD contains arrays and routines for archiving the ND04 diagnostic – CO2 emissions and fluxes.

INTERFACE:

```
MODULE DIAG04_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PUBLIC
```

PUBLIC DATA MEMBERS:

```
      ! Scalars
      INTEGER              :: ND04, LD04
      INTEGER, PARAMETER   :: PD04 = 10

      ! Arrays
      REAL*4,  ALLOCATABLE :: AD04(:,:,:)
      REAL*4,  ALLOCATABLE :: AD04_plane(:,:,:)
      REAL*4,  ALLOCATABLE :: AD04_chem(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_DIAG04
      PUBLIC :: INIT_DIAG04
      PUBLIC :: WRITE_DIAG04
      PUBLIC :: ZERO_DIAG04
```

PRIVATE MEMBER FUNCTIONS:

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%   BUYER BEWARE! Tagged CO2 tracers only work for 2 x 2.5 grid!   %%%
%%%   Someone will have to make this more general later on...        %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

.

REVISION HISTORY:

```
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
      (bmy, 9/5/06)
(3 ) Modified for ship emissions (2-D), aircraft emissions (3-D) and
     chemical source for CO2 (3-D) (RayNassar, 2009-12-23)
20 May 2010 - R. Yantosca - Added ProTeX headers
```

1.34.1 zero_diag04

Subroutine ZERO_DIAG04 zeroes the ND04 diagnostic array.

INTERFACE:

```
SUBROUTINE ZERO_DIAG04
```

USES:

```
USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
26 Jul 2005 - R. Yantosca - Initial version
18 May 2010 - R. Nassar   - Also zero AD04_PLANE, AD04_CHEM arrays
18 May 2010 - R. Yantosca - Added ProTeX headers
```

1.34.2 write_diag04

Subroutine WRITE_DIAG04 writes the ND04 diagnostic arrays to the binary punch file at the proper time.

INTERFACE:

```
SUBROUTINE WRITE_DIAG04
```

USES:

```
      USE BPCH2_MOD, ONLY : BPCH2, GET_MODELNAME, GET_HALFPOLAR
      USE FILE_MOD,  ONLY : IU_BPCH
      USE GRID_MOD,  ONLY : GET_XOFFSET, GET_YOFFSET
      USE TIME_MOD,  ONLY : GET_CT_EMIS, GET_DIAGb,  GET_DIAGe

      USE CMN_SIZE_MOD  ! Size parameters
      USE CMN_DIAG_MOD  ! TINDEX
```

REMARKS:

```
 # : Field     : Description                  : Units       : Scale factor
-------------------------------------------------------------------------
(1 ) CO2-SRCE  : CO2 fossil fuel emissions    : molec/cm2/s : SCALE
(2 ) CO2-SRCE  : CO2 ocean emissions          : molec/cm2/s : SCALE
(3 ) CO2-SRCE  : CO2 balanced biosphere       : molec/cm2/s : SCALE
(4 ) CO2-SRCE  : CO2 biomass emissions        : molec/cm2/s : SCALE
(5 ) CO2-SRCE  : CO2 biofuel emissions        : molec/cm2/s : SCALE
(6 ) CO2-SRCE  : CO2 net terrestrial exchange : molec/cm2/s : SCALE
(7 ) CO2-SRCE  : CO2 ship emissions           : molec/cm2/s : SCALE
(8 ) CO2-SRCE  : CO2 aircraft emissions (3-D) : molec/cm2/s : SCALE
(9 ) CO2-SRCE  : CO2 chemical source (3-D)    : molec/cm2/s : SCALE
(10) CO2-SRCE  : CO2 chem source surf correct : molec/cm2/s : SCALE!
```

REVISION HISTORY:

```
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
18 May 2010 - R. Nassar   - Now write out AD04_PLANE, AD04_CHEM
18 May 2010 - R. Yantosca - Added ProTeX headers
```

1.34.3 init_diag04

Subroutine INIT_DIAG04 allocates all module arrays.

INTERFACE:

```
      SUBROUTINE INIT_DIAG04
```

USES:

```
      USE ERROR_MOD, ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
26 Jul 2005 - R. Yantosca - Initial version
18 May 2010 - R. Nassar   - Now initialize AD04_PLANE, AD04_CHEM
18 May 2010 - R. Yantosca - Added ProTeX headers
```

1.34.4 cleanup_diag04

Subroutine CLEANUP_DIAG04 deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_DIAG04
```

REVISION HISTORY:

```
   26 Jul 2005 - R. Yantosca - Initial version
   18 May 2010 - R. Nassar   - Now ce
   18 May 2010 - R. Yantosca - Added ProTeX headers
```

1.35 Fortran: Module Interface diag41_mod

Module DIAG41_MOD contains arrays and routines for archiving the ND41 diagnostic – Afternoon PBL heights.

INTERFACE:

```
      MODULE DIAG41_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      INTEGER, PUBLIC            :: ND41
      INTEGER, PUBLIC, PARAMETER :: PD41 = 2
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: ZERO_DIAG41
      PUBLIC :: WRITE_DIAG41
      PUBLIC :: DIAG41
      PUBLIC :: INIT_DIAG41
      PUBLIC :: CLEANUP_DIAG41
```

REVISION HISTORY:

```
   17 Feb 2005 - R. Yantosca - Initial version
   (1 ) Updated for GCAP grid (bmy, 6/28/05)
   (2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (3 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
        (bmy, 9/5/06)
   02 Dec 2010 - R. Yantosca - Added ProTeX headers
   01 Mar 2012 - R. Yantosca - Use updated GET_LOCALTIME from time_mod.F
```

1.35.1 zero_diag41

Subroutine ZERO_DIAG41 zeroes the ND41 diagnostic arrays.

INTERFACE:

```
SUBROUTINE ZERO_DIAG41
```

USES:

```
USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
17 Feb 2005 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.35.2 write_diag41

Subroutine WRITE_DIAG41 writes the ND41 diagnostic arrays to the binary punch file at the proper time.

INTERFACE:

```
SUBROUTINE WRITE_DIAG41
```

USES:

```
USE BPCH2_MOD, ONLY : BPCH2
USE BPCH2_MOD, ONLY : GET_HALFPOLAR
USE BPCH2_MOD, ONLY : GET_MODELNAME
USE FILE_MOD,  ONLY : IU_BPCH
USE GRID_MOD,  ONLY : GET_XOFFSET
USE GRID_MOD,  ONLY : GET_YOFFSET
USE TIME_MOD,  ONLY : GET_CT_EMIS
USE TIME_MOD,  ONLY : GET_DIAGb
USE TIME_MOD,  ONLY : GET_DIAGe

USE CMN_SIZE_MOD  ! Size parameters
USE CMN_DIAG_MOD  ! TINDEX
```

REMARKS:

```
ND41: Afternoon PBL depth (between 1200 and 1600 Local Time)

 #  Field    : Description             : Units  : Scale factor
-------------------------------------------------------------------
(1) PBLDEPTH : Afternoon PBL heights   : m      : GOOD_CT
```

REVISION HISTORY:

```
17 Feb 2005 - R. Yantosca - Initial version
(1 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
     value for GEOS or GCAP grids. (bmy, 6/28/05)
(2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(3 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
     (bmy, 9/5/06)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.35.3 diag41

Subroutine DIAG41 produces monthly mean boundary layer height in meters between 1200-1600 local time for the U.S. geographical domain.

INTERFACE:

```
SUBROUTINE DIAG41
```

USES:

```
USE PBL_MIX_MOD, ONLY : GET_PBL_TOP_L
USE PBL_MIX_MOD, ONLY : GET_PBL_TOP_m
USE TIME_MOD,    ONLY : GET_LOCALTIME

USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
18 Nov 1999 - A. Fiore, S. Wu - Initial version
(1 ) DIAG41 is written in Fixed-Format F90.
(2 ) XTRA2 must be computed by turning TURBDAY on first.  Also,
     XTRA2 is a global-size array, so use window offsets IREF, JREF
     to index it correctly. (bmy, 11/18/99)
(3 ) Do a little rewriting so that the DO-loops get executed
     in the correct order (J first, then I). (bmy, 11/18/99)
(4 ) AD41 is now declared allocatable in "diag_mod.f". (bmy, 12/6/99)
(5 ) AFTTOT is now declared allocatable in "diag_mod.f". (bmy, 3/17/00)
(6 ) Remove NYMD from the argument list -- it wasn't used (bmy, 6/22/00)
(7 ) XTRA2(IREF,JREF,5) is now XTRA2(I,J).  Also updated comments.
     (bmy, 9/25/01)
(8 ) Removed obsolete code from 9/01 (bmy, 10/23/01)
(9 ) Now reference BXHEIGHT from "dao_mod.f".  Also removed obsolete
     code. (bmy, 9/18/02)
(10) Now use function GET_LOCALTIME from "dao_mod.f" (bmy, 2/11/03)
(11) Bug fix in DO-loop for calculating local time (bmy, 7/9/03)
(12) For GEOS-4, PBL depth is already in meters, so we only have to
     multiply that by the GOOD array.  Also now references PBL array
     from "dao_mod.f".  Bug fix: now use barometric law to compute PBL
```

```
      height in meters for GEOS-1, GEOS-STRAT, GEOS-3.  This eliminates an
      overprediction of the PBL height. (swu, bmy, 11/6/03)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_LOCALTIME(I,J,L) from time_mod.F90
```

1.35.4 init_diag41

Subroutine CLEANUP_DIAG41 allocates and zeroes all module arrays.

INTERFACE:

```
      SUBROUTINE INIT_DIAG41
```

USES:

```
      USE ERROR_MOD, ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
17 Feb 2005 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.35.5 cleanup_diag41

Subroutine CLEANUP_DIAG41 deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_DIAG41
```

REVISION HISTORY:

```
17 Feb 2005 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.36 Fortran: Module Interface diag42_mod

Module DIAG42_MOD contains arrays and routines for archiving the ND42 diagnostic – secondary organic aerosols [ug/m3].

INTERFACE:

```
      MODULE DIAG42_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

DEFINED PARAMETERS:

```
      ! Maximum number of output:
      ! SOA1, SOA2, SOA3, SOA4, SOA5, SUM(SOA1-3), SUM(SOA1-4), SUM(SOA1-5),
      ! SUM(SOA1-5+OC), SUM(SOA1-5+OC), SUM(SOA1-5+OC), OC, BC, SOA4, NH4, NIT,
      ! SSALT, SUM(aerosols), SOAG, SOAM, SUM(SOA1-5+SOAG+SOAM),
      ! SUM(SOA1-5+SOAG+SOAM+OC), SUM(SOA1-5+SOAG+SOAM),
      ! SUM(SOA1-5+SOAG+SOAM+OC)
      INTEGER, PUBLIC, PARAMETER   :: PD42 = 24
```

PUBLIC DATA MEMBERS:

```
      INTEGER, PUBLIC              :: ND42           ! ND42 on/off flag
      INTEGER, PUBLIC              :: LD42           ! # of levels for ND42

      ! Arrays
      REAL*4,  PUBLIC, ALLOCATABLE :: AD42(:,:,:,:)   ! Array for SOA [ug/m3]
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: DIAG42
      PUBLIC :: ZERO_DIAG42
      PUBLIC :: WRITE_DIAG42
      PUBLIC :: INIT_DIAG42
      PUBLIC :: CLEANUP_DIAG42
```

REVISION HISTORY:

```
    22 May 2006 - D. Henze, R. Yantosca - Initial version
    (1 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
         (bmy, 9/5/06)
    (2 ) Now use ratio of 2.1 instead of 1.4 for SOA4 (dkh, bmy, 3/29/07)
    (3 ) Add diagnostics for SOAG and SOAM (tmf, 1/7/09)
    (4 ) Increase PD42 to 24. (fp, hotp, 2/3/10)

    02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.36.1 diag42

Subroutine DIAG42 archives SOA concentrations [ug/m3] for the ND42 diagnostic.

INTERFACE:

```
      SUBROUTINE DIAG42
```

USES:

```
! References to F90 modules
USE DAO_MOD,      ONLY : AIRVOL, T
!USE DIAG_MOD,     ONLY : LTOTH
USE PRESSURE_MOD, ONLY : GET_PCENTER
USE TRACER_MOD,   ONLY : STT
USE TRACERID_MOD, ONLY : IDTSOA1, IDTSOA2, IDTSOA3, IDTSOA4
USE TRACERID_MOD, ONLY : IDTSOA5
USE TRACERID_MOD, ONLY : IDTOCPI, IDTOCPO
USE TRACERID_MOD, ONLY : IDTSOAG, IDTSOAM
! consider additional species (hotp 10/26/07)
USE TRACERID_MOD, ONLY : IDTSO4, IDTNIT, IDTNH4, IDTSALA, IDTSALC
USE TRACERID_MOD, ONLY : IDTBCPI, IDTBCPO

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! NDxx flags
```

REVISION HISTORY:

```
22 May 2006 - D. Henze, R. Yantosca - Initial version
(1 ) Now use ratio of 2.1 instead of 1.4 for SOA4 (dkh, bmy, 3/29/07)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.36.2 zero_diag42

Subroutine ZERO_DIAG42 zeroes all module arrays.

INTERFACE:

```
SUBROUTINE ZERO_DIAG42
```

REVISION HISTORY:

```
22 May 2006 - D. Henze, R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.36.3 write_diag42

Subroutine WRITE_DIAG42 writes the ND42 diagnostic arrays to the binary punch file at the proper time.

INTERFACE:

```
SUBROUTINE WRITE_DIAG42
```

USES:

```
      USE BPCH2_MOD,    ONLY : BPCH2
      USE BPCH2_MOD,    ONLY : GET_MODELNAME
      USE BPCH2_MOD,    ONLY : GET_HALFPOLAR
      !USE DIAG_MOD,     ONLY : CTOTH
      USE FILE_MOD,     ONLY : IU_BPCH
      USE GRID_MOD,     ONLY : GET_XOFFSET
      USE GRID_MOD,     ONLY : GET_YOFFSET
      USE TIME_MOD,     ONLY : GET_CT_DIAG
      USE TIME_MOD,     ONLY : GET_DIAGb
      USE TIME_MOD,     ONLY : GET_DIAGe

      USE CMN_SIZE_MOD     ! Size parameters
      USE CMN_DIAG_MOD     ! TINDEX
```

REMARKS:

```
 # : Field    : Description                 : Units    : Scale factor
-----------------------------------------------------------------------
(1 ) IJ-SOA-$ : SOA1                        : ug/m3    : SCALE_OTH
(2 ) IJ-SOA-$ : SOA2                        : ug/m3    : SCALE_OTH
(3 ) IJ-SOA-$ : SOA3                        : ug/m3    : SCALE_OTH
(4 ) IJ-SOA-$ : SOA4                        : ug/m3    : SCALE_OTH
(5 ) IJ-SOA-$ : SOA1 + SOA2 + SOA3          : ug/m3    : SCALE_OTH
(6 ) IJ-SOA-$ : SOA1 + SOA2 + SOA3 + SOA4   : ug/m3    : SCALE_OTH
(7 ) IJ-SOA-$ : Sum of all Org Carbon       : ug C/m3  : SCALE_OTH
(8 ) IJ-SOA-$ : Sum of all Org Carbon @ STP : ug C/sm3 : SCALE_OTH
```

REVISION HISTORY:

```
22 May 2006 - D. Henze, R. Yantosca - Initial version
(1 ) Replace TINY(1d0) with 1d-32 to avoid problems  on SUN 4100 platform
     (bmy, 9/5/06)
(2 ) Use TS_DIAG for scaling instead of TS_DYN. (ccc, 8/18/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.36.4 init_diag42

Subroutine INIT_DIAG42 allocates all module arrays.

INTERFACE:

```
      SUBROUTINE INIT_DIAG42
```

USES:

```
      USE ERROR_MOD,   ONLY : ALLOC_ERR
      USE LOGICAL_MOD, ONLY : LSOA

      USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
22 May 2006 - D. Henze, R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.36.5 cleanup_diag42

Subroutine CLEANUP_DIAG42 deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_DIAG42
```

REVISION HISTORY:

```
22 May 2006 - D. Henze, R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.37 Fortran: Module Interface diag49_mod

Module DIAG49_MOD contains variables and routines to save out 3-D instantaneous time-series output to disk.

INTERFACE:

```
      MODULE DIAG49_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      LOGICAL, PUBLIC :: DO_SAVE_DIAG49
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: DIAG49
      PUBLIC  :: ITS_TIME_FOR_DIAG49
      PUBLIC  :: INIT_DIAG49
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: ITS_TIME_TO_CLOSE_FILE
      PRIVATE :: GET_I
```

REMARKS:

```
ND49 tracer numbers:
================================================================================
1 - N_TRACERS : GEOS-CHEM transported tracers            [v/v        ]
76            : OH concentration                         [molec/cm3  ]
77            : NO2 concentration                        [v/v        ]
78            : PBL heights                              [m          ]
79            : PBL heights                              [levels     ]
80            : Air density                              [molec/cm3  ]
81            : 3-D Cloud fractions                      [unitless   ]
82            : Column optical depths                    [unitless   ]
83            : Cloud top heights                        [hPa        ]
84            : Sulfate aerosol optical depth            [unitless   ]
85            : Black carbon aerosol optical depth       [unitless   ]
86            : Organic carbon aerosol optical depth     [unitless   ]
87            : Accumulation mode seasalt optical depth  [unitless   ]
88            : Coarse mode seasalt optical depth        [unitless   ]
89            : Total dust optical depth                 [unitless   ]
90            : Total seasalt tracer concentration       [unitless   ]
91            : Pure O3 (not Ox) concentration           [v/v        ]
92            : NO concentration                         [v/v        ]
93            : NOy concentration                        [v/v        ]
94            : Grid box heights                         [m          ]
95            : Relative Humidity                        [%          ]
96            : Sea level pressure                       [hPa        ]
97            : Zonal wind (a.k.a. U-wind)               [m/s        ]
98            : Meridional wind (a.k.a. V-wind)          [m/s        ]
99            : PEDGE-$ (Pressure @ level edges          [hPa        ]
100           : Temperature                              [K          ]
101           : PAR direct                               [hPa        ]
102           : PAR diffuse                              [hPa        ]
103           : Daily LAI                                [hPa        ]
104           : Temperature at 2m                        [K          ]
105           : Isoprene emissions                       [atomC/cm2/s]
106           : Total Monoterpene emissions              [atomC/cm2/s]
107           : Methyl Butanol emissions                 [atomC/cm2/s]
108           : Alpha-Pinene emissions                   [atomC/cm2/s]
109           : Beta-Pinene emissions                    [atomC/cm2/s]
110           : Limonene emissions                       [atomC/cm2/s]
111           : Sabinene emissions                       [atomC/cm2/s]
112           : Myrcene emissions                        [atomC/cm2/s]
113           : 3-Carene emissions                       [atomC/cm2/s]
114           : Ocimene emissions                        [atomC/cm2/s]
115-121       : size resolved dust optical depth         [unitless   ]
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Bug fix: get I0, J0 properly for nested grids (bmy, 11/9/04)
(2 ) Now references "pbl_mix_mod.f" (bmy, 2/16/05)
```

```
(3 ) Now saves 3-D cld frac & grid box height (bmy, 4/20/05)
(4 ) Remove TRCOFFSET since it's always zero  Also now get HALFPOLAR for
     both GCAP and GEOS grids.  (bmy, 6/28/05)
(5 ) Bug fix: do not save SLP if it's not allocated (bmy, 8/2/05)
(6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(7 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(8 ) Modified INIT_DIAG49 to save out transects (cdh, bmy, 11/30/06)
(9 ) Bug fix: accumulate into Q(X,Y,K) for dust OD (qli, bmy, 4/30/07)
(10) Minor bug fixes in DIAG49 (cdh, bmy, 2/11/08)
(11) Bug fix: replace "PS-PTOP" with "PEDGE-$"
(12) Modified to archive O3, NO, NOy as tracers 89, 90, 91  (tmf, 9/26/07)
(13) Bug fix DIAG49 for diagnostic output of SLP (tai, bmy, 10/13/09)
(14) Modify AOD output to wavelength specified in jv_spec_aod.dat
     (clh, 05/07/10)
(15) Bug fix in ITS_TIME_TO_CLOSE: compare HR1 to 00 not 24. (ccc, 11/11/10)
(16) Now do not scale AOD output (recalculated in RDAER AND DUST_MOD)
     (skim, 02/02/11)
12 Nov 2010 - R. Yantosca - Changed tracer 99 to be PEDGE-$ (pressure at
                            level edges) instead of Psurface-PTOP.
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.37.1 diag49

Subroutine DIAG49 produces time series (instantaneous fields) for a geographical domain from the information read in timeseries.dat. Output will be in binary punch (BPCH) format.

INTERFACE:

```
SUBROUTINE DIAG49
```

USES:

```
USE BPCH2_MOD,     ONLY : BPCH2,   OPEN_BPCH2_FOR_WRITE
USE DAO_MOD,       ONLY : AD,      AIRDEN, BXHEIGHT, CLDF
USE DAO_MOD,       ONLY : CLDTOPS, OPTD,   RH,       SLP
USE DAO_MOD,       ONLY : T,       UWND,   VWND
USE DAO_MOD,       ONLY : TS
USE DAO_MOD,       ONLY : PARDF, PARDR
USE MODIS_LAI_MOD, ONLY : ISOLAI => GC_LAI
USE FILE_MOD,      ONLY : IU_ND49
USE GRID_MOD,      ONLY : GET_XOFFSET,        GET_YOFFSET
USE TIME_MOD,      ONLY : EXPAND_DATE
USE TIME_MOD,      ONLY : GET_NYMD,           GET_NHMS
USE TIME_MOD,      ONLY : GET_NYMD_DIAG,      GET_TS_DIAG
USE TIME_MOD,      ONLY : GET_TAU,            GET_HOUR
USE TIME_MOD,      ONLY : ITS_A_NEW_DAY,      TIMESTAMP_STRING
USE PBL_MIX_MOD,   ONLY : GET_PBL_TOP_L,      GET_PBL_TOP_m
USE TRACER_MOD,    ONLY : ITS_A_FULLCHEM_SIM, N_TRACERS
```

```
      USE TRACER_MOD,    ONLY : STT,               TCVV
      USE TRACER_MOD,    ONLY : XNUMOLAIR
      USE PRESSURE_MOD,  ONLY : GET_PEDGE
      USE TRACERID_MOD,  ONLY : IDTHNO3, IDTHNO4, IDTN2O5, IDTNOX
      USE TRACERID_MOD,  ONLY : IDTPAN,  IDTPMN,  IDTPPN,  IDTOX
      USE TRACERID_MOD,  ONLY : IDTR4N2, IDTSALA, IDTSALC
      USE LOGICAL_MOD,   ONLY : DO_DIAG_WRITE

      USE CMN_FJ_MOD,    ONLY : JPMAX,   JPPJ     ! FAST-J stuff
      USE JV_CMN_MOD                               ! ODAER, QAA, QAA_AOD (clh)
      USE CMN_O3_MOD                             ! Pure O3, SAVENO2
      USE CMN_GCTM_MOD                             ! XTRA2
```

REVISION HISTORY:

```
09 Apr 1999 - I. Bey, R. Martin, R. Yantosca - Initial version
(1 ) Now bundled into "diag49_mod.f".  Now reference STT from
     "tracer_mod.f".  Now scale aerosol & dust OD's to 400 nm.
     (bmy, rvm, aad, 7/9/04)
(2 ) Updated tracer # for NO2 (bmy, 10/25/04)
(3 ) Remove reference to "CMN".  Also now get PBL heights in meters and
     model layers from GET_PBL_TOP_m and GET_PBL_TOP_L of "pbl_mix_mod.f".
     (bmy, 2/16/05)
(4 ) Now reference CLDF and BXHEIGHT from "dao_mod.f".  Now save 3-D cloud
     fraction as tracer #79 and box height as tracer #93.  Now remove
     reference to PBL from "dao_mod.f"(bmy, 4/20/05)
(5 ) Remove references to TRCOFFSET because it is always zero (bmy, 6/24/05)
(6 ) Now do not save SLP data if it is not allocated (bmy, 8/2/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Now references XNUMOLAIR from "tracer_mod.f".  Bug fix: now must sum
     aerosol OD's over all RH bins.  Also zero Q array. (bmy, 11/1/05)
(9 ) Bug fix: accumulate into Q(X,Y,K) for dust OD (qli, bmy, 4/30/07)
(10) Bug fix: UNIT should be "levels" for tracer 77.  Also RH should be
     tracer #17 under "TIME-SER" category. (cdh, bmy, 2/11/08)
(11) Bug fix: replace "PS-PTOP" with "PEDGE-$" (bmy, phs, 10/7/08)
(12) Change the new day condition to open a new file. (ccc, 8/12/09)
(13) Change the timestamp for the filename when closing (ccc, 8/12/09)
(14) Add outputs for EMISS_BVOC (10 tracers), TS, PARDR, PARDF and ISOLAI
     (mpb, 11/19/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
11 Apr 2012 - R. Yantosca - Replace lai_mod.F with modis_lai_mod.F90
```

1.37.2 its_time_to_close_file

Function ITS_TIME_TO_CLOSE_FILE returns TRUE if it's time to close the ND49 bpch file before the end of the day.

INTERFACE:

```
FUNCTION ITS_TIME_TO_CLOSE_FILE() RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD, ONLY : GET_HOUR
USE TIME_MOD, ONLY : GET_MINUTE
```

RETURN VALUE:

```
LOGICAL :: ITS_TIME
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) The time is already updated to the next time step (ccc, 8/12/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.37.3 its_time_for_diag49

Function ITS_TIME_FOR_DIAG49 returns TRUE if ND49 is turned on and it is time to call DIAG49 – or FALSE otherwise.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_DIAG49() RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD,  ONLY : GET_ELAPSED_MIN
USE TIME_MOD,  ONLY : GET_TS_DIAG
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

RETURN VALUE:

```
LOGICAL :: ITS_TIME
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Add a check on the output frequency for validity compared to time
      steps used. (ccc, 5/21/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.37.4 get_i

Function GET_I returns the absolute longitude index (I), given the relative longitude index (X).

INTERFACE:

```
FUNCTION GET_I( X ) RESULT( I )
```

USES:

```
USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: X   ! Relative longitude index (used by Q array)
```

RETURN VALUE:

```
INTEGER             :: I   ! Absolute longitude index
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.37.5 init_diag49

Subroutine INIT_DIAG49 allocates and zeroes all module arrays. It also gets values for module variables from "input_mod.f".

INTERFACE:

```
SUBROUTINE INIT_DIAG49( DO_ND49, N_ND49, TRACERS, IMIN,
&                       IMAX,    JMIN,   JMAX,    LMIN,
&                       LMAX,    FREQ,   FILE )
```

USES:

```
USE BPCH2_MOD, ONLY : GET_MODELNAME
USE BPCH2_MOD, ONLY : GET_HALFPOLAR
USE GRID_MOD,  ONLY : GET_XOFFSET
USE GRID_MOD,  ONLY : GET_YOFFSET
USE GRID_MOD,  ONLY : ITS_A_NESTED_GRID
USE ERROR_MOD, ONLY : ERROR_STOP

USE CMN_SIZE_MOD ! Size parameters
```

INPUT PARAMETERS:

```
! DO_ND49 : Switch to turn on ND49 timeseries diagnostic
! N_ND50  : Number of ND49 read by "input_mod.f"
! TRACERS : Array w/ ND49 tracer #'s read by "input_mod.f"
! IMIN    : Min longitude index read by "input_mod.f"
! IMAX    : Max longitude index read by "input_mod.f"
! JMIN    : Min latitude index read by "input_mod.f"
! JMAX    : Min latitude index read by "input_mod.f"
! LMIN    : Min level index read by "input_mod.f"
! LMAX    : Min level index read by "input_mod.f"
! FREQ    : Frequency for saving to disk [min]
! FILE    : ND49 output file name read by "input_mod.f"
LOGICAL,            INTENT(IN) :: DO_ND49
INTEGER,            INTENT(IN) :: N_ND49, TRACERS(100)
INTEGER,            INTENT(IN) :: IMIN,   IMAX
INTEGER,            INTENT(IN) :: JMIN,   JMAX
INTEGER,            INTENT(IN) :: LMIN,   LMAX
INTEGER,            INTENT(IN) :: FREQ
CHARACTER(LEN=255), INTENT(IN) :: FILE
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now get I0 and J0 correctly for nested grid simulations (bmy, 11/9/04)
(2 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
     value for GEOS or GCAP grids. (bmy, 6/28/05)
(3 ) Now allow ND49_IMIN to be equal to ND49_IMAX and ND49_JMIN to be
     equal to ND49_JMAX.  This will allow us to save out longitude
     or latitude transects.  (cdh, bmy, 11/30/06)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.38 Fortran: Module Interface diag50_mod

Module DIAG50_MOD contains variables and routines to generate 24-hour average time-series data.

INTERFACE:

```
MODULE DIAG50_MOD
```

USES:

```
IMPLICIT NONE
#     include "define.h"
PRIVATE
```

PUBLIC DATA MEMBERS:

```
LOGICAL, PUBLIC :: DO_SAVE_DIAG50    ! On/off flag for ND50 diagnostic
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_DIAG50
PUBLIC  :: DIAG50
PUBLIC  :: INIT_DIAG50
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: ACCUMULATE_DIAG50
PRIVATE :: ITS_TIME_FOR_WRITE_DIAG50
PRIVATE :: WRITE_DIAG50
PRIVATE :: GET_I
```

REMARKS:

ND50 tracer numbers:

1 - N_TRACERS	GEOS-CHEM transported tracers	[v/v]
76	OH concentration	[molec/cm3]
77	NO2 concentration	[v/v]
78	PBL heights	[m]
79	PBL heights	[levels]
80	Air density	[molec/cm3]
81	3-D Cloud fractions	[unitless]
82	Column optical depths	[unitless]
83	Cloud top heights	[hPa]
84	Sulfate aerosol optical depth	[unitless]
85	Black carbon aerosol optical depth	[unitless]
86	Organic carbon aerosol optical depth	[unitless]
87	Accumulation mode seasalt optical depth	[unitless]
88	Coarse mode seasalt optical depth	[unitless]
89	Total dust optical depth	[unitless]
90	Total seasalt tracer concentration	[unitless]
91	Pure O3 (not Ox) concentration	[v/v]
92	NO concentration	[v/v]
93	NOy concentration	[v/v]
94	Grid box height	[m]
95	Relative humidity	[%]
96	Sea level pressure	[hPa]
97	Zonal wind (a.k.a. U-wind)	[m/s]
98	Meridional wind (a.k.a. V-wind)	[m/s]
99	P(surface) - PTOP	[hPa]
100	Temperature	[K]
115-121	size resolved dust optical depth	[unitless]

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Rewritten for clarity and to save extra quantities (bmy, 7/20/04)
(2 ) Added COUNT_CHEM to count the chemistry timesteps per day, since some
      quantities are only archived after a fullchem call (bmy, 10/25/04)
```

```
(3 ) Bug fix: Now get I0 and J0 properly for nested grids (bmy, 11/9/04)
(4 ) Now only archive AOD's once per chemistry timestep (bmy, 1/14/05)
(5 ) Now references "pbl_mix_mod.f" (bmy, 2/16/05)
(6 ) Now save cloud fractions & grid box heights (bmy, 4/20/05)
(7 ) Remove TRCOFFSET since it's always zero.  Also now get HALFPOLAR for
     both GCAP and GEOS grids. (bmy, 6/24/05)
(8 ) Bug fix: don't save SLP unless it is allocated (bmy, 8/2/05)
(9 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(10) Modified INIT_DIAG49 to save out transects (cdh, bmy, 11/30/06)
(11) Now use 3D timestep counter for full chem in the trop (phs, 1/24/07)
(12) Renumber RH diagnostic in WRITE_DIAG50 (bmy, 2/11/08)
(13) Bug fix: replace "PS-PTOP" with "PEDGE-$" (bmy, 10/7/08)
(14) Modified to archive O3, NO, NOy as tracers 89, 90, 91  (tmf, 9/26/07)
(15) Updates & bug fixes in WRITE_DIAG50 (ccc, tai, bmy, 10/13/09)
(16) Updates to AOD output.  Also have the option to write to HDF
     (amv, bmy, 12/21/09)
(17) Modify AOD output to wavelength specified in jv_spec_aod.dat
     (clh, 05/07/10)
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
02 Dec 2010 - R. Yantosca - Added ProTeX headers
03 Feb 2011 - S. Kim      - Now do not scale the AOD output
                            (recalculated in RDAER AND DUST_MOD)
```

1.38.1 DIAG50

Subroutine DIAG50 generates 24hr average time series. Output is to binary punch file format or HDF5 file.

INTERFACE:

```
SUBROUTINE DIAG50
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.38.2 accumulate_diag50

Subroutine ACCUMULATE_DIAG50 accumulates tracers into the Q array.

INTERFACE:

```
SUBROUTINE ACCUMULATE_DIAG50
```

USES:

```
      USE COMODE_MOD,     ONLY : JLOP
      USE DAO_MOD,        ONLY : AD,      AIRDEN, BXHEIGHT, CLDF
      USE DAO_MOD,        ONLY : CLDTOPS, OPTD,   RH,       T
      USE DAO_MOD,        ONLY : UWND,    VWND,   SLP
      USE PBL_MIX_MOD,    ONLY : GET_PBL_TOP_L, GET_PBL_TOP_m
      USE PRESSURE_MOD,   ONLY : GET_PEDGE
      USE TIME_MOD,       ONLY : GET_ELAPSED_MIN, GET_TS_CHEM
      USE TIME_MOD,       ONLY : TIMESTAMP_STRING
      USE TRACER_MOD,     ONLY : STT, TCVV, ITS_A_FULLCHEM_SIM
      USE TRACER_MOD,     ONLY : N_TRACERS
      USE TRACER_MOD,     ONLY : XNUMOLAIR
      USE TRACERID_MOD,   ONLY : IDTHNO3, IDTHNO4, IDTN2O5, IDTNOX
      USE TRACERID_MOD,   ONLY : IDTPAN,  IDTPMN,  IDTPPN,  IDTOX
      USE TRACERID_MOD,   ONLY : IDTR4N2, IDTSALA, IDTSALC
      USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_TROP

      USE CMN_FJ_MOD,     ONLY : JPMAX, JPPJ  ! includes F77_CMN_SIZE
      USE JV_CMN_MOD  ! ODAER, QAA, QAA_OUT
      USE COMODE_LOOP_MOD  ! NPVERT
      USE CMN_O3_MOD    ! FRACO3, FRACNO, SAVEO3, SAVENO2, SAVEHO2, FRACNO2
      USE CMN_GCTM_MOD  ! SCALE_HEIGHT
      USE LOGICAL_MOD,    ONLY : DO_DIAG_WRITE
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Rewrote to remove hardwiring and for better efficiency.  Added extra
     diagnostics and updated numbering scheme.  Now scale aerosol & dust
     optical depths to 400 nm. (rvm, aad, bmy, 7/20/04)
(2 ) Now reference GET_ELAPSED_MIN and GET_TS_CHEM from "time_mod.f".
     Also now use extra counter COUNT_CHEM to count the number of
     chemistry timesteps since NO, NO2, OH, O3 only when a full-chemistry
     timestep happens. (bmy, 10/25/04)
(3 ) Only archive AOD's when it is a chem timestep (bmy, 1/14/05)
(4 ) Remove reference to "CMN".  Also now get PBL heights in meters and
     model layers from GET_PBL_TOP_m and GET_PBL_TOP_L of "pbl_mix_mod.f".
     (bmy, 2/16/05)
(5 ) Now reference CLDF and BXHEIGHT from "dao_mod.f".  Now save 3-D
     cloud fraction as tracer #79 and box height as tracer #93.  Now
     remove references to CLMOSW, CLROSW, and PBL from "dao_mod.f".
     (bmy, 4/20/05)
(6 ) Remove references to TRCOFFSET because it's always zero (bmy, 6/24/05)
(7 ) Now do not save SLP data if it is not allocated (bmy, 8/2/05)
(8 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(9 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(10) Now account for time spent in the trop for non-tracers (phs, 1/24/07)
(11) IS_CHEM check is not appropriate anymore. Keep COUNT_CHEM3D for
     species known in troposphere only (ccc, 8/12/09)
```

```
(12) Output AOD at 3rd jv_spec.dat row wavelength.  Include all seven dust
     bin's individual AOD (amv, bmy, 12/21/09)
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.38.3 its_time_for_write_diag50

Function ITS_TIME_FOR_WRITE_DIAG50 returns TRUE if it's time to write the ND50 bpch file to disk. We test the time at the next dynamic timestep, so that we can close the file before the end of the run properly.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_WRITE_DIAG50() RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD, ONLY : GET_HOUR
USE TIME_MOD, ONLY : GET_MINUTE
USE TIME_MOD, ONLY : GET_TS_DYN
```

RETURN VALUE:

```
LOGICAL :: ITS_TIME
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) The time is already updated to the next time step in main.f
     (ccc, 8/12/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.38.4 write_diag50

Subroutine WRITE_DIAG50 computes the 24-hr time-average of quantities and saves to bpch file format.

INTERFACE:

```
SUBROUTINE WRITE_DIAG50
```

USES:

```
USE BPCH2_MOD,  ONLY : BPCH2
USE BPCH2_MOD,  ONLY : GET_MODELNAME
USE BPCH2_MOD,  ONLY : GET_HALFPOLAR
USE BPCH2_MOD,  ONLY : OPEN_BPCH2_FOR_WRITE
```

```
      USE ERROR_MOD,  ONLY : ALLOC_ERR
      USE FILE_MOD,   ONLY : IU_ND50
      USE GRID_MOD,   ONLY : GET_XOFFSET
      USE GRID_MOD,   ONLY : GET_YOFFSET
      USE LOGICAL_MOD,ONLY : LND50_HDF
      USE TIME_MOD,   ONLY : EXPAND_DATE
      USE TIME_MOD,   ONLY : GET_NYMD_DIAG
      USE TIME_MOD,   ONLY : GET_NHMS
      USE TIME_MOD,   ONLY : GET_TAU
      USE TIME_MOD,   ONLY : GET_TS_DYN
      USE TIME_MOD,   ONLY : TIMESTAMP_STRING
      USE TRACER_MOD, ONLY : N_TRACERS

#if   defined( USE_HDF5 )
      ! Only include this if we are linking to HDF5 library (bmy, 12/21/09)
      USE HDF_MOD,    ONLY : OPEN_HDF
      USE HDF_MOD,    ONLY : CLOSE_HDF
      USE HDF_MOD,    ONLY : WRITE_HDF
      USE HDF5,       ONLY : HID_T
      INTEGER(HID_T)      :: IU_ND50_HDF
#endif

      USE CMN_SIZE_MOD  ! Size Parameters
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   (1 ) Rewrote to remove hardwiring and for better efficiency.  Added extra
        diagnostics and updated numbering scheme. (bmy, 7/20/04)
   (2 ) Now only archive NO, NO2, OH, O3 on every chemistry timestep (i.e.
        only when fullchem is called).  Also remove reference to FIRST.
        (bmy, 10/25/04)
   (3 ) Now divide tracers 82-87 (i.e. various AOD's) by GOOD_CT_CHEM since
        these are only updated once per chemistry timestep (bmy, 1/14/05)
   (4 ) Now save grid box heights as tracer #93.  Now save 3-D cloud fraction
        as tracer #79. (bmy, 4/20/05)
   (5 ) Remove references to TRCOFFSET because it's always zero (bmy, 6/24/05)
   (6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (7 ) DIVISOR is now a 3-D array.  Now zero COUNT_CHEM3D.  Now zero Q
        array with array assignment statement. (phs, 1/24/07)
   (8 ) RH should be tracer #17 under "TIME-SER" category (bmy, 2/11/08)
   (9 ) Bug fix: replace "PS-PTOP" with "PEDGE-$" (bmy, 10/7/08)
   (10) Change timestamp for filename.  Now save SLP under tracer #18 in
        "DAO-FLDS".  Also set unit to 'K' for temperature field.
        (ccc, tai, bmy, 10/13/09)
   (11) Now have the option of saving out to HDF5 format.  NOTE: we have to
        bracket HDF-specific code with an #ifdef statement to avoid problems
        if the HDF5 libraries are not installed. (amv, bmy, 12/21/09)
```

```
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.38.5 get_i

Function GET_I returns the absolute longitude index (I), given the relative longitude index (X).

INTERFACE:

```
FUNCTION GET_I( X ) RESULT( I )
```

USES:

```
USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: X   ! Relative longitude index
```

RETURN VALUE:

```
INTEGER             :: I   ! Absolute longitude index
```

REMARKS:

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.38.6 init_diag50

Subroutine INIT_DIAG50 allocates and zeroes all module arrays. It also gets values for module variables from "input_mod.f".

INTERFACE:

```
SUBROUTINE INIT_DIAG50( DO_ND50, N_ND50, TRACERS, IMIN, IMAX,
&                       JMIN,    JMAX,   LMIN,    LMAX, FILE )
```

USES:

```
USE BPCH2_MOD,  ONLY : GET_MODELNAME
USE BPCH2_MOD,  ONLY : GET_HALFPOLAR
USE ERROR_MOD,  ONLY : ALLOC_ERR
USE ERROR_MOD,  ONLY : ERROR_STOP
USE GRID_MOD,   ONLY : GET_XOFFSET
```

```
USE GRID_MOD,   ONLY : GET_YOFFSET
USE GRID_MOD,   ONLY : ITS_A_NESTED_GRID
USE TIME_MOD,   ONLY : GET_TAUb
USE TRACER_MOD, ONLY : N_TRACERS

USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
! DO_ND50 : Switch to turn on ND50 timeseries diagnostic
! N_ND50  : Number of ND50 read by "input_mod.f"
! TRACERS : Array w/ ND50 tracer #'s read by "input_mod.f"
! IMIN    : Min longitude index read by "input_mod.f"
! IMAX    : Max longitude index read by "input_mod.f"
! JMIN    : Min latitude index read by "input_mod.f"
! JMAX    : Min latitude index read by "input_mod.f"
! LMIN    : Min level index read by "input_mod.f"
! LMAX    : Min level index read by "input_mod.f"
! FILE    : ND50 output file name read by "input_mod.f"
LOGICAL,             INTENT(IN) :: DO_ND50
INTEGER,             INTENT(IN) :: N_ND50, TRACERS(100)
INTEGER,             INTENT(IN) :: IMIN,   IMAX
INTEGER,             INTENT(IN) :: JMIN,   JMAX
INTEGER,             INTENT(IN) :: LMIN,   LMAX
CHARACTER(LEN=255), INTENT(IN) :: FILE
```

REMARKS:

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now get I0 and J0 correctly for nested grid simulations (bmy, 11/9/04)
(2 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
      value for GEOS or GCAP grids. (bmy, 6/28/05)
(3 ) Now allow ND50_IMIN to be equal to ND50_IMAX and ND50_JMIN to be
      equal to ND50_JMAX.  This will allow us to save out longitude
      or latitude transects.  Now allocate COUNT_CHEM3D array.
      (cdh, phs, 1/24/07)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.38.7 cleanup_diag50

Subroutine CLEANUP_DIAG50 deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG50
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now deallocate COUNT_CHEM3D (phs, 1/24/07)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.39 Fortran: Module Interface diag51b_mod

Module DIAG51b_MOD contains variables and routines to generate save timeseries data where the local time is between two user-defined limits. This facilitates comparisons with morning or afternoon-passing satellites such as GOME.

INTERFACE:

```
      MODULE DIAG51b_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      LOGICAL, PUBLIC :: DO_SAVE_DIAG51b   ! On/off switch for ND51b diagnostic
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_DIAG51b
      PUBLIC  :: DIAG51b
      PUBLIC  :: INIT_DIAG51b
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: ACCUMULATE_DIAG51
      PRIVATE :: GET_LOCAL_TIME
      PRIVATE :: ITS_TIME_FOR_WRITE_DIAG51
      PRIVATE :: WRITE_DIAG51
```

REMARKS:

```
ND51b tracer numbers:
============================================================================
1 - N_TRACERS : GEOS-CHEM transported tracers           [v/v        ]
76            : OH concentration                        [molec/cm3  ]
77            : NO2 concentration                       [v/v        ]
78            : PBL heights                             [m          ]
79            : PBL heights                             [levels     ]
80            : Air density                             [molec/cm3  ]
81            : 3-D Cloud fractions                     [unitless   ]
82            : Column optical depths                   [unitless   ]
```

```
83           : Cloud top heights                          [hPa        ]
84           : Sulfate aerosol optical depth              [unitless   ]
85           : Black carbon aerosol optical depth         [unitless   ]
86           : Organic carbon aerosol optical depth       [unitless   ]
87           : Accumulation mode seasalt optical depth    [unitless   ]
88           : Coarse mode seasalt optical depth          [unitless   ]
89           : Total dust optical depth                   [unitless   ]
90           : Total seasalt tracer concentration         [unitless   ]
91           : Pure O3 (not Ox) concentration             [v/v        ]
92           : NO concentration                           [v/v        ]
93           : NOy concentration                          [v/v        ]
94           : Grid box heights                           [m          ]
95           : Relative Humidity                          [%          ]
96           : Sea level pressure                         [hPa        ]
97           : Zonal wind (a.k.a. U-wind)                 [m/s        ]
98           : Meridional wind (a.k.a. V-wind)            [m/s        ]
99           : P(surface) - PTOP                          [hPa        ]
100          : Temperature                                [K          ]
101          : PAR direct                                 [hPa        ]
102          : PAR diffuse                                [hPa        ]
103          : Daily LAI                                  [hPa        ]
104          : Temperature at 2m                          [K          ]
105          : Isoprene emissions                         [atomC/cm2/s]
106          : Total Monoterpene emissions                [atomC/cm2/s]
107          : Methyl Butanol emissions                   [atomC/cm2/s]
108          : Alpha-Pinene emissions                     [atomC/cm2/s]
109          : Beta-Pinene emissions                      [atomC/cm2/s]
110          : Limonene emissions                         [atomC/cm2/s]
111          : Sabinene emissions                         [atomC/cm2/s]
112          : Myrcene emissions                          [atomC/cm2/s]
113          : 3-Carene emissions                         [atomC/cm2/s]
114          : Ocimene emissions                          [atomC/cm2/s]
115-121      : size resolved dust optical depth           [unitless   ]
```

REVISION HISTORY:

```
(1 ) Rewritten for clarity (bmy, 7/20/04)
(2 ) Added extra counters for NO, NO2, OH, O3.  Also all diagnostic counter
     arrays are 1-D since they only depend on longitude. (bmy, 10/25/04)
(3 ) Bug fix: Now get I0 and J0 properly for nested grids (bmy, 11/9/04)
(4 ) Now only archive AOD's once per chemistry timestep (bmy, 1/14/05)
(5 ) Now references "pbl_mix_mod.f" (bmy, 2/16/05)
(6 ) Now save cld frac and grid box heights (bmy, 4/20/05)
(7 ) Remove TRCOFFSET since it's always zero  Also now get HALFPOLAR for
     both GCAP and GEOS grids.  (bmy, 6/28/05)
(8 ) Bug fix: do not save SLP if it's not allocated (bmy, 8/2/05)
(9 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(10) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(11) Modified INIT_DIAG51 to save out transects (cdh, bmy, 11/30/06)
```

```
(12) Now use 3D timestep counter for full chem in the trop (phs, 1/24/07)
(13) Renumber RH in WRITE_DIAG50 (bmy, 2/11/08)
(14) Bug fix: replace "PS-PTOP" with "PEDGE-$" (bmy, phs, 10/7/08)
(15) Bug fix in GET_LOCAL_TIME (ccc, 12/10/08)
(16) Modified to archive O3, NO, NOy as tracers 89, 90, 91  (tmf, 9/26/07)
(17) Updates in WRITE_DIAG51b (ccc, tai, bmy, 10/13/09)
(18) Updates to AOD output.  Also have the option to write to HDF
      (amv, bmy, 12/21/09)
(19) Added MEGAN species (mpb, bmy, 12/21/09)
(20) Modify AOD output to wavelength specified in jv_spec_aod.dat
     (clh, 05/07/10)
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
03 Feb 2011 - S. Kim      - Now do not scale the AOD output
                            (recalculated in RDAER AND DUST_MOD)
01 Mar 2012 - R. Yantosca - Use updated GET_LOCALTIME from time_mod.F
```

1.39.1 diag51b

Subroutine DIAG51 generates time series (averages from ! 10am - 12pm LT or 1pm - 4pm LT) for the US grid area. Output is to binary punch files or HDF5 files.

INTERFACE:

```
SUBROUTINE DIAG51b
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Rewritten for clarity (bmy, 7/20/04)
(2 ) Added TAU_W as a local variable (bmy, 9/28/04)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.39.2 get_local_time

Subroutine GET_LOCAL_TIME computes the local time and returns an array of points where the local time is between two user-defined limits.

INTERFACE:

```
SUBROUTINE GET_LOCAL_TIME
```

USES:

```
USE TIME_MOD, ONLY : GET_LOCALTIME
USE TIME_MOD, ONLY : GET_TS_DYN
```

```
      USE CMN_SIZE_MOD   ! Size parameters
```

REMARKS:

```
For now use GET_LOCALTIME( I, 1, 1 ) which will be independent of J and L
for a pure cartesian grid.  This may need to be revisited once G-C is
interfaced into a GCM.
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) The 1d-3 in the computation of XLOCTM is to remove roundoff ambiguity
      if a the local time should fall exactly on an hour boundary.
      (bmy, 11/29/00)
(2 ) Bug fix: XMID(I) should be XMID(II).  Also updated comments.
      (bmy, 7/6/01)
(3 ) Updated comments (rvm, bmy, 2/27/02)
(4 ) Now uses function GET_LOCALTIME of "time_mod.f" (bmy, 3/27/03)
(5 ) Removed reference to CMN (bmy, 7/20/04)
(6 ) Bug fix: LT should be REAL*8 and not INTEGER (ccarouge, 12/10/08)
(7 ) We need to substract TS_DYN to the time to get the local time at
      the beginning of previous time step. (ccc, 8/11/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_LOCALTIME(I,J,L) from time_mod.F90
```

1.39.3 accumulate_diag51

Subroutine ACCUMULATE_DIAG51 accumulates tracers into the Q array.

INTERFACE:

```
      SUBROUTINE ACCUMULATE_DIAG51
```

USES:

```
      USE DAO_MOD,         ONLY : AD,      AIRDEN, BXHEIGHT, CLDF
      USE DAO_MOD,         ONLY : CLDTOPS, OPTD,   RH,       T
      USE DAO_MOD,         ONLY : UWND,    VWND,   SLP
      ! Now included T @ 2m (mpb,2009)
      USE DAO_MOD,         ONLY : TS
      ! Now included PAR direct and diffuse (mpb,2009)
      USE DAO_MOD,         ONLY : PARDF, PARDR
      USE MODIS_LAI_MOD,   ONLY : ISOLAI => GC_LAI
      USE PBL_MIX_MOD,     ONLY : GET_PBL_TOP_L,    GET_PBL_TOP_m
      USE PRESSURE_MOD,    ONLY : GET_PEDGE
      USE TIME_MOD,        ONLY : GET_ELAPSED_MIN,  GET_TS_CHEM
      USE TIME_MOD,        ONLY : TIMESTAMP_STRING, GET_TS_DYN
```

```
      USE TIME_MOD,       ONLY : GET_TS_DIAG,      GET_TS_EMIS
      USE TRACER_MOD,     ONLY : STT, TCVV, ITS_A_FULLCHEM_SIM
      USE TRACER_MOD,     ONLY : N_TRACERS, XNUMOLAIR
      USE TRACERID_MOD,   ONLY : IDTHNO3, IDTHNO4, IDTN2O5, IDTNOX
      USE TRACERID_MOD,   ONLY : IDTPAN,  IDTPMN,  IDTPPN,  IDTOX
      USE TRACERID_MOD,   ONLY : IDTR4N2, IDTSALA, IDTSALC
      USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_TROP

      USE CMN_FJ_MOD,     ONLY : JPMAX, JPPJ  ! includes F77_CMN_SIZE
      USE JV_CMN_MOD  ! ODAER, QAA, QAA_AOD
      USE CMN_O3_MOD    ! FRACO3, FRACNO, SAVEO3, SAVENO2, SAVEHO2, FRACNO2
      USE CMN_GCTM_MOD  ! SCALE_HEIGHT
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Rewrote to remove hardwiring and for better efficiency.  Added extra
     diagnostics and updated numbering scheme.  Now scale optical depths
     to 400 nm (which is usually what QAA(2,*) is.  (bmy, 7/20/04)
(2 ) Now reference GET_ELAPSED_MIN and GET_TS_CHEM from "time_mod.f".
     Also now all diagnostic counters are 1-D since they only depend on
     longitude. Now only archive NO, NO2, OH, O3 on every chemistry
     timestep (i.e. only when fullchem is called). (bmy, 10/25/04)
(3 ) Only archive AOD's when it is a chem timestep (bmy, 1/14/05)
(4 ) Remove reference to "CMN".  Also now get PBL heights in meters and
     model layers from GET_PBL_TOP_m and GET_PBL_TOP_L of "pbl_mix_mod.f".
     (bmy, 2/16/05)
(5 ) Now reference CLDF and BXHEIGHT from "dao_mod.f".  Now save 3-D cloud
     fraction as tracer #79 and box height as tracer #93.  Now remove
     references to CLMOSW, CLROSW, and PBL from "dao_mod.f". (bmy, 4/20/05)
(6 ) Remove TRCOFFSET since it's always zero  Also now get HALFPOLAR for
     both GCAP and GEOS grids.  (bmy, 6/28/05)
(7 ) Now do not save SLP data if it is not allocated (bmy, 8/2/05)
(8 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(9 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(10) Now account for time spent in the trop for non-tracers (phs, 1/24/07)
(11) We determine points corresponding to the time window at each timestep.
     But accumulate only when it's time for diagnostic (longest t.s.)
     (ccc, 8/12/09)
(12) Add outputs ("DAO-FLDS" and "BIOGSRCE" categories). Add GOOD_EMIS and
     GOOD_CT_EMIS to manage emission outputs. (ccc, 11/20/09)
(13) Output AOD at 3rd jv_spec.dat row wavelength.  Include all seven dust
     bin's individual AOD (amv, bmy, 12/21/09)
(12) Added MEGAN species (mpb, bmy, 12/21/09)
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
11 Apr 2012 - R. Yantosca - Replace lai_mod.F with modis_lai_mod.F
```

1.39.4 its_time_for_write_diag51

Function ITS_TIME_FOR_WRITE_DIAG51 returns TRUE if it's time to write the ND51 bpch file to disk. We test the time at the next dynamic timestep so that we can write to disk properly.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_WRITE_DIAG51( TAU_W ) RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD,  ONLY : GET_HOUR
USE TIME_MOD,  ONLY : GET_MINUTE
USE TIME_MOD,  ONLY : GET_TAU
USE TIME_MOD,  ONLY : GET_TAUb
USE TIME_MOD,  ONLY : GET_TAUe
USE TIME_MOD,  ONLY : GET_TS_DYN
USE TIME_MOD,  ONLY : GET_TS_DIAG
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

OUTPUT PARAMETERS:

```
REAL*8, INTENT(OUT) :: TAU_W   ! TAU at time of disk write
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Added TAU_W so to make sure the timestamp is accurate. (bmy, 9/28/04)
(2 ) Add check with TS_DIAG. (ccc, 7/21/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.39.5 write_diag51

Subroutine WRITE_DIAG51 computes the time-average of quantities between local time limits ND51_HR1 and ND51_HR2 and writes them to a bpch file or HDF5 file. Arrays and counters are also zeroed for the next diagnostic interval.

INTERFACE:

```
SUBROUTINE WRITE_DIAG51( TAU_W )
```

USES:

```
USE BPCH2_MOD,   ONLY : BPCH2
USE BPCH2_MOD,   ONLY : OPEN_BPCH2_FOR_WRITE
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE FILE_MOD,    ONLY : IU_ND51b
USE LOGICAL_MOD, ONLY : LND51b_HDF
USE TIME_MOD,    ONLY : EXPAND_DATE
```

```
      USE TIME_MOD,    ONLY : GET_NYMD_DIAG
      USE TIME_MOD,    ONLY : GET_NHMS
      USE TIME_MOD,    ONLY : GET_TAU
      USE TIME_MOD,    ONLY : TIMESTAMP_STRING
      USE TIME_MOD,    ONLY : GET_TS_DYN
      USE TRACER_MOD,  ONLY : N_TRACERS

#if   defined( USE_HDF5 )
      ! Only include this if we are linking to HDF5 library (bmy, 12/21/09)
      USE HDF_MOD,     ONLY : OPEN_HDF
      USE HDF_MOD,     ONLY : CLOSE_HDF
      USE HDF_MOD,     ONLY : WRITE_HDF
      USE HDF5,        ONLY : HID_T
      INTEGER(HID_T)        :: IU_ND51b_HDF
#endif

      USE CMN_SIZE_MOD   ! Size Parameters
```

INPUT PARAMETERS:

```
      REAL*8, INTENT(IN)  :: TAU_W   ! TAU value at time of disk write
   Arguments as Input:
   ============================================================================
   (1 ) TAU_W (REAL*8) : TAU value at time of writing to disk
   NOTES:
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   (1 ) Rewrote to‘ remove hardwiring and for better efficiency.  Added extra
        diagnostics and updated numbering scheme. (bmy, 7/20/04)
   (2 ) Added TAU_W to the arg list.  Now use TAU_W to set TAU0 and TAU0.
        Also now all diagnostic counters are 1-D since they only depend on
        longitude.  Now only archive NO, NO2, OH, O3 on every chemistry
        timestep (i.e. only when fullchem is called).  Also remove reference
        to FIRST. (bmy, 10/25/04)
   (3 ) Now divide tracers 82-87 (i.e. various AOD's) by GOOD_CT_CHEM since
        these are only updated once per chemistry timestep (bmy, 1/14/05)
   (4 ) Now save grid box heights as tracer #93.  Now save 3-D cloud fraction
        as tracer #79 (bmy, 4/20/05)
   (5 ) Remove references to TRCOFFSET because it's always zero (bmy, 6/24/05)
   (6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (7 ) DIVISOR is now a 3-D array.  Now zero COUNT_CHEM3D.  Now use CASE
        statement instead of IF statements.  Now zero counter arrays with
        array broadcast assignments. (phs, 1/24/07)
   (8 ) RH should be tracer #17 under "TIME-SER" category (bmy, 2/11/08)
   (9 ) Bug fix: replace "PS-PTOP" with "PEDGE-$" (bmy, phs, 10/7/08)
   (10) Change timestamp used for filename.  Now save SLP under tracer #18 in
        "DAO-FLDS". (ccc, tai, bmy, 10/13/09)
```

```
(11) Now have the option of saving out to HDF5 format.  NOTE: we have to
     bracket HDF-specific code with an #ifdef statement to avoid problems
     if the HDF5 libraries are not installed. (amv, bmy, 12/21/09)
(12) Add outputs ("DAO-FLDS" and "BIOGSRCE" categories). Add GOOD_EMIS and
    GOOD_CT_EMIS to manage emission outputs. (ccc, 11/20/09)
(13) Added MEGAN species (mpb, bmy, 12/21/09)
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
```

1.39.6 get_i

Function GET_I returns the absolute longitude index (I), given the relative longitude index (X).

INTERFACE:

```
FUNCTION GET_I( X ) RESULT( I )
```

USES:

```
USE CMN_SIZE_MOD   ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: X   ! Relative longitude index
```

RETURN VALUE:

```
INTEGER             :: I   ! Absolute longitude index
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.39.7 init_diag51

Subroutine INIT_DIAG51b allocates and zeroes all module arrays. It also gets values for module variables from "input_mod.f".

INTERFACE:

```
 SUBROUTINE INIT_DIAG51b( DO_ND51, N_ND51, TRACERS, HR_WRITE,
&                         HR1,     HR2,    IMIN,    IMAX,
&                         JMIN,    JMAX,   LMIN,    LMAX,  FILE )
```

USES:

```
      USE BPCH2_MOD,  ONLY : GET_MODELNAME
      USE BPCH2_MOD,  ONLY : GET_HALFPOLAR
      USE ERROR_MOD,  ONLY : ALLOC_ERR
      USE ERROR_MOD,  ONLY : ERROR_STOP
      USE GRID_MOD,   ONLY : GET_XOFFSET
      USE GRID_MOD,   ONLY : GET_YOFFSET
      USE GRID_MOD,   ONLY : ITS_A_NESTED_GRID
      USE TIME_MOD,   ONLY : GET_TAUb
      USE TRACER_MOD, ONLY : N_TRACERS

      USE CMN_SIZE_MOD   ! Size parameters
```

INPUT PARAMETERS:

```
      ! DO_ND51 : Switch to turn on ND51 timeseries diagnostic
      ! N_ND51  : Number of ND51 read by "input_mod.f"
      ! TRACERS : Array w/ ND51 tracer #'s read by "input_mod.f"
      ! HR_WRITE: GMT hour of day at which to write bpch file
      ! HR1     : Lower limit of local time averaging bin
      ! HR2     : Upper limit of local time averaging bin
      ! IMIN    : Min longitude index read by "input_mod.f"
      ! IMAX    : Max longitude index read by "input_mod.f"
      ! JMIN    : Min latitude index read by "input_mod.f"
      ! JMAX    : Min latitude index read by "input_mod.f"
      ! LMIN    : Min level index read by "input_mod.f"
      ! LMAX    : Min level index read by "input_mod.f"
      ! FILE    : ND51 output file name read by "input_mod.f"
      LOGICAL,            INTENT(IN) :: DO_ND51
      INTEGER,            INTENT(IN) :: N_ND51, TRACERS(100)
      INTEGER,            INTENT(IN) :: IMIN,   IMAX
      INTEGER,            INTENT(IN) :: JMIN,   JMAX
      INTEGER,            INTENT(IN) :: LMIN,   LMAX
      REAL*8,             INTENT(IN) :: HR1,    HR2
      REAL*8,             INTENT(IN) :: HR_WRITE
      CHARACTER(LEN=255), INTENT(IN) :: FILE
```

REVISION HISTORY:

```
    20 Jul 2004 - R. Yantosca - Initial version
    (1 ) Diagnostic counter arrays are now only 1-D.  Also add GOOD_CT_CHEM
         which is the counter array of "good" boxes at each chemistry
         timesteps.  Now allocate GOOD_CT_CHEM. (bmy, 10/25/04)
    (2 ) Now get I0 and J0 correctly for nested grid simulations (bmy, 11/9/04)
    (3 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
         value for GEOS or GCAP grids. (bmy, 6/28/05)
    (4 ) Now allow ND51_IMIN to be equal to ND51_IMAX and ND51_JMIN to be
         equal to ND51_JMAX.  This will allow us to save out longitude or
         latitude transects.  Allocate COUNT_CHEM3D. (cdh, bmy, phs, 1/24/07)
    (5 ) Allocate GOOD_EMIS and GOOD_CT_EMIS (ccc, 12/12/09)
    02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.39.8 cleanup_diag51

Subroutine CLEANUP_DIAG51 deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG51b
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now deallocate GOOD_CT_CHEM (bmy, 10/25/04)
(2 ) Also deallocate COUNT_CHEM3D (phs, 1/24/07)
(5 ) Also deallocate Allocate GOOD_EMIS and GOOD_CT_EMIS (ccc, 12/12/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.40 Fortran: Module Interface diag56_mod.f

Module DIAG56_MOD contains arrays and routines for archiving the ND56 diagnostic – lightning flash rates.

INTERFACE:

```
MODULE DIAG56_MOD
```

USES:

```
IMPLICIT NONE
#     include "define.h"
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: CLEANUP_DIAG56
PUBLIC :: INIT_DIAG56
PUBLIC :: WRITE_DIAG56
PUBLIC :: ZERO_DIAG56
```

PUBLIC DATA MEMBERS:

```
! Scalars
INTEGER,              PUBLIC :: ND56
INTEGER, PARAMETER,   PUBLIC :: PD56 = 3

! Arrays
REAL*4,  ALLOCATABLE, PUBLIC :: AD56(:,:,:)
```

REVISION HISTORY:

```
11 May 2006 - R. Yantosca - Initial version
(1 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
      (bmy, 9/5/06)
(2 ) Now divide AD56 by the # of A-6 timesteps (ltm, bmy, 3/7/07)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.40.1 zero_diag56

Subroutine ZERO_DIAG03 zeroes the ND03 diagnostic arrays.

INTERFACE:

```
SUBROUTINE ZERO_DIAG56
```

REVISION HISTORY:

```
11 May 2006 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.40.2 write_diag56

Subroutine WRITE_DIAG56 writes the ND03 diagnostic arrays to the binary punch file at the proper time.

INTERFACE:

```
SUBROUTINE WRITE_DIAG56
```

USES:

```
USE BPCH2_MOD,    ONLY : BPCH2, GET_MODELNAME, GET_HALFPOLAR
USE FILE_MOD,     ONLY : IU_BPCH
USE GRID_MOD,     ONLY : GET_XOFFSET, GET_YOFFSET
USE TIME_MOD,     ONLY : GET_CT_A6, GET_CT_A3, GET_CT_I3
USE TIME_MOD,     ONLY : GET_DIAGb,  GET_DIAGe

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! TINDEX
```

REMARKS:

```
 # : Field    : Description              : Units          : Scale factor
-----------------------------------------------------------------------
(1 ) LFLASH-$ : Lightning flash rate     : flashes/min/km2 : SCALE_A6
(2 ) LFLASH-$ : Intra-cloud flash rate   : flashes/min/km2 : SCALE_A6
(3 ) LFLASH-$ : Cloud-ground flash rate  : flashes/min/km2 : SCALE_A6
```

REVISION HISTORY:

```
11 May 2006 - R. Yantosca - Initial version
(1 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
     (bmy, 9/5/06)
(2 ) Now scale AD56 by the # of A-6 timesteps (ltm, bmy, 3/7/07)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.40.3 init_diag56

Subroutine INIT_DIAG56 allocates all module arrays, 5/11/06)

INTERFACE:

```
SUBROUTINE INIT_DIAG56
```

USES:

```
USE ERROR_MOD,    ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
11 May 2006 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.40.4 cleanup_diag56

Subroutine CLEANUP_DIAG56 deallocates all module arrays

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG56
```

REVISION HISTORY:

```
11 May 2006 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.41 Fortran: Module Interface diag63_mod

Module DIAG63_MOD contains variables and routines to save out the fraction of NOx remaining and integrated OPE to disk (gvinken, 25/02/11)

INTERFACE:

```
MODULE DIAG63_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
LOGICAL, PUBLIC :: DO_SAVE_DIAG63
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: DIAG63
PUBLIC :: ITS_TIME_FOR_DIAG63
PUBLIC :: INIT_DIAG63
```

REMARKS:

```
ND63 tracer numbers:
============================================================================
1  : Fraction of NOx remaining  [unitless]
2  : Integrated OPE             [molec O3 produced / molec NOx lost]
```

REVISION HISTORY:

```
25 Feb 2011 - G. Vinken   - Initial version based on the orig. diag49_mod.f
07 Feb 2012 - M. Payer    - Added ProTeX headers
24 Feb 2012 - M. Payer    - Rename module from diag59_mod to diag63_mod.
                            Diag59 is used by TOMAS. Fix this throughout.
```

1.41.1 diag63

Subroutine DIAG63 produces time series (instantaneous fields) for a geographical domain from the information read in timeseries.dat. Output will be in binary punch (BPCH) format.

INTERFACE:

```
SUBROUTINE DIAG63
```

USES:

```
USE BPCH2_MOD,    ONLY : BPCH2,   OPEN_BPCH2_FOR_WRITE
USE DAO_MOD,      ONLY : AD,      AIRDEN, BXHEIGHT, CLDF
USE DAO_MOD,      ONLY : CLDTOPS, OPTD,   RH,       SLP
USE DAO_MOD,      ONLY : T,       UWND,   VWND
USE DAO_MOD,      ONLY : TS
USE DAO_MOD,      ONLY : PARDF, PARDR
USE FILE_MOD,     ONLY : IU_ND63
USE GRID_MOD,     ONLY : GET_XOFFSET,        GET_YOFFSET
USE TIME_MOD,     ONLY : EXPAND_DATE
USE TIME_MOD,     ONLY : GET_NYMD,           GET_NHMS
```

```
USE TIME_MOD,     ONLY : GET_NYMD_DIAG,      GET_TS_DIAG
USE TIME_MOD,     ONLY : GET_TAU,            GET_HOUR
USE TIME_MOD,     ONLY : ITS_A_NEW_DAY,      TIMESTAMP_STRING
USE PBL_MIX_MOD,  ONLY : GET_PBL_TOP_L,      GET_PBL_TOP_m
USE TRACER_MOD,   ONLY : ITS_A_FULLCHEM_SIM, N_TRACERS
USE TRACER_MOD,   ONLY : STT,                TCVV
USE TRACER_MOD,   ONLY : XNUMOLAIR
USE PRESSURE_MOD, ONLY : GET_PEDGE
USE TRACERID_MOD, ONLY : IDTHNO3, IDTHNO4, IDTN2O5, IDTNOX
USE TRACERID_MOD, ONLY : IDTPAN,  IDTPMN,  IDTPPN,  IDTOX
USE TRACERID_MOD, ONLY : IDTR4N2, IDTSALA, IDTSALC
USE DIAG_MOD,     ONLY : AD63

USE CMN_FJ_MOD         ! FAST-J stuff, includes CMN_SIZE
USE JV_CMN_MOD         ! ODAER, QAA, QAA_AOD (clh)
USE CMN_O3_MOD      ! Pure O3, SAVENO2
USE CMN_GCTM_MOD       ! XTRA2
```

REVISION HISTORY:

```
25 Feb 2011 - G. Vinken   - Initial version based on DIAG49
07 Feb 2012 - M. Payer    - Added ProTeX headers
11 Apr 2012 - R. Yantosca - Remove reference to lai_mod.F, it's not needed
```

1.41.2 its_time_to_close_file

Function ITS_TIME_TO_CLOSE_FILE returns TRUE if it's time to close the ND63 bpch file before the end of the day.

INTERFACE:

```
FUNCTION ITS_TIME_TO_CLOSE_FILE() RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD, ONLY : GET_HOUR
USE TIME_MOD, ONLY : GET_MINUTE
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) The time is already updated to the next time step (ccc, 8/12/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.41.3 its_time_for_diag63

Function ITS_TIME_FOR_DIAG63 returns TRUE if ND63 is turned on and it is time to call DIAG63 – or FALSE otherwise.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_DIAG63() RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD,  ONLY : GET_ELAPSED_MIN
USE TIME_MOD,  ONLY : GET_TS_DIAG
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

RETURN VALUE:

```
LOGICAL :: ITS_TIME
```

REVISION HISTORY:

```
25 Feb 2011 - G. Vinken   - Initial version based on ITS_TIME_FOR_DIAG49
07 Feb 2012 - M. Payer    - Added ProTeX headers
```

1.41.4 get_i

Function GET_I returns the absolute longitude index (I), given the relative longitude index (X).

INTERFACE:

```
FUNCTION GET_I( X ) RESULT( I )
```

USES:

```
USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: X   ! Relative longitude index (used by Q array)
```

RETURN VALUE:

```
INTEGER             :: I   ! Absolute longitude index
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.41.5 init_diag63

Subroutine INIT_DIAG63 allocates and zeroes all module arrays. It also gets values for module variables from "input_mod.f".

INTERFACE:

```
 SUBROUTINE INIT_DIAG63( DO_ND63, N_ND63, TRACERS, IMIN,
&                        IMAX,    JMIN,   JMAX,    FREQ,
&                        FILE )
```

USES:

```
USE BPCH2_MOD, ONLY : GET_MODELNAME
USE BPCH2_MOD, ONLY : GET_HALFPOLAR
USE GRID_MOD,  ONLY : GET_XOFFSET
USE GRID_MOD,  ONLY : GET_YOFFSET
USE GRID_MOD,  ONLY : ITS_A_NESTED_GRID
USE ERROR_MOD, ONLY : ERROR_STOP

USE CMN_SIZE_MOD    ! Size parameters
```

INPUT PARAMETERS:

```
! DO_ND63 : Switch to turn on ND63 timeseries diagnostic
! N_ND63  : Number of ND63 read by "input_mod.f"
! TRACERS : Array w/ ND63 tracer #'s read by "input_mod.f"
! IMIN    : Min longitude index read by "input_mod.f"
! IMAX    : Max longitude index read by "input_mod.f"
! JMIN    : Min latitude index read by "input_mod.f"
! JMAX    : Min latitude index read by "input_mod.f"
! FREQ    : Frequency for saving to disk [min]
! FILE    : ND63 output file name read by "input_mod.f"
LOGICAL,            INTENT(IN) :: DO_ND63
INTEGER,            INTENT(IN) :: N_ND63, TRACERS(100)
INTEGER,            INTENT(IN) :: IMIN,   IMAX
INTEGER,            INTENT(IN) :: JMIN,   JMAX
INTEGER,            INTENT(IN) :: FREQ
CHARACTER(LEN=255), INTENT(IN) :: FILE
```

REVISION HISTORY:

```
25 Feb 2011 - G. Vinken   - Initial version based on INIT_DIAG49
07 Feb 2012 - M. Payer    - Added ProTeX headers
```

1.42 Fortran: Module Interface diag_pl_mod

Module DIAG_PL_MOD contains variables and routines which are used to compute the production and loss of chemical families in the "full chemistry" (NOx-Ox-Hydrocarbon-aerosol) mechanism.

INTERFACE:

```
MODULE DIAG_PL_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
! Scalars
LOGICAL, PUBLIC              :: DO_SAVE_PL
INTEGER, PUBLIC              :: TAGO3_PL_YEAR

! Arrays
REAL*4,  PUBLIC, ALLOCATABLE :: AD65  (:,:,:,:)
REAL*8,  PUBLIC, ALLOCATABLE :: FAM_PL(:,:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: DO_DIAG_PL
PUBLIC  :: CLEANUP_DIAG_PL
PUBLIC  :: GET_FAM_MWT
PUBLIC  :: GET_FAM_NAME
PUBLIC  :: GET_NFAM
PUBLIC  :: INIT_DIAG_PL
PUBLIC  :: SETJFAM
PUBLIC  :: SETPL
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: DIAG20
PRIVATE :: ITS_TIME_FOR_WRITE20
PRIVATE :: WRITE20
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Add TAUe as a module variable.  Bug fixes: Make sure WRITE20 uses the
     global FILENAME, and also write to disk on the last timestep before
     the end of the simulation. (bmy, 11/15/04)
(2 ) Added routine ITS_TIME_FOR_WRITE20 (bmy, 3/3/05)
(3 ) Added functions GET_NFAM, GET_FAM_MWT, GET_FAM_NAME (bmy, 5/2/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(6 ) Bug fix in DIAG20 (phs, 1/22/07)
(7 ) Now use LD65 as the vertical dimension instead of LLTROP or LLTROP_FIX
     in DO_DIAG_PL, DIAG20, and WRITE20 (phs, bmy, 12/4/07)
(8 ) Now make COUNT a 3-D array (phs, 11/18/08)
(9 ) Minor fix in DIAG20 (dbj, bmy, 10/26/09)
16 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.42.1 setjfam

Subroutine SETJFAM stores info into SMVGEAR arrays for the ND65 prod/loss diagnostic.

INTERFACE:

```
SUBROUTINE SETJFAM( NACTIVE, NINAC )
```

USES:

```
USE CMN_SIZE_MOD     ! Size parameters
USE COMODE_LOOP_MOD     ! SMVGEAR II arrays
```

INPUT/OUTPUT PARAMETERS:

```
INTEGER, INTENT(INOUT) :: NACTIVE   ! # of active chemical species
INTEGER, INTENT(INOUT) :: NINAC     ! # of inactive chemical species
```

REMARKS:

```
At present, the ND65 diagnostic works only with SMVGEAR and not with
KPP.  KPP is generated automatically and lacks the code to keep track of
the production/loss of chemical families. (bmy, 9/16/10)
```

REVISION HISTORY:

```
01 Feb 1999- L. Mickley, I. Bey, R. Yantosca - Initial version
(1 ) Replace NAMESPEC with NAMEGAS for SMVGEAR II.  Added comment header
      and updated comments.  Now references IU_FILE and IOERROR from
      F90 module "file_mod.f".  Now trap I/O errors using routine IOERROR.
      Make DEFMR a parameter for safety's sake.   Need to increment NACTIVE
      for SMVGEAR II or else the last species will be overwritten w/ the
      first ND65 family.  Set NCS = NCSURBAN, since we have defined our
      GEOS-CHEM mechanism in the urban slot of SMVGEAR II.(bmy, 4/21/03)
(2 ) Bundled into "diag65_mod.f" (bmy, 7/20/04)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.42.2 setpl

Subroutine SETPL flags the reactions and species which contribute to production or loss for a given ND65 prodloss diagnostic family.

INTERFACE:

```
SUBROUTINE SETPL
```

USES:

```
      USE ERROR_MOD,   ONLY : ERROR_STOP, GEOS_CHEM_STOP
      USE ERROR_MOD,   ONLY : DEBUG_MSG
      USE LOGICAL_MOD, ONLY : LPRT

      USE CMN_SIZE_MOD
      USE COMODE_LOOP_MOD
```

REMARKS:

```
At present, the ND65 diagnostic works only with SMVGEAR and not with
KPP.  KPP is generated automatically and lacks the code to keep track of
the production/loss of chemical families. (bmy, 9/16/10)
```

REVISION HISTORY:

```
01 Feb 1999- L. Mickley, I. Bey, R. Yantosca - Initial version
(1 ) Now references "file_mod.f" and "error_mod.f".  Also now use IOERROR
     to trap I/O errors, and ERROR_STOP to stop the run and deallocate
     all module arrays.  NAMESPEC is now NAMEGAS for SMVGEAR II. Now
     uses F90 declaration syntax.  Set NCS = NCSURBAN for now, since we
     have defined our GEOS-CHEM mechanism in the urban slot of SMVGEAR II
     Updated comments.  (bmy, 5/1/03)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.42.3 do_diag_pl

Subroutine DO_DIAG_PL saves info on production and loss of families into the FAM_PL diagnostic array.

INTERFACE:

```
      SUBROUTINE DO_DIAG_PL
```

USES:

```
      USE COMODE_MOD, ONLY : CSPEC, JLOP

      USE CMN_SIZE_MOD  ! Size parameters
      USE COMODE_LOOP_MOD  ! SMVGEAR II arrays
      USE CMN_DIAG_MOD  ! LD65
```

REVISION HISTORY:

```
16 Mar 2000 - I. Bey      - Initial version
(1 ) Now bundled into "prod_loss_diag_mod.f" (bmy, 7/20/04)
(2 ) Now only loop up thru LD65 levels (bmy, 12/4/07)
(3 ) Set FAM_PL to zero in the stratosphere (phs, 11/17/08)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.42.4 diag20

Subroutine DIAG20 computes production and loss rates of O3, and then calls subroutine WRITE20 to save the these rates to disk. By saving the production and loss rates from a full-chemistry run, a user can use these archived rates to perform a quick O3 chemistry run at a later time.

INTERFACE:

```
SUBROUTINE DIAG20
```

USES:

```
USE COMODE_MOD,    ONLY : JLOP
USE DIRECTORY_MOD, ONLY : O3PL_DIR
USE ERROR_MOD,     ONLY : ERROR_STOP
USE TIME_MOD,      ONLY : EXPAND_DATE,   GET_NYMD
USE TIME_MOD,      ONLY : GET_TAU,       GET_TAUb
USE TIME_MOD,      ONLY : ITS_A_NEW_DAY, TIMESTAMP_STRING
USE TRACER_MOD,    ONLY : STT,           XNUMOL
USE TRACERID_MOD,  ONLY : IDTOX

USE CMN_SIZE_MOD      ! Size parameters
USE CMN_DIAG_MOD      ! LD65
```

REMARKS:

```
DIAG20 assumes that ND65 (P-L diagnostics) have been turned on.
```

REVISION HISTORY:

```
09 Jun 1999 - I. Bey      - Initial version
(1 ) Now bundled into "diag20_mod.f" (bmy, 7/20/04)
(2 ) Now also write to disk when it is the last timestep before the end of
     the run.  Now references GET_TAUE from "time_mod.f". (bmy, 11/15/04)
(3 ) Now call function ITS_TIME_FOR_WRITE20 to determine if the next
     chemistry timestep is the start of a new day.  Remove reference
     to GET_TAUe and GET_TS_CHEM.  Now archive P(Ox) and L(Ox) first
     and then test if we have to save the file to disk. (bmy, 3/3/05)
(4 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(5 ) Now use LLTROP_FIX instead of LLTROP (phs, 1/22/07)
(6 ) Now use LD65 instead of LLTROP_FIX (phs, bmy, 12/4/07)
(7 ) Now take care of boxes that switch b/w stratospheric and tropospheric
     regimes (phs, 11/17/08)
(8 ) Bug fix: Now just zero arrays w/o loop indices (dbj, bmy, 10/26/09)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.42.5 write20

Subroutine WRITE20 saves production and loss rates to disk, where they will be later read by subroutine CHEMO3.

INTERFACE:

```
SUBROUTINE WRITE20
```

USES:

```
USE BPCH2_MOD,  ONLY : BPCH2,         GET_HALFPOLAR
USE BPCH2_MOD,  ONLY : GET_MODELNAME, OPEN_BPCH2_FOR_WRITE
USE FILE_MOD,   ONLY : IU_ND20
USE GRID_MOD,   ONLY : GET_XOFFSET,   GET_YOFFSET

USE CMN_SIZE_MOD   ! Size parameters
USE CMN_DIAG_MOD   ! LD65
```

REVISION HISTORY:

```
09 Jun 1999 - I. Bey      - Initial version
(1 ) Now bundled into "diag20_mod.f" (bmy, 7/20/04)
(2 ) Bug fix: remove declaration of FILENAME which masked the global
     declaration (bmy, 11/15/04)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now only write up to LD65 levels (phs, bmy, 12/4/07)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.42.6 its_time_for_write20

Function ITS_TIME_FOR_WRITE20 returns TRUE if it's time to write the ND20 ozone P/L rate file to disk. We test the time at the next chemistry timestep so that we can write to disk properly.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_WRITE20( TAU_W ) RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD, ONLY : GET_HOUR, GET_MINUTE, GET_TAU
USE TIME_MOD, ONLY : GET_TAUb, GET_TAUe,   GET_TS_CHEM, GET_TS_DYN
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: TAU_W      ! TAU value @ time of writing to disk
```

RETURN VALUE:

```
LOGICAL              :: ITS_TIME   ! =T if its time to write to disk
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.42.7 get_nfam

Function GET_NFAM returns the number of defined P/L families.

INTERFACE:

```
FUNCTION GET_NFAM() RESULT( N_FAM )
```

RETURN VALUE:

```
INTEGER :: N_FAM    ! Number of defined P/L families
```

REVISION HISTORY:

```
02 May 2005 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.42.8 get_fam_name

Function GET_FAM_NAME returns the name of the Nth P/L family.

INTERFACE:

```
FUNCTION GET_FAM_NAME( N ) RESULT( NAME )
```

USES:

```
USE ERROR_MOD, ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: N      ! Family # for desired molecular weight
```

RETURN VALUE:

```
CHARACTER(LEN=255)   :: NAME   ! Name of Nth P/L family
```

REVISION HISTORY:

```
02 May 2005 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.42.9 get_fam_mwt

Function GET_FAM_MWT returns the molecular weight of the Nth P/L family.

INTERFACE:

```
FUNCTION GET_FAM_MWT( N ) RESULT( MWT )
```

USES:

```
USE CHARPAK_MOD, ONLY : TRANUC
USE ERROR_MOD,   ONLY : ERROR_STOP
USE TRACER_MOD,  ONLY : N_TRACERS, TRACER_MW_KG, TRACER_NAME
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: N     ! Family # for desired molecular weight
```

RETURN VALUE:

```
REAL*8               :: MWT   ! Molecular weight
```

REVISION HISTORY:

```
02 May 2005 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.42.10 init_diag_pl

Subroutine INIT_DIAG_PL takes values read from the GEOS-Chem input file and saves to module variables w/in "diag_pl_mod.f"

INTERFACE:

```
SUBROUTINE INIT_DIAG_PL( DOPL, SAVEO3, N_FAM, NAME,
&                        TYPE, NMEM,   MEMB,  COEF )
```

USES:

```
USE ERROR_MOD,  ONLY : ALLOC_ERR
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM

USE CMN_SIZE_MOD   ! Size parameters
USE COMODE_LOOP_MOD   ! LFAMILY, NFAMILIES
USE CMN_DIAG_MOD   ! ND65,    LD65
```

INPUT PARAMETERS:

```
! Turn on P/L diagnostic?
LOGICAL,           INTENT(IN) :: DOPL

! Save out P(Ox), L(Ox) for future tagged Ox simulation?
```

```
LOGICAL,           INTENT(IN) :: SAVEO3

! Number of prod/loss families
INTEGER,           INTENT(IN) :: N_FAM

! Number of members w/in the prod/loss family
INTEGER,           INTENT(IN) :: NMEM(MAXFAM)

! Coefficients for each prod/loss family member
REAL*8,            INTENT(IN) :: COEF(MAXMEM,MAXFAM)

! Prod/loss family name
CHARACTER(LEN=14), INTENT(IN) :: NAME(MAXFAM)

! Prod/loss family type
CHARACTER(LEN=14), INTENT(IN) :: TYPE(MAXFAM)

! Names for each prod/loss family member
CHARACTER(LEN=14), INTENT(IN) :: MEMB(MAXMEM,MAXFAM)
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now allocate arrays up to LD65 levels (phs, bmy, 12/4/07)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.42.11 cleanup_diag_pl

Subroutine CLEANUP_DIAG_PL deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG_PL
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.43 Fortran: Module Interface diag_oh_mod

Module DIAG_OH_MOD contains routines and variables to archive OH mass and air mass concentrations. These are then used to print out the mass-weighted mean OH concentration in 1e5 molec/cm3. This is a metric of how certain chemisry simulations are performing.

INTERFACE:

```
      MODULE DIAG_OH_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_DIAG_OH
      PUBLIC  :: DO_DIAG_OH
      PUBLIC  :: DO_DIAG_OH_CH4
      PUBLIC  :: INIT_DIAG_OH
      PUBLIC  :: PRINT_DIAG_OH
```

REVISION HISTORY:

```
    (1 ) Remove code for obsolete CO-OH simulation (bmy, 6/24/05)
```

1.43.1 do_diag_oh

Subroutine DO_DIAG_OH sums the OH and air mass (from SMVGEAR arrays) for the mean OH concentration diagnostic.

INTERFACE:

```
      SUBROUTINE DO_DIAG_OH
```

USES:

```
      USE COMODE_MOD,   ONLY : AIRDENS, CSPEC, JLOP, T3, VOLUME
      USE TRACERID_MOD, ONLY : IDOH

      USE CMN_SIZE_MOD     ! Size parameters
      USE COMODE_LOOP_MOD     ! NPVERT, NLAT, NLONG
```

REVISION HISTORY:

```
    07 Jul 2004 - R. Yantosca - Initial version
    15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.43.2 do_diag_oh_ch4

Subroutine DO_DIAG_OH_CH4 passes the OH loss, OH mass, and air mass terms from "global_ch4_mod.f" to "diag_oh_mod.f"

INTERFACE:

```
SUBROUTINE DO_DIAG_OH_CH4( I, J, L, XOHMASS, XAIRMASS, XLOSS )
```

USES:

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I          ! Longitude index
INTEGER, INTENT(IN) :: J          ! Latitude index
INTEGER, INTENT(IN) :: L          ! Level index
REAL*8,  INTENT(IN) :: XOHMASS    ! OH Mass  (from global_ch4_mod.f)
REAL*8,  INTENT(IN) :: XAIRMASS   ! Air mass (from global_ch4_mod.f)
REAL*8,  INTENT(IN) :: XLOSS      ! OH loss  (from global_ch4_mod.f)
```

REVISION HISTORY:

```
07 Jul 2004 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.43.3 print_diag_oh

Subroutine PRINT_DIAG_OH prints the mass-weighted OH concentration at the end of a simulation.

INTERFACE:

```
SUBROUTINE PRINT_DIAG_OH
```

USES:

```
USE TRACER_MOD, ONLY : ITS_A_CH4_SIM
```

REVISION HISTORY:

```
21 Oct 2003 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.43.4 init_diag_oh

Subroutine INIT_DIAG_OH initializes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_DIAG_OH
```

USES:

```
      USE ERROR_MOD,   ONLY : ALLOC_ERR
      USE LOGICAL_MOD, ONLY : LCHEM
      USE TRACER_MOD,  ONLY : ITS_A_FULLCHEM_SIM, ITS_A_CH4_SIM

      USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
07 Jul 2004 - R. Yantosca - Initial version
(1 ) Remove references to CO-OH simulation and to CMN_DIAG (bmy, 6/24/05)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.43.5 cleanup_diag_oh

Subroutine CLEANUP_DIAG_OH deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_DIAG_OH
```

REVISION HISTORY:

```
07 Jul 2004 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.44 Fortran: Module Interface diag_mod

Module DIAG_MOD contains declarations for allocatable arrays for use with GEOS-CHEM diagnostics.

INTERFACE:

```
      MODULE DIAG_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PUBLIC
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_DIAG
```

PUBLIC DATA MEMBERS:

```
      ! For ND01 -- Rn, Pb, Be emissions
      REAL*4,  ALLOCATABLE :: AD01(:,:,:,:)

      ! For ND02 -- Rn, Pb, Be decay
      REAL*4,  ALLOCATABLE :: AD02(:,:,:,:)

      !------------------------------------------
      !! For ND03 -- Kr85 prod/loss
      !REAL*4,  ALLOCATABLE :: AD03(:,:,:,:)
      !------------------------------------------

      ! For ND05 -- Sulfate prod/loss diagnostics
      REAL*4,  ALLOCATABLE :: AD05(:,:,:,:)

      ! For ND06 -- Dust aerosol emission
      REAL*4,  ALLOCATABLE :: AD06(:,:,:)

      ! For ND07 -- Carbon aerosol emission
      REAL*4,  ALLOCATABLE :: AD07(:,:,:)
      REAL*4,  ALLOCATABLE :: AD07_BC(:,:,:)
      REAL*4,  ALLOCATABLE :: AD07_OC(:,:,:)
      REAL*4,  ALLOCATABLE :: AD07_HC(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD07_SOAGM(:,:,:,:)

#if   defined( APM )
      REAL*4,  ALLOCATABLE :: AD07_OM(:,:)
#endif

      ! For ND08 -- seasalt emission
      REAL*4,  ALLOCATABLE :: AD08(:,:,:)

      ! For ND09 -- HCN / CH3CN simulation
      REAL*4,  ALLOCATABLE :: AD09(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD09_em(:,:,:)

      ! For ND10 -- H2/HD prod, loss, & emiss diagnostics
      REAL*4,  ALLOCATABLE :: AD10(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD10em(:,:,:)

      ! For ND12 -- boundary layer multiplication factor
      REAL*4,  ALLOCATABLE :: AD11(:,:,:)

      ! For ND12 -- boundary layer multiplication factor
      REAL*4,  ALLOCATABLE :: AD12(:,:,:)

      ! For ND13 -- Sulfur emissions
      REAL*4,  ALLOCATABLE :: AD13_DMS(:,:)
      REAL*4,  ALLOCATABLE :: AD13_SO2_ac(:,:,:)
```

```
REAL*4,  ALLOCATABLE :: AD13_SO2_an(:,:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_bb(:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_bf(:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_nv(:,:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_ev(:,:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_sh(:,:)
REAL*4,  ALLOCATABLE :: AD13_SO4_an(:,:,:)
REAL*4,  ALLOCATABLE :: AD13_SO4_bf(:,:)
REAL*4,  ALLOCATABLE :: AD13_NH3_an(:,:,:)
REAL*4,  ALLOCATABLE :: AD13_NH3_na(:,:)
REAL*4,  ALLOCATABLE :: AD13_NH3_bb(:,:)
REAL*4,  ALLOCATABLE :: AD13_NH3_bf(:,:)

! For ND14 -- wet convection mass flux diagnostic
REAL*8,  ALLOCATABLE :: CONVFLUP(:,:,:,:)

! For ND15 -- BL mixing mass flux diagnostic
REAL*8,  ALLOCATABLE :: TURBFLUP(:,:,:,:)

! For ND16 -- Fraction of grid box that is precipitating
REAL*4,  ALLOCATABLE :: AD16(:,:,:,:)
INTEGER, ALLOCATABLE :: CT16(:,:,:,:)

! For ND17 -- Fraction of tracer lost to rainout
REAL*4,  ALLOCATABLE :: AD17(:,:,:,:,:)
INTEGER, ALLOCATABLE :: CT17(:,:,:,:)

! For ND18 -- Fraction of tracer lost to washout
REAL*4,  ALLOCATABLE :: AD18(:,:,:,:,:)
INTEGER, ALLOCATABLE :: CT18(:,:,:,:)

! For ND21 -- Optical Depth diagnostic
REAL*4,  ALLOCATABLE :: AD21(:,:,:,:)
REAL*4,  ALLOCATABLE :: AD21_cr(:,:,:)

! For ND22 -- J-value diagnostic
REAL*4,  ALLOCATABLE :: AD22(:,:,:,:)
INTEGER, ALLOCATABLE :: LTJV(:,:)
INTEGER, ALLOCATABLE :: CTJV(:,:)

! For ND23 -- CH3CCl3 lifetime diagnostic
REAL*8,  ALLOCATABLE :: DIAGCHLORO(:,:,:,:)

! For ND24 -- E/W transport mass flux diagnostic
REAL*8,  ALLOCATABLE :: MASSFLEW(:,:,:,:)

! For ND25 -- N/S transport mass flux diagnostic
REAL*8,  ALLOCATABLE :: MASSFLNS(:,:,:,:)
```

```
! For ND26 -- UP/DOWN transport mass flux diagnostic
REAL*8,  ALLOCATABLE :: MASSFLUP(:,:,:,:)

! For ND28 -- Biomass burning diagnostic
REAL*4,  ALLOCATABLE :: AD28(:,:,:)

! For ND29 -- CO source diagnostic
REAL*4,  ALLOCATABLE :: AD29(:,:,:)

! For ND30 -- land / water / ice flags
REAL*4,  ALLOCATABLE :: AD30(:,:)

! For ND31 -- surface pressures
REAL*4,  ALLOCATABLE :: AD31(:,:,:)

! For ND32 -- NOx sources
REAL*4,  ALLOCATABLE :: AD32_ac(:,:,:)
REAL*4,  ALLOCATABLE :: AD32_an(:,:,:)
REAL*4,  ALLOCATABLE :: AD32_bb(:,:)
REAL*4,  ALLOCATABLE :: AD32_bf(:,:)
REAL*4,  ALLOCATABLE :: AD32_fe(:,:)
REAL*4,  ALLOCATABLE :: AD32_li(:,:,:)
REAL*4,  ALLOCATABLE :: AD32_so(:,:)
REAL*4,  ALLOCATABLE :: AD32_ub(:,:)

! For ND33 -- tropopsheric sum of tracer
REAL*4,  ALLOCATABLE :: AD33(:,:,:)

! For ND34 -- biofuel emissions
REAL*4,  ALLOCATABLE :: AD34(:,:,:)

! For ND35 -- 500 mb tracer
REAL*4,  ALLOCATABLE :: AD35(:,:,:)

! For ND36 -- Anthropogenic source diagnostic
REAL*4,  ALLOCATABLE :: AD36(:,:,:)

! For ND37 -- Fraction of tracer scavenged in cloud updrafts
REAL*4,  ALLOCATABLE :: AD37(:,:,:,:)

! For ND38 -- Rainout in moist convection diagnostic
REAL*4,  ALLOCATABLE :: AD38(:,:,:,:)

! For ND39 -- Washout in aerosol wet deposition diagnostic
REAL*4,  ALLOCATABLE :: AD39(:,:,:,:)

! For ND43 -- OH, NO, NO2, HO2 chemical diagnostics
```

```
REAL*4,  ALLOCATABLE :: AD43(:,:,:,:)
INTEGER, ALLOCATABLE :: LTNO(:,:)
INTEGER, ALLOCATABLE :: CTNO(:,:,:)
INTEGER, ALLOCATABLE :: LTOH(:,:)
INTEGER, ALLOCATABLE :: CTOH(:,:,:)
INTEGER, ALLOCATABLE :: LTNO2(:,:)
INTEGER, ALLOCATABLE :: CTNO2(:,:,:)
INTEGER, ALLOCATABLE :: LTHO2(:,:)
INTEGER, ALLOCATABLE :: CTHO2(:,:,:)
INTEGER, ALLOCATABLE :: LTNO3(:,:)
INTEGER, ALLOCATABLE :: CTNO3(:,:,:)
! update for arom (dkh, 06/21/07)
INTEGER, ALLOCATABLE :: CTLBRO2H(:,:,:)
INTEGER, ALLOCATABLE :: CTLBRO2N(:,:,:)
INTEGER, ALLOCATABLE :: CTLTRO2H(:,:,:)
INTEGER, ALLOCATABLE :: CTLTRO2N(:,:,:)
INTEGER, ALLOCATABLE :: CTLXRO2H(:,:,:)
INTEGER, ALLOCATABLE :: CTLXRO2N(:,:,:)
INTEGER, ALLOCATABLE :: LTLBRO2H(:,:)
INTEGER, ALLOCATABLE :: LTLBRO2N(:,:)
INTEGER, ALLOCATABLE :: LTLTRO2H(:,:)
INTEGER, ALLOCATABLE :: LTLTRO2N(:,:)
INTEGER, ALLOCATABLE :: LTLXRO2H(:,:)
INTEGER, ALLOCATABLE :: LTLXRO2N(:,:)

! For ND44 -- Dry deposition fluxes & velocities
REAL*4,  ALLOCATABLE :: AD44(:,:,:,:)

! For ND45 -- Tracer concentration diagnostic
REAL*4,  ALLOCATABLE :: AD45(:,:,:,:)
INTEGER, ALLOCATABLE :: LTOTH(:,:)
INTEGER, ALLOCATABLE :: CTOTH(:,:)
INTEGER, ALLOCATABLE :: CTO3(:,:,:)
INTEGER, ALLOCATABLE :: LTO3(:,:)

! For ND46 -- Tracer concentration diagnostic
REAL*4,  ALLOCATABLE :: AD46(:,:,:)

! For ND47 -- 24-h tracer concentration diagnostic
REAL*4,  ALLOCATABLE :: AD47(:,:,:,:)

! For ND47(O3) / ND65 -- 24-h tracer diagnostic
INTEGER, ALLOCATABLE :: CTO3_24h(:,:,:)

! Dynamically allocatable array -- local only to DIAG50.F
REAL*8,  ALLOCATABLE :: STT_TEMPO2(:,:,:,:)

! For ND52 -- gamma HO2 diagnostic
```

```
      REAL*4,  ALLOCATABLE :: AD52(:,:,:)

      ! For ND54 -- tropopause diagnostics
      REAL*4,  ALLOCATABLE :: AD54(:,:,:)

      ! For ND55 -- tropopause diagnostics
      REAL*4,  ALLOCATABLE :: AD55(:,:,:)

      ! For ND57 -- theta, potential temp (FP 6/2009)
      REAL*4,  ALLOCATABLE :: AD57(:,:,:)

      ! -- for methane simulation diagnostics
      REAL*4,  ALLOCATABLE :: AD19(:,:,:)
      REAL*4,  ALLOCATABLE :: AD58(:,:,:)
      REAL*4,  ALLOCATABLE :: AD60(:,:)

      ! For ND63 -- fraction of NOx remaining and Integrated OPE
      REAL*4,  ALLOCATABLE :: AD63(:,:,:)

      ! For ND66 -- I-6 fields diagnostic
      REAL*4,  ALLOCATABLE :: AD66(:,:,:,:)

      ! For ND67 -- DAO surface fields diagnostic
      REAL*4,  ALLOCATABLE :: AD67(:,:,:)

      ! For ND68 -- BXHEIGHT, AD, AVGW diagnostic
      REAL*4,  ALLOCATABLE :: AD68(:,:,:,:)

      ! For ND69 -- DXYP diagnostic
      REAL*4,  ALLOCATABLE :: AD69(:,:,:)
```

REVISION HISTORY:

```
30 Nov 1999 - A. Fiore - Initial version
(1 ) DIAG_MOD is written in Fixed-Format F90.
(2 ) Call subroutine CLEANUP at the end of the MAIN program to deallocate
      the memory before the run stops.  It is always good style to free
      any memory we have dynamically allocated when we don't need it
      anymoren
(3 ) Added ND13 arrays for sulfur emissions (bmy, 6/6/00)
(4 ) Moved ND51 arrays to "diag51_mod.f" (bmy, 11/29/00)
(5 ) Added AD34 array for biofuel burning emissions (bmy, 3/15/01)
(6 ) Eliminated old commented-out code (bmy, 4/20/01)
(7 ) Added AD12 array for boundary layer emissions in routine "setemis.f".
      (bdf, bmy, 6/15/01)
(8 ) Added CHEML24, DRYDL24, CTCHDD for archiving daily mean chemical
      and drydep loss in chemo3 and chemo3.f (amf, bmy, 7/2/01)
(9 ) Add ND43 arrays LTNO2, CTNO2, LTHO2, CTHO2 (rvm, bmy, 2/27/02)
```

```
(10) Add AD01, AD02 arrays for Rn-Pb-Be simulation (hyl, bmy, 8/7/02)
(11) Add AD05 array for sulfate P-L diagnostic (rjp, bdf, bmy, 9/20/02)
(12) Added subroutine CLEANUP_DIAG...moved code here from "cleanup.f",
     so that it is internal to "diag_mod.f".  Added arrays AD13_NH3_bb,
     AD13_NH3_bf, AD13_NH3_an for NH3 emissons in ND13.  Deleted obsolete
     allocatable arrays CHEML24, DRYDL24, CTCHDD.  Now also added LTNO3
     and CTNO3 arrays for ND43 diagnostic.  Added AD13_SO2_bf array for
     SO2 biofuel. (bmy, 1/16/03)
(13) Added array AD13_NH3_na for ND13 diagnostic (rjp, bmy, 3/23/03)
(14) Removed P24H and L24H -- these are now defined w/in "tagged_ox_mod.f"
     Also added AD03 array for Kr85 prod/loss diag. (jsw, bmy, 8/20/03)
(15) Added ND06 (dust emission) and ND07 (carbon aerosol emission)
     diagnostic arrays (rjp, tdf, bmy, 4/5/04)
(16) Added AD13_SO2_sh diagnostic array for ND13 (bec, bmy, 5/20/04)
(17) Added AD07_HC diagnostic array for ND07 (rjp, bmy, 7/13/04)
(18) Moved AD65 & FAMPL to "diag65_mod.f" (bmy, 7/20/04)
(19) Added array AD13_SO4_bf (bmy, 11/17/04)!
(20) Added extra arrays for ND03 mercury diagnostics (eck, bmy, 12/7/04)
(21) Added extra ND21 array for crystalline sulfur tracers.  Also remove
     ND03 and ND48 arrays; they are obsolete (bmy, 1/21/05)
(22) Removed AD41 and AFTTOT arrays; they're obsolete (bmy, 2/17/05)
(23) Added AD09, AD09_em arrays for HCN/CH3CN simulation (xyp, bmy, 6/27/05)
(24) Added AD30 array for land/water/ice output (bmy, 8/18/05)
(25) Added AD54 array for time spend in the troposphere (phs, 9/22/06)
(26) Added CTO3 counter. Convert ND43 counter arrays from 2D to 3D, for
     the variable tropopause. (phs, 1/19/07)
(27) Added AD10 and AD10em arrays for ND10 H2-HD-sim diag (phs, 9/18/07)
(28) Added CTO3_24h to account for time in the troposphere for O3 in
     ND47 (phs, 11/17/08)
(29) Added AD52 for Gamma HO2 diagnostic. (jaegle, ccc, 2/26/09)
(30) Updated to save out GLYX production of SOAG in ND07.
     (tmf, 3/6/09)
(31) Add LTO3 for ND45 diag. (ccc, 7/20/09)
(32) Add AD19, AD58, AD60 for CH4 (kjw, 8/18/09)
(33) AD13_NH3_an is 3D now (phs, 10/22/09)
(34) Add counter for aromatics SOA and add AD57 diagnostic for potential
     temperature. (fp, 2/3/10)
26 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.44.1 cleanup_diag

Subroutine CLEANUP_DIAG deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG
```

REVISION HISTORY:

```
13 Dec 2002 - R. Yantosca - Initial version
(1 ) Now also deallocate AD13_NH3_an, AD13_NH3_bb, AD13_NH3_bf arrays
     for the ND13 diagnostic.  (bmy, 12/13/02)
(2 ) Now also deallocate AD13_NH3_na array for ND13 (rjp, bmy, 3/23/03)
(3 ) Removed P24H and L24H, these are now defined within "tagged_ox_mod.f".
     Now also deallocate AD03 array for Kr85 prod/loss (jsw, bmy, 8/20/03)
(4 ) Now also deallocate AD06 and AD07* arrays (rjp, bdf, bmy, 4/5/04)
(5 ) Now also deallocate AD08 array (rjp, bec, bmy, 4/20/04)
(6 ) Now also deallocaes AD13_SO2_sh array (bec, bmy, 5/20/04)
(7 ) Now also deallocates AD07_HC array (rjp, bmy, 7/13/04)
(8 ) Now also deallocate AD13_SO4_bf array (bmy, 11/17/04)
(9 ) Now deallocate extra arrays for ND03 diagnostics (eck, bmy, 12/7/04)
(10) Now deallocates AD21_cr array.  Remove reference to arrays for ND03
     and ND48 diagnostics, they're obsolete. (cas, sas, bmy, 1/21/05)
(11) Removed AD41 and AFTTOT arrays; they're obsolete (bmy, 2/17/05)
(12) Now also deallocate AD09 and AD09_em (bmy, 6/27/05)
(13) Now deallocate AD30 (bmy, 8/18/05)
(14) Now deallocate CTO3, AD10, AD10em arrays (phs, 9/18/07)
15 Feb 2011 - R. Yantosca - Add modifications for APM microphysics
```

1.45 Fortran: Module Interface drydep_mod

Module DRYDEP_MOD contains variables and routines for the GEOS-Chem dry deposition scheme.

INTERFACE:

```
MODULE DRYDEP_MOD
```

USES:

```
USE CMN_SIZE_MOD                        ! Size parameters
USE CMN_DIAG_MOD                        ! Diag counters & flags
USE CMN_GCTM_MOD                        ! Physical constants
USE CMN_DEP_MOD                         ! IREG, ILAND, IUSE, FRCLND
USE COMMSOIL_MOD                        ! CANOPYNOX
USE COMODE_MOD                          ! Large arrays for SMVGEAR
USE COMODE_LOOP_MOD                     ! Formerly "comode.h"
USE DAO_MOD                             ! Met field arrays
USE DIAG_MOD,       ONLY : AD44         ! Diagnostic arrays
USE DIRECTORY_MOD                       ! Data directory paths
USE ERROR_MOD                           ! Error handling routines
USE GRID_MOD,       ONLY : GET_AREA_CM2 ! Grid box surface areas [cm2]
USE LOGICAL_MOD                         ! GEOS-Chem logical switches
USE PBL_MIX_MOD                         ! Boundary layer quantities
USE PRESSURE_MOD,   ONLY : GET_PEDGE    ! Pressure @ level edges
USE TIME_MOD,       ONLY : GET_TS_CHEM  ! Chemistry timestep
```

```
      USE TRACER_MOD                          ! Tracer array STT etc.
      USE TRACERID_MOD                        ! Tracer ID flags

      IMPLICIT NONE

#     include "define.h"

      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_DRYDEP
      PUBLIC :: DO_DRYDEP
      PUBLIC :: DRYFLX
      PUBLIC :: DRYFLXH2HD
      PUBLIC :: DRYFLXRnPbBe
      PUBLIC :: DVZ_MINVAL
      PUBLIC :: INIT_DRYDEP
```

PUBLIC DATA MEMBERS:

```
      PUBLIC :: DEPNAME
      PUBLIC :: DEPSAV
      PUBLIC :: MAXDEP
      PUBLIC :: NUMDEP
      PUBLIC :: NTRAIND
      PUBLIC :: DRYHg0, DRYHg2, DryHgP    !CDH
```

REMARKS:

```
    References:
    ============================================================================
    (1 ) Baldocchi, D.D., B.B. Hicks, and P. Camara, "A canopy stomatal
         resistance model for gaseous deposition to vegetated surfaces",
         Atmos. Environ. 21, 91-101, 1987.
    (2 ) Brutsaert, W., "Evaporation into the Atmosphere", Reidel, 1982.
    (3 ) Businger, J.A., et al., "Flux-profile relationships in the atmospheric
         surface layer", J. Atmos. Sci., 28, 181-189, 1971.
    (4 ) Dwight, H.B., "Tables of integrals and other mathematical data",
         MacMillan, 1957.
    (5 ) Guenther, A., and 15 others, A global model of natural volatile
          organic compound emissions, J. Geophys. Res., 100, 8873-8892, 1995.
    (6 ) Hicks, B.B., and P.S. Liss, "Transfer of SO2 and other reactive
         gases across the air-sea interface", Tellus, 28, 348-354, 1976.
    (7 ) Jacob, D.J., and S.C. Wofsy, "Budgets of reactive nitrogen,
         hydrocarbons, and ozone over the Amazon forest during the wet season",
         J.  Geophys. Res., 95, 16737-16754, 1990.
    (8 ) Jacob, D.J., et al, "Deposition of ozone to tundra", J. Geophys. Res.,
         97, 16473-16479, 1992.
    (9 ) Levine, I.N., "Physical Chemistry, 3rd ed.", McGraw-Hill,
```

New York, 1988.
(10) Munger, J.W., et al, "Atmospheric deposition of reactive nitrogen oxides and ozone in a temperate deciduous forest and a sub-arctic woodland", J. Geophys. Res., in press, 1996.
(11) Walcek, C.J., R.A. Brost, J.S. Chang, and M.L. Wesely, "SO2, sulfate, and HNO3 deposition velocities computed using regional landuse and meteorological data", Atmos. Environ., 20, 949-964, 1986.
(12) Wang, Y.H., paper in preparation, 1996.
(13) Wesely, M.L, "Improved parameterizations for surface resistance to gaseous dry deposition in regional-scale numerical models", Environmental Protection Agency Report EPA/600/3-88/025, Research Triangle Park (NC), 1988.
(14) Wesely, M. L., Parameterization of surface resistance to gaseous dry deposition in regional-scale numerical models. Atmos. Environ., 23 1293-1304, 1989.
(15) Price, H., L. Jaegl, A. Rice, P. Quay, P.C. Novelli, R. Gammon, Global Budget of Molecular Hydrogen and its Deuterium Content: Constraints from Ground Station, Cruise, and Aircraft Observations, submitted to J. Geophys. Res., 2007.
(16) Karl, T., Harley, P., Emmons, L., Thornton, B., Guenther, A., Basu, C., Turnipseed, A., and Jardine, K.: Efficient Atmospheric Cleansing of Oxidized Organic Trace Gases by Vegetation, Science, 330, 816-819, 10.1126/science.1192534, 2010.

REVISION HISTORY:

27 Jan 2003 - R. Yantosca - Moved standalone routines into this module
(1) Bug fix: Do not assume NO2 is the 2nd drydep species. This causes a mis-indexing for CANOPYNOX. Now archive ND44 diagnostic in kg for Radon runs in routine DRYFLXRnPbBe; convert to kg/s in diag3.f (bmy, 1/27/03)
(2) Now references "grid_mod.f" and the new "time_mod.f". Renamed DRYDEP routine to DO_DRYDEP for consistency w/ other drivers called from the MAIN program. (bmy, 2/11/03)
(3) Added error check in DRYFLX for SMVGEAR II (bmy, 4/28/03)
(4) Added drydep of N2O5. Now added PBLFRAC array, which is the fraction of each level below the PBL top. Also now compute drydep throughout the entire PBL, in order to prevent short-lived species such as HNO3 from being depleted in the shallow GEOS-3 surface layer. (rjp, bmy, 7/21/03)
(5) Bug fix for GEOS-4 in DRYFLXRnPbBe (bmy, 12/2/03)
(6) Now made CFRAC, RADIAT local variables in DO_DRYDEP (bmy, 12/9/03)
(7) Now enclose AD44 in !$OMP CRITICAL block for drydep flux (bmy, 3/24/04)
(8) Now handle extra carbon & dust tracers (rjp, tdf, bmy, 4/1/04)
(9) Added routines AERO_SFCRS1, AERO_SFCRSII. Increased MAXDEP to 25. Now handles extra carbon & dust tracers. (rjp, tdf, bmy, 4/1/04)
(10) Increased MAXDEP to 26. Added A_RADI and A_DEN module variables. Other modifications for size-resolved drydep. (rjp, bec, bmy, 4/20/04)
(11) Increased MAXDEP to 35 and handle extra SOA tracers (rjp, bmy, 7/13/04)

```
(12) Now references "logical_mod.f", "directory_mod.f", and "tracer_mod.f"
     (bmy, 7/20/04)
(13) Add Hg2, HgP as drydep tracers (eck, bmy, 12/8/04)
(14) Updated for AS, AHS, LET, NH4aq, SO4aq (cas, bmy, 1/6/05)
(15) Now references "pbl_mix_mod.f".  Removed PBLFRAC array. (bmy, 2/22/05)
(16) Now include SO4s, NITs tracers.  Now accounts for hygroscopic growth
     of seasalt aerosols when computing aerodynamic resistances.
     (bec, bmy, 4/13/05)
(17) Now modified for GEOS-5 and GCAP met fields (bmy, 5/25/05)
(18) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(19) Now change Reynold's # criterion from 1 to 0.1 in DEPVEL.  Also
     change Henry's law constant for Hg2.  Also increase MAXDEP from
     35 to 37. (eck, djj, bmy, 2/1/06)
(20) Bug fix in INIT_DRYDEP (bmy, 4/17/06)
(21) Now bundle function DIFFG into "drydep_mod.f".  Also updated for SOG4
     and SOA4 tracers.  Bug fix in INIT_DRYDEP. (dkh, bmy, 5/24/06)
(22) Fix typo in INIT_DRYDEP (dkh, bmy, 6/23/06)
(23) Add H2 and HD as drydep tracers. Added subroutine DRYFLXH2HD for H2HD
     offline sim (phs, 9/18/07)
(24) Extra error check for small RH in AERO_SFCRII (phs, 6/11/08)
(25) Added 15 more dry deposition species (tmf, 7/31/08)
(26) Modify dry depostion to follow the non-local PBL scheme.
     (lin, ccc, 5/29/09)
(27) Minor bug fix in mol wts for ALPH, LIMO (bmy, 10/19/09)
(28) modified to use Zhang 2001 for all non-size resolved aerosols (hotp)
(29) Add aromatics SOA (dkh)
(30) Add new species. Some tracers give 2 deposition species: ISOPN-> ISOPNB
    and ISOPND. (fp)
(31) Updates for mercury simulation (ccc, 5/17/10)
(32) Increase MAXDEP to 51 for dicarbonyls simulation. (ccc, 10/8/10)
01 Aug 2011 - J. Fisher - Set aerosol dry deposition velocity to 0.03 cm/s
                          over snow and ice based on Nilsson & Rannik, 2001
21 Dec 2011 - M. Payer  - Updates for sea salt (jaegle 5/11/11)
22 Dec 2011 - M. Payer  - Added ProTeX headers
10 Jan 2012 - M. Payer  - Update to use local surface pressure
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
26 Mar 2012 - R. Yantosca - Now reference CMN_SIZE_MOD at the top of module
26 Mar 2012 - R. Yantosca - Replace NNTYPE, NNPOLY, NNVEGTYPE w/ the
                            values NTYPE, NPOLY, NVEGTYPE from CMN_SIZE
26 Mar 2012 - R. Yantosca - Now retire MODIN and RDDRYCF; read drydep inputs
                            from a netCDF file w/ routine READ_DRYDEP_INPUTS
26 Mar 2012 - R. Yantosca - Reorganize module USE statements for clarity
09 Apr 2012 - R. Yantosca - Now replace IJREG, IJLAND, IJUSE, XYLAI arrays
                            with IREG, ILAND, IUSE, XLAI.
```

1.45.1 do_drydep

Subroutine DO_DRYDEP is the driver for the GEOS-CHEM dry deposition scheme. DO_DRYDEP calls DEPVEL to compute deposition velocities [m/s], which are then converted to [cm/s]. Drydep frequencies are also computed. (lwh, gmg, djj, 1989, 1994; bmy, 2/11/03, 5/25/05)

INTERFACE:

```
SUBROUTINE DO_DRYDEP
```

REMARKS:

```
NOTE: Modeled aerosol dry deposition velocities over snow and ice surfaces
in the Arctic are much higher than estimated from measured values (e.g.,
Ibrahim et al. [1983]; Duan et al. [1988]; Nilsson and Rannik [2001]).
We will impose a dry deposition velocity of 0.03 cm/s for all aerosols
over snow and ice surfaces. (Jenny Fisher, 01 Aug 2011)
References (see full citations above):
=============================================================================
(1 ) Wesely, M. L., 1989
(2 ) Jacob, D.J., and S.C. Wofsy, 1990
```

REVISION HISTORY:

```
(1 ) Remove SUNCOS, USTAR, AZO, OBK from the arg list; now reference these
     as well as AD and T from "dao_mod.f".  Cleaned up code and updated
     comments.  Now only order tracer numbers into NTRAIND on the first
     call.  Now force double-precision with "D" exponents.  Now also
     reference IDTNOX, IDTOX, etc. from "tracerid_mod.f".  Bundled into
     "drydep_mod.f" (bmy, 11/19/02)
(2 ) Now make sure that the PBL depth (THIK) is greater than or equal to
     the thickness of the first layer.  Now initialize PBLFRAC array on
     each call. (rjp, bmy, 7/21/03)
(3 ) Now declare CFRAC, RADIAT, AZO, USTAR as local variables, which are
     returned by METERO.  CFRAC and RADIAT have also been deleted from
     "CMN_DEP". (bmy, 12/9/03)
(4 ) Now use explicit formula for IJLOOP to allow parallelization.
     Also reference LPRT from "logical_mod.f" (bmy, 7/20/04)
(5 ) Now use routines from "pbl_mix_mod.f" to get PBL quantities, instead
     of re-computing them here.  Removed PBLFRAC array.  Removed reference
     to "pressure_mod.f".  Removed reference to header file CMN.
     Parallelize DO-loops. (bmy, 2/22/05)
(6 ) Now define RHB as a local array, which is defined in METERO and then
     passed to DEPVEL. (bec, bmy, 4/13/05)
(7 ) Now dimension AZO for GEOS or GCAP met fields.  Remove obsolete
     variables. (swu, bmy, 5/25/05)
(8 ) Remove reference to TRACERID_MOD, it's not needed (bmy, 10/3/05)
01 Aug 2011 - J. Fisher - Set aerosol dry deposition velocity to 0.03 cm/s
                          over snow and ice based on Nilsson & Rannik, 2001
15 Aug 2011 - R. Yantosca - Now reference IDTxxx flags from tracerid_mod.f
```

```
07 Oct 2011 - R. Yantosca - Rename SUNCOS30 to SUNCOS_MID, which is the
                            cos(SZA) at the midpt of the chemistry timestep
22 Dec 2011 - M. Payer    - Added ProTeX headers
10 Jan 2012 - M. Payer    - Added local surface pressure
26 Mar 2012 - R. Yantosca - Now read drydep inputs from a netCDF file
                            via routine READ_DRYDEP_INPUTS
26 Mar 2012 - R. Yantosca - Remove calls to obsolete MODIN, RDDRYCF routines
```

1.45.2 dvz_minval

Function DVZ_MINVAL sets minimum values for drydep velocities for SULFATE TRACERS, according to Mian Chin's GOCART model. (rjp, bmy, 11/21/02, 10/3/05)

INTERFACE:

```
FUNCTION DVZ_MINVAL( N, LSNOW, DVZ ) RESULT( NEWDVZ )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: N      ! Tracer number
LOGICAL, INTENT(IN) :: LSNOW  ! Flag for denoting snow/ice
REAL*8,  INTENT(IN) :: DVZ    ! Deposition velocity [cm/s]
```

RETURN VALUE:

```
REAL*8              :: NEWDVZ
```

REVISION HISTORY:

```
(1 ) Don't put a min drydep value on H2O2 for offline run (rjp, bmy,3/31/03)
(2 ) Remove reference to CMN, it's obsolete (bmy, 7/20/04)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.45.3 metero

Subroutine METERO calculates meteorological constants needed for the dry deposition velocity module. (lwh, gmg, djj, 1989, 1994; bmy, 10/3/05)

INTERFACE:

```
SUBROUTINE METERO( CZ1, TC0,  OBK, CFRAC, RADIAT,
&                  AZ0, USTR, ZH,  LSNOW, RHB, PRESSU, W10 )
```

OUTPUT PARAMETERS:

```
LOGICAL, INTENT(OUT) :: LSNOW (MAXIJ)  ! Flag for denoting snow/ice
REAL*8,  INTENT(OUT) :: CZ1   (MAXIJ)  ! Midpt ht of 1st model level [m]
REAL*8,  INTENT(OUT) :: TC0   (MAXIJ)  ! Grid box sfc temperature [K]
```

```
      REAL*8,  INTENT(OUT) :: OBK   (MAXIJ)  ! Monin-Obhukov length [m]
      REAL*8,  INTENT(OUT) :: CFRAC (MAXIJ)  ! Column cloud fraction [unitless]
      REAL*8,  INTENT(OUT) :: RADIAT(MAXIJ)  ! Solar radiation @ ground [W/m2]
      REAL*8,  INTENT(OUT) :: RHB   (MAXIJ)  ! Rel humidity at sfc [unitless]
      REAL*8,  INTENT(OUT) :: USTR  (MAXIJ)  ! Friction velocity [m/s]
      REAL*8,  INTENT(OUT) :: ZH    (MAXIJ)  ! PBL height [m]
      REAL*8,  INTENT(OUT) :: PRESSU(MAXIJ)  ! Local surface pressure [Pa]
      REAL*8,  INTENT(OUT) :: W10   (MAXIJ)  ! 10 meter windspeed [m/s]

      ! Dimension AZO for GCAP or GEOS met fields (swu, bmy, 5/25/05)
#if   defined( GCAP )
      REAL*8, INTENT(OUT)  :: AZO(NTYPE)     ! Roughness heights, by landtype
#else
      REAL*8, INTENT(OUT)  :: AZO(MAXIJ)     ! Roughness heights, by grid box
#endif
```

REMARKS:

```
   References (see full citations above):
   ========================================================================
   (1 ) Wesely, M. L., 1989.
   (2 ) Jacob, D.J., and S.C. Wofsy, 1990
```

REVISION HISTORY:

```
   (1 ) Now reference GET_PEDGE from "pressure_mod.f".  Now reference T from
        "dao_mod.f".  Removed obsolete code & comments, and added new
         documentation header.  Now force double precision with "D"
         exponents.  Now compute OBK here as well.  Bundled into F90 module
         "drydep_mod.f" (bmy, 11/20/02)
   (2 ) Now reference CLDFRC, RADSWG, ZO, USTAR from "dao_mod.f".  Also now
         pass CFRAC, RADIAT, AZO, USTR back to the calling routine
         via the arg list. (bmy, 12/9/03)
   (3 ) Now use explicit formula for IJLOOP to allow parallelization
        (bmy, 7/20/04)
   (4 ) Now compute ZH and LSNOW here instead of w/in DO_DRYDEP.  Parallelize
        DO-loops.  Now use BXHEIGHT from "dao_mod.f" instead of computing
        the thickness of the 1st level here.  Remove reference to
        "pressure_mod.f".  Remove reference to T from "dao_mod.f".  Now
        reference ALBD from "dao_mod.f" (bmy, 2/22/05)
   (5 ) Now references RH from "dao_mod.f".  Now passes relative humidity
        from the surface layer back via RHB argument. (bec, bmy, 4/13/05)
   (6 ) Now call GET_OBK from "dao_mod.f" to get the M-O length for both
        GEOS or GCAP met fields.  Remove local computation of M-O length
        here.  Also now dimension AZO appropriately for GCAP or GEOS met
        fields.  Remove obsolete variables. (swu, bmy, 5/25/05)
   (7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (8 ) Move XLTMMP function to module MEGANUT_MOD. (ccc, 11/20/09)
   (9 ) Add sea level pressure and 10m windspeed as arguments (jaegle 5/11/11)
```

```
22 Dec 2011 - M. Payer    - Added ProTeX headers
10 Jan 2012 - M. Payer    - Added local surface pressure
```

1.45.4 dryflx

Subroutine DRYFLX sets up the dry deposition flux diagnostic for tracers which are part of the SMVGEAR mechanism. (bmy, bdf, 4/20/99, 3/24/04)

INTERFACE:

```
SUBROUTINE DRYFLX
```

REVISION HISTORY:

```
(1 ) Bug fix -- now skip tracers for which NTDEP(N) is zero, in order
     to avoid array-out-of-bounds errors. (bmy, 5/2/00)
(2 ) Now reference the CSPEC array from "comode_mod.f" instead of from
     common block header "comode.h". (bmy, 7/11/00)
(3 ) Also reference JLOP and VOLUME from "comode_mod.f" (bmy, 10/19/00)
(4 ) Updated comments, cosmetic changes (bmy, 3/14/02)
(5 ) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(6 ) Removed reference to "comtrid.h", "CMN_SAV", "CMN_DEP", and "CMN_O3",
     these are not used in this routine.  Also bundled into "drydep_mod.f"
     for more convenient packaging. (bmy, 11/19/02)
(7 ) Replaced DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid"mod.f".
     Also removed references to JREF and FLUXRUL.  Now use function
     GET_TS_CHEM from "time_mod.f". (bmy, 2/11/03)
(8 ) Now references ERROR_STOP from "error_mod.f" (bmy, 4/28/03)
(9 ) Now sum drydep fluxes throughout the entire PBL.  Added L variable.
     AREA_CM2 has now been made into a lookup table. Now implement a
     parallel DO loop for efficiency. (rjp, bmy, 7/21/03)
(10) Now bracket AD44 with a !$OMP CRITICAL block in order to avoid
     multiple threads writing to the same element (bmy, 3/24/04)
(11) Now reference GET_FRAC_UNDER_PBLTOP and GET_PBL_MAX_L from
     "pbl_mix_mod.f".  Remove reference to CMN. (bmy, 2/22/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

1.45.5 dryflxRnPbBe

Subroutine DRYFLXRnPbBe removes dry deposition losses from the STT tracer array and archives deposition fluxes to the ND44 diagnostic. (hyl, bmy, bdf, 4/2/99, 5/25/05)

INTERFACE:

```
      SUBROUTINE DRYFLXRnPbBe
```

REVISION HISTORY:

```
(1 ) Now eliminate DEPFLUX from CMN_SAV, in order to save memory.
     DEPFLUX is now a local variable (bdf, 4/2/99)
(2 ) Now make DEPFLUX of dimension (IIPAR,JJPAR,MAXDEP) (bmy, 4/2/99)
(3 ) Now use an allocatable array for the ND44 diagnostic.
     Also made cosmetic changes, updated comments. (bmy, 3/16/00)
(4 ) Eliminate obsolete code and ND63 diagnostic (bmy, 4/12/00)
(5 ) Added to module "RnPbBe_mod.f".  Also made cosmetic changes
     and updated comments (bmy, 6/14/01)
(6 ) Updated comments (bmy, 3/29/02)
(7 ) Replace all instances of IM, JM, IMX, JMX, with IIPAR, JJPAR, IIPAR,
     and JJPAR.  Now replaced DEPFLUX array w/ AMT_LOST scalar
     variable.  Also make sure that the amount of tracer lost to drydep
     is now accurately accounted in the ND44 diagnostic. (bmy, 8/7/02)
(8 ) Now call GEOS_CHEM_STOP or ERROR_STOP (from "error_mod.f") when
     stopping the run w/ an error condition. (bmy, 10/15/02)
(9 ) Now moved from "RnPbBe_mod.f" to "drydep_mod.f".  (bmy, 1/27/03)
(10) Now use function GET_TS_CHEM from "time_mod.f" (bmy, 2/11/03)
(11) Now compute drydep fluxes throughout the entire PBL.  Now references
     PBLFRAC.  Added L_PBLTOP variable. (bmy, 7/21/03)
(12) Now follow GEOS-3 algorithm for GEOS-4 model (bmy, 12/2/03)
(13) Now reference STT from "tracer_mod.f" and LDRYD from "logical_mod.f"
     (bmy, 7/20/04)
(14) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.45.6 dryflxh2hd

Subroutine DRYFLXH2HD removes dry deposition losses from the tracer array and archives deposition fluxes AND VELOCITY to the ND44 diagnostic. (adapted from DRYFLX v5-05, jaegle 11/02/2005).

INTERFACE:

```
      SUBROUTINE DRYFLXH2HD
```

USES:

```
      USE DIAG_MOD,     ONLY : AD44
      USE ERROR_MOD,    ONLY : ERROR_STOP, GEOS_CHEM_STOP
      USE TIME_MOD,     ONLY : GET_TS_CHEM
      USE GRID_MOD,     ONLY : GET_AREA_CM2, GET_XOFFSET, GET_YOFFSET
      USE DAO_MOD,      ONLY : T, TS, ALBD
      USE TRACER_MOD,   ONLY : STT
```

```
USE LOGICAL_MOD,  ONLY : LDRYD
USE DAO_MOD,      ONLY : BXHEIGHT
USE PBL_MIX_MOD,  ONLY : GET_PBL_TOP_m
USE PBL_MIX_MOD,  ONLY : GET_FRAC_UNDER_PBLTOP, GET_PBL_MAX_L
USE MEGANUT_MOD,  ONLY : XLTMMP

USE CMN_SIZE_MOD       ! Size parameters
USE CMN_DIAG_MOD       ! Diagnostic switches & arrays
USE CMN_DEP_MOD        ! Dry deposition variables
USE COMMSOIL_MOD       ! Soil pulsing & wetness variables
```

REVISION HISTORY:

```
(1) Now deposit through the PBL. Commented but kept code related to soil
    temperature (phs, 5/16/07)
(2) Move XLTMMP to module MEGANUT_MOD (ccc, 11/20/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
09 Apr 2012 - R. Yantosca - Replace IJLAND, IJUSE arrays w/ ILAND, IUSE
```

1.45.7 depvel

Subroutine DEPVEL computes the dry deposition velocities using a resistance-in-series model.

INTERFACE:

```
SUBROUTINE DEPVEL( NPTS,   RADIAT, TEMP,    SUNCOS, F0,
&                  HSTAR,  XMW,    AIROSOL, USTAR,  CZ1,
&                  OBK,    CFRAC,  ZH,      LSNOW,  DVEL,
&                  ZO,     RHB,    PRESSU,  W10 )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NPTS             ! # of grid boxes = IIPAR*JJPAR
REAL*8,  INTENT(IN) :: RADIAT (MAXIJ )  ! Solar radiation [W/m2]
REAL*8,  INTENT(IN) :: TEMP   (MAXIJ )  ! Temperature [K]
REAL*8,  INTENT(IN) :: SUNCOS (MAXIJ )  ! Cosine of solar zenith angle
LOGICAL, INTENT(IN) :: AIROSOL(MAXDEP)  ! =T denotes aerosol species
REAL*8,  INTENT(IN) :: F0     (MAXDEP)  ! Reactivity factor for oxidation
                                        !  of biological substances
REAL*8,  INTENT(IN) :: HSTAR  (MAXDEP)  ! Henry's law constant
REAL*8,  INTENT(IN) :: XMW    (MAXDEP)  ! Molecular weight [kg/mol]
REAL*8,  INTENT(IN) :: USTAR  (MAXIJ )  ! Friction velocity [m/s]
REAL*8,  INTENT(IN) :: CZ1    (MAXIJ )  ! Alt @ which Vd is computed [m]
REAL*8,  INTENT(IN) :: OBK    (MAXIJ )  ! Monin-Obhukov length [m]
REAL*8,  INTENT(IN) :: CFRAC  (MAXIJ )  ! Surface cloud fraction
```

```
      REAL*8,  INTENT(IN) :: ZH     (MAXIJ )  ! Roughness height [m]
      REAL*8,  INTENT(IN) :: RHB    (MAXIJ )  ! Relative humidity [%]
      REAL*8,  INTENT(IN) :: PRESSU (MAXIJ )  ! Surface pressure [hPa]
      REAL*8,  INTENT(IN) :: W10    (MAXIJ )  ! Wind speed @ 10m altitude [m/s]
```

OUTPUT PARAMETERS:

```
      REAL*8, INTENT(OUT) :: DVEL(MAXIJ,MAXDEP)   ! Drydep velocity [m/s]
```

REMARKS:

```
    Need as landtype input for each grid square (I,J); see CMN_DEP_mod.F
       IREG(I,J)       - # of landtypes in grid square
       ILAND(I,J,LDT)  - Land type ID for element LDT =1, IREG(I,J)
                         (could be from any source - mapped to deposition
                         surface ID in input unit 65)
       IJUSE(I,J,LDT) - Fraction ((per mil) of gridbox area occupied by
                        land type element LDT
                                                                             .
    Need as leaf area index; see CMN_DEP_mod.F
       XLAI(I,J,LDT)  - Leaf Area Index of land type element LDT
                                                                             .
    Need as meteorological input for each grid square(I,J) (passed):
       RADIAT(IJLOOP) - Solar radiation in W m-2
       TEMP(IJLOOP)   - Surface air temperature in K
       SUNCOS(IJLOOP) - Cosine of solar zenith angle
       LSNOW(IJLOOP)  - Logical for snow and sea ice
       RHB(IJLOOP)    - Relative humidity at the surface
       PRESSU(IJLOOP) - Local surface pressure
       W10(IJLOOP)    - 10m wind speed
                                                                             .
    Need as input for each species K (passed):
       F0(K)          - reactivity factor for oxidation of biological substances
       HSTAR(K)       - Henry's Law constant
       XMW(K)         - Molecular weight (kg/mole) of species K
                        (used to calculate molecular diffusivities)
       AIROSOL(K)     - LOGICAL flag (T = aerosol species;
                                      F = gas-phase species)
                                                                             .
    Also need to call the following subroutines to read drydep input data:
       READ_DRYDEP_INPUTS    - (in this module) Reads in Olson land type
                               indices, dry deposition land type indices,
                               default roughness heights, and polynomial
                               coefficients.  (This supersedes MODIN, RDDRYCF)
       COMPUTE_OLSON_LANDMAP - (in olson_landmap_mod.F90).  Reads in the
                               Olson land types at native resolution and re-bins
                               them on-the-fly to the GEOS-Chem grid resolution.
                               (This supersedes RDLAND)
       "rdlai.f"             - reads Leaf Area Indices from files "lai**.global"
```

```
      .
Some variables used in the subroutine (passed):
   LRGERA(IJLOOP) T -> stable atmosphere; a high aerodynamic resistance
                       (RA=1.E4 m s-1) is imposed; else RA is calculated
   USTAR(IJLOOP)  - Friction velocity (m s-1)
   CZ1(IJLOOP)    - Altitude (m) at which deposition velocity is computed
   OBK(IJLOOP)    - Monin-Obukhov length (m): set to 1.E5 m under neutral
                    conditions
   CFRAC(IJLOOP)  - Fractional cloud cover
   ZH(IJLOOP)     - Mixing depth (m)
      .
Some variables used in the subroutine:
   MAXDEP         - the maximum number of species for which the dry
                    deposition calculation is done
   ZO(LDT)        - Roughness height (m) for specific surface type indexed
                    by LDT
   RSURFC(K,LDT)  - Bulk surface resistance (s m-1) for species K to
                    surface LDT
   C1X(K)         - Total resistance to deposition (s m-1) for species K
      .
Returned:
   DVEL(IJLOOP,K) - Deposition velocity (m s-1) of species K
      .
References:
=======================================================================
   Baldocchi, D.D., B.B. Hicks, and P. Camara, A canopy stomatal
     resistance model for gaseous deposition to vegetated surfaces,
     Atmos. Environ. 21, 91-101, 1987.
   Brutsaert, W., Evaporation into the Atmosphere, Reidel, 1982.
   Businger, J.A., et al., Flux-profile relationships in the atmospheric
     surface layer, J. Atmos. Sci., 28, 181-189, 1971.
   Dwight, H.B., Tables of integrals and other mathematical data,
     MacMillan, 1957.
   Guenther, A., and 15 others, A global model of natural volatile
     organic compound emissions, J. Geophys. Res., 100, 8873-8892, 1995.
   Hicks, B.B., and P.S. Liss, Transfer of SO2 and other reactive
     gases across the air-sea interface, Tellus, 28, 348-354, 1976.
   Jacob, D.J., and S.C. Wofsy, Budgets of reactive nitrogen,
     hydrocarbons, and ozone over the Amazon forest during the wet season,
     J.  Geophys. Res., 95, 16737-16754, 1990.
   Jacob, D.J., and 9 others, Deposition of ozone to tundra,
     J. Geophys. Res., 97, 16473-16479, 1992.
   Levine, I.N., Physical Chemistry, 3rd ed., McGraw-Hill, New York, 1988.
   Munger, J.W., and 8 others, Atmospheric deposition of reactive
     nitrogen oxides and ozone in a temperate deciduous forest and a
     sub-arctic woodland, J. Geophys. Res., in press, 1996.
   Walcek, C.J., R.A. Brost, J.S. Chang, and M.L. Wesely, SO2, sulfate, and
     HNO3 deposition velocities computed using regional landuse and
```

meteorological data, Atmos. Environ., 20, 949-964, 1986.
Wang, Y.H., paper in preparation, 1996.
Wesely, M.L, Improved parameterizations for surface resistance to gaseous dry deposition in regional-scale numerical models, Environmental Protection Agency Report EPA/600/3-88/025, Research Triangle Park (NC), 1988.
Wesely, M.L., same title, Atmos. Environ., 23, 1293-1304, 1989.

REVISION HISTORY:

```
** Contact: D.J. Jacob, Harvard U. (djj@io.harvard.edu)
** Modularized by G.M. Gardner, Harvard U.
** Version 3.2:   5/27/97
** Version 3.2.1: 3/4/99   -- bug fix in expression for RT
** Version 3.2.2: 3/26/99  -- bug fix: specify a large Ra for aerosols
** Version 3.2.3: 11/12/99 -- change Reynolds # criterion from 10 to 1
                           -- force double precision w/ "D" exponents
** Version 3.3:   5/8/00   -- bug fixes, cleanup, updated comments.
** Version 3.4:   1/22/03  -- remove hardwire for CANOPYNOX
** Version 3.5    7/21/03  -- Remove cap of surface resistance in RLUXX
** Version 3.6    4/01/04  -- Now do drydep of DUST aerosol tracers
** Version 3.7    4/20/04  -- Now also do drydep of SEASALT aerosol tracers
** Version 3.8    4/13/05  -- Accounts for hygroscopic growth of SEASALT
**                            aerosol tracers.  DUST aerosol tracers do
**                            not grow hygroscopically.  Added RHB as
**                            an input argument.
** Version 3.9    5/25/05  -- Now restore GISS-specific code for GCAP model
** Version 3.9.1  11/17/05 -- change Reynolds # criterion from 1 to 0.1
  11 May 2011 - L. Jaegle   - Updated to use actual Sea level pressure instead
                              of 1000 hPa
                            - Modified to used Slinn & Slinn (1980) over Ocean
                              surfaces
  22 Dec 2011 - M. Payer    - Added ProTeX headers
  10 Jan 2012 - M. Payer    - Updated to use local surface pressure
  09 Apr 2012 - R. Yantosca - Remove IJREG, IJLAND, IJUSE, XYLAI arrays and
                              replace w/ IREG, ILAND, IUSE, XLAI
  09 Apr 2012 - R. Yantosca - Remove reference to CMN_VEL_mod.F
  09 Apr 2012 - R. Yantosca - Now use INTENT(IN), INTENT(OUT) for arguments
*******************************************************************
   Changes from Version 3.2 to Version 3.3:                      ***
   * We now suppress dry deposition over aerodynamically smooth   ***
     surfaces.  The previous algorithm yielded negative numbers  ***
     when u* was very small (due to the logarithm going negative).***
     See the comments below for more information.                ***
   * Now eliminate obsolete variables ZLMO and SIH from the code. ***
   * Obsolete comments have been updated or removed.             ***
*******************************************************************
   Changes from version 3.1 to version 3.2:                      ***
   * In unstable atmospheres with |ZLMO| < ZO, as can happen      ***
```

```
     occasionally under very low wind conditions with tall canopies, ***
     application of Monin-Obukhov similarity yields negative values  ***
     for RA.  This was a problem in version 3.1.  In fact,           ***
     Monin-Obukhov similarity does not apply under such conditions,  ***
     so we now set RA to zero and let the boundary                   ***
     resistance RB define the overall aerodynamic resistance.  Since ***
     RB varies inversely with U* it will impose a large aerodynamic  ***
     resistance under very low wind conditions.                      ***
    * The range of applicability of stability correction functions   ***
     to Monin-Obukhov similarity has been extended to                ***
     -2.5 < z/zMO < 1.5, based on Figure 2 of Businger et al. [1971].***
     The range used to be -1 < z/zMO < 1 in version 3.1.             ***
 ************************************************************************
```

1.45.8 diffg

Subroutine DIFFG calculates the molecular diffusivity [m2/s] in air for a gas X of molecular weight XM [kg] at temperature TK [K] and pressure PRESS [Pa]. (bmy, 5/16/06)

INTERFACE:

```
      FUNCTION DIFFG( TK, PRESS, XM ) RESULT( DIFF_G )
```

USES:

INPUT PARAMETERS:

```
      REAL*8, INTENT(IN) :: TK     ! Temperature [K]
      REAL*8, INTENT(IN) :: PRESS  ! Pressure [Pa]
      REAL*8, INTENT(IN) :: XM     ! Molecular weight of gas [kg]
```

REMARKS:

```
We specify the molecular weight of air (XMAIR) and the hard-sphere molecular
radii of air (RADAIR) and of the diffusing gas (RADX).  The molecular
radius of air is given in a Table on p. 479 of Levine [1988].  The Table
also gives radii for some other molecules.  Rather than requesting the user
to supply a molecular radius we specify here a generic value of 2.E-10 m for
all molecules, which is good enough in terms of calculating the diffusivity
as long as molecule is not too big.
```

REVISION HISTORY:

```
(1 ) Originally was a standalone function; now bundled into drydep_mod.f.
     Also now force REAL*8 precision with D exponents.  Now use F90
     style syntax and updated comments. (bmy, 5/16/06)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.45.9 read_drydep_inputs

Subroutine READ_DRYDEP_INPUTS reads inputs for the dry deposition module corresponding to either the Olson 1992 (GEOS-Chem default) or Olson 2001 (planned replacement for Olson 1992) land map.

INTERFACE:

```
      SUBROUTINE READ_DRYDEP_INPUTS( DRYCOEFF, IOLSON, IDEP,    IWATER,
     &                               NWATER,   IZO,    IDRYDEP, IRI,
     &                               IRLU,     IRAC,   IRGSS,   IRGSO,
     &                               IRCLS,    IRCLO,  IVSMAX          )
```

USES:

```
      ! Modules for netCDF read
      USE m_netcdf_io_open
      USE m_netcdf_io_get_dimlen
      USE m_netcdf_io_read
      USE m_netcdf_io_readattr
      USE m_netcdf_io_close

#     include "netcdf.inc"
```

OUTPUT PARAMETERS:

```
      !-------------------------------------------------------------------------
      ! DRYCOEFF : Baldocchi polynomial coeffs
      ! IOLSON   : Olson land type indices (+1)
      ! IDEP     : Mapping: Olson ==> drydep ID
      ! IWATER   : Olson types that represent water
      ! NWATER   : Number of Olson types that are water
      ! IZO      : Default Z0 (routgness height) for each Olson land type
      ! IDRYDEP  : Dry deposition land type indices
      ! IRI      : RI   resistance for drydep
      ! IRLU     : RLU  resistance for drydep
      ! IRAC     : RAC  resistance for drydep
      ! IRGSS    : RGSS resistance for drydep
      ! IRGSO    : RGSO resistance for drydep
      ! IRCLS    : RCLS resistance for drydep
      ! IRCLO    : RCLO resistance for drydep
      ! IVSMAX   : Max drydep velocity (for aerosol) perr drydep land type
      !-------------------------------------------------------------------------
      REAL*8,  INTENT(OUT) :: DRYCOEFF(NPOLY    )
      INTEGER, INTENT(OUT) :: IOLSON  (NVEGTYPE )
      INTEGER, INTENT(OUT) :: IDEP    (NVEGTYPE )
      INTEGER, INTENT(OUT) :: IWATER  (NVEGTYPE )
      INTEGER, INTENT(OUT) :: NWATER
      INTEGER, INTENT(OUT) :: IZO     (NVEGTYPE )
      INTEGER, INTENT(OUT) :: IDRYDEP (NDRYDTYPE)
```

```
      INTEGER, INTENT(OUT) :: IRI     (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRLU    (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRAC    (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRGSS   (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRGSO   (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRCLS   (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRCLO   (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IVSMAX  (NDRYDTYPE)
```

REMARKS:

```
    Routine READ_DRYDEP_INPUTS replaces routines MODIN (which read the ASCII
    file "drydep.table") and RDDRYCF (which read the ASCII file "drydep.coef").
                                                                             .
    READ_DRYDEP_INPUTS was generated from the Perl script "ncCodeRead", which
    is part of the NcdfUtilities package (with subsequent hand-editing).
                                                                             .
    Assumes that you have:
    (1) A netCDF library (either v3 or v4) installed on your system
    (2) The NcdfUtilities package (from Bob Yantosca) source code
```

REVISION HISTORY:

```
    26 Mar 2012 - R. Yantosca - Initial version
```

1.45.10 aero_sfcrsii

Function AERO_SFCRSII computes the aerodynamic resistance of seasalt aerosol tracers according to Zhang et al 2001. We account for hygroscopic growth of the seasalt aerosol particles. (rjp, tdf, bec, bmy, 4/1/04, 6/11/08)

INTERFACE:

```
      FUNCTION AERO_SFCRSII( K, II, PRESS, TEMP, USTAR, RHB,
     &                               W10 ) RESULT(RS)
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: K     ! Drydep tracer index (range: 1-NUMDEP)
      INTEGER, INTENT(IN) :: II    ! Surface type index of GEOS-CHEM
      REAL*8,  INTENT(IN) :: PRESS ! Pressure [kPa] (1 mb = 100 Pa = 0.1 kPa)
      REAL*8,  INTENT(IN) :: TEMP  ! Temperature [K]
      REAL*8,  INTENT(IN) :: USTAR ! Friction velocity [m/s]
      REAL*8,  INTENT(IN) :: RHB   ! Relative humidity (fraction)
      ! Added 10m windspeed (jaegle 5/11/11)
      REAL*8,  INTENT(IN) :: W10   ! 10 m windspeed [m/s]
```

RETURN VALUE:

```
      REAL*8              :: RS    ! Surface resistance for particles [s/m]
```

REVISION HISTORY:

```
(1 ) Updated comments.  Also now force double precision w/ "D" exponents.
      (bmy, 4/1/04)
(2 ) Now limit relative humidity to [tiny(real*8),0.99] range for DLOG
       argument (phs, 6/11/08)
(3 ) Bug fixes to the Gerber (1985) growth function (jaegle 5/11/11)
(4)  Update growth function to Lewis and Schwartz (2006) and density
     calculation based on Tang et al. (1997) (bec, jaegle 5/11/11)
(5 ) Updates of sea salt deposition over water to follow the Slinn & Slinn
     (1980) formulation over water surface. Described in Jaegle et al. (ACP,
     11, 2011) (jaegle 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.45.11 init_weightss

Subroutine INIT_WEIGHTSS calculates the volume size distribution of sea-salt. This only has to be done once. We assume that sea-salt is the combination of a coarse mode and accumulation model log-normal distribution functions. The resulting arrays are: DMID = diameter of bin and SALT_V = dV/dln(D) [in um3]. (jaegle 5/11/11)

INTERFACE:

```
SUBROUTINE INIT_WEIGHTSS
```

REVISION HISTORY:

```
11 May 2011 - L. Jaegle   - Initial version
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.45.12 dust_sfcrsi

Function DUST_SFCRSI computes the aerodynamic resistance of dust aerosol tracers according to Seinfeld et al 96. We do not consider hygroscopic growth of the dust aerosol particles. (rjp, tdf, bmy, bec, 4/1/04, 4/15/05)

INTERFACE:

```
FUNCTION DUST_SFCRSI( K, II, PRESS, TEMP, USTAR ) RESULT( RS )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: K     ! Drydep tracer index (range: 1-NUMDEP)
INTEGER, INTENT(IN) :: II    ! Surface type index of GEOS-CHEM
REAL*8,  INTENT(IN) :: PRESS ! Pressure [kPa] (1 mb = 100 Pa = 0.1 kPa)
REAL*8,  INTENT(IN) :: TEMP  ! Temperature [K]
REAL*8,  INTENT(IN) :: USTAR ! Friction velocity [m/s]
```

RETURN VALUE:

```
REAL*8              :: RS    ! Surface resistance for particles [s/m]
```

REVISION HISTORY:

```
(1 ) Updated comments.  Also now force double precision w/ "D" exponents.
     (bmy, 4/1/04)
(2 ) Renamed to DUST_SFCRSII, since this will only be used to compute
     aerodynamic resistance of dust aerosols.  (bec, bmy, 4/15/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.45.13 adust_sfcrsii

Function ADUST_SFCRSII computes the aerodynamic resistance of non-size resolved aerosol according to Zhang et al 2001. We do not consider the hygroscopic growth of the aerosol particles. (rjp, tdf, bec, bmy, 4/1/04, 4/15/05)

This routine is used for all aerosols except dust, sulfate, and seasalt (hotp 7/31/09)

INTERFACE:

```
FUNCTION ADUST_SFCRSII( K, II, PRESS, TEMP, USTAR ) RESULT( RS )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: K     ! Drydep tracer index (range: 1-NUMDEP)
INTEGER, INTENT(IN) :: II    ! Surface type index of GEOS-CHEM
REAL*8,  INTENT(IN) :: PRESS ! Pressure [kPa] (1 mb = 100 Pa = 0.1 kPa)
REAL*8,  INTENT(IN) :: TEMP  ! Temperature [K]
REAL*8,  INTENT(IN) :: USTAR ! Friction velocity [m/s]
```

RETURN VALUE:

```
REAL*8              :: RS    ! Surface resistance for particles [s/m]
```

REVISION HISTORY:

```
(1 ) Updated comments.  Also now force double precision w/ "D" exponents.
     (bmy, 4/1/04)
(2 ) Renamed to DUST_SFCRSII, since this will only be used to compute
     aerodynamic resistance of dust aerosols.  (bec, bmy, 4/15/05)
(3 ) Modified hotp for non size resolved aerosols. This is just DUST_SFCRSII
     renamed and the diameter and density fixed. (hotp 7/12/07)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.45.14 dust_sfcrsii

Function DUST_SFCRSII computes the aerodynamic resistance of dust aerosol tracers according to Zhang et al 2001. We do not consider the hygroscopic growth of the aerosol particles. (rjp, tdf, bec, bmy, 4/1/04, 4/15/05)

INTERFACE:

```
FUNCTION DUST_SFCRSII( K, II, PRESS, TEMP, USTAR ) RESULT( RS )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: K     ! Drydep tracer index (range: 1-NUMDEP)
INTEGER, INTENT(IN) :: II    ! Surface type index of GEOS-CHEM
REAL*8,  INTENT(IN) :: PRESS ! Pressure [kPa] (1 mb = 100 Pa = 0.1 kPa)
REAL*8,  INTENT(IN) :: TEMP  ! Temperature [K]
REAL*8,  INTENT(IN) :: USTAR ! Friction velocity [m/s]
```

RETURN VALUE:

```
REAL*8              :: RS    ! Surface resistance for particles [s/m]
```

REVISION HISTORY:

```
(1 ) Updated comments.  Also now force double precision w/ "D" exponents.
     (bmy, 4/1/04)
(2 ) Renamed to DUST_SFCRSII, since this will only be used to compute
     aerodynamic resistance of dust aerosols.  (bec, bmy, 4/15/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.45.15 init_drydep

Subroutine INIT_DRYDEP initializes certain variables for the GEOS-CHEM dry deposition subroutines. (bmy, 11/19/02, 10/19/09)

INTERFACE:

```
SUBROUTINE INIT_DRYDEP
```

REVISION HISTORY:

```
(1 ) Added N2O5 as a drydep tracer, w/ the same drydep velocity as
     HNO3.  Now initialize PBLFRAC array. (rjp, bmy, 7/21/03)
(2 ) Added extra carbon & dust aerosol tracers (rjp, tdf, bmy, 4/1/04)
(3 ) Added seasalt aerosol tracers.  Now use A_RADI and A_DEN to store
     radius & density of size-resolved tracers.  Also added fancy
     output. (bec, rjp, bmy, 4/26/04)
(3 ) Now handles extra SOA tracers (rjp, bmy, 7/13/04)
(4 ) Now references LDRYD from "logical_mod.f" and N_TRACERS,
```

```
      SALA_REDGE_um, and SALC_REDGE_um from "tracer_mod.f" (bmy, 7/20/04)
(5 ) Included Hg2, HgP tracers (eck, bmy, 12/14/04)
(6 ) Included AS, AHS, LET, NH4aq, SO4aq tracers (cas, bmy, 1/6/05)
(7 ) Remove reference to PBLFRAC array -- it's obsolete (bmy, 2/22/05)
(8 ) Included SO4s, NITs tracers (bec, bmy, 4/13/05)
(9 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(10) Now set Henry's law constant to 1.0d+14 for Hg2.  Now use ID_Hg2,
      ID_HgP, and ID_Hg_tot from "tracerid_mod.f".  Bug fix: split up
      compound IF statements into separate 2 IF statements for ID_Hg2,
      ID_HgP to avoid seg faults. (eck, cdh, bmy, 4/17/06)
(11) Now also initialize SOG4, SOA4 drydep species.  Bug fix: Remove 2nd
      "IF ( IS_Hg ) THEN" statement. (dkh, bmy, 5/24/06)
(12) Bug fix: fix TYPO in IF block for IDTSOA4 (dkh, bmy, 6/23/06)
(13) Included H2/HD tracers for offline H2-HD sim (phs, 9/18/07)
(14) Add dicarbonyl chemistry species (tmf, ccc, 3/6/09)
(15) Minor bug fix: ALPH, LIMO should have molwt = 136.23, not 136 even
      (bmy, 10/19/09)
15 Dec 2011 - M. Payer    - Update OVOC drydep according to Karl et al. 2010
                            and add drydep for MVK and MACR. (J. Mao)
21 Dec 2011 - M. Payer    - Add allocation for size distribution of sea salt
                            SALT_V and DMID (jaegle, 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.45.16 cleanup_drydep

Subroutine CLEANUP_DRYDEP deallocates all module arrays. (bmy, 2/27/03, 2/22/05)

INTERFACE:

```
SUBROUTINE CLEANUP_DRYDEP
```

REVISION HISTORY:

```
(1 ) Remove reference to PBLFRAC array; it's obsolete (bmy, 2/22/05)
(2 ) Added SALT_V and DMID (jaegle, 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.46 Fortran: Module Interface dust_mod

Module DUST_MOD contains routines for computing dust aerosol emissions, chemistry, and optical depths.

INTERFACE:

```
MODULE DUST_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CHEMDUST
      PUBLIC  :: EMISSDUST
      PUBLIC  :: RDUST_ONLINE
      PUBLIC  :: RDUST_OFFLINE
      PUBLIC  :: INIT_DUST
      PUBLIC  :: CLEANUP_DUST
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: DRY_SETTLING
      PRIVATE :: DRY_DEPOSITION
      PRIVATE :: SRC_DUST_DEAD
      PRIVATE :: SRC_DUST_GINOUX
```

REVISION HISTORY:

```
   30 Mar 2004 - T. D. Fairlie - Initial version
   (1 ) Bug fix in SRC_DUST_DEAD (bmy, 4/14/04)
   (2 ) Now references "logical_mod.f", "directory_mod.f", and "tracer_mod.f"
        Added comments. (bmy, 7/2/04)
   (3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (4 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
   (5 ) Bug fix in snow height computation (bmy, 11/18/05)
   (6 ) Now only do drydep if LDRYD=T (bmy, 5/23/06)
   (7 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
   (8 ) Updated output print statement in SRC_DUST_DEAD (bmy, 1/23/07)
   (9 ) Modifications for GEOS-5 (bmy, 1/24/07)
   (10) Modified to archive only hydrophilic aerosol/aqueous dust surface area
        (excluding BCPO and OCPO) for aqueous chemistry calculations
        Dust surfaces are considered aqueous only when RH > 35% (tmf, 3/6/09)
   (11) Add AOD output for all dust size bins (clh, 5/7/10)
   (12) Modify AOD output to wavelength specified in jv_spec_aod.dat
       (clh, 05/07/10)
   25 Aug 2010 - R. Yantosca - Added ProTeX headers
   03 Sep 2010 - R. Yantosca - Bug fix in SRC_DUST_DEAD
   08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x
   01 Mar 2012 - R. Yantosca - Now reference the new grid_mod.F90
```

1.46.1 chemdust

Subroutine CHEMDUST is the interface between the GEOS-Chem main program and the dust chemistry routines that mostly calculates dust dry deposition.

INTERFACE:

```
SUBROUTINE CHEMDUST
```

USES:

```
USE ERROR_MOD,    ONLY : ERROR_STOP
USE LOGICAL_MOD,  ONLY : LDRYD,   LDUST
USE DRYDEP_MOD,   ONLY : DEPNAME, NUMDEP
USE TRACER_MOD,   ONLY : STT
USE TRACERID_MOD, ONLY : IDTDST1, IDTDST2, IDTDST3, IDTDST4

USE CMN_SIZE_MOD       ! Size parameters
```

REVISION HISTORY:

```
30 Mar 2004 - T. D. Fairlie - Initial version
(1 ) Now references STT from "tracer_mod.f" and LDUST from "logical_mod.f"
     (bmy, 7/20/04)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Now only do dry deposition if LDRYD = T (bmy, 5/23/06)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.46.2 dry_settling

Subroutine DRY_SETTLING computes the dry settling of dust tracers.

INTERFACE:

```
SUBROUTINE DRY_SETTLING( TC )
```

USES:

```
USE DAO_MOD,      ONLY : T, BXHEIGHT
USE DIAG_MOD,     ONLY : AD44
USE PRESSURE_MOD, ONLY : GET_PCENTER
USE TIME_MOD,     ONLY : GET_TS_CHEM
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TRACER_MOD,   ONLY : XNUMOL
USE TRACERID_MOD, ONLY : IDTDST1

USE CMN_SIZE_MOD       ! Size parameters
USE CMN_DIAG_MOD       ! ND44
USE CMN_GCTM_MOD       ! g0
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8, INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR,NDSTBIN)  ! Dust mass [kg]
```

REVISION HISTORY:

```
30 Mar 2004 - T. D. Fairlie - Initial version
(1 ) Updated comments, cosmetic changes (bmy, 3/30/04)
(2 ) Remove reference to CMN, it's not needed (bmy, 7/20/04)
(3 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.46.3 dry_deposition

Subroutine DRY_DEPOSITION computes the loss of dust due to dry deposition at the surface using an implicit method.

INTERFACE:

```
SUBROUTINE DRY_DEPOSITION( TC )
```

USES:

```
USE DIAG_MOD,     ONLY : AD44
USE DRYDEP_MOD,   ONLY : DEPSAV
USE TIME_MOD,     ONLY : GET_TS_CHEM
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TRACER_MOD,   ONLY : XNUMOL
USE TRACERID_MOD, ONLY : IDTDST1

USE CMN_SIZE_MOD       ! Size parameters
USE CMN_DIAG_MOD       ! ND44
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8, INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR,NDSTBIN)  ! Dust mass [kg]
```

REVISION HISTORY:

```
30 Mar 2004 - T. D. Fairlie - Initial version
(1 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.46.4 emissdust

Subroutine EMISSDUST is the driver routine for the dust emission module. You may call either the GINOUX or the DEAD dust source function.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISSDUST( SFLX )
#else
      SUBROUTINE EMISSDUST
#endif
```

USES:

```
      USE ERROR_MOD,    ONLY : ERROR_STOP, DEBUG_MSG
      USE LOGICAL_MOD,  ONLY : LDEAD, LDUST, LPRT
      USE TRACER_MOD,   ONLY : STT
      USE TRACERID_MOD, ONLY : IDTDST1, IDTDST2, IDTDST3, IDTDST4

      USE CMN_SIZE_MOD       ! Size parameters
#if defined( DEVEL )
      USE TRACER_MOD,   ONLY : N_TRACERS
      USE TIME_MOD,     ONLY : GET_TS_EMIS
#endif
```

REVISION HISTORY:

```
   30 Mar 2004 - T. D. Fairlie - Initial version
   (1 ) Now reference LDEAD, LDUST, LPRT from "logical_mod.f".  Now reference!
        STT from "tracer_mod.f" (bmy, 7/20/04)
   (2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   25 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.46.5 src_dust_dead

Subroutine SRC_DUST_DEAD is the DEAD model dust emission scheme, alternative to Ginoux scheme. Increments the TC array with emissions from the DEAD model.

INTERFACE:

```
      SUBROUTINE SRC_DUST_DEAD( TC )
```

USES:

```
      USE DAO_MOD,       ONLY : BXHEIGHT,     GWETTOP,   LWI
      USE DAO_MOD,       ONLY : SNOW,         SPHU,      T
      USE DAO_MOD,       ONLY : TS,           UWND,      VWND
      USE DAO_MOD,       ONLY : SNOMAS
      USE DUST_DEAD_MOD, ONLY : GET_TIME_INVARIANT_DATA, GET_ORO
      USE DUST_DEAD_MOD, ONLY : GET_MONTHLY_DATA,        DST_MBL
      USE DIAG_MOD,      ONLY : AD06
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE FILE_MOD,      ONLY : IOERROR
      USE ERROR_MOD,     ONLY : GEOS_CHEM_STOP
```

```
      USE GRID_MOD,      ONLY : GET_YMID_R
      USE PRESSURE_MOD,  ONLY : GET_PEDGE,       GET_PCENTER
      USE TIME_MOD,      ONLY : GET_TS_EMIS,     GET_MONTH
      USE TIME_MOD,      ONLY : GET_DAY_OF_YEAR, ITS_A_NEW_MONTH
      USE TRANSFER_MOD,  ONLY : TRANSFER_2D

      USE CMN_SIZE_MOD        ! Size parameters
      USE CMN_DIAG_MOD        ! ND06
      USE CMN_GCTM_MOD        ! g0
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8, INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR,NDSTBIN)  ! Dust mass [kg]
```

REMARKS:

```
    Input:
           SRCE_FUNK Source function                                (-)
           for 1: Sand, 2: Silt, 3: Clay
           DUSTDEN   Dust density                                   (kg/m3)
           DUSTREFF  Effective radius                               (um)
           AD        Air mass for each grid box                     (kg)
           NTDT      Time step                                      (s)
           W10M      Velocity at the anemometer level (10meters)    (m/s)
           GWET      Surface wetness                                (-)
                                                                              .
    Parameters used in GEOS-CHEM
                                                                              .
    Longitude: IIPAR
    Latitude : JJPAR
    Levels   : LLPAR  =  20 (GEOS-1), 26 (GEOS-strat), 30 (GEOS-terra)
    Size bins: NDSTBIN  =   4
                                                                              .
    Dust properties used in GOCART
                                                                              .
    Size classes: 01-1, 1-1.8, 1.8-3, 3-6 (um)
    Radius: 0.7, 1.5, 2.5, 4  (um)
    Density: 2500, 2650, 2650, 2650 (kg/m3)!
```

REVISION HISTORY:

```
    08 Apr 2004 - T. D. Fairlie - Initial version
    (1 ) Added OpenMP parallelization, added comments (bmy, 4/8/04)
    (2 ) Bug fix: DSRC needs to be held PRIVATE (bmy, 4/14/04)
    (3 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
    (4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (5 ) Bug fix: It should be SNOW/1d3 not SNOW*1d3 (tdf, bmy, 11/18/05)
    (6 ) Updated output statement (bmy, 1/23/07)
    (7 ) Use SNOMAS (m H2O) for GEOS-5 (bmy, 1/24/07)
```

```
25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as for GEOS-5
25 Aug 2010 - R. Yantosca - Added ProTeX headers
03 Sep 2010 - R. Yantosca - Bug fix, SNOMAS was mislabled in GEOS-5
                            and has units of mm H2O instead of m H2O
                            so we need to convert to m H2O.
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R(I,J,L) from grid_mod.F90
```

1.46.6 src_dust_ginoux

Paul GINOUX dust source function. This subroutine updates the surface mixing ratio of dust aerosols for NDSTBIN size bins. The uplifting of dust depends in space on the source function, and in time and space on the soil moisture and surface wind speed (10 meters). Dust is uplifted if the wind speed is greater than a threshold velocity which is calculated with the formula of Marticorena et al. (JGR, v.102, pp 23277-23287, 1997). To run this subroutine you need the source function which can be obtained by contacting Paul Ginoux at ginoux@rondo.gsfc.nasa.gov/ If you are not using GEOS DAS met fields, you will most likely need to adapt the adjusting parameter.

INTERFACE:

```
SUBROUTINE SRC_DUST_GINOUX( TC )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_RES_EXT
USE DAO_MOD,       ONLY : GWETTOP
USE DIAG_MOD,      ONLY : AD06
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IOERROR
USE TIME_MOD,      ONLY : GET_TS_EMIS
USE GRID_MOD,      ONLY : GET_AREA_M2

USE CMN_SIZE_MOD        ! Size parameters
USE CMN_DIAG_MOD        ! ND19, LD13 (for now)
USE CMN_GCTM_MOD        ! g0
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8, INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR,NDSTBIN)  ! Dust mass [kg]
```

REMARKS:

```
Input:
  SRCE_FUNK Source function                              (-)
            for 1: Sand, 2: Silt, 3: Clay

  DUSTDEN   Dust density                                 (kg/m3)
  DUSTREFF  Effective radius                             (um)
```

```
  AD        Air mass for each grid box                    (kg)
  NTDT      Time step                                     (s)
  W10m      Velocity at the anemometer level (10meters)   (m/s)
  GWET      Surface wetness                               (-)
                                                                      .
Parameters used in GEOS-CHEM
                                                                      .
Longitude: IIPAR
Latitude : JJPAR
Levels   : LLPAR  =  20 (GEOS-1), 26 (GEOS-strat), 30 (GEOS-terra)
Size bins: NDSTBIN  =   4
                                                                      .
Dust properties used in GOCART
                                                                      .
Size classes: 01-1, 1-1.8, 1.8-3, 3-6 (um)
Radius: 0.7, 1.5, 2.5, 4  (um)
Density: 2500, 2650, 2650, 2650 (kg/m3)
                                                                      .
References:
=============================================================================
(1 ) Ginoux, P., M. Chin, I. Tegen, J. Prospero, B. Hoben, O. Dubovik,
      and S.-J. Lin, "Sources and distributions of dust aerosols simulated
      with the GOCART model", J. Geophys. Res., 2001
(2 ) Chin, M., P. Ginoux, S. Kinne, B. Holben, B. Duncan, R. Martin,
      J. Logan, A. Higurashi, and T. Nakajima, "Tropospheric aerosol
      optical thickness from the GOCART model and comparisons with
      satellite and sunphotometers measurements", J. Atmos Sci., 2001.
                                                                      .
Contact: Paul Ginoux (ginoux@rondo.gsfc.nasa.gov)
```

REVISION HISTORY:

```
08 Apr 2004 - T. D. Fairlie - Initial version
(1 ) Added OpenMP parallelization (bmy, 4/8/04)
(2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

1.46.7 rdust_online

Subroutine RDUST_ONLINE reads global mineral dust concentrations as determined by P. Ginoux. Calculates dust optical depth at each level for the FAST-J routine "set_prof.f".

INTERFACE:

```
SUBROUTINE RDUST_ONLINE( DUST, WAVELENGTH )
```

USES:

```
USE COMODE_MOD,    ONLY : ERADIUS, IXSAVE, IYSAVE
USE COMODE_MOD,    ONLY : IZSAVE,  JLOP,   TAREA
USE DAO_MOD,       ONLY : BXHEIGHT
USE DIAG_MOD,      ONLY : AD21
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE ERROR_MOD,     ONLY : ERROR_STOP
USE TRANSFER_MOD,  ONLY : TRANSFER_3D
USE COMODE_MOD,    ONLY : WTAREA, WERADIUS
USE DAO_MOD,       ONLY : RH

 USE CMN_FJ_MOD,    ONLY : IPAR, JPAR, LPAR, JPMAX, JPPJ
USE JV_CMN_MOD          ! ODMDUST, QAA, RAA, QAA_AOD (clh)
USE COMODE_LOOP_MOD     ! NTTLOOP

USE CMN_DIAG_MOD        ! ND21, LD21
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8, INTENT(IN)  :: DUST(IIPAR,JJPAR,LLPAR,NDUST)   ! Dust [kg/m3]
INTEGER, INTENT(IN) :: WAVELENGTH
```

REVISION HISTORY:

```
01 Apr 2004 - R. Martin, R. Park - Initial version
(1 ) Bundled into "dust_mod.f" (bmy, 4/1/04)
(2 ) Now references DATA_DIR from "directory_mod.f".  Now parallelize over
     the L-dimension for ND21 diagnostics. (bmy, 7/20/04)
(3 ) Archive only hydrophilic aerosol/aqueous dust surface area
     (excluding BCPO and OCPO), WTAREA and WERADIUS. (tmf, 3/6/09)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
03 Feb 2011 - S. Kim.     - Include wavelength argument to determine the
                            wavelength at which the AOD should be computed.
                            This will set the optical properties that are
                            used for the calculation of the AOD. The ND21
                            diagnostic should only be updated when
                            WAVELENGTH = 1. (skim, 02/03/11)
```

1.46.8 rdust_offline

Subroutine RDUST_OFFLINE reads global mineral dust concentrations as determined by P. Ginoux. Calculates dust optical depth at each level for the FAST-J routine "set_prof.f".

INTERFACE:

```
SUBROUTINE RDUST_OFFLINE( THISMONTH, THISYEAR, WAVELENGTH )
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
      USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
      USE COMODE_MOD,    ONLY : ERADIUS, IXSAVE, IYSAVE
      USE COMODE_MOD,    ONLY : IZSAVE,  JLOP,   TAREA
      USE DAO_MOD,       ONLY : BXHEIGHT
      USE DIAG_MOD,      ONLY : AD21
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE ERROR_MOD,     ONLY : ERROR_STOP
      USE TRANSFER_MOD,  ONLY : TRANSFER_3D
      USE COMODE_MOD,    ONLY : WTAREA, WERADIUS
      USE DAO_MOD,       ONLY : RH

#     include "define.h"

      USE CMN_FJ_MOD,    ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD,    ONLY : ODMDUST, QAA, RAA, RAA_AOD, QAA_AOD
      USE COMODE_LOOP_MOD     ! NTTLOOP
      USE CMN_DIAG_MOD        ! ND21, LD21

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: THISMONTH   ! Current month (1-12)
      INTEGER, INTENT(IN) :: THISYEAR    ! Current year  (YYYY format)
      ! Determine which wavelength to use for optical properties
      INTEGER, INTENT(IN) :: WAVELENGTH
```

REVISION HISTORY:

```
(1 ) RDUST was patterned after rdaerosol.f (rvm, 9/30/00)
(2 ) Don't worry about rewinding the binary file...reading from
     binary files is pretty fast.  And it's only done once a month.
(3 ) Now references punch file utility routines from F90 module
     "bpch2_mod.f".  Also reference variable DATA_DIR from the
      header file "CMN_SETUP". (bmy, 9/30/00)
(4 ) Now selects proper GEOS-STRAT dust field for 1996 or 1997.
     Also need to pass THISYEAR thru the arg list. (rvm, bmy, 11/21/00)
(5 ) CONC is now declared as REAL*8 (rvm, bmy, 12/15/00)
(6 ) Removed obsolete code from 12/15/00 (bmy, 12/21/00)
(7 ) CONC(IIPAR,JJPAR,LGLOB,NDUST) is now CONC(IIPAR,JJPAR,LLPAR,NDUST).
     Now use routine TRANSFER_3D from "transfer_mod.f" to cast from REAL*4
     to REAL*8 and also to convert from {IJL}GLOB to IIPAR,JJPAR,LLPAR
     space.  Use 3 arguments in call to GET_TAU0.  Updated comments.
     (bmy, 9/26/01)
(8 ) Removed obsolete code from 9/01 (bmy, 10/24/01)
(9 ) Now reference ERADIUS, IXSAVE, IYSAVE, IZSAVE, TAREA from
     "comode_mod.f".  Compute ERADIUS and TAREA for the NDUST dust
     size bins from FAST-J.  Renamed CONC to DUST to avoid conflicts.
```

```
      Also reference NTTLOOP from "comode.h".  Also added parallel
      DO-loops.  Also renamed MONTH and YEAR to THISMONTH and THISYEAR
      to avoid conflicts w/ other variables. (bmy, 11/15/01)
(10) Bug fix: Make sure to use 1996 dust data for Dec 1995 for the
      GEOS-STRAT met field dataset.  Set off CASE statement with an
      #if defined( GEOS_STRAT ) block. (rvm, bmy, 1/2/02)
(11) Eliminate obsolete code from 1/02 (bmy, 2/27/02)
(12) Now report dust optical depths in ND21 diagnostic at 400 nm.  Now
     report dust optical depths as one combined diagnostic field instead
      of 7 separate fields.  Now reference JLOP from "comode_mod.f".
      Now save aerosol surface areas as tracer #5 of the ND21 diagnostic.
      (rvm, bmy, 2/28/02)
(13) Remove declaration for TIME, since that is also defined in the
      header file "comode.h" (bmy, 3/20/02)
(14) Now read mineral dust files directly from the DATA_DIR/dust_200203/
      subdirectory (bmy, 4/2/02)
(15) Now reference BXHEIGHT from "dao_mod.f".  Also reference ERROR_STOP
      from "error_mod.f". (bmy, 10/15/02)
(16) Now call READ_BPCH2 with QUIET=TRUE to suppress extra informational
      output from being printed.  Added cosmetic changes. (bmy, 3/14/03)
(17) Since December 1997 dust data does not exist, use November 1997 dust
      data as a proxy. (bnd, bmy, 6/30/03)
(18) Bundled into "dust_mod.f" and renamed to RDUST_OFFLINE. (bmy, 4/1/04)
(19) Now references DATA_DIR from "directory_mod.f".  Now parallelize over
      the L-dimension for ND21 diagnostic. (bmy, 7/20/04)
(20) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(21) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(22) Archive only hydrophilic aerosol/aqueous dust surface area
     (excluding BCPO and OCPO), WTAREA and WERADIUS. (tmf, 3/6/09)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
03 Feb 2011 - S. Kim      - Include third input argument to determine the
                            wavelength at which the AOD should be computed.
                            This will set the optical properties that are
                            used for the calculation of the AOD.  The ND21
                            diagnostic should only be updated when
                            WAVELENGTH = 1.
```

1.46.9 init_dust

Subroutine INIT_DUST allocates all module arrays.

INTERFACE:

```
SUBROUTINE INIT_DUST
```

USES:

```
USE LOGICAL_MOD, ONLY : LDEAD
```

```
      USE ERROR_MOD,   ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD      ! Size parameters
```

REVISION HISTORY:

```
30 Mar 2004 - R. Yantosca - Initial version
(1 ) Now references LDEAD from "logical_mod.f" (bmy, 7/20/04)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.46.10 cleanup_dust

Subroutine CLEANUP_DUST deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_DUST
```

REVISION HISTORY:

```
30 Mar 2004 - R. Yantosca - Initial version
25 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.47 Fortran: Module Interface emep_mod

Overview

Module EMEP_MOD contains variables and routines to read the EMEP European anthropogenic emission inventory for CO, NOz, and some NMVOCs. The EMEP files come from Marion Auvray and Isabelle Bey at EPFL. (bdf, bmy, amv, phs, 11/1/05, 1/28/09)

References

1. Vestreng, V., and H. Klein (2002), *Emission data reported to UNECE/EMEP: Quality insurance and trend analysis and presentation of Web-Dab*, MSC-W Status Rep. 2002:, 101 pp., Norw. Meteorol. Inst., Oslo, Norway. This paper is on the EMEP web site:

   ```
   http://www.emep.int/mscw/mscw\_publications.html
   http://www.emep.int/publ/reports/2002/mscw\_note\_1\_2002.pdf
   ```

2. Auvray, M., and I. Bey, *Long-Range Transport to Europe: Seasonal Variations and Implications for the European Ozone Budget*, J. Geophys. Res., **110**, D11303, doi: 10.1029/2004JD005503, 2005.

INTERFACE:

```
      MODULE EMEP_MOD
```

USES:

```
      USE ERROR_MOD, ONLY: ALLOC_ERR

      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: EMISS_EMEP
      PUBLIC  :: EMISS_EMEP_05x0666
      PUBLIC  :: CLEANUP_EMEP
      PUBLIC  :: GET_EUROPE_MASK
      PUBLIC  :: GET_EMEP_ANTHRO
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: EMEP_SCALE_FUTURE
      PRIVATE :: READ_EMEP_UPDATED
      PRIVATE :: READ_EMEP_UPDATED_05x0666
      PRIVATE :: READ_EUROPE_MASK
      PRIVATE :: READ_EUROPE_MASK_05x0666
      PRIVATE :: INIT_EMEP
```

REVISION HISTORY:

```
   01 Nov 2005 - B. Field, R. Yantosca - Initial version
   (1 ) Now only print totals for defined tracers (bmy, 2/6/06)
   (2 ) Now modified for IPCC future emissions (swu, bmy, 5/30/06)
   (3 ) Now yearly scale factors can be applied (phs, amv, 3/17/08)
   (4 ) Now include emep SOx and emep emissions to 2005 (amv, 06/08)
   (5 ) Modify to access SHIP emissions from outside (phs, 06/08)
   (6 ) Account for monthly variations (amv, 12/9/08)
   18 Dec 2009 - Aaron van D - Created routine EMISS_EMEP_05x0666
   18 Dec 2009 - Aaron van D - Created routine READ_EMEP_UPDATED_05x0666
   18 Dec 2009 - Aaron van D - Created routine READ_EUROPE_MASK_05x0666
   11 Jan 2010 - Aaron van D - Max scale year is now 2007, for consistency
   11 Jan 2010 - Aaron van D - Extend 1x1 emission files to 2007.  Routine
                               READ_EMEP_UPDATED now mimics routine
                               READ_EMEP_UPDATED_05x0666.
   26 Jan 2010 - R. Yantosca - Minor bug fix in INIT_EMEP
   31 Aug 2010 - R. Yantosca - Updated comments
   24 Nov 2010 - G. Vinken   - Updated EMEP mask file
   13 Mar 2012 - M. Cooper   - Changed gridding algorithm to map_a2a
   22 Mar 2012 - M. Payer    - C2H6 emissions are too low. Use Yaping
                               Xiao's C2H6 emissions instead.
```

1.47.1 get_europe_mask

Function GET_EUROPE_MASK returns the value of the EUROPE mask for EMEP emissions at grid box (I,J). MASK=1 if (I,J) is in the European region, or MASK=0 otherwise.

INTERFACE:

```
FUNCTION GET_EUROPE_MASK( I, J ) RESULT( EUROPE )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I        ! Longitude index
INTEGER, INTENT(IN) :: J        ! Latitude  index
```

RETURN VALUE:

```
REAL*8              :: EUROPE   ! Returns the mask value @ (I,J)
```

REVISION HISTORY:

```
01 Nov 2005 - B. Field, R. Yantosca - Initial version
```

1.47.2 get_emep_anthro

Function GET_EMEP_ANTHRO returns the EMEP emission for GEOS-CHEM grid box (I,J) and tracer N.

INTERFACE:

```
FUNCTION GET_EMEP_ANTHRO( I, J, N, KG_S, SHIP ) RESULT( EMEP )
```

USES:

```
USE TRACERID_MOD, ONLY : IDTNOX,  IDTCO,   IDTALK4, IDTMEK
USE TRACERID_MOD, ONLY : IDTALD2, IDTPRPE, IDTC2H6, IDTSO2
USE TRACERID_MOD, ONLY : IDTNH3
USE TRACER_MOD,   ONLY : XNUMOL
USE GRID_MOD,     ONLY : GET_AREA_CM2
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)           :: I       ! Longitude index
INTEGER, INTENT(IN)           :: J       ! Latitude index
INTEGER, INTENT(IN)           :: N       ! Tracer number
LOGICAL, INTENT(IN), OPTIONAL :: KG_S    ! Return emissions in [kg/s]
LOGICAL, INTENT(IN), OPTIONAL :: SHIP    ! Return ship emissions
RETURN VALUE:

REAL*8                        :: EMEP    ! Returns emissions at (I,J)
```

REVISION HISTORY:

```
   01 Nov 2005 - B. Field, R. Yantosca - Initial version
   (1 ) added SOx, SOx ship and NH3 emissions, plus optional kg/s output
        (amv, 06/2008)
   (2 ) Now returns ship emissions if requested (phs, 6/08)
   (3 ) Added checks to avoid calling unavailable ship emissions (phs, 6/08)
   01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
   22 Mar 2012 - M. Payer    - C2H6 emissions are too low. Use Yaping
                               Xiao's C2H6 emissions instead.
```

1.47.3 emiss_emep

Subroutine EMISS_EMEP reads the EMEP emission fields at 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISS_EMEP( EMISS )
#else
      SUBROUTINE EMISS_EMEP
#endif
```

USES:

```
      USE BPCH2_MOD,         ONLY : GET_TAU0,     OPEN_BPCH2_FOR_READ
      USE FILE_MOD,          ONLY : IU_FILE,      IOERROR
      USE DIRECTORY_MOD,     ONLY : DATA_DIR_1x1
      USE LOGICAL_MOD,       ONLY : LFUTURE
      USE REGRID_A2A_MOD,    ONLY : DO_REGRID_A2A
      USE TIME_MOD,          ONLY : EXPAND_DATE,  GET_YEAR
      USE TIME_MOD,          ONLY : GET_MONTH
      USE SCALE_ANTHRO_MOD, ONLY : GET_ANNUAL_SCALAR

      USE CMN_SIZE_MOD           ! Size parameters
      USE CMN_O3_MOD             ! SCALEYEAR

#if defined( DEVEL )
      USE TRACERID_MOD, ONLY : IDTNOX,  IDTCO,   IDTALK4, IDTMEK
      USE TRACERID_MOD, ONLY : IDTALD2, IDTPRPE, IDTC2H6, IDTSO2
      USE TRACERID_MOD, ONLY : IDTNH3
      USE TRACER_MOD,   ONLY : XNUMOL
      USE TRACER_MOD,   ONLY : N_TRACERS
      USE GRID_MOD,     ONLY : GET_AREA_CM2
      USE LOGICAL_MOD,  ONLY : LEMEPSHIP
#endif
```

REVISION HISTORY:

```
   01 Nov 2005 - B. Field, R. Yantosca - Initial version
   (1 ) Modified for IPCC future emissions.  Now references LFUTURE from
        "logical_mod.f". (bmy, 5/30/06)
   13 Mar 2012 - M. Cooper   - Changed gridding algorithm to map_a2a
   24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.47.4 emiss_emep_05x0666

Subroutine EMISS_EMEP reads the EMEP emission fields at 05x0666 resolution and regrids them to the current model resolution.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISS_EMEP_05x0666( EMISS )
#else
      SUBROUTINE EMISS_EMEP_05x0666
#endif
```

USES:

```
      USE BPCH2_MOD,         ONLY : GET_TAU0,     READ_BPCH2
      USE DIRECTORY_MOD,     ONLY : DATA_DIR
      USE LOGICAL_MOD,       ONLY : LFUTURE
      USE TIME_MOD,          ONLY : EXPAND_DATE,  GET_YEAR
      USE TIME_MOD,          ONLY : GET_MONTH
      USE SCALE_ANTHRO_MOD, ONLY : GET_ANNUAL_SCALAR_05x0666_NESTED

      USE CMN_SIZE_MOD       ! Size parameters
      USE CMN_O3_MOD         ! SCALEYEAR

#if defined( DEVEL )
      USE TRACERID_MOD, ONLY : IDTNOX,  IDTCO,   IDTALK4, IDTMEK
      USE TRACERID_MOD, ONLY : IDTALD2, IDTPRPE, IDTC2H6, IDTSO2
      USE TRACERID_MOD, ONLY : IDTNH3
      USE TRACER_MOD,   ONLY : XNUMOL
      USE TRACER_MOD,   ONLY : N_TRACERS
      USE GRID_MOD,     ONLY : GET_AREA_CM2
      USE LOGICAL_MOD,  ONLY : LEMEPSHIP
#endif
```

REVISION HISTORY:

```
   23 Oct 2006 - A. v. Donkelaar - Initial version, modified from EMISS_EMEP
```

1.47.5 emep_scale_future

Subroutine EMEP_SCALE_FUTURE applies the IPCC future scale factors to the EMEP anthropogenic emissions.

INTERFACE:

```
SUBROUTINE EMEP_SCALE_FUTURE
```

USES:

```
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_ALK4ff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_C2H6ff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_COff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_PRPEff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_TONEff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_VOCff

USE CMN_SIZE_MOD             ! Size parameters
```

REVISION HISTORY:

```
30 May 2006 - S. Wu & R. Yantosca - Initial version
```

1.47.6 total_anthro_Tg

Subroutine TOTAL_ANTHRO_TG prints the amount of EMEP anthropogenic emissions that are emitted each month in Tg or Tg C.

INTERFACE:

```
SUBROUTINE TOTAL_ANTHRO_TG( EMEP_YEAR, EMISS_YEAR, EMEP_MONTH )
```

USES:

```
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE LOGICAL_MOD,  ONLY : LEMEPSHIP
USE TIME_MOD,     ONLY : ITS_A_LEAPYEAR
USE TRACER_MOD,   ONLY : XNUMOL
USE TRACERID_MOD, ONLY : IDTNOX,  IDTCO,   IDTALK4, IDTMEK
USE TRACERID_MOD, ONLY : IDTALD2, IDTPRPE, IDTC2H6, IDTSO2
USE TRACERID_MOD, ONLY : IDTNH3

USE CMN_SIZE_MOD     ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)   :: EMEP_YEAR    ! EMEP base year
INTEGER, INTENT(IN)   :: EMISS_YEAR   ! Current simulated year
INTEGER, INTENT(IN)   :: EMEP_MONTH   ! Current simulated month
```

REVISION HISTORY:

```
10 Nov 2004 - R. Hudman, R. Yantosca - Initial version
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) Now replace FMOL with TRACER_MW_KG (bmy, 10/25/05)
(3 ) Now only print totals of defined tracers; other totals will be
     printed as zeroes. (bmy, 2/6/06)
(4 ) Now emissions and base year are arguments. Output in Tg/month
     since this is called monthly (phs, 12/9/08)
(5 ) Bug fix, now print out correct monthly EMEP totals (bmy, 1/30/09)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
22 Mar 2012 - M. Payer    - Remove print for C2H6 emissions.
```

1.47.7 read_europe_mask

Subroutine READ_EUROPE_MASK reads and regrids the Europe mask for the EMEP anthropogenic emissions.

INTERFACE:

```
SUBROUTINE READ_EUROPE_MASK
```

USES:

```
USE BPCH2_MOD,      ONLY : READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE CMN_SIZE_MOD         ! Size parameters
```

REVISION HISTORY:

```
18 Oct 2006 - R. Yantosca - Initial version
(1 ) Now read the Europe mask from a disk file instead of defining it as
     a rectangular box (bmy, 10/18/06)
(2 ) Updated the mask file to correspond with the 200911 EMEP emissions
     (gvinken, 11/24/10)
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.47.8 read_europe_mask_05x0666

Subroutine READ_EUROPE_MASK reads and regrids the Europe mask for the EMEP anthropogenic emissions.

INTERFACE:

```
SUBROUTINE READ_EUROPE_MASK_05x0666
```

USES:

```
      USE BPCH2_MOD,      ONLY : READ_BPCH2
      USE DIRECTORY_MOD,  ONLY : DATA_DIR

      USE CMN_SIZE_MOD       ! Size parameters
```

REVISION HISTORY:

```
    18 Oct 2006 - R. Yantosca - Initial version
    (1 ) Now read the Europe mask from a disk file instead of defining it as
         a rectangular box (bmy, 10/18/06)
```

1.47.9 read_emep_updated

Subroutine READ_EMEP_UPDATED reads updated EMEP emissions from the year 1990 including SOx emissions. These are regridded to the simulation resolution. Ship emissions can also be included.

INTERFACE:

```
      SUBROUTINE READ_EMEP_UPDATED( TRACER, EMEP_YEAR, ARRAY, wSHIP )
```

USES:

```
      USE BPCH2_MOD,      ONLY : READ_BPCH2, GET_TAU0
      USE TIME_MOD,       ONLY : EXPAND_DATE, GET_MONTH
      USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
      USE LOGICAL_MOD,    ONLY : LEMEPSHIP
      USE GRID_MOD,       ONLY : GET_AREA_CM2
      USE TRACERID_MOD,   ONLY : IDTNOx, IDTCO, IDTSO2, IDTNH3
      USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

      USE CMN_SIZE_MOD         ! Size parameters
      USE CMN_O3_MOD           ! SCALEYEAR
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: TRACER             ! Tracer number
      INTEGER, INTENT(IN)  :: EMEP_YEAR          ! Year of emissions to read
      INTEGER, INTENT(IN)  :: wSHIP              ! Use ground, ship, or both?
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: ARRAY(IIPAR,JJPAR)  ! Output array
```

REVISION HISTORY:

```
    28 Jan 2009 - A. v. Donkelaar, P. Le Sager - Initial version
    28 Jan 2009 - P. Le Sager - Now account for LEMEPSHIP
    29 Oct 2009 - Added multi-species seasonality (amv)
    04 Jan 2010 - Extended to 2007, changed input format (amv)
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
    24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.47.10 read_emep_updated_05x0666

Subroutine READ_EMEP_UPDATED reads updated EMEP emissions from the year 1990 including SOx emissions. These are regridded to the simulation resolution. Ship emissions can also be included.

INTERFACE:

```
      SUBROUTINE READ_EMEP_UPDATED_05x0666( TRACER, EMEP_YEAR, ARRAY,
     &                   wSHIP )
```

USES:

```
      USE BPCH2_MOD,      ONLY : READ_BPCH2, GET_TAU0
      USE TIME_MOD,       ONLY : EXPAND_DATE, GET_MONTH
      USE DIRECTORY_MOD,  ONLY : DATA_DIR
      USE LOGICAL_MOD,    ONLY : LEMEPSHIP
      USE TRACERID_MOD,   ONLY : IDTNOx, IDTCO, IDTSO2, IDTNH3
      USE GRID_MOD,       ONLY : GET_AREA_CM2

      USE CMN_SIZE_MOD       ! Size parameters
      USE CMN_O3_MOD         ! SCALEYEAR
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: TRACER             ! Tracer number
      INTEGER, INTENT(IN)  :: EMEP_YEAR          ! Year of emissions to read
      INTEGER, INTENT(IN)  :: wSHIP              ! Use ground, ship, or both?
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: ARRAY(IIPAR,JJPAR)  ! Output array
```

REVISION HISTORY:

```
   28 Jan 2009 - A. v. Donkelaar, P. Le Sager - Initial version
   28 Jan 2009 - P. Le Sager - Now account for LEMEPSHIP
   29 Oct 2009 - Added multi-species seasonality (amv)
   01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.47.11 init_emep

Subroutine INIT_EMEP allocates and zeroes EMEP module arrays, and also creates the mask which defines the European region.

INTERFACE:

```
      SUBROUTINE INIT_EMEP
```

USES:

```
      ! References to F90 modules
      USE ERROR_MOD,   ONLY : ALLOC_ERR
      USE GRID_MOD,    ONLY : GET_XMID, GET_YMID
      USE LOGICAL_MOD, ONLY : LEMEP

      USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
   01 Nov 2005 - B. Field, R. Yantosca - Initial version
   (1 ) Now call READ_EUROPE_MASK to read & regrid EUROPE_MASK from disk
        instead of just defining it as a rectangular box. (bmy, 10/18/06)
   26 Jan 2010 - R. Yantosca - Fixed cut-n-paste error.  Now make sure to zero
                               EMEP_CO_SHIP and EMEP_NOx_SHIP.
```

1.47.12 cleanup_emep

Subroutine CLEANUP_EMEP deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_EMEP
```

REVISION HISTORY:

```
   1 Nov 2005 - R. Yantosca - Initial Version
```

1.48 Fortran: Module Interface emissions_mod

Module EMISSIONS_MOD is used to call the proper emissions subroutines for the various GEOS-Chem simulations.

INTERFACE:

```
      MODULE EMISSIONS_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: DO_EMISSIONS
  !PUBLIC MEMBER DATA:
      !FP_ISOP (6/2009)
      PUBLIC :: ISOP_SCALING,NOx_SCALING
```

REVISION HISTORY:

```
11 Feb 2003 - R. Yantosca - Initial version
(1 ) Now references DEBUG_MSG from "error_mod.f"
(2 ) Now references "Kr85_mod.f" (jsw, bmy, 8/20/03)
(3 ) Now references "carbon_mod.f" and "dust_mod.f" (rjp, tdf, bmy, 4/2/04)
(4 ) Now references "seasalt_mod.f" (rjp, bmy, bec, 4/20/04)
(5 ) Now references "logical_mod" & "tracer_mod.f" (bmy, 7/20/04)
(6 ) Now references "epa_nei_mod.f" and "time_mod.f" (bmy, 11/5/04)
(7 ) Now references "emissions_mod.f" (bmy, 12/7/04)
(8 ) Now calls EMISSSULFATE if LCRYST=T.  Also read EPA/NEI emissions for
     the offline aerosol simulation. (bmy, 1/11/05)
(9 ) Remove code for the obsolete CO-OH param simulation (bmy, 6/24/05)
(10) Now references "co2_mod.f" (pns, bmy, 7/25/05)
(11) Now references "emep_mod.f" (bdf, bmy, 10/1/05)
(12) Now references "gfed2_biomass_mod.f" (bmy, 3/30/06)
(13) Now references "bravo_mod.f" (rjp, kfb, bmy, 6/26/06)
(14) Now references "edgar_mod.f" (avd, bmy, 7/6/06)
(15) Now references "streets_anthro_mod.f" (yxw, bmy, 8/18/06)
(16) Now references "h2_hd_mod.f" (lyj, phs, 9/18/07)
(17) Now calls EMISSDR for tagged CO simulation (jaf, mak, bmy, 2/14/08)
(18) Now references "cac_anthro_mod.f" (amv, phs, 03/11/08)
(19) Now references "vistas_anthro_mod.f" (amv, 12/02/08)
(20) Bug fixe : add specific calls for Streets for the grid 0.5x0.666.
     (dan, ccc, 3/11/09)
18 Dec 2009 - Aaron van D - Added emissions for nested grids @ 0.5 x 0.666
26 Fev 2010 - Fabien P.   - Add scaling for isoprene and Nox emissions
07 Feb 2011 - R. Yantosca - Now use EPA/NEI99 biofuel emissions when
                            EPA/NEI05 anthro emissions are selected.
```

1.48.1 do_emissions

Subroutine DO_EMISSIONS is the driver routine which calls the appropriate emissions subroutine for the various GEOS-CHEM simulations.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE DO_EMISSIONS(CHEM_STATE)
#else
      SUBROUTINE DO_EMISSIONS
#endif
```

USES:

```
      USE BIOMASS_MOD,            ONLY : COMPUTE_BIOMASS_EMISSIONS
      USE ARCTAS_SHIP_EMISS_MOD,  ONLY : EMISS_ARCTAS_SHIP
      USE BRAVO_MOD,              ONLY : EMISS_BRAVO
```

```
      USE C2H6_MOD,               ONLY : EMISSC2H6
      USE CAC_ANTHRO_MOD,         ONLY : EMISS_CAC_ANTHRO
      USE CAC_ANTHRO_MOD,         ONLY : EMISS_CAC_ANTHRO_05x0666
      USE CARBON_MOD,             ONLY : EMISSCARBON
      USE CH3I_MOD,               ONLY : EMISSCH3I
      USE CO2_MOD,                ONLY : EMISSCO2
      USE DUST_MOD,               ONLY : EMISSDUST
      USE EDGAR_MOD,              ONLY : EMISS_EDGAR
      USE EMEP_MOD,               ONLY : EMISS_EMEP
      USE EMEP_MOD,               ONLY : EMISS_EMEP_05x0666
      USE EPA_NEI_MOD,            ONLY : EMISS_EPA_NEI
      USE ERROR_MOD,              ONLY : DEBUG_MSG
      USE GLOBAL_CH4_MOD,         ONLY : EMISSCH4
      USE H2_HD_MOD,              ONLY : EMISS_H2_HD
      USE HCN_CH3CN_MOD,          ONLY : EMISS_HCN_CH3CN
      USE LOGICAL_MOD
      USE MERCURY_MOD,            ONLY : EMISSMERCURY
      USE NEI2005_ANTHRO_MOD,     ONLY : EMISS_NEI2005_ANTHRO
      USE NEI2005_ANTHRO_MOD,     ONLY : EMISS_NEI2005_ANTHRO_05x0666
      USE RETRO_MOD,              ONLY : EMISS_RETRO
      USE RnPbBe_MOD,             ONLY : EMISSRnPbBe
      USE SEASALT_MOD,            ONLY : EMISSSEASALT
      USE STREETS_ANTHRO_MOD,     ONLY : EMISS_STREETS_ANTHRO
      USE STREETS_ANTHRO_MOD,     ONLY : EMISS_STREETS_ANTHRO_05x0666
      USE SULFATE_MOD,            ONLY : EMISSSULFATE
      USE TIME_MOD,               ONLY : GET_MONTH,       GET_YEAR
      USE TIME_MOD,               ONLY : ITS_A_NEW_MONTH, ITS_A_NEW_YEAR
      USE TRACER_MOD
      USE TAGGED_CO_MOD,          ONLY : EMISS_TAGGED_CO
      USE VISTAS_ANTHRO_MOD,      ONLY : EMISS_VISTAS_ANTHRO
      USE ICOADS_SHIP_MOD,        ONLY : EMISS_ICOADS_SHIP !(cklee,7/09/09)
      USE PARANOX_MOD,            ONLY : READ_PARANOX_LUT
      USE SSA_BROMINE_MOD,        ONLY : EMIT_Br2          !jpp, 8/4/10

      USE CMN_SIZE_MOD                 ! Size parameters
      USE CMN_O3_MOD                   ! FSCLYR

#if defined( DEVEL )
      USE GC_TYPE_MOD ,           ONLY : GC_MET_LOCAL
      USE GC_TYPE2_MOD,           ONLY : CHEMSTATE, NULL
      USE TRACERID_MOD,           ONLY : IDTSO2, IDTC2H6
#endif
```

REVISION HISTORY:

(1) Now references DEBUG_MSG from "error_mod.f" (bmy, 8/7/03)
(2) Now calls Kr85 emissions if NSRCX == 12 (jsw, bmy, 8/20/03)
(3) Now calls EMISSCARBON and EMISSDUST for carbon aerosol and dust

```
      aerosol chemistry (rjp, tdf, bmy, 4/2/04)
(4 ) Now calls EMISSSEASALT for seasalt emissions (rjp, bec, bmy, 4/20/04)
(5 ) Now use inquiry functions from "tracer_mod.f".  Now references
      "logical_mod.f" (bmy, 7/20/04)
(6 ) Now references ITS_A_NEW_MONTH from "time_mod.f".  Now references
      EMISS_EPA_NEI from "epa_nei_mod.f" (bmy, 11/5/04)
(7 ) Now calls EMISSMERCURY from "mercury_mod.f" (eck, bmy, 12/7/04)
(8 ) Now calls EMISSSULFATE if LCRYST=T.  Also read EPA/NEI emissions for
      the offline sulfate simulation.  Also call EMISS_EPA_NEI for the
      tagged CO simulation. (cas, bmy, stu, 1/10/05).
(9 ) Now call EMISSSEASALT before EMISSSULFATE (bec, bmy, 4/13/05)
(10) Now call EMISS_HCN_CH3CN from "hcn_ch3cn_mod.f".   Also remove all
      references to the obsolete CO-OH param simulation. (xyp, bmy, 6/23/05)
(11) Now call EMISSCO2 from "co2_mod.f" (pns, bmy, 7/25/05)
(12) Now references EMISS_EMEP from "emep_mod.f" (bdf, bmy, 11/1/05)
(13) Now call GFED2_COMPUTE_BIOMASS to read 1x1 biomass emissions and
      regrid to the model resolution once per month. (bmy, 3/30/06)
(14) Now references EMISS_BRAVO from "bravo_mod.f" (rjp, kfb, bmy, 6/26/06)
(15) Now references EMISS_EDGAR from "edgar_mod.f" (avd, bmy, 7/6/06)
(16) Now references EMISS_STREETS_ANTHRO from "streets_anthro_mod.f"
      (yxw, bmy, 8/17/06)
(17) Now calls EMISSDR for tagged CO simulation (jaf, mak, bmy, 2/18/08)
(18) Now references EMISS_CAC_ANTHRO from "cac_anthro_mod.f"
      (amv, phs, 3/11/08)
(19) Now references EMISS_ARCTAS_SHIP from "arctas_ship_emiss_mod.f"
      (phs, 5/12/08)
(20) Now references EMISS_VISTAS_ANTHR from "vistas_anthro_mod.f". Call
      EMEP, and Streets every month (amv, 12/2/08)
(21) Now references EMISS_NEI2005_ANTHRO from "nei2005_anthro_mod.f"
      (amv, 10/19/09)
18 Dec 2009 - Aaron van D - Added emissions for nested grids @ 0.5 x 0.666
08 Feb 2010 - NBIOMAX is now in CMN_SIZE
07 Feb 2011 - R. Yantosca - Use NEI99 biofuels when useing NEI05 anthro
17 Aug 2011 - R. Yantosca - Added call to RETRO anthro emissions
07 Feb 2012 - M. Payer    - Added call to read PARANOX look up tables
22 Mar 2012 - M. Payer    - Added call to EMISSC2H6
```

1.49 Fortran: Module Interface fjx_acet_mod

Overview

This module contains functions used for the new acetone pressure dependency calculation in JRATET.f introduced in FAST-JX version 6.4 The temperature interpolation factors and the Xsect are different for both acetone photolysis reactions and interdependant. See use in JRATET.f

Reference

Blitz, M. A., D. E. Heard, M. J. Pilling, S. R. Arnold, M. P. Chipperfield 2004: *Pressure and temperature-dependent quantum yields for the photodissociation of acetone between 279 and 327.5 nm*, GRL, **31**, 9, L09104.

INTERFACE:

```
      MODULE FJX_ACET_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: QQ2_F
      PUBLIC :: QQ1_F
      PUBLIC :: TFACA_F
      PUBLIC :: TFAC0_F
      PUBLIC :: TFAC_F
```

AUTHOR:

```
  Original code from Michael Prather.
  Implemented into GEOS-Chem by Claire Carouge (ccarouge@seas.harvard.edu)
```

REVISION HISTORY:

```
  20 Apr 2009 - C. Carouge - Created the module from fastJX64.f code.
```

1.49.1 tfaca_f

Calculates temperature interpolation factors for acetone

INTERFACE:

```
      FUNCTION TFACA_F(TTT, IV)
  !USES
      USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD
```

INPUT PARAMETERS:

```
      ! Index of the specie in jv_spec.dat (should be between 4 and NJVAL)
      INTEGER :: IV

      ! Temperature in 1 grid box
      REAL*8  :: TTT
  !OUTPUT VALUE:
      ! Temperature interpolation factor
      REAL*8  :: TFACA_F
                                with the "D" double-precision exponent.
```

1.49.2 tfac0_f

Calculates temperature interpolation factors for acetone

INTERFACE:

```
      FUNCTION TFAC0_F(TTT, IV)
```

USES:

```
      USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD
```

INPUT PARAMETERS:

```
      ! Index of the specie in jv_spec.dat (should be between 4 and NJVAL)
      INTEGER :: IV

      ! Temperature in 1 grid box
      REAL*8  :: TTT
  !OUTPUT VALUE:
      ! Temperature interpolation factor
      REAL*8  :: TFAC0_F
```

1.49.3 tfac_f

Calculates temperature interpolation factors for acetone

INTERFACE:

```
      FUNCTION TFAC_F(TTT, IV)
```

USES:

```
      USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD
```

INPUT PARAMETERS:

```
      ! Index of the specie in jv_spec.dat (should be between 4 and NJVAL)
      INTEGER :: IV

      ! Temperature in 1 grid box
      REAL*8  :: TTT

  !OUTPUT VALUE:
      ! Temperature interpolation factor
      REAL*8  :: TFAC_F
```

1.49.4 qq2_f

This routine computes the cross-section for acetone.

INTERFACE:

```
FUNCTION QQ2_F(TFAC0, IV, K, TTT)
```

USES:

```
USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
USE JV_CMN_MOD
```

INPUT PARAMETERS:

```
! Index of the specie in jv_spec.dat (should be between 4 and NJVAL)
INTEGER :: IV

! Wavelength
INTEGER :: K

! Temperature in 1 grid box
REAL*8  :: TTT

! Temperature interpolation factor from TFAC0_F function
REAL*8  :: TFAC0
!OUTPUT VALUE:
! Xsect (total abs) for Acetone
REAL*8  :: QQ2_F
!NOTES:
 (1 ) We use IV-3 and not IV because there is no QQQ values for O2, O3
      and O1-D. (ccc, 4/20/19)
```

1.49.5 qq1_f

This routine computes the cross-section for acetone.

INTERFACE:

```
FUNCTION QQ1_F(TFAC, IV, K)
```

USES:

```
USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
USE JV_CMN_MOD
```

INPUT PARAMETERS:

```
! Index of the specie in jv_spec.dat (should be between 4 and NJVAL)
INTEGER :: IV
```

```
      ! Wavelength
      INTEGER :: K

      ! Temperature interpolation factor from TFAC_F function
      REAL*8  :: TFAC
  !OUTPUT VALUE:
      ! Xsect (total abs) for Acetone
      REAL*8  :: QQ1_F
  !NOTES:
   (1 ) We use IV-3 and not IV because there is no QQQ values for O2, O3
        and O1-D. (ccc, 4/20/19)
```

1.50 Fortran: Module Interface gamap_mod

Module GAMAP_MOD contains routines to create GAMAP "tracerinfo.dat" and "diaginfo.dat" files which are customized to each particular GEOS-Chem simulation.

INTERFACE:

```
      MODULE GAMAP_MOD
```

USES:

```
      USE CMN_SIZE_MOD             ! Dimensions of arrays
      USE CMN_DIAG_MOD             ! Diagnostic parameters

      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: DO_GAMAP
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: CREATE_DINFO
      PRIVATE :: CREATE_TINFO
      PRIVATE :: WRITE_TINFO
      PRIVATE :: WRITE_SEPARATOR
      PRIVATE :: INIT_DIAGINFO
      PRIVATE :: INIT_TRACERINFO
      PRIVATE :: INIT_GAMAP
      PRIVATE :: CLEANUP_GAMAP
```

REMARKS:

```
   For more information, please see the GAMAP Online Users' Manual:
    http://acmg.seas.harvard.edu/gamap/doc/index.html
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
(1 ) Minor bug fix for Rn/Pb/Be simulations (bmy, 5/11/05)
(2 ) Added ND09 diagnostic for HCN/CH3CN simulation. (bmy, 6/30/05)
(3 ) Added ND04 diagnostic for CO2 simulation (bmy, 7/25/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Add MBO to ND46 diagnostic (tmf, bmy, 10/20/05)
(6 ) Updated for tagged Hg simulation (cdh, bmy, 4/6/06)
(7 ) Updated for ND56 lightning flash diagnostics (ltm, bmy, 5/5/06)
(8 ) Updated for ND42 SOA concentration diagnostics (dkh, bmy, 5/22/06)
(9 ) Updated for ND36 CH3I simulation diagnostics (bmy, 7/25/06)
(10) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(11) Add routines INIT_DIAGINFO, INIT_TRACERINFO for clarity.  Added new
      entries for biomass burning (ND28) and time in tropopshere (ND54)
      in INIT_DIAGINFO and INIT_TRACERINFO. (phs, bmy, 10/17/06)
(12) Now write GPROD & APROD info to diaginfo.dat, tracerinfo.dat files,
      for the SOA restart files (tmf, havala, bmy, 2/6/07)
(13) Added ND10 diagnostic for H2/HD simulation. (phs, 9/18/07)
(14) Change category name for ND31 diagnostic (bmy, 11/16/07)
(15) Add to tracerinfo.dat file for timeseries and Rn-Pb-Be (bmy, 2/22/08)
(16) Added ND52 diagnostic for gamma HO2 (jaegle 02/26/09)
(17) Add gamap info for dicarbonyl simulation (tmf, 3/10/09)
(18) Add C2H4 in ND46 (ccc, 3/10/09)
(19) Add EFLUX to ND67 (lin, ccc, 5/29/09)
(20) Minor bug fixes (bmy, phs, 10/9/09)
(20) Minor bug fixes (dkh, bmy, 11/19/09)
(21) Include second satellite overpass diagnostic.  Adjust AOD name to 550
      nm from 400 nm.  Add additional dust AOD bins.  Output values to
      hdf_mod. (amv, bmy, 12/1/09)
03 Aug 2010 - R. Yantosca - Added ProTeX headers
03 Aug 2010 - R. Yantosca - Now move the #include "CMN_SIZE" and
                            #include "CMN_DIAG" to the top of module
13 Aug 2010 - R. Yantosca - Added modifications for MERRA
21 Sep 2010 - R. Yantosca - Removed duplicates in INIT_DIAGINFO
21 Oct 2010 - R. Yantosca - Bug fix in INIT_DIAGINFO
09 Dec 2010 - C. Carouge  - Modify MAXTRACER definition to account for
 8 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x
```

1.50.1 do_gamap

Subroutine DO_GAMAP is the driver program for creating the customized GAMAP files "diaginfo.dat" and "tracerinfo.dat".

INTERFACE:

```
SUBROUTINE DO_GAMAP( DIAGINFO, TRACERINFO )
```

USES:

```
USE TIME_MOD,   ONLY : SYSTEM_TIMESTAMP
USE TRACER_MOD, ONLY : GET_SIM_NAME
```

INPUT PARAMETERS:

```
CHARACTER(LEN=255), INTENT(IN) :: DIAGINFO    ! Path of "diaginfo.dat"
CHARACTER(LEN=255), INTENT(IN) :: TRACERINFO  ! Path of "tracerinfo.dat"
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
03 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.50.2 create_dinfo

Subroutine CREATE_DINFO writes information about diagnostic categories to a customized "diaginfo.dat" file. (bmy, 5/3/05)

INTERFACE:

```
SUBROUTINE CREATE_DINFO
```

USES:

```
USE FILE_MOD, ONLY : IOERROR, IU_FILE
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
03 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.50.3 create_tinfo

Subroutine CREATE_TINFO writes information about tracers to a customized tracerinfo.dat" file.

INTERFACE:

```
SUBROUTINE CREATE_TINFO
```

USES:

```
USE FILE_MOD,    ONLY : IOERROR, IU_FILE
USE LOGICAL_MOD, ONLY : LSOA
```

REVISION HISTORY:

```
21 Apr 2005 - R. Yantosca - Initial version
(1 ) Now write out tracers in ug/m3 (dkh, bmy, 5/22/06)
(2 ) Now write out GPROD & APROD info (tmf, havala, bmy, 2/6/07)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.50.4 write_tinfo

Subroutine WRITE_TINFO writes one line to the customized "tracerinfo.dat" file.

INTERFACE:

```
SUBROUTINE WRITE_TINFO( NAME, FNAME, MWT, MOLC, SCALE, UNIT, N )
```

USES:

```
USE FILE_MOD, ONLY : IU_FILE, IOERROR
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*), INTENT(IN) :: NAME    ! GAMAP short tracer name
CHARACTER(LEN=*), INTENT(IN) :: FNAME   ! GAMAP long tracer name
REAL*4,           INTENT(IN) :: MWT     ! Molecular weight [kg/mole]
INTEGER,          INTENT(IN) :: MOLC    ! Moles C/mole tracer (for HC's)
INTEGER,          INTENT(IN) :: N       ! Tracer number
REAL*4,           INTENT(IN) :: SCALE   ! GAMAP scale factor
CHARACTER(LEN=*), INTENT(IN) :: UNIT    ! Unit string
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
03 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.50.5 write_separator

Subroutine WRITE_SEPARATOR writes a separator block to the customized "tracerinfo.dat" file.

INTERFACE:

```
SUBROUTINE WRITE_SEPARATOR( DIAG )
```

USES:

```
USE FILE_MOD, ONLY : IU_FILE, IOERROR
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: DIAG   ! GEOS-Chem diagnostic number
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
06 Feb 2007 - R. Yantosca - Added new header for GPROD & APROD info
03 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.50.6 init_diaginfo

Subroutine INIT_DIAGINFO initializes the CATEGORY, DESCRIPT, and OFFSET variables, which are used to define the "diaginfo.dat" file for GAMAP.

INTERFACE:

```
SUBROUTINE INIT_DIAGINFO
```

REVISION HISTORY:

```
17 Oct 1996 - R. Yantosca - Initial version
(1 ) Split this code off from INIT_GAMAP, for clarity.  Now declare biomass
     burning emissions w/ offset of 45000.  Now declare time in the
     troposphere diagnostic with offset of 46000. (phs, bmy, 10/17/06)
(2 ) Now add IJ-GPROD & IJ-APROD w/ offset of SPACING*6, for the SOA
     GPROD & APROD restart file. (tmf, havala, bmy, 2/6/07)
(3 ) Now declare H2-HD sources w/ offset of 48000. Now declare H2-HD
     production/loss w/ offset of 47000. (phs, 9/18/07)
(4 ) Change diagnostic category for ND31 diagnostic from "PS-PTOP"
     to "PEDGE-$" (bmy, 11/16/07)
(5 ) Add categories CH4-LOSS, CH4-EMISS and WET-FRAC (kjw, 8/18/09)
(6 ) Add potential temperature category. (fp, 2/26/10)
21 May 2010 - C. Carouge  - Add diagnostic for mercury simulation
03 Aug 2010 - R. Yantosca - Added ProTeX headers
21 Sep 2010 - R. Yantosca - Remove duplicate definitions of CV-FLX-$,
                            TURBMC-$, EW-FLX-$, NS-FLX-$, UP-FLX-$
21 Oct 2010 - R. Yantosca - Bug fix: MC-FRC-$ should have an offset of
                            SPACING*3 since it has units of kg/s.
```

1.50.7 init_tracerinfo

Subroutine INIT_TRACERINFO initializes the NAME, FNAME, MWT, MOLC, INDEX, MOLC, UNIT arrays which are used to define the "tracerinfo.dat" file.

INTERFACE:

```
SUBROUTINE INIT_TRACERINFO
```

USES:

```
      USE DIAG03_MOD,   ONLY : ND03, PD03, PD03_PL
      USE DIAG04_MOD,   ONLY : ND04
      USE DIAG41_MOD,   ONLY : ND41
      USE DIAG42_MOD,   ONLY : ND42
      USE DIAG48_MOD,   ONLY : DO_SAVE_DIAG48
      USE DIAG49_MOD,   ONLY : DO_SAVE_DIAG49
      USE DIAG50_MOD,   ONLY : DO_SAVE_DIAG50
      USE DIAG51_MOD,   ONLY : DO_SAVE_DIAG51
      USE DIAG51b_MOD,  ONLY : DO_SAVE_DIAG51b
      USE DIAG56_MOD,   ONLY : ND56
      USE DIAG63_MOD,   ONLY:  DO_SAVE_DIAG63
      USE DIAG_PL_MOD,  ONLY : DO_SAVE_PL,  GET_NFAM
      USE DIAG_PL_MOD,  ONLY : GET_FAM_MWT, GET_FAM_NAME
      USE DRYDEP_MOD,   ONLY : DEPNAME,     NUMDEP,    NTRAIND
      USE LOGICAL_MOD,  ONLY : LSOA
      USE TRACER_MOD,   ONLY : ITS_A_CO2_SIM,    ITS_A_H2HD_SIM
      USE TRACER_MOD,   ONLY : ITS_A_CH3I_SIM,   ITS_A_FULLCHEM_SIM
      USE TRACER_MOD,   ONLY : ITS_A_HCN_SIM,    ITS_A_MERCURY_SIM
      USE TRACER_MOD,   ONLY : ITS_A_RnPbBe_SIM, ITS_A_TAGOX_SIM
      USE TRACER_MOD,   ONLY : N_TRACERS,        TRACER_COEFF
      USE TRACER_MOD,   ONLY : TRACER_MW_KG,     TRACER_NAME
      USE TRACERID_MOD, ONLY : IDTBCPI, IDTOCPI, IDTALPH, IDTLIMO
      USE TRACERID_MOD, ONLY : IDTSOA1, IDTSOA2, IDTSOA3, NEMANTHRO
      !(hotp, 7/31/08)
      USE TRACERID_MOD, ONLY : IDTSOA4, IDTSOAM, IDTSOAG, IDTSOA5
      USE TRACERID_MOD, ONLY : IDTGLYX, IDTMGLY, IDTC2H4, IDTC2H2
      USE TRACERID_MOD, ONLY : IDTGLYC, IDTHAC
      USE WETSCAV_MOD,  ONLY : GET_WETDEP_IDWETD, GET_WETDEP_NSOL
      !(FP, 6/2009) To remove hard-wired for biomass burning
      USE TRACERID_MOD, ONLY : IDBNOX,  IDBCO,   IDBALK4, IDBACET
      USE TRACERID_MOD, ONLY : IDBMEK,  IDBALD2, IDBPRPE, IDBC3H8
      USE TRACERID_MOD, ONLY : IDBCH2O, IDBC2H6
      USE TRACERID_MOD, ONLY : IDBSO2,  IDBNH3
      USE TRACERID_MOD, ONLY : IDBBC,   IDBOC
      USE TRACERID_MOD, ONLY : IDBXYLE, IDBBENZ, IDBTOLU
      USE TRACERID_MOD, ONLY : IDBGLYX, IDBMGLY, IDBC2H4, IDBC2H2
      USE TRACERID_MOD, ONLY : IDBGLYC, IDBHAC
      USE TRACERID_MOD, ONLY : IDTNOX,  IDTCO,   IDTALK4, IDTACET
      USE TRACERID_MOD, ONLY : IDTMEK,  IDTALD2, IDTPRPE, IDTC3H8
      USE TRACERID_MOD, ONLY : IDTCH2O, IDTC2H6
      USE TRACERID_MOD, ONLY : IDTSO2,  IDTNH3
      USE TRACERID_MOD, ONLY : IDTBCPI,   IDTOCPI
      USE TRACERID_MOD, ONLY : IDTXYLE, IDTBENZ, IDTTOLU
      USE TRACERID_MOD, ONLY : N_Hg_CATS  !CDH for snowpack
```

REVISION HISTORY:

```
17 Oct 1996 - R. Yantosca & P. Le Sager - Initial version
```

```
(1 ) Split this code off from INIT_GAMAP, for clarity.  Also now declare
     biomass burning emissions w/ offset of 45000.  Bug fix: write out
     26 tracers for ND48, ND49, ND50, ND51 timeseries.  Also define
     ND54 diagnostic with offset of 46000. (bmy, 10/17/06)
(2 ) Modifications for H2/HD in ND10, ND44 diagnostics (phs, 9/18/07)
(3 ) Now write out PBLDEPTH diagnostic information to "tracerinfo.dat" if
     any of ND41, ND48, ND49, ND50, ND51 are turned on.  Also set the
     unit to "kg/s" for the Rn-Pb-Be ND44 drydep diag. (cdh, bmy, 2/22/08)
(4 ) Added C2H4 in ND46 (ccc, 2/2/09)
(5 ) Add EFLUX to ND67 (lin, ccc, 5/29/08)
(6 ) Bug fix in ND28: ALD2 should have 2 carbons, not 3.  Also bug fix
     in ND66 to print out the name of ZMMU correctly. (dbm, bmy, 10/9/09)
(7 ) Previous bug fix was erroneous; now corrected (dkh, bmy, 11/19/09)
(8 ) Include second satellite overpass diagnostic.  Adjust AOD name to 550
     nm from 400 nm.  Add additional dust AOD bins (amv, bmy, 12/18/09)
20 Jul 2010 - C. Carouge  - Modifications to ND03 for mercury.
03 Aug 2010 - R. Yantosca - Added ProTeX headers
13 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
02 Sep 2010 - R. Yantosca - In ND28: Omit SOA tracers if LSOA = .FALSE.
09-Dec-2010 - H. Amos     - Added RGM and PBM  tracers for the
                            mercury simulation
09-Dec-2010 - H. Amos     - fix spacing and #s for PL-HG2-$ diagnostics
12 Nov 2010 - R. Yantosca - Need to save out surface pressure line to
                            tracerinfo.dat for the timeseries diagnostics
24 Jan 2012 - M. Payer    - Change scale factors for Rn-Pb-Be simulation so
                            units are in mBq/SCM
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
19 Mar 2012 - M. Payer    - Remove ACETdl and ACETgr from ND11 diagnostic.
                            Acetone from dry leaf matter and grasses is now
                            included in the direct emissions (ACETbg).
                            (E. Fischer)
```

1.50.8 init_gamap

Subroutine INIT_GAMAP allocates and initializes all module variables.

INTERFACE:

```
SUBROUTINE INIT_GAMAP( DIAGINFO, TRACERINFO )
```

USES:

```
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE TIME_MOD,    ONLY : EXPAND_DATE, GET_NHMSb, GET_NYMDb
USE LOGICAL_MOD, ONLY : LND50_HDF,   LND51_HDF, LND51b_HDF
USE HDF_MOD,     ONLY : INIT_HDF
USE HDF_MOD,     ONLY : HDFCATEGORY
USE HDF_MOD,     ONLY : HDFDESCRIPT
```

```
USE HDF_MOD,     ONLY : HDFNAME
USE HDF_MOD,     ONLY : HDFFNAME
USE HDF_MOD,     ONLY : HDFUNIT
USE HDF_MOD,     ONLY : HDFMOLC
USE HDF_MOD,     ONLY : HDFMWT
USE HDF_MOD,     ONLY : HDFSCALE
```

INPUT PARAMETERS:

```
CHARACTER(LEN=255), INTENT(IN) :: DIAGINFO    ! Path for "diaginfo.dat"
CHARACTER(LEN=255), INTENT(IN) :: TRACERINFO  ! Path for "tracerinfo.dat"
```

REVISION HISTORY:

```
22 Apr 2005 - R. Yantosca - Initial version
(1 ) Now add proper UNIT & SCALE for Rn/Pb/Be simulations (bmy, 5/11/05)
(2 ) Added HCN & CH3CN source & sink info for ND09 (bmy, 6/27/05)
(3 ) Bug fix: removed duplicate category names.  Updated for CO2-SRCE
     diagnostic.  Now references ND04 from "diag04_mod.f.
     (pns, bmy, 7/25/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Now save MBO as tracer #5 for ND46 (tmf, bmy, 10/20/05)
(6 ) Now add categories CV-FLX-$, TURBMC-$, EW-FLX-$, NS-FLX-$, UP-FLX-$
     which had been inadvertently omitted.  Also add OCEAN-HG category.
     Rewrote do loop and case statement to add new diagnostics to ND03.
     Now make units of Hg tracers "pptv", not "ppbv".  Now remove
     restriction on printing out cloud mass flux in GEOS-4 for the ND66
     diagnostic.  Added new sea salt category. (cdh, eck, bmy, 4/6/06)
(7 ) Now references ND56 from "diag56_mod.f" (ltm, bmy, 5/5/06)
(8 ) Now references ND42 from "diag42_mod.f".  Also updated for extra SOA
     tracers in ND07 diagnostic. (dkh, bmy, 5/22/06)
(9 ) Updated ND36 for CH3I simulation (bmy, 7/25/06)
(10) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(11) Split into INIT_DIAGINFO, INIT_TRACERINFO for clarity (bmy, 9/28/06)
(12) Save output to HDF_MOD (amv, bmy, 12/18/09)
03 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.50.9 cleanup_gamap

Subroutine CLEANUP_GAMAP deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_GAMAP
```

REVISION HISTORY:

```
25 Apr 2005 - R. Yantosca - Initial version
03 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.51 Fortran: Module Interface geos57_read_mod

Module GEOS57_READ_MOD contains subroutines for reading the GEOS-5.7.2 data from disk (in netCDF format).

INTERFACE:

```
MODULE Geos57_Read_Mod
```

USES:

```
  ! NcdfUtil modules for netCDF I/O
  USE m_netcdf_io_open                    ! netCDF open
  USE m_netcdf_io_get_dimlen              ! netCDF dimension queries
  USE m_netcdf_io_read                    ! netCDF data reads
  USE m_netcdf_io_close                   ! netCDF close

  ! GEOS-Chem modules
  USE CMN_SIZE_MOD                        ! Size parameters
  USE CMN_GCTM_MOD                        ! Physical constants
  USE CMN_DIAG_MOD                        ! Diagnostic arrays & counters
  USE DIAG_MOD,      ONLY : AD66          ! Array for ND66 diagnostic
  USE DIAG_MOD,      ONLY : AD67          ! Array for ND67 diagnostic
  USE DIRECTORY_MOD                       ! Directory paths
  USE ERROR_MOD,     ONLY : ERROR_STOP    ! Stop w/ error message
  USE TIME_MOD                            ! Date & time routines
  USE TRANSFER_MOD                        ! Routines for casting

  IMPLICIT NONE
  PRIVATE

# include "netcdf.inc"                    ! Include file for netCDF library
```

PRIVATE MEMBER FUNCTIONS:

```
  PRIVATE :: Check_Dimensions
  PRIVATE :: Geos57_Read_A3cld
  PRIVATE :: Geos57_Read_A3dyn
  PRIVATE :: Geos57_Read_A3mstC
  PRIVATE :: Geos57_Read_A3mstE
  PRIVATE :: Get_Resolution_String
```

PUBLIC MEMBER FUNCTIONS:

```
  PUBLIC  :: Geos57_Read_CN
  PUBLIC  :: Geos57_Read_A1
  PUBLIC  :: Geos57_Read_A3
  PUBLIC  :: Geos57_Read_I3_1
  PUBLIC  :: Geos57_Read_I3_2
```

REMARKS:

```
Assumes that you have a netCDF library (either v3 or v4) installed on
your system.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
03 Feb 2012 - R. Yantosca - Add Geos57_Read_A3 wrapper function
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Add function Get_Resolution_String
05 Apr 2012 - R. Yantosca - Convert units for specific humidity properly
```

1.51.1 get_resolution_string

Function Get_Resolution_String returns the proper filename extension for the GEOS-Chem horizontal grid resolution. This is used to construct the various file names.

INTERFACE:

```
FUNCTION Get_Resolution_String() RESULT( resString )
```

USES:

```
#   include "define.h"
```

RETURN VALUE:

```
CHARACTER(LEN=255) :: resString
```

REVISION HISTORY:

```
10 Feb 2012 - R. Yantosca - Initial version
```

1.51.2 check_dimensions

Subroutine CHECK_DIMENSIONS checks to see if dimensions read from the netCDF file match the defined GEOS-Chem dimensions. If not, then it will stop the GEOS-Chem simulation with an error message.

INTERFACE:

```
SUBROUTINE Check_Dimensions( lon, lat, lev, time, time_expected, caller )
```

INPUT PARAMETERS:

```
INTEGER,          OPTIONAL, INTENT(IN)  :: lon            ! Lon dimension
INTEGER,          OPTIONAL, INTENT(IN)  :: lat            ! Lat dimension
INTEGER,          OPTIONAL, INTENT(IN)  :: lev            ! Alt dimension
INTEGER,          OPTIONAL, INTENT(IN)  :: time           ! Time dimension
INTEGER,          OPTIONAL, INTENT(IN)  :: time_expected  ! Expected # of
```

```
                                                          !  time slots
  CHARACTER(LEN=*), OPTIONAL, INTENT(IN)  :: caller       ! Name of caller
                                                          !  routine
```

REMARKS:

```
Call this routine with keyword arguments, e.g
   CALL CHECK_DIMENSION( lon=X,  lat=Y,           lev=Z,         &
                         time=T, time_expected=8, caller=caller )
```

REVISION HISTORY:

```
02 Feb 2012 - R. Yantosca - Initial version
03 Feb 2012 - R. Yantosca - Now pass the caller routine name as an argument
```

1.51.3 geos57_read_cn

Routine to read variables and attributes from a GEOS-5.7.2 met fields file containing constant (CN) data.

INTERFACE:

```
SUBROUTINE Geos57_Read_CN()
```

USES:

```
 USE DAO_MOD, ONLY : FRLAKE
 USE DAO_MOD, ONLY : FRLAND
 USE DAO_MOD, ONLY : FRLANDIC
 USE DAO_MOD, ONLY : FROCEAN
 USE DAO_MOD, ONLY : PHIS
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

Even though the netCDF file is self-describing, the GEOS-5.7.2 data,
dimensions, and units are pre-specified according to the GMAO GEOS-5.7.2
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
```

1.51.4 geos57_read_a1

Routine to read variables and attributes from a GEOS-5.7.2 met fields file containing 1-hr time-averaged (A1) data.

INTERFACE:

```
SUBROUTINE Geos57_Read_A1( YYYYMMDD, HHMMSS )
```

USES:

```
USE DAO_MOD, ONLY : ALBEDO   => ALBD
USE DAO_MOD, ONLY : CLDTOT   => CLDFRC
USE DAO_MOD, ONLY : EFLUX
USE DAO_MOD, ONLY : EVAP
USE DAO_MOD, ONLY : FRSEAICE
USE DAO_MOD, ONLY : FRSNO
USE DAO_MOD, ONLY : GRN
USE DAO_MOD, ONLY : GWETROOT
USE DAO_MOD, ONLY : GWETTOP
USE DAO_MOD, ONLY : HFLUX
USE DAO_MOD, ONLY : LAI
USE DAO_MOD, ONLY : LWI
USE DAO_MOD, ONLY : LWGNT    => RADLWG
USE DAO_MOD, ONLY : PARDF
USE DAO_MOD, ONLY : PARDR
USE DAO_MOD, ONLY : PBLH     => PBL
USE DAO_MOD, ONLY : PRECANV  => PREANV
USE DAO_MOD, ONLY : PRECCON  => PRECON
USE DAO_MOD, ONLY : PRECLSC  => PRELSC
USE DAO_MOD, ONLY : PRECSNO
USE DAO_MOD, ONLY : PRECTOT  => PREACC
USE DAO_MOD, ONLY : SEAICE00
USE DAO_MOD, ONLY : SEAICE10
USE DAO_MOD, ONLY : SEAICE20
USE DAO_MOD, ONLY : SEAICE30
USE DAO_MOD, ONLY : SEAICE40
USE DAO_MOD, ONLY : SEAICE50
USE DAO_MOD, ONLY : SEAICE60
USE DAO_MOD, ONLY : SEAICE70
USE DAO_MOD, ONLY : SEAICE80
USE DAO_MOD, ONLY : SEAICE90
USE DAO_MOD, ONLY : SLP
USE DAO_MOD, ONLY : SNODP
USE DAO_MOD, ONLY : SNOMAS
USE DAO_MOD, ONLY : SWGDN    => RADSWG
USE DAO_MOD, ONLY : SWGNT    => RADSWG
USE DAO_MOD, ONLY : TROPPT   => TROPP
USE DAO_MOD, ONLY : T2M      => TS
USE DAO_MOD, ONLY : TS       => TSKIN
```

```
USE DAO_MOD, ONLY : U10M
USE DAO_MOD, ONLY : USTAR
USE DAO_MOD, ONLY : V10M
USE DAO_MOD, ONLY : Z0M      => Z0
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: YYYYMMDD    ! GMT date in YYYY/MM/DD format
INTEGER, INTENT(IN) :: HHMMSS      ! GMT time in hh:mm:ss   format
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

.

Even though the netCDF file is self-describing, the GEOS-5.7.2 data,
dimensions, and units are pre-specified according to the GMAO GEOS-5.7.2
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.

.

Special handling for surface precipitation fields:
-------------------------------------------------------------------------
In GEOS-5.7.x (and in MERRA), the PRECTOT etc. surface precipitation
met fields fields have units of [kg/m2/s].  In all other GEOS
versions, PREACC and PRECON have units of [mm/day].

.

Therefore, for backwards compatibility with existing code, apply
the following unit conversion to the GEOS-5 PRECTOT and PRECCON
fields:

.

   kg  |    m3    | 86400 s | 1000 mm
 ------+----------+---------+--------- = 86400
  m2 s |  1000 kg |  day    |   m
           ^
           |
     1 / density of water
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
```

1.51.5 geos57_read_a3

Convenience wrapper for the following routines which read 3-hour time averaged data from disk:

- Geos57_Read_A3cld

- Geos57_Read_A3dyn
- Geos57_Read_A3mstC
- Geos57_Read_A3mstE

INTERFACE:

```
SUBROUTINE Geos57_Read_A3( YYYYMMDD, HHMMSS )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: YYYYMMDD       ! GMT date in YYYY/MM/DD format
INTEGER, INTENT(IN) :: HHMMSS         ! GMT time in hh:mm:ss   format
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
```

1.51.6 geos57_read_a3cld

Routine to read variables and attributes from a GEOS-5.7.2 met fields file containing 3-hr time-averaged (A3) data (cloud fields).

INTERFACE:

```
SUBROUTINE Geos57_Read_A3cld( YYYYMMDD, HHMMSS )
```

USES:

```
USE DAO_MOD, ONLY : CLOUD    => CLDF
USE DAO_MOD, ONLY : OPTDEPTH => OPTDEP
USE DAO_MOD, ONLY : QI
USE DAO_MOD, ONLY : QL
USE DAO_MOD, ONLY : TAUCLI
USE DAO_MOD, ONLY : TAUCLW
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: YYYYMMDD    ! GMT date in YYYY/MM/DD format
INTEGER, INTENT(IN) :: HHMMSS      ! GMT time in hh:mm:ss   format
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

Even though the netCDF file is self-describing, the GEOS-5.7.2 data,
dimensions, and units are pre-specified according to the GMAO GEOS-5.7.2
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
05 Apr 2012 - R. Yantosca - Fixed bug: TAUCLI was overwritten w/ TAUCLW
```

1.51.7 geos57_read_a3dyn

Routine to read variables and attributes from a GEOS-5.7.2 met fields file containing 3-hr time-averaged (A3) data (dynamics fields).

INTERFACE:

```
SUBROUTINE GEOS57_READ_A3dyn( YYYYMMDD, HHMMSS )
```

USES:

```
 USE DAO_MOD, ONLY : CLDTOPS
 USE DAO_MOD, ONLY : CMFMC
 USE DAO_MOD, ONLY : DTRAIN
!USE DAO_MOD, ONLY : OMEGA
 USE DAO_MOD, ONLY : RH
 USE DAO_MOD, ONLY : U      => UWND
 USE DAO_MOD, ONLY : V      => VWND
```

INPUT PARAMETERS:

```
 INTEGER, INTENT(IN) :: YYYYMMDD    ! GMT date in YYYY/MM/DD format
 INTEGER, INTENT(IN) :: HHMMSS      ! GMT time in hh:mm:ss   format
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

Even though the netCDF file is self-describing, the GEOS-5.7.2 data,
dimensions, and units are pre-specified according to the GMAO GEOS-5.7.2
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
```

1.51.8 geos57_read_a3mstc

Routine to read variables and attributes from a GEOS-5.7.2 met fields file containing 3-hr time-averaged (A3) data (moist fields, saved on level centers).

INTERFACE:

```
SUBROUTINE GEOS57_READ_A3mstC( YYYYMMDD, HHMMSS )
```

USES:

```
USE DAO_MOD, ONLY : DQRCU
USE DAO_MOD, ONLY : DQRLSAN
USE DAO_MOD, ONLY : REEVAPCN
USE DAO_MOD, ONLY : REEVAPLS
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: YYYYMMDD    ! GMT date in YYYY/MM/DD format
INTEGER, INTENT(IN) :: HHMMSS      ! GMT time in hh:mm:ss   format
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

Even though the netCDF file is self-describing, the GEOS-5.7.2 data,
dimensions, and units are pre-specified according to the GMAO GEOS-5.7.2
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
```

1.51.9 geos57_read_a3mste

Routine to read variables and attributes from a GEOS-5.7.2 met fields file containing 3-hr time-averaged (A3) data (moist fields, saved on level edges).

INTERFACE:

```
SUBROUTINE GEOS57_READ_A3mstE( YYYYMMDD, HHMMSS )
```

USES:

```
USE DAO_MOD, ONLY : PFICU
USE DAO_MOD, ONLY : PFILSAN
USE DAO_MOD, ONLY : PFLCU
USE DAO_MOD, ONLY : PFLLSAN
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: YYYYMMDD    ! GMT date in YYYY/MM/DD format
INTEGER, INTENT(IN) :: HHMMSS      ! GMT time in hh:mm:ss   format
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

Even though the netCDF file is self-describing, the GEOS-5.7.2 data,
dimensions, and units are pre-specified according to the GMAO GEOS-5.7.2
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
```

1.51.10 geos57_read_I3_1

Routine to read variables and attributes from a GEOS-5.7.2 met fields file containing 3-hr instantaneous (I3) data.

INTERFACE:

```
SUBROUTINE Geos57_Read_I3_1( YYYYMMDD, HHMMSS )
```

USES:

```
 USE DAO_MOD, ONLY : PS1
!USE DAO_MOD, ONLY : PV1
 USE DAO_MOD, ONLY : QV1 => SPHU1
 USE DAO_MOD, ONLY : T1  => TMPU1
```

INPUT PARAMETERS:

```
 INTEGER, INTENT(IN) :: YYYYMMDD    ! GMT date in YYYY/MM/DD format
 INTEGER, INTENT(IN) :: HHMMSS      ! GMT time in hh:mm:ss   format
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

Even though the netCDF file is self-describing, the GEOS-5.7.2 data,
dimensions, and units are pre-specified according to the GMAO GEOS-5.7.2
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
05 Apr 2012 - R. Yantosca - Now convert QV1 from [kg/kg] to [g/kg]
```

1.51.11 geos57_read_I3_2

Routine to read variables and attributes from a GEOS-5.7.2 met fields file containing 3-hr instantaneous (I3) data.

INTERFACE:

```
SUBROUTINE Geos57_Read_I3_2( YYYYMMDD, HHMMSS )
```

USES:

```
 USE DAO_MOD, ONLY : PS2
!USE DAO_MOD, ONLY : PV2
 USE DAO_MOD, ONLY : QV2 => SPHU2
 USE DAO_MOD, ONLY : T2  => TMPU2
```

INPUT PARAMETERS:

```
 INTEGER, INTENT(IN) :: YYYYMMDD    ! GMT date in YYYY/MM/DD format
 INTEGER, INTENT(IN) :: HHMMSS      ! GMT time in hh:mm:ss   format
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

Even though the netCDF file is self-describing, the GEOS-5.7.2 data,
dimensions, and units are pre-specified according to the GMAO GEOS-5.7.2
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
05 Apr 2012 - R. Yantosca - Now convert QV2 from [kg/kg] to [g/kg]
```

1.52 Fortran: Module Interface gfed3_biomass_mod

Module GFED3_BIOMASS_MOD contains routines and variables used to incorporate GFED3 emissions into GEOS-Chem

INTERFACE:

```
      MODULE GFED3_BIOMASS_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: GFED3_COMPUTE_BIOMASS
      PUBLIC  :: CLEANUP_GFED3_BIOMASS
      PUBLIC  :: GFED3_IS_NEW
   PRIVATE MEMBER FUNCTIONS:
      PRIVATE :: CHECK_GFED3
      PRIVATE :: GFED3_AVAILABLE
      PRIVATE :: GFED3_SCALE_FUTURE
      PRIVATE :: GFED3_TOTAL_Tg
      PRIVATE :: INIT_GFED3_BIOMASS
      PRIVATE :: REARRANGE_BIOM
      PRIVATE :: READ_BPCH2_GFED3
```

REMARKS:

Monthly emissions of DM are read from disk,
multiplied by daily and 3hourly fractions (if necessary), and then
multiplied by the appropriate emission factors to produce biomass
burning emissions on the GFED3 0.5x0.5 degree grid The emissions are
then regridded to the current GEOS-Chem or GCAP grid (1x1, 2x25, or 4x5).

.

GFED3 biomass burning emissions are computed for the following gas-phase
and aerosol-phase species:

.

(1) NOx	[molec/cm2/s]	(13) BC	[atoms C/cm2/s]
(2) CO	[molec/cm2/s]	(14) OC	[atoms C/cm2/s]
(3) ALK4	[atoms C/cm2/s]	(15) GLYX	[molec/cm2/s]
(4) ACET	[atoms C/cm2/s]	(16) MGLY	[molec/cm2/s]
(5) MEK	[atoms C/cm2/s]	(17) BENZ	[atoms C/cm2/s]
(6) ALD2	[atoms C/cm2/s]	(18) TOLU	[atoms C/cm2/s]
(7) PRPE	[atoms C/cm2/s]	(19) XYLE	[atoms C/cm2/s]
(8) C3H8	[atoms C/cm2/s]	(20) C2H4	[atoms C/cm2/s]
(9) CH2O	[molec/cm2/s]	(21) C2H2	[atoms C/cm2/s]
(10) C2H6	[atoms C/cm2/s]	(22) GLYC	[molec/cm2/s]
(11) SO2	[molec/cm2/s]	(23) HAC	[molec/cm2/s]
(12) NH3	[molec/cm2/s]	(24) CO2	[molec/cm2/s]

.

References:

==========

(1) Original GFED3 database from Guido van der Werf
http://www.falw.vu/~gwerf/GFED/GFED3/emissions/

(2) Giglio, L., Randerson, J. T., van der Werf, G. R., Kasibhatla, P. S., Collatz, G. J., Morton, D. C., and DeFries, R. S.: Assessing variability and long-term trends in burned area by merging multiple satellite fire products, Biogeosciences, 7, 1171-1186, doi:10.5194/bg-7-1171-2010, 2010.

(3) van der Werf, G. R., Randerson, J. T., Giglio, L., Collatz, G. J., Mu, M., Kasibhatla, P. S., Morton, D. C., DeFries, R. S., Jin, Y.,

```
and van Leeuwen, T. T.: Global fire emissions and the contribution of
deforestation, savanna, forest, agricultural, and peat fires
(19972009), Atmos. Chem. Phys., 10, 11707-11735,
doi:10.5194/acp-10-11707-2010, 2010.
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
14 Feb 2012 - M. Payer      - Add modifications for CH4 (K. Wecht)
01 Mar 2012 - R. Yantosca   - Now reference new grid_mod.F90
06 Mar 2012 - P. Kasibhatla - Final version
```

1.52.1 gfed3_is_new

Function GFED3_IS_NEW returns TRUE if GFED3 emissions have been updated.

INTERFACE:

```
FUNCTION GFED3_IS_NEW( ) RESULT( IS_UPDATED )
```

RETURN VALUE:

```
LOGICAL :: IS_UPDATED    ! =T if GFED3 is updated; =F otherwise
```

REMARKS:

```
Called from carbon_mod.f and sulfate_mod.f
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
```

1.52.2 check_gfed3

Subroutine CHECK_GFED3 checks if we entered a new GFED period since last emission timestep (ie, last call). The result depends on the emissions time step, and the GFED time period used, as well as MMDDHH at beginning of the GEOS-Chem run

INTERFACE:

```
SUBROUTINE CHECK_GFED3( DOY, HH )
```

USES:

```
USE LOGICAL_MOD, ONLY : LDAYBB3
USE LOGICAL_MOD, ONLY : L3HRBB3
USE TIME_MOD,    ONLY : ITS_A_NEW_MONTH
USE TIME_MOD,    ONLY : ITS_A_NEW_DAY
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: DOY   ! Day of year (0-365 or 0-366 leap years)
INTEGER, INTENT(IN) :: HH    ! Hour of day (0-23)
```

REMARKS:

```
The routine computes the DOY (resp. HOUR) at start of the 1-day (resp.
3-hour) period we are in, if the 1-day (resp. 3-hr ) GFED3
option is on. Result is compared to previous value to indicate if new
data should be read.
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
06 Mar 2012 - P. Kasibhatla - final GFED3 version
```

1.52.3 gfed3_available

Function GFED3_AVAILABLE checks an input YYYY year and MM month against the available data dates. If the requested YYYY and MM lie outside of the valid range of dates, then GFED3_AVAILABLE will return the last valid YYYY and MM.

INTERFACE:

```
SUBROUTINE GFED3_AVAILABLE( YYYY, YMIN, YMAX, MM, MMIN, MMAX )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)              :: YMIN, YMAX   ! Min & max years
INTEGER, INTENT(IN),    OPTIONAL :: MMIN, MMAX   ! Min & max months
```

INPUT/OUTPUT PARAMETERS:

```
INTEGER, INTENT(INOUT)           :: YYYY         ! Year of GFED3 data
INTEGER, INTENT(INOUT), OPTIONAL :: MM           ! Month of GFED3 data
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
```

1.52.4 gfed3_compute_biomass

Subroutine GFED3_COMPUTE_BIOMASS computes the monthly GFED3 biomass burning emissions for a given year and month.

INTERFACE:

```
      SUBROUTINE GFED3_COMPUTE_BIOMASS( THIS_YYYY, THIS_MM, BIOM_OUT )
```

USES:

```
      USE BPCH2_MOD,        ONLY : GET_TAU0
      USE DIRECTORY_MOD,    ONLY : DATA_DIR_NATIVE => DATA_DIR_1x1
      USE JULDAY_MOD,       ONLY : JULDAY
      USE JULDAY_MOD,       ONLY : CALDATE
      USE LOGICAL_MOD,      ONLY : LFUTURE
      USE LOGICAL_MOD,      ONLY : LDAYBB3
      USE LOGICAL_MOD,      ONLY : L3HRBB3
      USE LOGICAL_MOD,      ONLY : LGFED3BB
      USE TIME_MOD,         ONLY : EXPAND_DATE
      USE TIME_MOD,         ONLY : TIMESTAMP_STRING
      USE TIME_MOD,         ONLY : GET_DAY
      USE TIME_MOD,         ONLY : GET_HOUR
      USE TIME_MOD,         ONLY : GET_DAY_OF_YEAR
      USE TIME_MOD,         ONLY : ITS_A_LEAPYEAR
      USE GLOBAL_GRID_MOD, ONLY : GET_XEDGE_G
      USE GLOBAL_GRID_MOD, ONLY : GET_YEDGE_G
      USE GRID_MOD,         ONLY : GET_XEDGE
      USE GRID_MOD,         ONLY : GET_YEDGE
      USE GRID_MOD,         ONLY : GET_XOFFSET
      USE GRID_MOD,         ONLY : GET_YOFFSET
      USE ERROR_MOD,        ONLY : ALLOC_ERR
      USE REGRID_A2A_MOD,   ONLY : MAP_A2A

      USE CMN_SIZE_MOD                                          ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: THIS_YYYY                         ! Current year
      INTEGER, INTENT(IN)  :: THIS_MM                           ! Current month
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: BIOM_OUT(IIPAR,JJPAR,NBIOMAX)  ! BB emissions
                                                                ! [molec/cm2/s]
```

REMARKS:

```
    This routine has to be called on EVERY emissions-timestep if you use one
    of the GFED3 options.
```

REVISION HISTORY:

```
    07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
    07 Sep 2011 - R. Yantosca   - Added ProTeX headers
    03 May 2012 - M. Payer      - Now use 3D indices for grid_mod.F90 routines
                                  GET_XEDGE and GET_YEDGE. Nested grids still
```

```
use 1D indices for routines GET_XEDGE_G and
GET_YEDGE_G found in global_grid_mod.90. This
will maintain grid-independent functionality.
```

1.52.5 gfed3_scale_future

Subroutine GFED3_SCALE_FUTURE applies the IPCC future emissions scale factors to the GFED3 biomass burning emisisons in order to compute the future emissions of biomass burning for NOx, CO, and VOC's.

INTERFACE:

```
SUBROUTINE GFED3_SCALE_FUTURE( BB )
```

USES:

```
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_BCbb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_CObb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_NH3bb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_NOxbb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_OCbb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_SO2bb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_VOCbb
USE TRACER_MOD,             ONLY : ITS_A_CO2_SIM
USE TRACER_MOD,             ONLY : ITS_A_CH4_SIM
USE TRACERID_MOD,           ONLY : IDBNOx,  IDBCO,   IDBSO2
USE TRACERID_MOD,           ONLY : IDBNH3,  IDBBC,   IDBOC

USE CMN_SIZE_MOD                 ! Size parameters
```

OUTPUT PARAMETERS:

```
!  Array w/ biomass burning emisisons [molec/cm2]
REAL*8, INTENT(INOUT) :: BB(IIPAR,JJPAR,N_SPEC)
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
```

1.52.6 gfed3_total_Tg

Subroutine GFED3_TOTAL_Tg prints the amount of biomass burning emissions that are emitted each month/day/3-hr in Tg or Tg C.

INTERFACE:

```
SUBROUTINE GFED3_TOTAL_Tg
```

USES:

```
USE GRID_MOD,    ONLY : GET_AREA_CM2

USE CMN_SIZE_MOD      ! Size parameters
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

1.52.7 init_gfed3_biomass

Subroutine INIT_GFED3_BIOMASS allocates all module arrays. It also reads the emission factors at the start of a GEOS-Chem simulation.

INTERFACE:

```
SUBROUTINE INIT_GFED3_BIOMASS
```

USES:

```
USE DIRECTORY_MOD,   ONLY : DATA_DIR_NATIVE => DATA_DIR_1x1
USE ERROR_MOD,       ONLY : ALLOC_ERR
USE FILE_MOD,        ONLY : IOERROR
USE FILE_MOD,        ONLY : IU_FILE
USE LOGICAL_MOD,     ONLY : LDICARB
USE LOGICAL_MOD,     ONLY : LDAYBB3
USE LOGICAL_MOD,     ONLY : L3HRBB3
USE TRACERID_MOD,    ONLY : IDBNOx,  IDBCO,   IDBALK4
USE TRACERID_MOD,    ONLY : IDBACET, IDBMEK,  IDBALD2
USE TRACERID_MOD,    ONLY : IDBPRPE, IDBC3H8, IDBCH2O
USE TRACERID_MOD,    ONLY : IDBC2H6, IDBBC,   IDBOC
USE TRACERID_MOD,    ONLY : IDBSO2,  IDBNH3,  IDBCO2
USE TRACERID_MOD,    ONLY : IDBGLYX, IDBMGLY, IDBBENZ
USE TRACERID_MOD,    ONLY : IDBTOLU, IDBXYLE, IDBC2H4
USE TRACERID_MOD,    ONLY : IDBC2H2, IDBGLYC, IDBHAC
USE TRACERID_MOD,    ONLY : IDBCH4   !kjw
USE GLOBAL_GRID_MOD, ONLY : GET_IIIPAR
USE GLOBAL_GRID_MOD, ONLY : GET_JJJPAR

USE CMN_SIZE_MOD          ! Size parameters
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
```

1.52.8 rearrange_biom

Subroutine REARRANGE_BIOM takes GFED3 emissions (which have their own, unique ID numbers and associates them with the IDBxxxs of tracerid_mod.F.

INTERFACE:

```
SUBROUTINE REARRANGE_BIOM( BIOM_OUT, BIOM_OUTM )
```

USES:

```
USE CMN_SIZE_MOD     ! Size parameters
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN)  :: BIOM_OUT (IIPAR,JJPAR,N_SPEC)
```

OUTPUT PARAMETERS:

```
REAL*8, INTENT(OUT) :: BIOM_OUTM(IIPAR,JJPAR,NBIOMAX) !+1 from CO2
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
```

1.52.9 cleanup_gfed3_biomass

Subroutine CLEANUP_GFED3_BIOMASS deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_GFED3_BIOMASS
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
```

1.52.10 read_bpch2_gfed3

Subroutine READ_BPCH2_GFED3 reads GFED3 DM burnt and and humid tropical forest map files

INTERFACE:

```
 SUBROUTINE READ_BPCH2_GFED3( FILENAME, CATEGORY_IN, TRACER_IN,
&                             TAU0_IN,  IX,          JX,
&                             LX,       ARRAY,       QUIET )
```

USES:

```
      USE ERROR_MOD, ONLY : ERROR_STOP
      USE FILE_MOD,  ONLY : IU_FILE, IOERROR
      USE BPCH2_MOD, ONLY : OPEN_BPCH2_FOR_READ

#     include "define.h"
```

INPUT PARAMETERS:

```
      CHARACTER(LEN=*),  INTENT(IN)  :: FILENAME         ! Bpch file to read
      CHARACTER(LEN=*),  INTENT(IN)  :: CATEGORY_IN      ! Diag. category name
      INTEGER,           INTENT(IN)  :: TRACER_IN        ! Tracer index #
      REAL*8,            INTENT(IN)  :: TAU0_IN          ! TAU timestamp
      INTEGER,           INTENT(IN)  :: IX, JX, LX       ! Dimensions of ARRAY
      LOGICAL, OPTIONAL, INTENT(IN)  :: QUIET            ! Don't print output
```

OUTPUT PARAMETERS:

```
      REAL*4,            INTENT(OUT) :: ARRAY(IX,JX,LX)  ! Data array from file
```

REVISION HISTORY:

```
    (1 ) Adapted from READ_BPCH2 to facilitate reading of 0.5x0.5 GFED3 files (psk, 2/7/12)
```

1.53 Fortran: Module Interface global_Br_mod

Module GLOBAL_Br_MOD contains variables and routines for reading the global monthly mean Br concentration from disk.

INTERFACE:

```
      MODULE GLOBAL_Br_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      ! Array to store global monthly mean BR field
      REAL*8, PUBLIC, ALLOCATABLE :: BR_TROP(:,:,:)
      REAL*8, PUBLIC, ALLOCATABLE :: BR_STRAT(:,:,:)
      REAL*8, PUBLIC, ALLOCATABLE :: BR_MERGE(:,:,:)

      ! Array to store global monthly mean BrO field
      REAL*8, PUBLIC, ALLOCATABLE :: BRO_TROP(:,:,:)
```

```
REAL*8, PUBLIC, ALLOCATABLE :: BRO_STRAT(:,:,:)
REAL*8, PUBLIC, ALLOCATABLE :: BRO_MERGE(:,:,:)

! Array to store global monthly J-BrO field
REAL*8, PUBLIC, ALLOCATABLE :: J_BRO(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
! Remove obsolete routine
!PUBLIC :: GET_GLOBAL_Br_NEW
PUBLIC :: GET_GLOBAL_Br
PUBLIC :: INIT_GLOBAL_Br
PUBLIC :: CLEANUP_GLOBAL_Br
```

REVISION HISTORY:

```
05 Jul 2006 - C. Holmes   - Copied from "global_oh_mod.f"
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.53.1 get_global_Br

Subroutine GET_GLOBAL_Br reads global Br from binary punch files stored in the /data/ctm/GEOS_MEAN directory. This Br data is needed as oxidant for mercury chemistry.

INTERFACE:

```
! Rename to GET_GLOBAL_Br
!SUBROUTINE GET_GLOBAL_Br_NEW( THISMONTH )
SUBROUTINE GET_GLOBAL_Br( THISMONTH )
```

USES:

```
!USE LOGICAL_MOD,    ONLY : LVARTROP     ! Comment this out for now
USE BPCH2_MOD,      ONLY : GET_NAME_EXT
USE BPCH2_MOD,      ONLY : GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0
USE BPCH2_MOD,      ONLY : READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR ! cdh
USE TRANSFER_MOD,   ONLY : TRANSFER_3D
USE TRANSFER_MOD,   ONLY : TRANSFER_3D_TROP
USE TROPOPAUSE_MOD, ONLY : GET_TPAUSE_LEVEL

USE CMN_SIZE_MOD                ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH   ! Current month
```

REMARKS:

```
THIS IS A NEW VERSION OF THIS SUBROUTINE WHICH COMBINES Br CONCENTRATIONS
FROM MULTIPLE DATA SOURCES
```

REVISION HISTORY:

```
05 Jul 2006 - C. Holmes   - Copied from "global_oh_mod.f"
(1 ) GET_GLOBAL_BR assumes that we are reading global BR data that occupies
      all CTM levels.  Contact Bob Yantosca (bmy@io.harvard.edu) for IDL
      regridding code which will produce the appropriate BR files.
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.53.2 init_global_Br

Subroutine INIT_GLOBAL_Br allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_Br
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
05 Jul 2006 - C. Holmes   - Copied from "global_oh_mod.f"
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.53.3 cleanup_global_Br

Subroutine CLEANUP_GLOBAL_Br deallocates module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_Br
```

REVISION HISTORY:

```
05 Jul 2006 - C. Holmes   - Copied from "global_oh_mod.f"
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.54 Fortran: Module Interface global_ch4_mod

Module GLOBAL_CH4_MOD contains variables and routines for simulating CH4 chemistry in the troposphere (jsw, bnd, bmy, 1/17/01,10/1/09)

INTERFACE:

```
      MODULE GLOBAL_CH4_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CH4_AVGTP
      PUBLIC :: EMISSCH4
      PUBLIC :: CHEMCH4
      PUBLIC :: INIT_GLOBAL_CH4
      PUBLIC :: CLEANUP_GLOBAL_CH4
```

PUBLIC DATA MEMBERS:

```
      REAL*8, PARAMETER,   PUBLIC :: XNUMOL_CH4 = 6.0221d23 / 16d-3
      REAL*8, ALLOCATABLE, PUBLIC :: TCH4(:,:,:,:)
```

REVISION HISTORY:

```
(1 ) Merged routines from jsw's CH4 code  into "global_ch4_mod.f"
     (bmy, 1/16/01)
(2 ) XNUMOL_CH4 and TCH4 have to be public - all other variables can
     be made private, so as not to conflict with other common-block
     definitions (bmy, 1/17/01)
(3 ) Minor fixes from jsw added (jsw, bmy, 2/17/01)
(4 ) Removed some F90 module references from EMISSCH4 (bmy, 3/20/01)
(5 ) Eliminate obsolete commented-out code (bmy, 4/20/01)
(6 ) Updated comments (bmy, 9/4/01)
(7 ) Fixes for binary punch file in READ_COPROD (bmy, 9/26/01)
(8 ) Removed obsolete code from READ_COPROD (bmy, 10/24/01)
(9 ) Minor bug fixes for compilation on ALPHA (bmy, 11/15/01)
(10) Eliminate obsolete code from 11/01 (bmy, 2/27/02)
(11) Now eliminate PS from the arg list to CH4_AVGTP (4/11/02)
(12) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
     MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(13) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(14) Now reference "file_mod.f".  Also removed obsolete code. (bmy, 6/27/02)
(15) Now references "pressure_mod.f" (bmy, 8/21/02)
(16) Now reference AD and T from "dao_mod.f".  Now reference "error_mod.f".
```

```
      Remove obsolete code from various routines.  Remove reference to
      header file "comtrid.h" -- it's not used. (bmy, 11/6/02)
(17) Minor bug fix in FORMAT statements (bmy, 3/23/03)
(18) Now references "grid_mod.f" and "time_mod.f" (bmy, 3/27/03)
(19) Updates to GET_GLOBAL_CH4 (bmy, 7/1/03)
(20) Now references "directory_mod.f", "tracer_mod.f", and "diag_oh_mod.f"
      (bmy, 7/20/04)
(21) Now can read data for both GEOS and GCAP grids (bmy, 8/16/05)
(22) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(23) Updated CH4 simulation (kjw, cph, ccarouge, 10/1/09)
(24) Added modifications for MERRA (bmy, 8/13/10)
08 Feb 2012 - R. Yantosca - Added modifications for GEOS-5.7.x
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.1 ch4_avgtp

Subroutine CH4_AVGTP gets the 24-h average surface pressure and temperature needed for the CH4 simulation. (jsw, bnd, bmy, 1/16/01, 7/20/04)

INTERFACE:

```
SUBROUTINE CH4_AVGTP
```

USES:

```
USE DAO_MOD,      ONLY : T
USE ERROR_MOD,    ONLY : GEOS_CHEM_STOP
USE PRESSURE_MOD, ONLY : GET_PCENTER
USE TIME_MOD,     ONLY : GET_TS_DYN, GET_TS_CHEM, GET_ELAPSED_MIN

USE CMN_SIZE_MOD       ! Size parameters
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry and
      placed into module "global_ch4_mod.f" by Bob Yantosca. (bmy, 1/16/01)
(2 ) CH4_AVGTP is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
      (bmy, 1/16/01)
(3 ) Removed duplicate definition for NTDT, NMIN (bmy, 11/15/01)
(4 ) Removed PS from argument list.  Now use P(I,J)+PTOP instead of
      PS, this ensures that we have consistency between P and AD.
      (bmy, 4/11/02)
(5 ) Removed obsolete code (bmy, 6/27/02)
(6 ) Now uses GET_PCENTER from "pressure_mod.f" to return the pressure
      at the midpoint of the box (I,J,L).  Also added parallel DO-loops.
      Updated comments. (dsa, bdf, bmy, 8/21/02)
```

```
(7 ) Now reference T from "dao_mod.f".  Now reference GEOS_CHEM_STOP from
     "error_mod.f" (bmy, 10/15/02)
(8 ) Removed NTDT, NMIN from the arg list.  Now uses functions GET_TS_DYN,
     GET_TS_CHEM, and GET_ELAPSED_MIN from "time_mod.f" (bmy, 3/27/03)
(9 ) Remove reference to CMN, it's not needed (bmy, 7/20/04)
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.2 emissch4

Subroutine EMISSCH4 places emissions of CH4 [kg] into the STT array. (jsw, bnd, bey, bmy, 1/16/01, 10/3/05)

INTERFACE:

```
SUBROUTINE EMISSCH4
```

USES:

```
USE TIME_MOD,      ONLY : ITS_A_NEW_MONTH, ITS_A_NEW_YEAR
USE TIME_MOD,      ONLY : GET_MONTH,       GET_YEAR
USE TIME_MOD,      ONLY : GET_TS_EMIS
USE GRID_MOD,      ONLY : GET_AREA_CM2,    GET_XOFFSET
USE GRID_MOD,      ONLY : GET_YOFFSET
USE TRACER_MOD,    ONLY : STT
USE LOGICAL_MOD,   ONLY : LSPLIT
USE DIAG_MOD,      ONLY : AD58
USE ERROR_MOD,     ONLY : GEOS_CHEM_STOP,  IT_IS_NAN
USE TRACER_MOD,    ONLY : N_TRACERS, ID_TRACER
USE LOGICAL_MOD,   ONLY : LWETL,           LBMCH4,       LRICE
USE LOGICAL_MOD,   ONLY : LBFCH4
USE VDIFF_PRE_MOD, ONLY : EMIS_SAVE ! (ccc, 08/31/09)
USE LOGICAL_MOD,   ONLY : LNLPBL    ! (ccc, 08/31/09)


USE CMN_SIZE_MOD        ! Size parameters
USE CMN_DIAG_MOD        ! Diagnostic switches
```

REMARKS:

```
WARNING: Soil absorption has to be the 11th field in CH4_EMIS
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
     James Wang (7/00).  Inserted into module "global_ch4_mod.f"
     by Bob Yantosca. (bmy, 1/16/01)
(2 ) EMISSCH4 is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
```

```
      (bmy, 1/16/01)
(3 ) GLOBASEAEMIS, GLOBSEAEMIS are diagnostics by jsw.
(4 ) Do not multiply CO emissions by 1.28 anymore (jsw, bmy, 2/12/01)
(5 ) Renamed input files to CH4_monthly.geos.{RES} and
      CH4_aseasonal.geos.{RES}. (bmy, 2/12/01)
(6 ) Add reference to "CMN_SETUP" for the DATA_DIR variable (bmy, 2/13/01)
(7 ) Removed references to "biofuel_mod.f" and "biomass_mod.f"; these
      weren't necessary (bmy, 3/20/01)
(8 ) Now reference IU_FILE and IOERROR from "file_mod.f".  Now use IU_FILE
      instead of IUNIT as the file unit #. (bmy, 6/27/02)
(9 ) Now reference BXHEIGHT and SUNCOS from "dao_mod.f".  Remove reference
      to header file "comtrid.h" -- it's not used.  Make FIRSTEMISS a local
      SAVEd variable.  Also use MONTH from "CMN" instead of the variable
      LMN. (bmy, 11/15/02)
(10) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid_mod.f".
      Now use function GET_MONTH and GET_TS_EMIS from "time_mod.f".
      Now use functions GET_XOFFSET and GET_YOFFSET from "grid_mod.f".
      I0 and J0 are now local variables. (bmy, 3/27/03)
(11) Now reference STT from "tracer_mod.f".  Now reference DATA_DIR from
      "directory_mod.f". (bmy, 7/20/04)
(12) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(13) Add non-local PBL capability (ccc, 8/31/09)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.3 wetland_emis

Subroutine WETLAND_EMIS calculates emissions of CH4 [kg] by Wetland. For a description of the GEOS-Chem wetland CH4 emission routine, see a paper titled, "Magnitude and trends of wetland methane emissions from the Hudson Bay Lowlands (Canada)" by C. Pickett-Heaps

INTERFACE:

```
SUBROUTINE WETLAND_EMIS
```

USES:

```
USE DAO_MOD,       ONLY : GWETTOP,      LWI
USE DAO_MOD,       ONLY : TSKIN,        TS
USE DAO_MOD,       ONLY : FRLAND,       FRLAKE
USE DAO_MOD,       ONLY : FROCEAN,      FRLANDIC
USE BPCH2_MOD,     ONLY : GET_RES_EXT,  GET_MODELNAME
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_NAME_EXT_2D
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IU_FILE,      IOERROR
USE GRID_MOD,      ONLY : GET_AREA_M2
```

```
      USE TIME_MOD,      ONLY : GET_MONTH,    GET_YEAR,    GET_TS_EMIS
      USE TIME_MOD,      ONLY : ITS_A_NEW_MONTH, ITS_A_NEW_YEAR
      USE TRANSFER_MOD,  ONLY : TRANSFER_2D
      USE DIAG_MOD,      ONLY : AD60, AD58

      USE CMN_SIZE_MOD        ! Size parameters
      USE CMN_DIAG_MOD        ! Diagnostic switches
```

REVISION HISTORY:

```
    (1 ) Adapted by Jrme Drevet (3/06) from the BIOME-TG Wetland-Methane
         scheme provided by Jed O. Kaplan.
    (2 ) CH4 Emissions from Wetland depend on:
   a - Soil Carbon content.
   b - Vegetation type
   c - Wetland area (%)
   d - Soil moisture.
         a, b, c are taken from the LPJ, a vegetation model. Data are provided
   by J.O.Kaplan. Soil moisture is read from GEOS Met input files.
    (3 ) Corrected order of DO loops (bmy, 10/1/09)
    08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
    07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.4 bioburn_emis

Subroutine BIOBURN_EMIS calculates CH4 emissions from GFED2 or GFED3 biomass burning. (kjw, 6/03/09)

INTERFACE:

```
      SUBROUTINE BIOBURN_EMIS
```

USES:

```
      USE BIOMASS_MOD,      ONLY : BIOMASS
      USE LOGICAL_MOD,      ONLY : LGFED2BB,      LGFED3BB
      USE TRACERID_MOD,     ONLY : IDBCH4
      USE CMN_SIZE_MOD,     ONLY : IIPAR, JJPAR
```

REVISION HISTORY:

```
    03 Jun 2009 - K. Wecht    - The code used to read, scale & regrid emissions
                                is from SUBROUTINE GFED2_COMPUTE_BIOMASS in
                                gfed2_biomass_mod.f
    14 Feb 2012 - M. Payer    - Now obtain emissions from BIOMASS array. Also
                                update for GFED3 (K. Wecht)
    07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.5 rice_emis

Subroutine RICE_EMIS calculates CH4 emissions from rice and places CH4 [kg] into the STT array. (kjw, 6/03/09)

INTERFACE:

```
SUBROUTINE RICE_EMIS
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_RES_EXT,  GET_MODELNAME
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_NAME_EXT_2D
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE GRID_MOD,      ONLY : GET_AREA_CM2
USE TIME_MOD,      ONLY : GET_MONTH,    GET_YEAR
USE LOGICAL_MOD,   ONLY : LSPLIT
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD        ! Size parameters
USE CMN_DIAG_MOD        ! Diagnostic switches
```

REMARKS:

```
Rice Emissions are scaled to GEOS soil wetness.  Scaling sceme developed
   and implemented by Jerome Drevet.
Wetland emissions are modified by the presence of rice emissions.  Sceme
   developed by Jerome Drevet.
```

REVISION HISTORY:

```
(1 ) CH4 emissions from rice calculated with a routine created by Jerome
     Drevet.  Adapted as its own subroutine by Kevin Wecht (6/03/09)
(2 ) Corrected ordering of DO loops (bmy, 10/1/09)
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.6 aseasonal_anthro_emis

Subroutine ASEASONAL_ANTHRO_EMIS reads CH4 emissions from anthropogenic sources. (kjw, 6/03/09)

INTERFACE:

```
SUBROUTINE ASEASONAL_ANTHRO_EMIS
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_RES_EXT,  GET_MODELNAME
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D
      USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE TIME_MOD,      ONLY : GET_YEAR
      USE TRANSFER_MOD,  ONLY : TRANSFER_2D
      USE LOGICAL_MOD,   ONLY : LGAO,         LCOL,         LLIV
      USE LOGICAL_MOD,   ONLY : LWAST,        LOTANT, LBFCH4

      USE CMN_SIZE_MOD        ! Size parameters
      USE CMN_DIAG_MOD        ! Diagnostic switches
```

REMARKS:

Aseasonal anthropogenic emissions currently include EDGAR v4 categories that are not called in their own subroutines. Current emission categories read in this subroutine are: gas & oil, coal, livestock, waste, and other anthropogenic sources.

REVISION HISTORY:

07 Mar 2012 - M. Payer - Added ProTeX headers

1.54.7 aseasonal_natural_emis

Subroutine ASEASONAL_NATURAL_EMIS reads CH4 emissions from natural sources. (kjw, 6/03/09)

INTERFACE:

```
      SUBROUTINE ASEASONAL_NATURAL_EMIS
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_RES_EXT,    GET_MODELNAME
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D
      USE BPCH2_MOD,     ONLY : GET_TAU0,       READ_BPCH2
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE TIME_MOD,      ONLY : GET_YEAR
      USE TRANSFER_MOD,  ONLY : TRANSFER_2D
      USE LOGICAL_MOD,   ONLY : LSOABS,         LOTNAT

      USE CMN_SIZE_MOD        ! Size parameters
      USE CMN_DIAG_MOD        ! Diagnostic switches
```

REMARKS:

```
Aseasonal natural emissions currently include termites (Fung et. al. 1991)
and soil absorption (Fung et. al. 1991).  Future additions may include
emissions from permafrost, clathrates, thermokarst lakes, or
geothermal vents.
```

REVISION HISTORY:

```
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.8 chemch4

Subroutine CHEMCH4 computes the chemical loss of CH4 (sources - sinks). (jsw, bnd, bmy, 6/8/00, 10/3/05)

INTERFACE:

```
SUBROUTINE CHEMCH4
```

USES:

```
USE DAO_MOD,       ONLY : AD
USE DIAG_MOD,      ONLY : AD43
USE DIRECTORY_MOD, ONLY : DATA_DIR, OH_DIR
USE ERROR_MOD,     ONLY : GEOS_CHEM_STOP, IT_IS_NAN, IT_IS_FINITE
USE GLOBAL_OH_MOD, ONLY : GET_GLOBAL_OH, OH
USE TIME_MOD,      ONLY : GET_DAY, GET_MONTH, GET_NYMDb, GET_NYMDe
USE TIME_MOD,      ONLY : GET_TAU, GET_YEAR
USE BPCH2_MOD,     ONLY : GET_TAU0, READ_BPCH2, GET_MODELNAME
USE TRANSFER_MOD,  ONLY : TRANSFER_2D
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE TRACER_MOD,    ONLY : STT
USE LOGICAL_MOD,   ONLY : LSPLIT, LCH4BUD
USE TIME_MOD,      ONLY : ITS_A_NEW_MONTH

USE CMN_SIZE_MOD        ! Size parameters
USE CMN_DIAG_MOD        ! ND43, AD43
USE CMN_MOD             ! LPAUSE
```

REMARKS:

```
CH4 SOURCES
============================================================================
(1 ) Oxidation of methane, isoprene and monoterpenes (SRCO_fromHCs).
(2 ) Direct emissions of CO from fossil fuel combustion, biomass
      burning and wood (for fuel) burning (SR SETEMIS).
(3 ) Emissions.
```

.

```
CH4 SINKS:
============================================================================
(1 ) Removal of CO by OH (SR OHparam & CO_decay).
(2 ) CO uptake by soils (neglected).
(3 ) Transport of CO to stratosphere from troposphere
      (in dynamical subroutines).
(4 ) Removal by OH (Clarissa's OH--climatol_OH.f and CO_decay.f)
(5 ) Transport of CH4 between troposphere and stratosphere, and
      destruction in strat (CH4_strat.f).
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
      James Wang (6/8/00).  Inserted into module "global_ch4_mod.f"
      by Bob Yantosca. (bmy, 1/16/01)
(2 ) CHEMCH4 is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
      (bmy, 1/16/01)
(3 ) Updated comments (jsw, bmy, 2/12/01)
(4 ) LD43 is already declared in CMN_DIAG; don't redefine it (bmy, 11/15/01)
(5 ) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
      to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(6 ) Now reference AD from "dao_mod.f".  Now reference GEOS_CHEM_STOP from
      "error_mod.f"  Now make FIRSTCHEM a local SAVEd variable.  Now
      reference ALBD from "dao_mod.f".  Now use MONTH and JDATE from "CMN"
      instead of LMN and LDY. (bmy, 11/15/02)
(7 ) Remove NYMDb, NYMDe from the arg list.  Now use functions GET_MONTH,
      GET_NYMDb, GET_NYMDe, GET_MONTH, GET_DAY from the new "time_mod.f"
      (bmy, 3/27/03)
(8 ) Now reference DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(9 ) Remove reference to BPCH2_MOD, it's not needed (bmy, 10/3/05)
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.9 read_coprod

Subroutine READ_COPROD reads production and destruction rates for CO in the stratosphere. CO destruction rate is assumed equal to CH4 production rate for the GEOS-Chem CH4 simulation. (bnd, bmy, 1/17/01, 10/3/05)

INTERFACE:

```
SUBROUTINE READ_COPROD
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
USE BPCH2_MOD,     ONLY : GET_NAME_EXT,    GET_MODELNAME
```

```
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE TRANSFER_MOD,  ONLY : TRANSFER_ZONAL

      USE CMN_SIZE_MOD        ! Size parameters

      IMPLICIT NONE
#     include "define.h"
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
     James Wang (6/8/00).  Inserted into module "global_ch4_mod.f"
     by Bob Yantosca. (bmy, 1/16/01)
(2 ) READ_COPROD is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
     (bmy, 1/16/01)
(3 ) ARRAY needs to be dimensioned (1,JJPAR,LGLOB) (bmy, 9/26/01)
(4 ) Remove obsolete code from 9/01 (bmy, 10/24/01)
(5 ) Now reference DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(6 ) Now reads data for both GEOS and GCAP grids (bmy, 8/16/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Treat MERRA in the same way as for GEOS-5 (bmy, 8/13/10)
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.10 read_ch4loss

Subroutine READ_CH4LOSS reads CH4 loss frequencies in the stratosphere. These values constitute a linearized stratospheric CH4 chemistry scheme. Loss frequencies from 4x5 degree output from the GMI model. Thanks to Lee Murray for the ch4 loss frequencies. (kjw, 11/19/2011)

INTERFACE:

```
      SUBROUTINE READ_CH4LOSS
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
      USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT,    GET_MODELNAME
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE TRANSFER_MOD,  ONLY : TRANSFER_3D

      USE CMN_SIZE_MOD        ! Size parameters

      IMPLICIT NONE
#     include "define.h"
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
      James Wang (6/8/00).  Inserted into module "global_ch4_mod.f"
      by Bob Yantosca. (bmy, 1/16/01)
(2 ) READ_CH4LOSS is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
      (bmy, 1/16/01)
(3 ) ARRAY needs to be dimensioned (1,JJPAR,LGLOB) (bmy, 9/26/01)
(4 ) Remove obsolete code from 9/01 (bmy, 10/24/01)
(5 ) Now reference DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(6 ) Now reads data for both GEOS and GCAP grids (bmy, 8/16/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Treat MERRA in the same way as for GEOS-5 (bmy, 8/13/10)
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.11 ch4_decay

Subroutine CH4_DECAY calculates the decay rate of CH4 by OH. OH is the only sink for CH4 considered here. (jsw, bnd, bmy, 1/16/01, 7/20/04)

INTERFACE:

```
SUBROUTINE CH4_DECAY
```

USES:

```
USE DAO_MOD,    ONLY : AIRVOL, T
USE TIME_MOD,   ONLY : GET_TS_CHEM, ITS_A_NEW_YEAR, GET_MONTH
USE TRACER_MOD, ONLY : STT
USE DIAG_MOD,   ONLY : AD19

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! ND19
USE CMN_MOD          ! STT, LPAUSE
```

REMARKS:

```
The annual mean tropopause is stored in the LPAUSE array
(from header file "CMN").  LPAUSE is defined such that:

                                                                             .
Levels            1 <= L <= LPAUSE(I,J) - 1 are tropospheric
       LPAUSE(I,J) <= L <= LLPAR            are stratospheric
                                                                             .
We now use LPAUSE instead of NSKIPL to denote the strat/trop boundary.
(bmy, 4/18/00)
                                                                             .
Monthly loss of CH4 is summed in TCH4(3)
   TCH4(3)  = CH4 sink by OH
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
      James Wang (7/00).  Inserted into module "global_ch4_mod.f"
      by Bob Yantosca. (bmy, 1/16/01)
(2 ) CH4_DECAY is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
      (bmy, 1/16/01)
(3 ) Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(4 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.12 ch4_ohsave

Subroutine CH4_OHSAVE archives the CH3CCl3 lifetime from the OH used in the CH4 simulation. (bnd, jsw, bmy, 1/16/01, 7/20/04)

INTERFACE:

```
SUBROUTINE CH4_OHSAVE
```

USES:

```
! References to F90 modules
USE DIAG_OH_MOD, ONLY : DO_DIAG_OH_CH4
USE TIME_MOD,    ONLY : GET_MONTH
USE DAO_MOD,     ONLY : T

USE CMN_SIZE_MOD      ! Size parameters
USE CMN_MOD           ! LPAUSE
```

REMARKS:

```
The annual mean tropopause is stored in the LPAUSE array
(from header file "CMN").  LPAUSE is defined such that:

Levels            1 <= L <= LPAUSE(I,J) - 1 are tropospheric
        LPAUSE(I,J) <= L <= LLPAR           are stratospheric
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
      James Wang (7/00).  Inserted into module "global_ch4_mod.f"
      by Bob Yantosca. (bmy, 1/16/01)
(2 ) CH4_OHSAVE is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
      (bmy, 1/16/01)
(3 ) Now call DO_DIAG_OH_CH4 to pass OH diagnostic info to the
      "diag_oh_mod.f" (bmy, 7/20/04)
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.13 ch4_strat

Subroutine CH4_STRAT calculates uses production rates for CH4 to calculate loss of CH4 in above the tropopause. (jsw, bnd, bmy, 1/16/01, 7/20/04)

INTERFACE:

```
SUBROUTINE CH4_STRAT
```

USES:

```
USE DAO_MOD,    ONLY : AIRVOL
USE TIME_MOD,   ONLY : GET_MONTH, GET_TS_CHEM
USE TRACER_MOD, ONLY : STT, CHECK_STT

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_MOD          ! STT, LPAUSE
```

REMARKS:

```
Production (mixing ratio/sec) rate provided by Dylan Jones.
Only production by CH4 + OH is considered.

The annual mean tropopause is stored in the LPAUSE array
(from header file "CMN").  LPAUSE is defined such that:

Levels           1 <= L <= LPAUSE(I,J) - 1 are tropospheric
       LPAUSE(I,J) <= L <= LLPAR           are stratospheric (bmy, 4/18/00)
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
      James Wang (7/00).  Inserted into module "global_ch4_mod.f"
      by Bob Yantosca. (bmy, 1/16/01)
(2 ) CH4_STRAT is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
      (bmy, 1/16/01)
(3 ) Removed LMN from the arg list and made it a local variable.  Now use
      functions GET_MONTH and GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(4 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.14 ch4_budget

Subroutine CH4_BUDGET calculates the budget of CH4. This SR only works for monthly averages, so be sure to start on the first of the month and run to another first of the month! (jsw, bnd, bmy, 1/16/01, 10/3/05)

INTERFACE:

```
      SUBROUTINE CH4_BUDGET
```

USES:

```
      USE BPCH2_MOD,  ONLY : BPCH2,       BPCH2_HDR,   GET_MODELNAME
      USE GRID_MOD,   ONLY : GET_XOFFSET, GET_YOFFSET
      USE TIME_MOD,   ONLY : GET_MONTH,   GET_YEAR
      USE TIME_MOD,   ONLY : GET_DIAGb,   GET_CT_DYN
      USE TRACER_MOD, ONLY : STT

      USE CMN_SIZE_MOD     ! Size parameters
      USE CMN_MOD          ! STT, LPAUSE
```

REMARKS:

```
    Store the sources/sinks of CH4 in TCH4 in total molecules
             ( 1) = Initial burden
             ( 2) = Final burden
    SINKS
             ( 3) = Tropospheric CH4 sink by OH
    SOURCES
             ( 4) = Total Sources
             ( 5) = Industrial  ( Gas + Oil + Mine )
             ( 6) = Agriculture ( Enteric fermentation + Manure + Rice + Waste
                                + Waste water )
             ( 7) = Biomass burning
             ( 8) = Termites
             ( 9) = Wetland
             (10) = Soil absorption
             (11) = Interhemispheric Exchange (+ = northward)
```

REVISION HISTORY:

```
    (1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
         James Wang (7/00).  Inserted into module "global_ch4_mod.f"
         by Bob Yantosca. (bmy, 1/16/01)
    (2 ) CH4_BUDGET is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
         (bmy, 1/16/01)
    (3 ) Updated comments (jsw, bmy, 2/13/01)
    (4 ) Renamed XLABEL to LABEL so as not to conflict w/ "CMN"
    (5 ) Now use functions GET_MONTH, GET_YEAR, GET_DIAGb, and GET_CT_DYN from
         "time_mod.f".  Removed LMN from the arg list and made it a local
         variable.  Use functions GET_XOFFSET and GET_YOFFSET from
         "grid_mod.f".  (bmy, 3/27/03)
    (6 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
    (7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (8 ) Modified for the run with new emissions (j drevet, 03/06)
    07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.15 sum_ch4

Function SUM_CH4 sums a section of the TCH4 array bounded by the input variables I1, I2, J1, J2, L1, L2, K1, K2. SUM_CH4 is called by module subroutine CH4_BUDGET. (jsw, bnd, bmy, 1/16/01)

INTERFACE:

```
REAL*8 FUNCTION SUM_CH4( I1, I2, J1, J2, L1, L2, K1, K2, UPDOWN )
```

USES:

```
USE CMN_SIZE_MOD     ! Size parameters
USE CMN_MOD          ! LPAUSE
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I1, I2 ! Min/max longitude indices of TCH4 to sum
INTEGER, INTENT(IN) :: J1, J2 ! Min/max latitude  indices of TCH4 to sum
INTEGER, INTENT(IN) :: L1, L2 ! Min/max altitude  indices of TCH4 to sum
INTEGER, INTENT(IN) :: K1, K2 ! Min/max tracer    indices of TCH4 to sum
INTEGER, INTENT(IN) :: UPDOWN ! Sum in trop (=1) or in strat (=0)
```

REMARKS:

```
Store the sources/sinks of CH4 in TCH4 in total molecules
         ( 1) = Initial burden
         ( 2) = Final burden
SINKS
         ( 3) = Tropospheric CH4 sink by OH
SOURCES
         ( 4) = Total Source
         ( 5) = Industral
         ( 6) = Agriculture
         ( 7) = Biomass Burning
         ( 8) = Termites
         ( 9) = Wetland
         (10) = Soil absorption
         (11) = Interhemispheric Exchange (+ = northward)
         (12) = ...
                                                                              .
Levels            1 <= L <= LPAUSE(I,J) - 1 are tropospheric
        LPAUSE(I,J) <= L <= LLPAR           are stratospheric (bmy, 4/17/00)
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
      James Wang (7/00).  Inserted into module "global_ch4_mod.f"
      by Bob Yantosca. (bmy, 1/16/01)
(2 ) CH4_BUDGET is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
      (bmy, 1/16/01)
(3 ) Updated comments (jsw, bmy, 2/12/01)
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.16 ch4_distrib

Subroutine CH4_DISTRIB allocates the chemistry sink to different emission tracers. (ccc, 10/2/09)

INTERFACE:

```
      SUBROUTINE CH4_DISTRIB(PREVCH4)
```

USES:

```
      USE TRACER_MOD,    ONLY : STT, N_TRACERS
      USE ERROR_MOD,     ONLY : SAFE_DIV

      USE CMN_SIZE_MOD        ! Size parameters

      IMPLICIT NONE
#     include "define.h"
```

INPUT PARAMETERS:

```
      REAL*8                :: PREVCH4(IIPAR, JJPAR, LLPAR) ! CH4 before chem
```

REVISION HISTORY:

```
    07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.17 init_global_ch4

Subroutine INIT_GLOBAL_CH4 allocates and zeroes module arrays. (bmy, 1/16/01, 10/15/02)

INTERFACE:

```
      SUBROUTINE INIT_GLOBAL_CH4
```

USES:

```
      USE ERROR_MOD, ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD
      USE CMN_DIAG_MOD
```

REVISION HISTORY:

```
    (1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
    07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.54.18 cleanup_global_ch4

Subroutine CLEANUP_GLOBAL_CH4 deallocates module arrays. (bmy, 1/16/01)

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_CH4
```

REVISION HISTORY:

```
(1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.55 Fortran: Module Interface global_NO3_mod

Module GLOBAL_NO3_MOD contains variables and routines for reading the global monthly mean NO3 concentration from disk. These are needed for the offline sulfate/aerosol simulation.

INTERFACE:

```
MODULE GLOBAL_NO3_MOD
```

USES:

```
IMPLICIT NONE
#     include "define.h"
PRIVATE
```

PUBLIC DATA MEMBERS:

```
! Array to store global monthly mean OH field
REAL*8, PUBLIC, ALLOCATABLE :: NO3(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: GET_GLOBAL_NO3
PUBLIC  :: CLEANUP_GLOBAL_NO3
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: INIT_GLOBAL_NO3
```

REVISION HISTORY:

```
15 Oct 2002 - R. Yantosca - Initial version
(1 ) Adapted from "global_oh_mod.f" (bmy, 10/3/02)
(2 ) Minor bug fix in FORMAT statements (bmy, 3/23/03)
(3 ) Cosmetic changes (bmy, 3/27/03)
(4 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(5 ) Now suppress output from READ_BPCH2 with QUIET=T (bmy, 1/14/05)
(6 ) Now read from "sulfate_sim_200508/offline" directory (bmy, 8/1/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Bug fix: now zero ARRAY (phs, 1/22/07)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.55.1 get_global_NO3

Subroutine GET_GLOBAL_NO3 reads monthly mean NO3 data fields. These are needed for simulations such as offline sulfate/aerosol.

INTERFACE:

```
SUBROUTINE GET_GLOBAL_NO3( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT
USE BPCH2_MOD,     ONLY : GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0
USE BPCH2_MOD,     ONLY : READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_3D_TROP

USE CMN_SIZE_MOD                 ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: THISMONTH   ! Current month
```

REVISION HISTORY:

```
15 Oct 2002 - R. Yantosca - Initial version
(1 ) Minor bug fix in FORMAT statements (bmy, 3/23/03)
(2 ) Cosmetic changes (bmy, 3/27/03)
(3 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(4 ) Now suppress output from READ_BPCH2 with QUIET=T (bmy, 1/14/05)
(5 ) GEOS-3 & GEOS-4 data comes from model runs w/ 30 levels.  Also now
      read from "sulfate_sim_200508/offline" directory.  Also now read
      up to LLTROP levels.  Now reference TRANSFER_3D_TROP from
      "transfer_mod.f". (bmy, 8/1/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Now zero local variable ARRAY (phs, 1/22/07)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.55.2 init_global_NO3

Subroutine INIT_GLOBAL_NO3 allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_NO3
```

USES:

```
      USE ERROR_MOD, ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
    15 Oct 2002 - R. Yantosca - Initial version
    (1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
    (2 ) Now allocate NO3 array up to LLTROP levels (bmy, 8/1/05)
    01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.55.3 cleanup_global_no3

Subroutine CLEANUP_GLOBAL_NO3 deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_GLOBAL_NO3
```

REVISION HISTORY:

```
    15 Oct 2002 - R. Yantosca - Initial version
    01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.56 Fortran: Module Interface global_NOx_mod

Module GLOBAL_NOx_MOD contains variables and routines for reading the global monthly mean NOx concentration from disk.

INTERFACE:

```
      MODULE GLOBAL_NOX_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      ! Array to store global monthly mean BNOX field
      REAL*8, PUBLIC, ALLOCATABLE :: BNOX(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_GLOBAL_NOx
      PUBLIC :: GET_GLOBAL_NOx
      PUBLIC :: INIT_GLOBAL_NOx
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
(1 ) Updated comments, made cosmetic changes (bmy, 6/13/01)
(2 ) Updated comments (bmy, 9/4/01)
(3 ) Now regrid BNOX array from 48L to 30L for GEOS-3 if necessary.
     (bmy, 1/14/02)
(4 ) Eliminated obsolete code from 1/02 (bmy, 2/27/02)
(5 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
     MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(6 ) Now references "error_mod.f" (bmy, 10/15/02)
(7 ) Minor bug fix in FORMAT statements (bmy, 3/23/03)
(8 ) Cosmetic changes to improve output (bmy, 3/27/03)
(9 ) Now references "directory_mod.f" and "unix_cmds_mod.f" (bmy, 7/20/04)
(10) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.56.1 get_global_nox

Subroutine GET_GLOBAL_NOx reads global NOx from binary punch files from a full chemistry run. This NOx data is needed to calculate the CO yield from isoprene oxidation.

INTERFACE:

```
SUBROUTINE GET_GLOBAL_NOx( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT
USE BPCH2_MOD,     ONLY : GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0
USE BPCH2_MOD,     ONLY : READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE DIRECTORY_MOD, ONLY : TEMP_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_3D
USE UNIX_CMDS_MOD, ONLY : REDIRECT
USE UNIX_CMDS_MOD, ONLY : UNZIP_CMD
USE UNIX_CMDS_MOD, ONLY : ZIP_SUFFIX

USE CMN_SIZE_MOD                  ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: THISMONTH   ! Current month
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
(1 ) Now use version of GET_TAU0 with 3 arguments.  Now call READ_BPCH2
```

```
      with IIPAR,JJPAR,LGLOB.  Call TRANSFER_3D to cast from REAL*4 to
      REAL*8 and to regrid to 30 levels for GEOS-3 (if necessary).  ARRAY
      should now be of size (IIPAR,JJPAR,LGLOB). (bmy, 1/14/02)
(2 ) Eliminated obsolete code from 1/02 (bmy, 2/27/02)
(3 ) Bug fix in FORMAT statement: replace missing commas.  Also make sure
      to define FILENAME before printing it (bmy, 4/28/03)
(4 ) Now references TEMP_DIR, DATA_DIR from "directory_mod.f".  Also
      references Unix unzipping commands from "unix_cmds_mod.f".
      (bmy, 7/20/04)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.56.2 init_global_NOx

Subroutine INIT_GLOBAL_NOx allocates and zeroes all module arrays.

INTERFACE:

```
      SUBROUTINE INIT_GLOBAL_NOX
```

USES:

```
      USE ERROR_MOD, ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
(1 ) BNOX now needs to be sized (IIPAR,JJPAR,LLPAR) (bmy, 1/14/02)
(2 ) Eliminated obsolete code from 1/02 (bmy, 2/27/02)
(3 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.56.3 cleanup_global_nox

Subroutine CLEANUP_GLOBAL_NOx deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_GLOBAL_NOX
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.57 Fortran: Module Interface global_o1d_mod

Module GLOBAL_O1D_MOD contains variables and routines for reading the global monthly mean O1D stratospheric concentration from disk. This is used in the H2/HD simulation. The O1D fields were obtained from Gabriele Curci GEOS-Chem simulation in the stratosphere (v5.03).

INTERFACE:

```
      MODULE GLOBAL_O1D_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      ! Array to store global monthly mean O1D field
      REAL*8, PUBLIC, ALLOCATABLE :: O1D(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_GLOBAL_O1D
      PUBLIC :: GET_GLOBAL_O1D
      PUBLIC :: INIT_GLOBAL_O1D
```

REVISION HISTORY:

```
   18 Sep 2007 - H. U. Price, P. Le Sager - Initial version
   01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.57.1 get_global_O1D

Subroutine GET_GLOBAL_O1D reads global O1D from binary punch files stored in the /data/ctm/GEOS_MEAN directory. This O1D data is needed for the H2/HD mechanisms in Tagged H2.

INTERFACE:

```
      SUBROUTINE GET_GLOBAL_O1D( THISMONTH )
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT
      USE BPCH2_MOD,     ONLY : GET_RES_EXT
      USE BPCH2_MOD,     ONLY : GET_TAU0
      USE BPCH2_MOD,     ONLY : READ_BPCH2
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE TRANSFER_MOD,  ONLY : TRANSFER_3D

      USE CMN_SIZE_MOD                 ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: THISMONTH   ! Current month
```

REVISION HISTORY:

```
18 Sep 2007 - H. U. Price, P. Le Sager - Initial version
(1 ) GET_GLOBAL_O1D assumes that we are reading global O1D data that
      occupies all CTM levels.  Contact Bob Yantosca (bmy@io.harvard.edu)
      for IDL regridding code which will produce the appropriate O1D files.
(2 ) ARRAY should now be of size (IIPAR,JJPAR,LGLOB). (bmy, 1/11/02)
(3 ) Now point to new O1D files in the ??? subdirectory.
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.57.2 init_global_o1d

Subroutine INIT_GLOBAL_O1D allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_O1D
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
18 Sep 2007 - H. U. Price, P. Le Sager - Initial version
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.57.3 cleanup_global_O1D

Subroutine CLEANUP_GLOBAL_O1D deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_O1D
```

REVISION HISTORY:

```
18 Sep 2007 - H. U. Price, P. Le Sager - Initial version
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.58 Fortran: Module Interface global_o3_mod

Module GLOBAL_O3_MOD contains variables and routines for reading the global monthly mean O3 concentration from disk. These are needed for the offline sulfate/aerosol simulation.

INTERFACE:

```
      MODULE GLOBAL_O3_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC              :: CLEANUP_GLOBAL_O3
      PUBLIC              :: GET_GLOBAL_O3
```

PUBLIC DATA MEMBERS:

```
      PUBLIC              :: O3
      REAL*8, ALLOCATABLE :: O3(:,:,:)        ! Global monthly mean OH field
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE             :: INIT_GLOBAL_O3
```

REVISION HISTORY:

```
(1 ) Now references "directory_mod.f" (bmy, 7/20/04)
(2 ) Now reads O3 data from "sulfate_sim_200508/offline" dir (bmy, 8/30/05)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Bug fixes in GET_GLOBAL_O3 (bmy, 12/1/05)
(5 ) Now reads O3 from MERGE files, which include stratospheric O3 from
     COMBO, for GEOS-3 and GEOS-4 met fields (phs, 1/19/07)
(6 ) Bug fix in GET_GLOBAL_O3 (bmy, 1/14/09)
13 Aug 2010 - R. Yantosca - Added modifications for MERRA
13 Aug 2010 - R. Yantosca - Added ProTeX headers
08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x
```

1.58.1 get_global_o3

Subroutine GET_GLOBAL_O3 reads monthly mean O3 data fields. These are needed for simulations such as offline sulfate/aerosol.

INTERFACE:

```
      SUBROUTINE GET_GLOBAL_O3( THISMONTH )
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
      USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE TRANSFER_MOD,  ONLY : TRANSFER_3D

      USE CMN_SIZE_MOD                     ! Size parameters
      IMPLICIT NONE
#     include "define.h"
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: THISMONTH       ! Current month
```

REVISION HISTORY:

```
   23 Mar 2003 - R. Yantosca - Initial version
   (1 ) Minor bug fix in FORMAT statements (bmy, 3/23/03)
   (2 ) Cosmetic changes (bmy, 3/27/03)
   (3 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
   (4 ) Now reads O3 data from "sulfate_sim_200508/offline" dir (bmy, 8/30/05)
   (5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (6 ) Tracer number for O3 is now 51.  Also need to call TRANSFER_3D_TROP
        since the new O3 data file only goes up to LLTROP. (bmy, 11/18/05)
   (7 ) Modified to include stratospheric O3 -- Requires access to new
        MERGE.O3* files. (phs, 1/19/07)
   (8 ) Renamed GRID30LEV to GRIDREDUCED (bmy, 2/7/07)
   (9 ) Bug fix: don't call TRANSFER_3D if you use GRIDREDUCED (bmy, 1/14/09)
   13 Aug 2010 - R. Yantosca - Rewrote logic more cleanly
   13 Aug 2010 - R. Yantosca - Treat MERRA in same way as GEOS-5
   08 Dec 2009 - R. Yantosca - Added ProTeX headers
   19 Aug 2010 - R. Yantosca - Removed hardwiring of data directory
   08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
```

1.58.2 init_global_o3

Subroutine INIT_GLOBAL_O3 allocates the O3 module array.

INTERFACE:

```
      SUBROUTINE INIT_GLOBAL_O3
```

USES:

```
      USE ERROR_MOD, ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
13 Jul 2004 - R. Yantosca - Initial version
(1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 7/13/04)
(2 ) Now dimension O3 with LLTROP (bmy, 12/1/05)
(3 ) Now dimension O3 with LLPAR (phs, 1/19/07)
13 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.58.3 cleanup_global_o3

Subroutine CLEANUP_GLOBAL_O3 deallocates the O3 array.

INTERFACE:

```
      SUBROUTINE CLEANUP_GLOBAL_O3
```

REVISION HISTORY:

```
13 Jul 2004 - R. Yantosca - Initial version
13 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.59 Fortran: Module Interface global_oh_mod

Module GLOBAL_OH_MOD contains variables and routines for reading the global monthly mean OH concentration from disk.

INTERFACE:

```
      MODULE GLOBAL_OH_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      ! Array to store global monthly mean OH field [molec/cm3]
      REAL*8, PUBLIC, ALLOCATABLE :: OH(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_GLOBAL_OH
      PUBLIC :: GET_GLOBAL_OH
      PUBLIC :: INIT_GLOBAL_OH
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
(1 ) Updated comments (bmy, 9/4/01)
(2 ) Now use routines from "transfer_mod.f" to regrid OH to 30 levels
      for reduced GEOS-3 grid.  Also size OH array properly. (bmy, 1/14/02)
(3 ) Eliminate obsolete code from 11/01 (bmy, 2/27/02)
(4 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
      MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(5 ) Now use updated OH fields (bmy, 10/2/02)
(6 ) Now references "error_mod.f" (bmy, 10/15/02)
(7 ) Minor bug fixes in FORMAT statements (bmy, 3/23/03)
(8 ) Cosmetic changes to simplify output (bmy, 3/27/03)
(9 ) Bug fix: OH should be (IIPAR,JJPAR,LLPAR) (bmy, 5/4/04)
(10) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.59.1 get_global_oh

Subroutine GET_GLOBAL_OH reads global OH from binary punch files stored in the /data/ctm/GEOS_MEAN directory. This OH data is needed as oxidant for various offline chemistry mechanisms.

INTERFACE:

```
SUBROUTINE GET_GLOBAL_OH( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT
USE BPCH2_MOD,     ONLY : GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0
USE BPCH2_MOD,     ONLY : READ_BPCH2
USE DIRECTORY_MOD, ONLY : OH_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_3D

USE CMN_SIZE_MOD                  ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: THISMONTH   ! Current month
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
(1 ) GET_GLOBAL_OH assumes that we are reading global OH data that occupies
      all CTM levels.  Contact Bob Yantosca (bmy@io.harvard.edu) for IDL
      regridding code which will produce the appropriate OH files.
(2 ) Now use version of GET_TAU0 with 3 arguments.  Now call READ_BPCH2
      with IIPAR,JJPAR,LGLOB.  Call TRANSFER_3D to cast from REAL*4 to
```

```
      REAL*8 and to regrid to 30 levels for GEOS-3 (if necessary).
      ARRAY should now be of size (IIPAR,JJPAR,LGLOB). (bmy, 1/11/02)
(3 ) Now point to new OH files in the v4-26 subdirectory.  Also eliminated
      obsolete code from 11/01. (bmy, 2/27/02)
(4 ) Now point to OH files in the v4-33 subdirectory. (bmy, 10/2/02)
(5 ) Replace missing commas in the FORMAT statement (bmy, 3/23/03)
(6 ) Cosmetic changes to simplify output (bmy, 3/27/03)
(7 ) Add Mat's OH as an option.  Also read bpch file quietly (bmy, 5/4/04)
(8 ) Now use OH_DIR from "directory_mod.f" (bmy, 7/20/04)
(9 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.59.2 init_global_oh

Subroutine INIT_GLOBAL_OH allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_OH
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
(1 ) OH array now needs to be sized (IIPAR,JJPAR,LGLOB) (bmy, 1/14/02)
(2 ) Also eliminated obsolete code from 11/01 (bmy, 2/27/02)
(3 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
(4 ) OH should be (IIPAR,JJPAR,LLPAR): avoid subscript errors (bmy, 5/4/04)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.59.3 cleanup_global_oh

Subroutine CLEANUP_GLOBAL_OH deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_OH
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.60 Fortran: Module Interface

Module H2_HD_MOD contains variables and routines used for the geographically tagged H2-HD simulation.

INTERFACE:

```
      MODULE H2_HD_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CHEM_H2_HD
      PUBLIC  :: CLEANUP_H2_HD
      PUBLIC  :: EMISS_H2_HD
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: INIT_H2_HD
      PRIVATE :: READ_OCEAN_H2
      PRIVATE :: READ_H2YIELD
```

REVISION HISTORY:

```
   18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
   02 Dec 2010 - R. Yantosca - Added ProTeX headers
   07 Sep 2011 - P. Kasibhatla - Modified to include GFED3 (psk, 1/5/11)
   01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
```

1.60.1 emiss_h2_hd

Subroutine EMISS_H2_HD reads in emissions for the H2/HD simulation.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISS_H2_HD( BIO_EMISS )
#else
      SUBROUTINE EMISS_H2_HD
#endif
```

USES:

```
      USE BIOFUEL_MOD,      ONLY : BIOFUEL,     BIOFUEL_BURN
      USE BIOMASS_MOD,      ONLY : BIOMASS
      USE DAO_MOD,          ONLY : SUNCOS,      BXHEIGHT
      USE DAO_MOD,          ONLY : PARDF,       PARDR
```

```
      USE DAO_MOD,          ONLY : SUNCOS_MID
      USE DIAG_MOD,         ONLY : AD29,        AD46,          AD10em
      USE GEIA_MOD,         ONLY : GET_IHOUR,   GET_DAY_INDEX, READ_GEIA
      USE GEIA_MOD,         ONLY : READ_LIQCO2, READ_TOTCO2,   READ_TODX
      USE GRID_MOD,         ONLY : GET_XOFFSET, GET_YOFFSET
      USE GRID_MOD,         ONLY : GET_AREA_CM2
      USE LOGICAL_MOD,      ONLY : LANTHRO,     LGFED2BB,      LGFED3BB
      USE LOGICAL_MOD,      ONLY : LBIOMASS,    LBIOFUEL,      LNEI99
      USE LOGICAL_MOD,      ONLY : LSTREETS,    LEDGAR,        LBRAVO
      USE LOGICAL_MOD,      ONLY : LMEGAN
      USE MEGANUT_MOD,      ONLY : XLTMMP
      USE MEGAN_MOD,        ONLY : GET_EMMONOT_MEGAN
      USE MEGAN_MOD,        ONLY : GET_EMISOP_MEGAN
      USE TRACERID_MOD,     ONLY : IDBCO
      USE TIME_MOD,         ONLY : GET_MONTH,   GET_TAU
      USE TIME_MOD,         ONLY : GET_YEAR,    GET_TS_EMIS
      USE TRACER_MOD,       ONLY : STT
      USE TRACERID_MOD,     ONLY : IDBFCO,      IDTH2,         IDTHD
      USE TAGGED_CO_MOD,    ONLY : INIT_TAGGED_CO
      USE TAGGED_CO_MOD,    ONLY : READ_ACETONE,  EMACET
      USE SCALE_ANTHRO_MOD, ONLY : GET_ANNUAL_SCALAR

      USE CMN_SIZE_MOD      ! Size parameters
      USE CMN_O3_MOD        ! FSCALYR, SCNR89, TODH, EMISTCO
      USE CMN_DIAG_MOD      ! Diagnostic arrays & switches
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
(1 ) Now references GET_ANNUAL_SCALAR (phs, 3/11/08)
(2 ) Move XLTMMP to module MEGANUT_MOD (ccc, 11/20/09)
(3 ) IDBCO is in TRACERID_MOD now (hotp 7/31/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
08 Dec 2011 - M. Payer    - Remove obsolete GEIA biogenic emissions and add
                            MEGAN biogenic emissions.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.60.2 chem_h2_hd

Subroutine CHEM_H2_HD performs H2 and HD chemistry. Chemical production is by oxidation of BVOC and CH4. Loss is via reaction with OH and uptake by soils. In the stratosphere, H2 is also lost by reaction with O(1D). For HD, we include the fractionation from photochemical oxidation (162 permil), and loss by OH and soil uptake.

INTERFACE:

```
      SUBROUTINE CHEM_H2_HD
```

USES:

```
USE DAO_MOD,         ONLY : AD, AIRVOL, T
USE DIAG_MOD,        ONLY : AD10
USE ERROR_MOD,       ONLY : CHECK_VALUE
USE GLOBAL_OH_MOD,   ONLY : GET_GLOBAL_OH,   OH
USE GLOBAL_O1D_MOD, ONLY : GET_GLOBAL_O1D, O1D
USE GLOBAL_NOX_MOD, ONLY : GET_GLOBAL_NOX,  BNOX
USE GRID_MOD,        ONLY : GET_YMID, GET_AREA_M2, GET_AREA_CM2
USE PRESSURE_MOD,    ONLY : GET_PCENTER, GET_PEDGE
USE TIME_MOD,        ONLY : GET_TS_CHEM,     GET_MONTH, GET_YEAR
USE TIME_MOD,        ONLY : ITS_A_NEW_MONTH, ITS_A_NEW_YEAR
USE DRYDEP_MOD,      ONLY : DEPSAV
USE TRACER_MOD,      ONLY : N_TRACERS,       STT
USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_STRAT
USE TRACERID_MOD,    ONLY : IDTH2, IDTHD
USE TAGGED_CO_MOD,   ONLY : GET_ALPHA_ISOP,    READ_PCO_LCO_STRAT
USE TAGGED_CO_MOD,   ONLY : GET_PCO_LCO_STRAT

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! ND65
USE CMN_DEP_MOD      ! FRCLND
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
```

1.60.3 read_ocean_h2

Subroutine READ_OCEAN_H2 reads in oceanic H2 emissions from nitrogen fixation.

INTERFACE:

```
SUBROUTINE READ_OCEAN_H2( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD  ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH   ! Current month
```

REMARKS:

```
Ocean H2 emissions are based on the N2 oceanic fixation rates
determined by Curtis Deutsch (University of Washington) by
assimilating observed nutrient distributions in the oceans:
"Spatial coupling of nitrogen inputs and losses in the ocean",
Deutsch et al., Nature 445, 163-167 (2007).

The oceanic N2 fixation rates are read in and then scaled to
obtain a total ocean H2 source of 6 TgH2/yr. This source is
assumed to be constant and does not vary annually.
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.60.4 read_h2yield

Subroutine READ_H2YIELD reads in the relative H2/CO yield from photochemical production. This has been archived monthly (PH2/PCO using the PRODLOSS diagnostic and turning H2 on as an active species) from a full chemistry simulation at 4x5, v7-03-03, year 2001, GEOS-3 met fields.

INTERFACE:

```
SUBROUTINE READ_H2YIELD( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE TRANSFER_MOD,  ONLY : TRANSFER_3D
USE DIRECTORY_MOD, ONLY : DATA_DIR
 USE GRID_MOD,      ONLY : GET_YMID

USE CMN_SIZE_MOD                ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH   ! Current month
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.60.5 init_h2_hd

Subroutine INIT_H2_HD allocates memory to module arrays.

INTERFACE:

```
SUBROUTINE INIT_H2_HD
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.60.6 cleanup_h2_hd

Subroutine CLEANUP_H2_HD deallocates memory from previously allocated module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_H2_HD
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.61 Fortran: Module Interface icoads_ship_mod

Module ICOADS_SHIP_MOD contains variables and routines to read the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) ship emissions. Base year is 2002.

INTERFACE:

```
MODULE ICOADS_SHIP_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_ICOADS_SHIP
PUBLIC  :: EMISS_ICOADS_SHIP
PUBLIC  :: GET_ICOADS_SHIP
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: ICOADS_SCALE_FUTURE
PRIVATE :: INIT_ICOADS_SHIP
PRIVATE :: TOTAL_ICOADS_SHIP_TG
```

REMARKS:

```
Source: ICOADS Emissions data for NOx, SOx, and CO were downloaded from
http://coast.cms.udel.edu/GlobalShipEmissions/Inventories/
Reference: Wang, C., J. J. Corbett, and J. Firestone, \emph{Improving
Spatial representation of Global Ship Emissions Inventories},
Environ. Sci. Technol., 42, (1), 193-199, 2008.
```

REVISION HISTORY:

```
21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
01 Mar 2012 - R. Yantosca - Remove A_CM2 array, use GET_AREA_CM2 instead
```

1.61.1 get_icoads_ship

Function GET_ICOADS_SHIP returns the ICOADS ship emissions for GEOS-Chem grid box (I,J) and tracer N. Emissions can be returned in units of [kg/s] or [molec/cm2/s].

INTERFACE:

```
FUNCTION GET_ICOADS_SHIP( I,    J,     N,
&                         MOLEC_CM2_S, KG_S ) RESULT( VALUE )
```

USES:

```
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TRACER_MOD,   ONLY : XNUMOL
USE TRACERID_MOD, ONLY : IDTNOx, IDTCO, IDTSO2, IDTNH3
USE TIME_MOD,     ONLY : GET_YEAR, GET_MONTH
```

INPUT PARAMETERS:

```
! Longitude, latitude, and tracer indices
INTEGER, INTENT(IN)           :: I, J, N

! OPTIONAL -- return emissions in [molec/cm2/s]
LOGICAL, INTENT(IN), OPTIONAL :: MOLEC_CM2_S

! OPTIONAL -- return emissions in [kg/s]
LOGICAL, INTENT(IN), OPTIONAL :: KG_S
```

RETURN VALUE:

```
      ! Emissions output
      REAL*8                         :: VALUE
```

REVISION HISTORY:

```
   21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
   01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.61.2 emiss_icoads_ship

Subroutine EMISS_ICOADS_SHIP reads the ICOADS emission fields at 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISS_ICOADS_SHIP( EMISS )
#else
      SUBROUTINE EMISS_ICOADS_SHIP
#endif
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
      USE LOGICAL_MOD,        ONLY : LFUTURE
      USE TIME_MOD,           ONLY : GET_YEAR,      GET_MONTH
      USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR_1x1
      USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A

      USE CMN_SIZE_MOD              ! Size parameters
      USE CMN_O3_MOD                ! FSCALYR

#if defined( DEVEL )
      USE TRACER_MOD,   ONLY : XNUMOL, N_TRACERS
      USE TRACERID_MOD, ONLY : IDTNOx, IDTCO, IDTSO2, IDTNH3
#endif
```

REVISION HISTORY:

```
   21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
   13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
   24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a algorithm
```

1.61.3 icoads_scale_future

applies the IPCC future scale factors

INTERFACE:

```
SUBROUTINE ICOADS_SCALE_FUTURE
```

USES:

```
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_COff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff

USE CMN_SIZE_MOD             ! Size parameters
```

REVISION HISTORY:

```
21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
```

1.61.4 total_icoads_ship_Tg

Subroutine TOTAL_ICOADS_SHIP_TG prints the totals for ship emissions of NOx, CO, and SO2.

INTERFACE:

```
SUBROUTINE TOTAL_ICOADS_SHIP_TG( MONTH )
```

USES:

```
USE CMN_SIZE_MOD            ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: MONTH   ! Month of data to compute totals
```

REVISION HISTORY:

```
21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
```

1.61.5 init_icoads_ship

Subroutine INIT_ICOADS_SHIP allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_ICOADS_SHIP
```

USES:

```
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE LOGICAL_MOD, ONLY : LICOADSSHIP

USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
02 Mar 2012 - R. Yantosca - Remove A_CM2 array
```

1.61.6 cleanup_icoads_ship

Subroutine CLEANUP_ICOADS_SHIP deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_ICOADS_SHIP
```

REVISION HISTORY:

```
21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
```

1.62 Fortran: Module Interface input_mod

Module INPUT_MOD contains routines that read the GEOS-Chem input file at the start of the run and pass the information to several other GEOS-Chem F90 modules.

INTERFACE:

```
MODULE INPUT_MOD
```

USES:

```
IMPLICIT NONE
#     include "define.h"
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: READ_INPUT_FILE
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: READ_ONE_LINE
PRIVATE :: SPLIT_ONE_LINE
PRIVATE :: READ_SIMULATION_MENU
PRIVATE :: READ_TRACER_MENU
PRIVATE :: READ_AEROSOL_MENU
```

```
  PRIVATE :: READ_EMISSIONS_MENU
  PRIVATE :: READ_FUTURE_MENU
  PRIVATE :: READ_CHEMISTRY_MENU
  PRIVATE :: READ_TRANSPORT_MENU
  PRIVATE :: READ_CONVECTION_MENU
  PRIVATE :: READ_DEPOSITION_MENU
  PRIVATE :: READ_OUTPUT_MENU
  PRIVATE :: READ_DIAGNOSTIC_MENU
  PRIVATE :: SET_TINDEX
  PRIVATE :: READ_ND49_MENU
  PRIVATE :: READ_ND50_MENU
  PRIVATE :: READ_ND51_MENU
  PRIVATE :: READ_ND51b_MENU
  PRIVATE :: READ_ND63_MENU
  PRIVATE :: READ_PROD_LOSS_MENU
  PRIVATE :: READ_UNIX_CMDS_MENU
  PRIVATE :: READ_NESTED_GRID_MENU
  PRIVATE :: READ_ARCHIVED_OH_MENU
  PRIVATE :: READ_O3PL_MENU
  PRIVATE :: READ_BENCHMARK_MENU
  PRIVATE :: READ_CH4_MENU
  PRIVATE :: VALIDATE_DIRECTORIES
  PRIVATE :: CHECK_DIRECTORY
  PRIVATE :: CHECK_TIME_STEPS
  PRIVATE :: IS_LAST_DAY_GOOD
  PRIVATE :: INIT_INPUT
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now references LSOA in READ_AEROSOL_MENU (bmy, 9/28/04)
(2 ) Fixed error checks and assign LSPLIT for tagged Hg.  Also now
     refernces LAVHRRLAI from "logical_mod.f" (eck, bmy, 12/20/04)
(3 ) Updated for crystalline/aqueous aerosol tracers.  Also moved routine
     IS_LAST_DAY_GOOD here from "main.f".  Also now references
     "ocean_mercury_mod.f".  Also now open the bpch file for output in
     READ_DIAGNOSTIC_MENU instead of in "main.f".  (cas, sas, bmy, 2/3/05)
(4 ) Now references "diag03_mod.f" and "diag41_mod.f".  Fixed minor
     bugs.  Now references FILE_EXISTS from "file_mod.f".  Updated
     comments. (bmy, 3/28/05)
(5 ) Now modified for GEOS-5 and GCAP met fields.  Also now set LSPLIT
     correctly for HCN/CH3CN simulation. (swu, xyp, bmy, 6/30/05)
(6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(7 ) Now read LMEGAN switch for MEGAN biogenics.  Now read variable
     DATA_DIR_1x1 for 1x1 emissions files, etc.  Now reference XNUMOL and
     XNUMOLAIR from "tracer_mod.f" (tmf, bmy, 10/25/05)
(8 ) Now read LEMEP switch for EMEP emissions (bdf, bmy, 11/1/05)
(9 ) Now added MERCURY MENU section.  Also fixed bug in READ_ND48_MENU.
```

```
      (eck, cdh, bmy, 3/6/06)
(10) Now read LGFED2BB switch for GFED2 biomass emissions (bmy, 4/5/06)
(11) Bug fix for GCAP in IS_LAST_DAY_GOOD.  Also now read LCTH, LMFLUX,
      LPRECON in READ_EMISSIONS_MENU. (bmy, 5/10/06)
(12) Updated for ND42 SOA concentration diagnostic (dkh, bmy, 5/22/06)
(13) Modified for future emissions (swu, bmy, 6/1/06)
(14) Modified for BRAVO emissions (rjp, kfb, bmy, 6/26/06)
(15) Remove support for GEOS-1 and GEOS-STRAT met fields.  Also modified
      for David Streets' emissions. (bmy, 8/17/06)
(16) Modified for variable tropopause.  Also set dimension of ND28 diag
      for GFED2 or default biomass burning.  Now read if Time Spent in
      Troposphere is wanted (phs, bmy, 10/17/06)
(17) Now modified for OTD-LIS local redistribution.  Remove references
      to GEOS-1 and GEOS-STRAT run dirs. (bmy, 11/5/07)
(18) New error traps for OTD-LIS scaling, dependent on met field type.
      Bug fix, create string variables for ERROR_STOP.  Bug fix: use ND52
      in call to SET_TINDEX in READ_DIAGNOSTIC_MENU. (ltm, bmy, 2/11/08)
(19) Bug fix: use (0,0) in call to INIT_TRANSFER (phs, 6/17/08)
(20) Minor fix in READ_TRANSPORT_MENU (cdh, bmy, 7/7/08)
(21) Fixed typo READ_EMISSIONS_MENU for GEOS-3 (bmy, 10/30/08)
(22) Set upper limit on dynamic timestep for 0.5 x 0.666 nested
      grids (yxw, bmy, dan, 11/6/08)
(23) Now read LCAC switch for CAC emissions (amv, 1/09/2008)
(24) Move the call to NDXX_SETUP (phs, 11/18/08)
(25) Minor bug fix in READ_DIAGNOSTIC_MENU (tmf, 2/10/09)
(26) Add LMEGANMONO switch in emission menu (ccc, 3/2/09)
(27) Add LDICARB switch in aerosol menu (ccc, tmf, 3/10/09)
(28) Now read LCOOKE in aerosol menu (phs, 5/18/09)
(29) Add CH4_MENU in input.geos (kjw, 8/18/09)
(30) Corrected typos in CHECK_TIME_STEPS (bmy, 8/21/09)
(31) Now read LLINOZ in READ_SIMULATION_MENU (dbm, bmy, 10/16/09)
(32) Remove reference to obsolete embedded chemistry stuff (bmy, 2/25/10)
(33) Remove depreciated lightning options (ltm, bmy, 1/24/11)
25 Aug 2010 - R. Yantosca - Added modifications for MERRA
27 Aug 2010 - R. Yantosca - Added ProTeX headers
29 Jul 2011 - R. Yantosca - Bug fix in READ_EMISSIONS_MENU for nested NA
16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
07 Sep 2011 - P. Kasibhatla - Modified to include monthly GFED3
17 Jan 2012 - P. Kasibhatla - Modified to include daily and 3-hourly GFED3
08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met data
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
```

1.62.1 read_input_file

Subroutine READ_INPUT_FILE is the driver program for reading the GEOS-Chem input file "input.geos" from disk.

INTERFACE:

```
SUBROUTINE READ_INPUT_FILE
```

USES:

```
USE CHARPAK_MOD, ONLY : STRREPL
USE FILE_MOD,    ONLY : IU_GEOS, IOERROR
USE GAMAP_MOD,   ONLY : DO_GAMAP
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now call DO_GAMAP from "gamap_mod.f" to create "diaginfo.dat" and
     "tracerinfo.dat" files after all diagnostic menus have been read in
(2 ) Now call NDXX_setup from this routine (phs, 11/18/08)
(3 ) Now call READ_ND51b_MENU (amv, bmy, 12/18/09)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.2 read_one_line

Subroutine READ_ONE_LINE reads a line from the input file. If the global variable VERBOSE is set, the line will be printed to stdout. READ_ONE_LINE can trap an unexpected EOF if LOCATION is passed. Otherwise, it will pass a logical flag back to the calling routine, where the error trapping will be done.

INTERFACE:

```
FUNCTION READ_ONE_LINE( EOF, LOCATION ) RESULT( LINE )
```

USES:

```
USE FILE_MOD, ONLY : IU_GEOS, IOERROR
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*), INTENT(IN), OPTIONAL :: LOCATION    ! Msg to display
```

OUTPUT PARAMETERS:

```
LOGICAL,          INTENT(OUT)          :: EOF         ! Denotes EOF
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.3 split_one_line

Subroutine SPLIT_ONE_LINE reads a line from the input file (via routine READ_ONE_LINE), and separates it into substrings.

SPLIT_ONE_LINE also checks to see if the number of substrings found is equal to the number of substrings that we expected to find. However, if you don't know a-priori how many substrings to expect a-priori, you can skip the error check.

INTERFACE:

```
SUBROUTINE SPLIT_ONE_LINE( SUBSTRS, N_SUBSTRS, N_EXP, LOCATION )
```

USES:

```
USE CHARPAK_MOD, ONLY: STRSPLIT
```

INPUT PARAMETERS:

```
! Number of substrings we expect to find
INTEGER,            INTENT(IN)  :: N_EXP

! Name of routine that called SPLIT_ONE_LINE
CHARACTER(LEN=*),   INTENT(IN)  :: LOCATION
```

OUTPUT PARAMETERS:

```
! Array of substrings (separated by " ")
CHARACTER(LEN=255), INTENT(OUT) :: SUBSTRS(MAXDIM)

! Number of substrings actually found
INTEGER,            INTENT(OUT) :: N_SUBSTRS
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.4 read_simulation_menu

Subroutine READ_SIMULATION_MENU reads the SIMULATION MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_SIMULATION_MENU
```

USES:

```
USE DIRECTORY_MOD, ONLY : DATA_DIR,    DATA_DIR_1x1, GCAP_DIR
USE DIRECTORY_MOD, ONLY : GEOS_4_DIR,  GEOS_5_DIR
USE DIRECTORY_MOD, ONLY : MERRA_DIR,   GEOS_57_DIR
USE DIRECTORY_MOD, ONLY : RUN_DIR
USE DIRECTORY_MOD, ONLY : TEMP_DIR
USE GRID_MOD,      ONLY : SET_XOFFSET, SET_YOFFSET
USE LOGICAL_MOD,   ONLY : LSVGLB,      LUNZIP,       LWAIT
USE LOGICAL_MOD,   ONLY : LVARTROP
USE RESTART_MOD,   ONLY : SET_RESTART
USE TIME_MOD,      ONLY : SET_BEGIN_TIME,   SET_END_TIME
USE TIME_MOD,      ONLY : SET_CURRENT_TIME, SET_DIAGb
USE TIME_MOD,      ONLY : SET_NDIAGTIME,    GET_TAU
USE TRANSFER_MOD,  ONLY : INIT_TRANSFER
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Bug fix: Read LSVGLB w/ the * format and not w/ '(a)'. (bmy, 2/23/05)
(2 ) Now read GEOS_5_DIR and GCAP_DIR from input.geos (swu, bmy, 5/25/05)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now references DATA_DIR_1x1 for 1x1 emissions files (bmy, 10/24/05)
(5 ) Now read switch for using variable tropopause or not (phs, 9/14/06)
(6 ) Remove references to GEOS-1 and GEOS-STRAT run dirs.  Now calls
     INIT_TRANSFER (bmy, 11/5/07)
(7 ) Fix typo in "print to screen" section  (phs, 6/1/08)
(8 ) Call INIT_TRANSFER w/ (0,0) instead of (I0,J0) (phs, 6/17/08)
(10) Now read LLINOZ switch from input.geos file (dbm, bmy, 10/16/09)
13 Aug 2010 - R. Yantosca - Now read MERRA_DIR
19 Aug 2010 - R. Yantosca - Set LUNZIP=F for MERRA met fields.
27 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Feb 2012 - R. Yantosca - Now read GEOS_57_DIR for GEOS-5.7.x met
08 Feb 2012 - R. Yantosca - Set LUNZIP=F for GEOS-5.7.x met fields
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now call routine INITIALIZE_GEOS_GRID to
                            initialize horizontal grid parameters
10 Jun 2012 - L. Murray   - Move Linoz to chemistry menu
```

1.62.5 initialize_geos_grid

Subroutine INITIALIZE_GEOS_GRID calls routines from grid_mod.F90 to initialize the horizontal grid parameters.

INTERFACE:

```
SUBROUTINE INITIALIZE_GEOS_GRID()
```

USES:

```
USE CMN_SIZE_MOD
USE GLOBAL_GRID_MOD, ONLY : COMPUTE_GLOBAL_GRID
USE GRID_MOD,        ONLY : INIT_GRID, COMPUTE_GRID
```

REMARKS:

The module grid_mod.F90 has been modified to save grid parameters in 3D format, which will facilitate interfacing GEOS-Chem to a GCM.

.

The module global_grid_mod.F90 contains several of the global grid arrays (*_g) originally in grid_mod.F. These arrays are used in regridding GFED3 biomass emissions, which are available on a 0.5x0.5 global grid. The global arrays may need to be used in the future for regridding other emissions for nested grids.

REVISION HISTORY:

```
01 Mar 2012 - R. Yantosca - Initial version
01 May 2012 - M. Payer    - Add call to COMPUTE_GLOBAL_GRID for nested grids
```

1.62.6 read_tracer_menu

Subroutine READ_TRACER_MENU reads the TRACER MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_TRACER_MENU
```

USES:

```
USE CHARPAK_MOD,  ONLY : ISDIGIT
USE BIOFUEL_MOD,  ONLY : SET_BFTRACE
USE BIOMASS_MOD,  ONLY : SET_BIOTRCE
USE ERROR_MOD,    ONLY : ALLOC_ERR, ERROR_STOP
USE LOGICAL_MOD,  ONLY : LSPLIT
USE TRACER_MOD,   ONLY : ID_EMITTED,     ID_TRACER
USE TRACER_MOD,   ONLY : SIM_TYPE,       N_TRACERS
USE TRACER_MOD,   ONLY : TCVV,           TRACER_COEFF
USE TRACER_MOD,   ONLY : TRACER_CONST,   TRACER_MW_G
USE TRACER_MOD,   ONLY : TRACER_MW_KG,   TRACER_N_CONST
USE TRACER_MOD,   ONLY : TRACER_NAME,    INIT_TRACER
USE TRACER_MOD,   ONLY : XNUMOL,         XNUMOLAIR
USE TRACER_MOD,   ONLY : ITS_A_FULLCHEM_SIM
USE TRACER_MOD,   ONLY : ITS_A_HCN_SIM
USE TRACER_MOD,   ONLY : ITS_A_MERCURY_SIM
USE TRACERID_MOD, ONLY : TRACERID

USE CMN_SIZE_MOD       ! Size parameters
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now set LSPLIT correctly for Tagged Hg simulation (eck, bmy, 12/13/04)
(2 ) Now initialize ocean mercury module (sas, bmy, 1/20/05)
(3 ) Now set LSPLIT correctly for Tagged HCN/CH3CN sim (xyp, bmy, 6/30/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Now reference XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(6 ) Now move call to INIT_OCEAN_MERCURY to READ_MERCURY_MENU (bmy, 2/24/06)
(7 ) Now do not call SET_BIOTRCE anymore; it's obsolete (bmy, 4/5/06)
(8 ) Add SET_BIOTRCE to initialize IDBxxxs. (fp, 2/26/10)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.7 read_aerosol_menu

Subroutine READ_AEROSOL_MENU reads the AEROSOL MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_AEROSOL_MENU
```

USES:

```
USE ERROR_MOD,    ONLY : ERROR_STOP
USE LOGICAL_MOD,  ONLY : LSULF, LCARB, LSOA
USE LOGICAL_MOD,  ONLY : LDUST, LDEAD, LSSALT, LCRYST
USE LOGICAL_MOD,  ONLY : LDICARB
USE TRACER_MOD,   ONLY : N_TRACERS
USE TRACER_MOD,   ONLY : SALA_REDGE_um,      SALC_REDGE_um
USE TRACER_MOD,   ONLY : ITS_AN_AEROSOL_SIM, ITS_A_FULLCHEM_SIM
USE TRACERID_MOD, ONLY : IDTDMS,   IDTSO2,   IDTSO4,  IDTSO4s
USE TRACERID_MOD, ONLY : IDTMSA,   IDTNH3,   IDTNH4,  IDTNITs
USE TRACERID_MOD, ONLY : IDTAS,    IDTAHS,   IDTLET,  IDTNH4aq
USE TRACERID_MOD, ONLY : IDTSO4aq, IDTBCPO,  IDTBCPI, IDTOCPO
USE TRACERID_MOD, ONLY : IDTOCPI,  IDTALPH,  IDTLIMO, IDTALCO
USE TRACERID_MOD, ONLY : IDTSOG1,  IDTSOG2,  IDTSOG3, IDTSOG4
USE TRACERID_MOD, ONLY : IDTSOA1,  IDTSOA2,  IDTSOA3, IDTSOA4
USE TRACERID_MOD, ONLY : IDTDST1,  IDTDST2,  IDTDST3, IDTDST4
USE TRACERID_MOD, ONLY : IDTSALA,  IDTSALC
USE TRACERID_MOD, ONLY : IDTSOAG,  IDTSOAM,  IDTSOA5
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now reference LSOA (bmy, 9/28/04)
(2 ) Now stop run if LSOA=T and SOA tracers are undefined (bmy, 11/19/04)
(3 ) Now reference LCRYST from "logical_mod.f".  Also now check to make
```

```
      prevent aerosol tracers from being undefined if the corresponding
      logical switch is set. (cas, bmy, 1/14/05)
(4 ) Now also require LSSALT=T when LSULF=T, since we now compute the
      production of SO4 and NIT w/in the seasalt aerosol (bec, bmy, 4/13/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Now update error check for SOG4, SOA4 (dkh, bmy, 6/1/06)
(7 ) Add LDICARB switch to cancel SOG condensation onto OC aerosols.
    (ccc, tmf, 3/10/09)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.8 read_emissions_menu

Subroutine READ_EMISSIONS_MENU reads the EMISSIONS MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_EMISSIONS_MENU
```

USES:

```
USE ERROR_MOD,     ONLY : ERROR_STOP
USE LOGICAL_MOD
USE MODIS_LAI_MOD, ONLY : INIT_MODIS_LAI
USE EMISSIONS_MOD, ONLY : ISOP_SCALING
USE EMISSIONS_MOD, ONLY : NOx_SCALING
USE BROMOCARB_MOD, ONLY : Br_SCALING
USE TIME_MOD,      ONLY : SET_HISTYR
USE TRACER_MOD,    ONLY : ITS_A_FULLCHEM_SIM

USE CMN_SIZE_MOD        ! Size parameters
USE CMN_O3_MOD          ! FSCALYR
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now read LNEI99 -- switch for EPA/NEI99 emissions (bmy, 11/5/04)
(2 ) Now read LAVHRRLAI-switch for using AVHRR-derived LAI (bmy, 12/20/04)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now read LMEGAN -- switch for MEGAN biogenics (tmf, bmy, 10/20/05)
(5 ) Now read LEMEP -- switch for EMEP emissions (bdf, bmy, 11/1/05)
(6 ) Now read LGFED2BB -- switch for GFED2 biomass emissions (bmy, 4/5/06)
(7 ) Now read LOTDLIS, LCTH, LMFLUX, LPRECON for lightning options
      (bmy, 5/10/06)
(8 ) Now read LBRAVO for BRAVO Mexican emissions (rjp, kfb, bmy, 6/26/06)
(9 ) Now read LEDGAR for EDGAR emissions (avd, bmy, 7/11/06)
(10) Now read LSTREETS for David Streets' emissions (bmy, 8/17/06)
```

```
(11) Kludge: Reset LMFLUX or LPRECON to LCTH, as the MFLUX and PRECON
     lightning schemes have not yet been implemented.  Rename LOTDLIS
     to LOTDREG.  Also read LOTDLOC for the OTD-LIS local redistribution
     of lightning flashes (cf B. Sauvage).  Make sure LOTDREG and
     LOTDLOC are not both turned on at the same time. (bmy, 1/31/07)
(12) Add LOTDSCALE to the list of LNOx options (ltm, bmy, 9/24/07)
(13) Add new error traps for OTD-LIS options, dependent on met field type
     (ltm, bmy, 11/29/07)
(14) Bug fix, create string variables for ERROR_STOP (bmy, 1/24/08)
(15) Now read LCAC for CAC emissions (amv, 1/09/2008)
(16) Now read LEDGARSHIP, LARCSHIP and LEMEPSHIP (phs, 12/5/08)
(17) Fixed typo in message for GEOS-3 (bmy, 10/30/08)
(18) Now read LVISTAS (amv, 12/2/08)
(19) Now read L8DAYBB, L3HRBB and LSYNOPBB for GFED2 8-days and 3hr
     emissions, and LICARTT for corrected EPA (phs, yc, 12/17/08)
(20) Add a specific switch for MEGAN emissions for monoterpenes and MBO
     (ccc, 2/2/09)
(21) Now read LICOADSSHIP (cklee, 6/30/09)
(22) Bug fix: for now, if LEMEPSHIP is turned on but LEMEP is turned off,
     just turn off LEMEPSHIP and print a warning msg. (mak, bmy, 10/18/09)
(23) Now accounts for NEI2005 (amv, phs, 10/9/09)
(24) Included optional flag for using MODIS LAI data (mpb,2009).
(25) Included optional flag for using PCEEA model (mpb, 2009)
(26) Now force settings for EU, NA, CC nested grids (amv, bmy, 12/18/09)
(27) Now force MEGAN to use MODIS LAI (ccarouge, bmy, 2/24/10)
(28) Add separate switch for NOx fertilizer. (fp, 2/29/10)
(29) Add scaling for isoprene and NOx emissions. (fp, 2/29/10)
(30) Remove depreciated lightning options. (ltm, 1/25,11)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
27 Aug 2010 - R. Yantosca - Added warning msg for MERRA
29 Jul 2011 - L. Zhang    - Fix bug that turns off CAC/BRAVO emissions
                            inadvertently during nested NA simulations
11 Aug 2011 - E. Leibensperger - Added flag for historical emissions and
                                 base year
07 Sep 2011 - P. Kasibhatla - Add modifications for GFED3
14 Feb 2012 - R. Yantosca - Reorganize error checks for logical switches
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
05 Apr 2012 - R. Yantosca - Now call INIT_MODIS_LAI
05 Apr 2012 - R. Yantosca - Reorganized USE statements for clarity
10 Apr 2012 - R. Yantosca - Bug fix: do not turn off LAVHRRLAI or LMODISLAI
                            when emissions are turned off.  LAI is used
                            in other areas of the code.
```

1.62.9 read_co2_sim_menu

Subroutine READ_CO2_SIM_MENU reads the CO2 SIM MENU section of the GEOS-Chem input file.

INTERFACE:

```
      SUBROUTINE READ_CO2_SIM_MENU
```

USES:

```
      USE LOGICAL_MOD
      USE ERROR_MOD,   ONLY : ERROR_STOP
      USE TRACER_MOD,  ONLY : ITS_A_CO2_SIM

      USE CMN_SIZE_MOD      ! Size parameters
      USE CMN_O3_MOD        ! FSCALYR
```

REVISION HISTORY:

```
   02 Mar 2009 - R. Nassar   - Initial version
   27 Aug 2010 - R. Yantosca - Added ProTeX headers
   07 Sep 2011 - P. Kasibhatla - Modified for GFED3
```

1.62.10 read_future_menu

Subroutine READ_FUTURE_MENU reads the FUTURE MENU section of the GEOS-Chem input file; this defines IPCC future emissions options.

INTERFACE:

```
      SUBROUTINE READ_FUTURE_MENU
```

USES:

```
      USE FUTURE_EMISSIONS_MOD, ONLY : DO_FUTURE_EMISSIONS
      USE LOGICAL_MOD,          ONLY : LFUTURE

#     include "define.h"             ! C-preprocessor switches
```

REVISION HISTORY:

```
   01 Jun 2006 - S. Wu       - Initial version
   27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.11 read_chemistry_menu

Subroutine READ_CHEMISTRY_MENU reads the CHEMISTRY MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_CHEMISTRY_MENU
```

USES:

```
USE ERROR_MOD,   ONLY : ERROR_STOP
USE LOGICAL_MOD, ONLY : LCHEM, LSCHEM, LLINOZ
USE LOGICAL_MOD, ONLY : LSVCSPEC, LKPP
USE TIME_MOD,    ONLY : SET_CT_CHEM
USE TRACER_MOD,  ONLY : N_TRACERS

USE CMN_SIZE_MOD      ! Size parameters
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1) added optional test on KPPTRACER (phs, 6/17/09)
(2) Remove reference to obsolete embedded chemistry stuff in "CMN"
    (bmy, 2/25/10)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
10 Jun 2012 - L. Murray   - Move all strat chemistry switches here
```

1.62.12 read_transport_menu

Subroutine READ_TRANSPORT_MENU reads the TRANSPORT MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_TRANSPORT_MENU
```

USES:

```
USE ERROR_MOD,      ONLY : ERROR_STOP
USE LOGICAL_MOD,    ONLY : LTRAN
USE LOGICAL_MOD,    ONLY : LMFCT,               LFILL
USE TRACER_MOD,     ONLY : ITS_A_FULLCHEM_SIM, ITS_A_TAGOX_SIM
USE TRANSPORT_MOD,  ONLY : SET_TRANSPORT
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now define MAX_DYN for 1 x 1.25 grid (bmy, 12/1/04)
(2 ) Update text in error message (bmy, 2/23/05)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Don't stop run if TS_DYN > MAX_DYN but transport is turned off
     (cdh, bmy, 7/7/08)
(5 ) Set MAX_DYN for the 0.5 x 0.666 nested grid (yxw, dan, bmy, 11/6/08)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
10 Jun 2012 - L. Murray - Move strat to chemistry menu
```

1.62.13 read_convection_menu

Subroutine READ_CONVECTION_MENU reads the CONVECTION MENU section of the GEOS-Chem input file.

INTERFACE:

```
      SUBROUTINE READ_CONVECTION_MENU
```

USES:

```
      USE ERROR_MOD,   ONLY : ERROR_STOP
      USE LOGICAL_MOD, ONLY : LCONV, LTURB
      USE LOGICAL_MOD, ONLY : LNLPBL        ! (Lin, 03/31/09)
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   (1 ) Add option for new non-local PBL scheme. And a check on GEOS-5,
        LNLPBL turned to false if GEOS-5 is not used (lin, ccc 5/13/09)
   27 Aug 2010 - R. Yantosca - Now allow non-local PBL for MERRA met data
   27 Aug 2010 - R. Yantosca - Added ProTeX headers
   02 Feb 2012 - R. Yantosca - Added modifications for MERRA met data
   13 Apr 2012 - R. Yantosca - Fixed typo ( defined( GEOS_57 ) should have
                               been !defined( GEOS_57 ) )
```

1.62.14 read_deposition_menu

Subroutine READ_DEPOSITION_MENU reads the DEPOSITION MENU section of the GEOS-Chem input file.

INTERFACE:

```
      SUBROUTINE READ_DEPOSITION_MENU
```

USES:

```
      USE ERROR_MOD,   ONLY : ERROR_STOP
      USE DRYDEP_MOD,  ONLY : INIT_DRYDEP
      USE LOGICAL_MOD, ONLY : LCONV,             LDRYD
      USE LOGICAL_MOD, ONLY : LWETD,             LSPLIT
      USE LOGICAL_MOD, ONLY : USE_OLSON_2001
      USE TRACER_MOD,  ONLY : ITS_A_C2H6_SIM,    ITS_A_CH3I_SIM
      USE TRACER_MOD,  ONLY : ITS_A_CH4_SIM,     ITS_A_HCN_SIM
      USE TRACER_MOD,  ONLY : ITS_A_MERCURY_SIM, ITS_A_TAGCO_SIM
      USE TRACER_MOD,  ONLY : ITS_A_TAGOX_SIM
      USE WETSCAV_MOD, ONLY : WETDEPID
#if   defined( APM )
      USE APM_WETS_MOD, ONLY : WETDEPBINID
#endif
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now print an informational message for tagged Hg (bmy, 12/15/04)
(2 ) We need to call WETDEPID for both wetdep and cloud convection
      since this sets up the list of soluble tracers (bmy, 3/1/05)
(3 ) Remove references to obsolete CO_OH simulation (bmy, 6/24/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
```

1.62.15 read_gamap_menu

Subroutine READ_GAMAP_MENU reads the GAMAP MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_GAMAP_MENU
```

REVISION HISTORY:

```
25 Apr 2005 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.16 read_output_menu

Subroutine READ_OUTPUT_MENU reads the OUTPUT MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_OUTPUT_MENU
```

USES:

```
USE FILE_MOD, ONLY : IU_GEOS, IOERROR

USE CMN_SIZE_MOD   ! Size parameters
USE CMN_DIAG_MOD   ! NJDAY
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.17 read_diagnostic_menu

Subroutine READ_DIAGNOSTIC_MENU reads the DIAGNOSTIC MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_DIAGNOSTIC_MENU
```

USES:

```
USE BIOFUEL_MOD,  ONLY : NBFTRACE
USE BPCH2_MOD,    ONLY : OPEN_BPCH2_FOR_WRITE
USE DIAG03_MOD,   ONLY : ND03,      PD03,      INIT_DIAG03
USE DIAG04_MOD,   ONLY : ND04,      PD04,      INIT_DIAG04
USE DIAG41_MOD,   ONLY : ND41,      PD41,      INIT_DIAG41
USE DIAG42_MOD,   ONLY : ND42,      PD42,      INIT_DIAG42
USE DIAG56_MOD,   ONLY : ND56,      PD56,      INIT_DIAG56
USE DIAG_OH_MOD,  ONLY : INIT_DIAG_OH
USE DRYDEP_MOD,   ONLY : NUMDEP
USE ERROR_MOD,    ONLY : ERROR_STOP
USE FILE_MOD,     ONLY : IU_BPCH
USE LOGICAL_MOD,  ONLY : LBIOMASS,  LBIOFUEL,  LCARB, LCONV
USE LOGICAL_MOD,  ONLY : LDRYD,     LDUST,     LPRT,  LSULF
USE LOGICAL_MOD,  ONLY : LSSALT,    LTURB,     LWETD, LGFED2BB
USE LOGICAL_MOD,  ONLY : LGFED3BB
USE TIME_MOD,     ONLY : GET_NYMDb, GET_NHMSb, EXPAND_DATE
USE TRACER_MOD,   ONLY : N_TRACERS
USE TRACER_MOD,   ONLY : ITS_A_CO2_SIM,        ITS_A_FULLCHEM_SIM
USE TRACER_MOD,   ONLY : ITS_A_MERCURY_SIM,    ITS_A_RnPbBe_SIM
USE TRACER_MOD,   ONLY : ITS_A_TAGOX_SIM,      ITS_A_CH3I_SIM
USE TRACER_MOD,   ONLY : SALA_REDGE_um,        ITS_A_CH4_SIM
USE TRACERID_MOD, ONLY : NEMANTHRO
USE WETSCAV_MOD,  ONLY : GET_WETDEP_NMAX

USE CMN_SIZE_MOD       ! Size parameters
USE CMN_DIAG_MOD       ! NDxx flags
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now reference IU_BPCH from "file_mod.f" and OPEN_BPCH2_FOR_WRITE
     from "bpch2_mod.f".  Now opens the bpch file for output here
     instead of w/in "main.f" (bmy, 2/3/05)
(2 ) Now references "diag03_mod.f" and "diag41_mod.f".  Now turn off ND38
     when both LWETD=F and LCONV=F.  Now calls EXPAND_DATE to replace
     YYYYMMDD and HHMMSS tokens in the bpch file name with the actual
     starting date & time of the run. (bmy, 3/25/05)
(3 ) Now get diag info for ND09 for HCN/CH3CN sim (bmy, 6/27/05)
(4 ) Now references "diag04_mod.f" (bmy, 7/26/05)
```

```
(5 ) Now make sure all USE statements are USE, ONLY.  Also remove reference
     to DIAG_MOD, it's not needed. (bmy, 10/3/05)
(6 ) Now remove reference to NBIOTRCE; Replace w/ NBIOMAX. (bmy, 4/5/06)
(7 ) Now reference ND56, PD56, INIT_DIAG56 from "diag56_mod.f"
     (bmy, 5/10/06)
(8 ) Now reference ND42, PD42, INIT_DIAG42 from "diag42_mod.f"
     (dkh, bmy, 5/22/06)
(9 ) Now set max dimension for GFED2 or default biomass (bmy, 9/22/06)
(10) Bug fix: Should use ND52 in call to SET_TINDEX (cdh, bmy, 2/11/08)
(11) Remove call to NDXX_SETUP; this is now called in READ_INPUT_FILE.
     (phs, 11/18/08)
(12) Now set TINDEX with PD45=NNPAR+1 tracers instead of N_TRACERS.
     (tmf, 2/10/09)
(13) NBIOMAX now in CMN_SIZE (fp, 6/2009)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
26 May 2011 - R. Yantosca - For ND17, ND18, ND37, ND38, ND39, we need to
                            set N_TMP = N_TRACERS, or else wetdep tracers
                            with indices higher than #32 won't print out.
```

1.62.18 set_tindex

Subroutine SET_TINDEX sets the TINDEX and TMAX arrays, which determine how many tracers to print to the punch file.

INTERFACE:

```
SUBROUTINE SET_TINDEX( N_DIAG, L_DIAG, SUBSTRS, N, NMAX )
```

USES:

```
USE CMN_SIZE_MOD                              ! Size parameters
USE CMN_DIAG_MOD                              ! TMAX, TINDEX
```

INPUT PARAMETERS:

```
INTEGER,            INTENT(IN) :: N_DIAG      ! GEOS-Chem diagnostic #
INTEGER,            INTENT(IN) :: N           ! # of valid substrs passed
INTEGER,            INTENT(IN) :: NMAX        ! Max # of tracers allowed
INTEGER,            INTENT(IN) :: L_DIAG      ! # of levels to save
CHARACTER(LEN=255), INTENT(IN) :: SUBSTRS(N)  ! Substrs passed from
                                              !  READ_DIAGNOSTIC_MENU
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Bug fix: now do not drop the last tracer number if "all" is not
     explicitly specified (tmf, bmy, 11/15/04)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.19 read_planeflight_menu

Subroutine READ_PLANEFLIGHT_MENU reads the PLANEFLIGHT MENU section of the GEOS-Chem input file. This turns on the ND40 flight track diagnostic.

INTERFACE:

```
SUBROUTINE READ_PLANEFLIGHT_MENU
```

USES:

```
USE ERROR_MOD,       ONLY : ERROR_STOP
USE PLANEFLIGHT_MOD, ONLY : SET_PLANEFLIGHT

USE CMN_SIZE_MOD          ! MAXFAM
USE CMN_DIAG_MOD          ! ND40
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.20 read_nd48_menu

Subroutine READ_ND48_MENU reads the ND48 MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_ND48_MENU
```

USES:

```
USE DIAG48_MOD, ONLY : INIT_DIAG48, ND48_MAX_STATIONS
USE ERROR_MOD,  ONLY : ERROR_STOP
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Bug fix: ND48 stations should now be read correctly. (bmy, 3/6/06)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.21 read_nd49_menu

Subroutine READ_ND49_MENU reads the ND49 MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_ND49_MENU
```

USES:

```
USE DIAG49_MOD, ONLY : INIT_DIAG49
USE ERROR_MOD,  ONLY : ERROR_STOP

USE CMN_SIZE_MOD     ! Size parameters
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.22 read_nd50_menu

Subroutine READ_ND50_MENU reads the ND50 MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_ND50_MENU
```

USES:

```
USE DIAG50_MOD,  ONLY : INIT_DIAG50
USE ERROR_MOD,   ONLY : ERROR_STOP
USE LOGICAL_MOD, ONLY : LND50_HDF
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now include option to save ND51 diagnostic to HDF5 file format
      (amv, bmy, 12/21/09)
(2 ) Increase tracer number to 121. (ccc, 4/20/10)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.23 read_nd51_menu

Subroutine READ_ND51_MENU reads the ND51 MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_ND51_MENU
```

USES:

```
      USE DIAG51_MOD,  ONLY : INIT_DIAG51
      USE ERROR_MOD,   ONLY : ERROR_STOP
      USE LOGICAL_MOD, ONLY : LND51_HDF

      USE CMN_SIZE_MOD      ! Size parameters
      USE CMN_DIAG_MOD      ! NDxx flags
```

REVISION HISTORY:

```
    20 Jul 2004 - R. Yantosca - Initial version
    (1 ) Now include option to save ND51 diagnostic to HDF5 file format
         (amv, bmy, 12/21/09)
    (2 ) Increase # of tracers to 121 (ccc, 4/20/10)
    27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.24 read_nd51b_menu

Subroutine READ_ND51b_MENU reads the ND51 MENU section of the GEOS-Chem input file.

INTERFACE:

```
      SUBROUTINE READ_ND51b_MENU
```

USES:

```
      USE DIAG51b_MOD, ONLY : INIT_DIAG51b
      USE ERROR_MOD,   ONLY : ERROR_STOP
      USE LOGICAL_MOD, ONLY : LND51b_HDF

      USE CMN_SIZE_MOD      ! Size parameters
      USE CMN_DIAG_MOD      ! NDxx flags
```

REVISION HISTORY:

```
    21 Dec 2009 - Aaron van D - Initial version
    27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.25 read_nd63_menu

Subroutine READ_ND63_MENU reads the ND63 MENU section of the GEOS-Chem input file. (gvinken, 02/25/11)

INTERFACE:

```
      SUBROUTINE READ_ND63_MENU
```

USES:

```
USE DIAG63_MOD, ONLY : INIT_DIAG63
USE ERROR_MOD,  ONLY : ERROR_STOP

USE CMN_SIZE_MOD     ! Size parameters
```

REVISION HISTORY:

```
25 Feb 2011 - G. Vinken   - Initial version
07 Feb 2012 - M. Payer    - Added ProTeX headers
24 Feb 2012 - M. Payer    - Renamed routine from READ_ND59_MENU to
                            READ_ND63 MENU. ND59 is used by TOMAS.
```

1.62.26 read_prod_loss_menu

Subroutine READ_PROD_LOSS_MENU reads the PROD AND LOSS MENU section of the GEOS-Chem input file

INTERFACE:

```
SUBROUTINE READ_PROD_LOSS_MENU
```

USES:

```
USE CHARPAK_MOD, ONLY : ISDIGIT,          STRSPLIT
USE DIAG_PL_MOD, ONLY : INIT_DIAG_PL
USE ERROR_MOD,   ONLY : ERROR_STOP
USE TRACER_MOD,  ONLY : N_TRACERS,        ITS_A_TAGCO_SIM
USE TRACER_MOD,  ONLY : ITS_A_TAGOX_SIM, ITS_AN_AEROSOL_SIM
USE LOGICAL_MOD, ONLY : LKPP

USE CMN_SIZE_MOD      ! MAXFAM
USE CMN_DIAG_MOD      ! ND65
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Bug fixes.  Only error check # of prod/loss families for TagOx and
      TagCO runs if DO_SAVE_PL=T.  Also turn off this diagnostic for
      the offline aerosol run. (bmy, 10/29/04)
(2 ) Add error trap is P/L families are asked when using KPP. (ccc, 3/10/10)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.27 read_unix_cmds_menu

Subroutine READ_UNIX_CMDS_MENU reads the UNIX CMDS MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_UNIX_CMDS_MENU
```

USES:

```
USE CHARPAK_MOD,   ONLY : STRSQUEEZE
USE UNIX_CMDS_MOD, ONLY : BACKGROUND, REDIRECT,  REMOVE_CMD
USE UNIX_CMDS_MOD, ONLY : SEPARATOR,  SPACE,     UNZIP_CMD
USE UNIX_CMDS_MOD, ONLY : WILD_CARD,  ZIP_SUFFIX
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.28 read_nested_grid_menu

Subroutine READ_NESTED_GRID_MENU reads the NESTED GRID MENU section of the GEOS-CHEM input file.

INTERFACE:

```
SUBROUTINE READ_NESTED_GRID_MENU
```

USES:

```
USE DIRECTORY_MOD, ONLY : TPBC_DIR
USE DIRECTORY_MOD, ONLY : TPBC_DIR_NA, TPBC_DIR_EU, TPBC_DIR_CH
USE DIRECTORY_MOD, ONLY : TPBC_DIR_SE
USE LOGICAL_MOD,   ONLY : LWINDO,      LWINDO2x25,  LWINDO_CU
USE LOGICAL_MOD,   ONLY : LWINDO_NA,   LWINDO_EU,   LWINDO_CH
USE LOGICAL_MOD,   ONLY : LWINDO_SE
USE TPCORE_BC_MOD, ONLY : INIT_TPCORE_BC
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now give user the option of saving out nested grid boundary conditions
      at 2 x 2.5 resolution for the EU, CH, or NA grids (amv, bmy, 12/18/09)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.29 read_benchmark_menu

Subroutine READ_BENCHMARK_MENU reads the BENCHMARK MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_BENCHMARK_MENU
```

USES:

```
USE BENCHMARK_MOD, ONLY : INITIAL_FILE, FINAL_FILE
USE LOGICAL_MOD,   ONLY : LSTDRUN
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.30 read_archived_oh_menu

Subroutine READ_ARCHIVED_OH_MENU reads the ARCHIVED OH MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_ARCHIVED_OH_MENU
```

USES:

```
USE DIRECTORY_MOD, ONLY : OH_DIR
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.31 read_o3pl_menu

Subroutine READ_O3PL_MENU reads the O3 P/L MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_O3PL_MENU
```

USES:

```
USE DIRECTORY_MOD, ONLY : O3PL_DIR
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.32 read_mercury_menu

Subroutine READ_MERCURY_MENU reads the BENCHMARK MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_MERCURY_MENU
```

USES:

```
! References to F90 modules
USE LOGICAL_MOD,       ONLY : LDYNOCEAN, LPREINDHG, LGTMM
USE MERCURY_MOD,       ONLY : INIT_MERCURY
USE OCEAN_MERCURY_MOD, ONLY : INIT_OCEAN_MERCURY
USE DEPO_MERCURY_MOD,  ONLY : INIT_DEPO_MERCURY
USE LAND_MERCURY_MOD,  ONLY : INIT_LAND_MERCURY
USE TRACER_MOD,        ONLY : ITS_A_MERCURY_SIM
```

REVISION HISTORY:

```
24 Feb 2006 - R. Yantosca - Initial version
( 1) Update for Chris Holmes's mercury version. (ccc, 5/6/10)
( 2) Add options to use GTMM for mercury soil emissions (ccc, 9/16/09)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.33 read_ch4_menu

Subroutine READ_CH4_MENU reads the CH4 MENU section of the GEOS-Chem input file; this defines emissions options for CH4 tagged simulations.

INTERFACE:

```
SUBROUTINE READ_CH4_MENU
```

USES:

```
! References to F90 modules
USE LOGICAL_MOD, ONLY : LGAO,    LCOL,    LLIV,   LWAST
USE LOGICAL_MOD, ONLY : LBFCH4,  LBMCH4,  LWETL,  LRICE
```

```
      USE LOGICAL_MOD, ONLY : LOTANT,  LSOABS,  LOTNAT
      USE LOGICAL_MOD, ONLY : LCH4BUD
      ! kjw
      USE LOGICAL_MOD, ONLY : LBIOMASS
      USE LOGICAL_MOD, ONLY : LGFED3BB, LDAYBB3
      USE LOGICAL_MOD, ONLY : LGFED2BB, L8DAYBB
      USE ERROR_MOD,   ONLY : ERROR_STOP

#     include "define.h"             ! C-preprocessor switches
```

REVISION HISTORY:

```
03 Aug 2009 - K. Wecht, C. Pickett-Heaps - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.34 read_apm_menu

Subroutine READ_APM_MENU reads the APM MENU section of the GEOS-Chem input file.

INTERFACE:

```
      SUBROUTINE READ_APM_MENU
```

USES:

```
      USE ERROR_MOD,     ONLY : ERROR_STOP
      USE APM_INIT_MOD,  ONLY : APMTRACER_MW_G
      USE APM_INIT_MOD,  ONLY : APMTRACER_MW_Kg
      USE APM_INIT_MOD,  ONLY : IFNUCL
      USE APM_INIT_MOD,  ONLY : FEO
      USE APM_INIT_MOD,  ONLY : LAPM
      USE TRACER_MOD,    ONLY : N_APMTRA
      USE TRACER_MOD,    ONLY : N_TRACERS
      USE TRACER_MOD,    ONLY : TCVV
      USE TRACER_MOD,    ONLY : XNUMOL
```

REMARKS:

```
This subroutine is only compiled when you build GEOS-Chem with the
APM=yes makefile option.
```

REVISION HISTORY:

```
30 Sep 2008 - G. Luo, F. Yu - Initial version
16 Feb 2011 - R. Yantosca - Added ProTeX headers
```

1.62.35 validate_directories

Subroutine VALIDATE_DIRECTORIES makes sure that each of the directories that we have read from the GEOS-Chem input file are valid. Also, trailing separator characters will be added.

INTERFACE:

```
      SUBROUTINE VALIDATE_DIRECTORIES
```

USES:

```
      USE DIRECTORY_MOD
      USE GRID_MOD,      ONLY : ITS_A_NESTED_GRID
      USE LOGICAL_MOD,   ONLY : LWINDO_CU,   LUNZIP
      USE LOGICAL_MOD,   ONLY : LWINDO_NA,   LWINDO_EU,    LWINDO_CH
      USE LOGICAL_MOD,   ONLY : LWINDO_SE
      USE TIME_MOD,      ONLY : EXPAND_DATE, GET_NYMDb,    GET_NYMDe

#     include "define.h"
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   (1 ) Now make sure all USE statements are USE, ONLY.  Now also validate
        GCAP and GEOS-5 directories. (bmy, 10/3/05)
   (2 ) Now references DATA_DIR_1x1 from directory_mod.f (bmy, 10/24/05)
   (3 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
   (4 ) Now check TPBC_DIR_NA, TPBC_DIR_CH, TPBC_DIR_EU (amv, bmy, 12/18/09)
   27 Aug 2010 - R. Yantosca - Added ProTeX headers
   27 Aug 2010 - R. Yantosca -  Now check MERRA directory
   08 Feb 2012 - R. Yantosca - Now check GEOS-5.7.x directory
   09 Feb 2012 - R. Yantosca - Rewrote USE statements for clarity
   28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.62.36 check_directory

Subroutine CHECK_DIRECTORY makes sure that the given directory is valid. Also a trailing slash character will be added if necessary.

INTERFACE:

```
      SUBROUTINE CHECK_DIRECTORY( DIR )
```

USES:

```
      ! References to F90 modules
      USE ERROR_MOD,     ONLY : ERROR_STOP
      USE FILE_MOD,      ONLY : FILE_EXISTS
```

```
      USE UNIX_CMDS_MOD, ONLY : SEPARATOR

#     include "define.h"                         ! C-preprocessor flags
```

INPUT PARAMETERS:

```
      CHARACTER(LEN=*), INTENT(INOUT) :: DIR    ! Directory to be checked
```

REVISION HISTORY:

```
    20 Mar 2003 - R. Yantosca - Initial version
    (1 ) Now references FILE_EXISTS from "file_mod.f" (bmy, 3/23/05)
    27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.37 check_time_steps

Subroutine CHECK_TIME_STEPS computes the smallest dynamic time step for the model, based on which operation are turned on. This is called from routine READ_INPUT_FILE, after all of the timesteps and logical flags have been read from "input.geos".

INTERFACE:

```
      SUBROUTINE CHECK_TIME_STEPS
```

USES:

```
      USE LOGICAL_MOD, ONLY : LCONV, LCHEM, LDRYD
      USE LOGICAL_MOD, ONLY : LEMIS, LTRAN, LTURB
      USE TIME_MOD,    ONLY : SET_TIMESTEPS
      USE ERROR_MOD,   ONLY : GEOS_CHEM_STOP
      USE TRACER_MOD,  ONLY : ITS_A_CH4_SIM
```

REVISION HISTORY:

```
    20 Jul 2004 - R. Yantosca - Initial version
    (1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (2 ) Add TS_DIAG, the largest time steps used for diagnostics.
         And test that all time steps are multiple of the smallest one.
         (ccc, 5/13/09)
    (3 ) Corrected typos -99999 instead of -999999 (phs, bmy, 8/21/09)
    (4 ) Now compute TS_SUN_2 which is 1/2 of the chemistry timestep (or
         smallest timestep if LCHEM=LEMIS=LDRYD=F).  This is used to compute
         SUNCOS at the midpoint of the timestep instead of the beginning.
         (bmy, 4/27/10)
    27 Aug 2010 - R. Yantosca - Added ProTeX headers
    07 Oct 2011 - R. Yantosca - Add extra error checks for centralizing
                                chemistry timestep algorithm
    07 Oct 2011 - R. Yantosca - Remove TS_SUN_2 from call to SET_TIMESTEPS
```

1.62.38 is_last_day_good

Suborutine IS_LAST_DAY_GOOD tests to see if there is output scheduled on the last day of the run.

INTERFACE:

```
SUBROUTINE IS_LAST_DAY_GOOD
```

USES:

```
USE ERROR_MOD,  ONLY : ERROR_STOP
USE JULDAY_MOD, ONLY : JULDAY
USE TIME_MOD,   ONLY : GET_NYMDe, ITS_A_LEAPYEAR, YMD_EXTRACT

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! NJDAY
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Moved to "input_mod.f" from "main.f" (bmy, 1/11/05)
(2 ) Now call ITS_A_LEAPYEAR with FORCE=.TRUE. to always return whether
      the year Y would be a leap year, regardless of met field type.
      (swu, bmy, 4/24/06)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.62.39 init_input

Subroutine INIT_INPUT initializes all variables from "directory_mod.f" and "logical_mod.f" for safety's sake.

INTERFACE:

```
SUBROUTINE INIT_INPUT
```

USES:

```
USE DIRECTORY_MOD
USE LOGICAL_MOD
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now also initialize LNEI99 from "logical_mod.f" (bmy, 11/5/04)
(2 ) Now also initialize LAVHRRLAI from "logical_mod.f" (bmy, 12/20/04)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now also initialize LMEGAN switch (tmf, bmy, 10/20/05)
(5 ) Now also initialize LEMEP, LGFED2BB switches and DATA_DIR_1x1
```

```
      directory (bmy, 4/5/06)
(6 ) Now also intitialize LFUTURE (swu, bmy, 6/1/06)
(7 ) Now reference the EDGAR logical switches from "logical_mod.f"
      (avd, bmy, 7/11/06)
(8 ) Now initialize the LVARTROP switch (phs, 9/14/06)
(9 ) Now initialize LOTDREG, LOTDLOC, LCTH, LMFLUX, LPRECON (bmy, 1/31/07)
(10) Now initialize LOTDSCALE (ltm, bmy, 9/24/07)
(11) Add MEGAN Monoterpenes switch (ccc, 2/2/09)
16 Oct 2009 - R. Yantosca - Now initialize LLINOZ
19 Nov 2009 - C. Carouge  - Initialize LMODISLAI and LPECCA
01 Dec 2009 - C. Carouge  - Initialize LNEI05
27 Aug 2010 - R. Yantosca - Added ProTeX headers
07 Sep 2011 - P. Kasibhatla - Modified for GFED3
17 Jan 2012 - P. Kasibhatla - Modified for GFED3
 8 Feb 2012 - R. Yantosca - Rewrote USE statements for clarity
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
26 Mar 2012 - R. Yantosca - Now turn off switch USE_OLSON_2001 by default
                            (except for GEOS-5.7.2 met)
27 Mar 2012 - R. Yantosca - Cosmetic changes
```

1.63 Fortran: Module Interface isoropiaii_mod

Module ISOROPIAII_MOD contains the routines that provide the interface between ISORROPIA II and GEOS-Chem.

The actual ISORROPIA II code which performs Na-SO4-NH3-NO3-Cl-(Ca-K-Mg) aerosol thermodynamic equilibrium is in `isoropiaIIcode.f`.

INTERFACE:

```
      MODULE ISOROPIAII_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_ISOROPIAII
      PUBLIC  :: DO_ISOROPIAII
      PUBLIC  :: GET_GNO3
      PUBLIC  :: GET_ISRINFO
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: GET_HNO3
      PRIVATE :: INIT_ISOROPIAII
      PRIVATE :: SAFELOG10
      PRIVATE :: SET_HNO3
```

REMARKS:

```
Original Author:
*** COPYRIGHT 1996-2006, UNIVERSITY OF MIAMI, CARNEGIE MELLON UNIVERSITY,
*** GEORGIA INSTITUTE OF TECHNOLOGY
*** WRITTEN BY ATHANASIOS NENES
*** UPDATED BY CHRISTOS FOUNTOUKIS
                                                                             .
Original v1.3 isoropia implementation into GEOS-Chem by
Becky Alexander and Bob Yantosca (bec, bmy, 4/12/05, 11/2/05)
                                                                             .
For Ca,K,Mg = 0, ISOROPIA II performs exactly like ISOROPIAv1.7
Ca, K, Mg, Na from dust is not currently considered
                                                                             .
To implement ISOROPIA II into GEOS-Chem:
  * cleanup_isoropiaII needs to be called from cleanup.f
  * DO_ISOROPIA needs to be replaced with DO_ISOROPIAII in chemistry_mod.f
  * Change ISOROPIA to ISOROPIAII in sulfate_mod.f
  * add isoropiaII_mod.f, isoropiaIIcode.f, and irspia.inc to Makefile
                                                                             .
ISOROPIA II implementation notes by Havala O.T. Pye:
(1) The original isoropia code from T.Nenes is left as unmodified as
     possible. Original isoropia code can be found in isoropiaIIcode.f
     and common blocks can be found in isrpia.inc. For future upgrades
     to isoropia, replace isrpia.inc and isoropiaIIcode.f with the new
     version of isoropia and modify the call to ISOROPIA in this module.
     Please let the original author know of any changes made to ISOROPIA.
(2) As of Nov 2007, routines using non-zero Ca, K, and Mg do not always
     conserve mass. Ca, K, and Mg are set to zero.
                                                                             .
NOTE: ISORROPIA is Greek for "equilibrium", in case you were wondering.
```

REVISION HISTORY:

```
06 Jul 2007 - H. O. T. Pye - Initial version
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
21 Apr 2010 - R. Yantosca  - Bug fix in DO_ISOROPIAII for offline aerosol
16 Feb 2011 - R. Yantosca  - Add modifications for APM from G. Luo
```

1.63.1 do_isoropiaii

Subroutine DO_ISOROPIAII is the interface between the GEOS-Chem model and the aerosol thermodynamical equilibrium routine ISORROPIA II.

INTERFACE:

```
SUBROUTINE DO_ISOROPIAII
```

USES:

```
      USE DAO_MOD,          ONLY : AIRVOL, RH, T
      USE ERROR_MOD,        ONLY : DEBUG_MSG,       ERROR_STOP
      USE ERROR_MOD,        ONLY : SAFE_DIV
      USE GLOBAL_HNO3_MOD, ONLY : GET_GLOBAL_HNO3
      USE LOGICAL_MOD,      ONLY : LPRT
      USE TIME_MOD,         ONLY : GET_MONTH,       ITS_A_NEW_MONTH
      USE TRACER_MOD
      USE TRACERID_MOD,     ONLY : IDTHNO3, IDTNIT, IDTNH4, IDTNH3
      USE TRACERID_MOD,     ONLY : IDTSALA, IDTSO4
      USE TROPOPAUSE_MOD,   ONLY : ITS_IN_THE_STRAT
#if   defined( APM )
      USE APM_INIT_MOD,     ONLY : NSO4
      USE APM_INIT_MOD,     ONLY : IDTSO4BIN1,IDTCTSEA
      USE APM_INIT_MOD,     ONLY : IDTCTBCOC, IDTCTDST,IDTCTSO4
#endif

      USE CMN_SIZE_MOD        ! Size parameters
```

REMARKS:

```
   Original isoropia v1.3 implmentation: (rjp, bec, bmy, 12/17/01, 8/22/05)
```

REVISION HISTORY:

```
   24 Aug 2007 - H. O. T. Pye - Initial version, in ISORROPIA II
   18 Dec 2009 - H. O. T. Pye - Added division checks
   29 Jan 2010 - R. Yantosca  - Added ProTeX headers
   21 Apr 2010 - E. Sofen     - Prevent out-of-bounds errors for offline
                                aerosol simulations where HNO3 is undefined
   23 Jul 2010 - R. Yantosca  - Bug fix: corrected typo in ND42 diag section
```

1.63.2 safelog10

Calculates the LOG (base 10) of a number X. Returns a minimum value if X is too small, in order to avoid NaN or Infinity problems.

INTERFACE:

```
      FUNCTION SAFELOG10( X ) RESULT ( SAFLOG )
```

INPUT PARAMETERS:

```
      REAL*8, INTENT(IN) :: X        ! Argument for LOG10 function
```

RETURN VALUE:

```
      REAL*8             :: SAFLOG   ! LOG10 output --
```

REVISION HISTORY:

```
11 Aug 2009 - H. O. T. Pye - Initial version, in ISORROPIA II
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.63.3 get_isrinfo

Subroutine GET_ISRINFO returns information related to aerosol pH.

INTERFACE:

```
FUNCTION GET_ISRINFO( I, J, L, N ) RESULT ( RETURNVALUE )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I   ! GEOS-Chem longitude index
INTEGER, INTENT(IN) :: J   ! GEOS-Chem latitude index
INTEGER, INTENT(IN) :: L   ! GEOS-Chem level index
INTEGER, INTENT(IN) :: N   ! Flag for which information is desired
```

RETURN VALUE:

```
REAL*8              :: RETURNVALUE
```

REVISION HISTORY:

```
11 Aug 2009 - H. O. T. Pye - Initial version
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.63.4 get_hno3

Subroutine GET_HNO3 allows the HNO3 concentrations to evolve with time, but relaxes back to the monthly mean concentrations every 3 hours.

INTERFACE:

```
FUNCTION GET_HNO3( I, J, L ) RESULT ( HNO3_UGM3 )
```

USES:

```
USE GLOBAL_HNO3_MOD, ONLY : GET_HNO3_UGM3
USE TIME_MOD,        ONLY : GET_ELAPSED_MIN
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I  ! GEOS-Chem longitude index
INTEGER, INTENT(IN) :: J  ! GEOS-Chem latitude index
INTEGER, INTENT(IN) :: L  ! GEOS-Chem level index
```

REVISION HISTORY:

```
16 Dec 2002 - R. Yantosca  - Initial version, in ISORROPIA I
24 Mar 2003 - R. Yantosca  - Now use function GET_ELAPSED_MIN() from the
                             new "time_mod.f" to get the elapsed minutes
                             since the start of run.
06 Jul 2007 - H. O. T. Pye - Initial version, in ISORROPIA II
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.63.5 set_hno3

Subroutine SET_HNO3 stores the modified HNO3 value back into the HNO3_sav array for the next timestep.

INTERFACE:

```
SUBROUTINE SET_HNO3( I, J, L, HNO3_UGM3 )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I           ! GEOS-Chem longitude index
INTEGER, INTENT(IN) :: J           ! GEOS-Chem longitude index
INTEGER, INTENT(IN) :: L           ! GEOS-Chem longitude index
REAL*8,  INTENT(IN) :: HNO3_UGM3   ! HNO3 concentration [ug/m3]
```

REVISION HISTORY:

```
16 Dec 2002 - R. Yantosca  - Initial version, in ISORROPIA I
06 Jul 2007 - H. O. T. Pye - Initial version, in ISORROPIA II
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.63.6 get_gno3

Function GET_GNO3 returns the gas-phase HNO3 [v/v] for calculation of sea-salt chemistry in sulfate_mod (SEASALT_CHEM).

INTERFACE:

```
SUBROUTINE GET_GNO3( I, J, L, HNO3_kg )
```

USES:

```
USE DAO_MOD, ONLY : AIRVOL, AD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: I       ! GEOS-Chem longitude index
INTEGER, INTENT(IN)  :: J       ! GEOS-Chem latitude index
INTEGER, INTENT(IN)  :: L       ! GEOS-Chem level index
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: HNO3_kg ! Gas-phase HNO3 [kg]
```

REVISION HISTORY:

```
15 Apr 2005 - B. Alexander - Initial version, in ISORROPIA I
06 Jul 2007 - H. O. T. Pye - Initial version, in ISORROPIA II
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.63.7 init_isoropiaII

Subroutine INIT_ISOROPIAII initializes all module arrays.

INTERFACE:

```
      SUBROUTINE INIT_ISOROPIAII
```

USES:

```
      USE ERROR_MOD, ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
06 Jul 2007 - H. O. T. Pye - Initial version
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.63.8 cleanup_isoropiaII

Subroutine CLEANUP_ISOROPIAII deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_ISOROPIAII
```

REVISION HISTORY:

```
06 Jul 2007 - H. O. T. Pye - Initial version
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.64 Fortran: Module Interface land_mercury_mod

Module LAND_MERCURY_MOD contains variables and routines for the land emissions for the GEOS-Chem mercury simulation.

INTERFACE:

```
      MODULE LAND_MERCURY_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: BIOMASSHG
      PUBLIC :: VEGEMIS
      PUBLIC :: SOILEMIS
      PUBLIC :: LAND_MERCURY_FLUX
      PUBLIC :: GTMM_DR
      PUBLIC :: SNOWPACK_MERCURY_FLUX
      PUBLIC :: INIT_LAND_MERCURY
      PUBLIC :: CLEANUP_LAND_MERCURY
```

REVISION HISTORY:

```
   02 Jun 2010 - N. E. Selin, C. Carouge - Initial version
   02 Jun 2010 - C. Carouge  - Group all land emissions routine for mercury
                               into this new module.
   13 Aug 2010 - R. Yantosca - Added modifications for MERRA
   25 Aug 2010 - R. Yantosca - Treat MERRA in same way as GEOS-5
   30 Aug 2010 - R. Yantosca - Added more ProTeX headers
   12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
   08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
   01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
   11 Apr 2012 - R. Yantosca - Now reference new modis_lai_mod.F90
```

1.64.1 land_mercury_flux

Subroutine LAND_MERCURY_FLUX calculates emissions of Hg(0) from prompt recycling of previously deposited mercury to land, in [kg/s].

INTERFACE:

```
      SUBROUTINE LAND_MERCURY_FLUX( LFLUX, LHGSNOW )
```

USES:

```
      USE TRACERID_MOD,     ONLY : ID_Hg0,          N_Hg_CATS
      USE LOGICAL_MOD,      ONLY : LSPLIT
      USE TIME_MOD,         ONLY : GET_TS_EMIS
      USE DAO_MOD,          ONLY : SNOW, SNOMAS
      USE DEPO_MERCURY_MOD, ONLY : WD_HGP, WD_HG2, DD_HGP, DD_HG2
      USE DAO_MOD,          ONLY : IS_ICE, IS_LAND
      USE DAO_MOD,          ONLY : FRSNO, FRSEAICE, FRLANDIC, FRLAND

      USE CMN_SIZE_MOD        ! Size parameters
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: LHGSNOW                       ! Use Hg0 from snow?
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: LFLUX(IIPAR,JJPAR,N_Hg_CATS) ! Hg0 flux [kg/s]
```

REVISION HISTORY:

```
30 Aug 2010 - N. E. Selin, C. Holmes, B. Corbitt - Initial version
(1 ) Now uses SNOWMAS from DAO_MOD for compatibility with GEOS-5.
     (eds 7/30/08)
(2 ) Now includes REEMFRAC in parallelization; previous versions may have
     overwritten variable. (cdh, eds 7/30/08)
(3 ) Now also reemit Hg(0) from ice surfaces, including sea ice
     (cdh, 8/19/08)
13 Aug 2010 - R. Yantosca - Add modifications for MERRA
25 Aug 2010 - R. Yantosca - Treat MERRA in same way as GEOS-5
26 Apr 2011 - J. Fisher   - Use MERRA land fraction information
12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
```

1.64.2 biomasshg

Subroutine BIOMASSHG is the subroutine for Hg(0) emissions from biomass burning. These emissions are active only for present day simulations and not for preindustrial simulations.

INTERFACE:

```
SUBROUTINE BIOMASSHG( EHg0_bb )
```

USES:

```
USE BIOMASS_MOD,  ONLY : BIOMASS
USE TRACERID_MOD, ONLY : IDBCO
USE LOGICAL_MOD,  ONLY : LBIOMASS, LPREINDHG
USE TIME_MOD,     ONLY : GET_TS_EMIS
USE GRID_MOD,     ONLY : GET_AREA_CM2

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! Diagnostic arrays & switches
```

OUTPUT PARAMETERS:

```
REAL*8, DIMENSION(:,:),INTENT(OUT) :: EHg0_bb
```

REMARKS:

```
Emissions are based on an inventory of CO emissions from biomass burning
(Duncan et al. J Geophys Res 2003), multiplied by a Hg/CO ratio in BB
plumes from Franz Slemr (Poster, EGU 2006).

Slemr surveyed emission factors from measurements worldwide. Although his
best estimate was 1.5e-7 mol Hg/ mol CO, we chose the highest value
(2.1e-7 mol Hg/ mol CO) in the range because the simulations shown in
Selin et al. (GBC 2008) required large Hg(0) emissions to sustain
reasonable atmospheric Hg(0) concentrations. (eck, 11/13/2008)
```

REVISION HISTORY:

```
30 Jul 2008 - N. E. Selin, C. Holmes, B. Corbitt - Initial version
12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.64.3 vegemis

Subroutine VEGEMIS is the subroutine for Hg(0) emissions from vegetation by evapotranspiration.

INTERFACE:

```
! Bug fix: VEGEMIS shouldn't be tied to GCAP emissions
! (jaf, eds, 4/1/11)
SUBROUTINE VEGEMIS( LVEGEMIS, EHg0_dist, EHg0_vg )
```

USES:

```
USE DAO_MOD,        ONLY: RADSWG, IS_LAND
USE TIME_MOD,       ONLY: GET_MONTH, ITS_A_NEW_MONTH
USE TIME_MOD,       ONLY: GET_TS_EMIS
USE GRID_MOD,       ONLY: GET_AREA_M2

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DEP_MOD      ! FRCLND
```

INPUT PARAMETERS:

```
! Bug fix: VEGEMIS shouldn't be tied to GCAP emissions
! (jaf, eds, 4/1/11)
!LOGICAL,                INTENT(IN)  :: LGCAPEMIS
LOGICAL,                INTENT(IN)  :: LVEGEMIS
REAL*8, DIMENSION(:,:), INTENT(IN)  :: EHg0_dist
```

OUTPUT PARAMETERS:

```
REAL*8, DIMENSION(:,:), INTENT(OUT) :: EHg0_vg
```

REMARKS:

```
 Vegetation emissions are proportional to the evapotranspiration rate and the
 soil water mercury content. We assume a constant concentration of mercury
 in soil matter, based on the preindustrial and present-day simulations
 described in Selin et al. (GBC 2008) and in SOILEMIS subroutine. From the
 soil matter Hg concentration, we calculate a soil water Hg concentration in
 equilibrium (Allison and Allison, 2005).
 NASA provides a climatology of evapotranspiration based on a water budget
 model (Mintz and Walker, 1993).
Calculate vegetation emissions following Xu et al (1999)
   Fc = Ec Cw
   Fc is Hg0 flux (ng m-2 s-1)
   Ec is canopy transpiration (m s-1)
   Cw is conc of Hg0 in surface soil water (ng m-3)
Calculate Cw from the Allison and Allison (2005) equilibrium formula
   Cw = Cs / Kd
   Cs is the concentration of Hg is surface soil solids, ng/g
   Kd is the equilibrium constant = [sorbed]/[dissolved]
      log Kd = 3.8 L/kg -> Kd = 6310 L /kg = 6.31D-3 m3/g
We assume a global mean Cs = 45 ng/g for the preindustrial period. In
iterative simulations we redistribute this according to the deposition
pattern while maintining the global mean. The scaling factor, EHg0_dist,
also accounts for the anthropogenic enhancement of soil Hg in the present
day.
```

REVISION HISTORY:

```
 30 Aug 2010 - N. Eckley, C. Holmes, B. Corbitt - Initial version
 01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

1.64.4 soilemis

Subroutine SOILEMIS is the subroutine for Hg(0) emissions from soils.

INTERFACE:

```
      SUBROUTINE SOILEMIS( EHg0_dist, EHg0_so )
```

USES:

```
      USE MODIS_LAI_MOD, ONLY : ISOLAI  => GC_LAI
      USE DAO_MOD,       ONLY : RADSWG, SUNCOS, TS, IS_LAND
      USE TIME_MOD,      ONLY : GET_MONTH, ITS_A_NEW_MONTH
      USE TIME_MOD,      ONLY : GET_TS_EMIS
      USE GRID_MOD,      ONLY : GET_AREA_M2
      USE DAO_MOD,       ONLY : SNOW, SNOMAS
      USE DAO_MOD,       ONLY : FRSNO, FRLAND

      USE CMN_SIZE_MOD     ! Size parameters
      USE CMN_DEP_MOD      ! FRCLND
```

INPUT PARAMETERS:

```
REAL*8, DIMENSION(:,:), INTENT(IN) :: EHg0_dist
```

OUTPUT PARAMETERS:

```
REAL*8, DIMENSION(:,:), INTENT(OUT):: EHg0_so
```

REMARKS:

```
Soil emissions are a function of solar radiation at ground level
(accounting for attenuation by leaf canopy) and surface temperature.
The radiation dependence from Zhang et al. (2000) is multiplied by the
temperature dependence from Poissant and Casimir (1998).
Finally, this emission factor is multiplied by the soil mercury
concentration and scaled to meet the global emission total.
Comments on soil Hg concentration:
---------------------------------
We chose the preindustrial value of 45 ng Hg /g dry soil as the mean of
the range quoted in Selin et al. (GBC 2008): 20-70 ng/g (Andersson, 1967;
Shacklette et al., 1971; Richardson et al., 2003; Frescholtz and Gustin,
2004). Present-day soil concentrations are thought to be 15% greater than
preindustrial (Mason and Sheu 2002), but such a difference is much less
than the range of concentrations found today, so not well constrained.
We calculate the present-day soil Hg distribution by adding a global mean
6.75 ng/g (=0.15 * 45 ng/g) according to present-day Hg deposition.
(eck, 11/13/08)
```

REVISION HISTORY:

```
30 Aug 2010 - N. Eckley, B. Corbitt - Initial version
(1 ) Added comments. (cdh, eds, 7/30/08)
(2 ) Now include light attenuation by the canopy after sunset. Emissions
     change by < 1% in high-emission areas  (cdh, 8/13/2008)
(3 ) Removed FRCLND for consistency with other Hg emissions (cdh, 8/19/08)
2 June 2010 - C. Carouge  - Solve
13 Aug 2010 - R. Yantosca - Added modifications for MERRA
25 Aug 2010 - R. Yantosca - Treat MERRA in same way as GEOS-5
26 Apr 2011 - J. Fisher   - Use MERRA land fraction information
12 Apr 2011 - J. Fisher   - Bug fixes, add missing code from Holmes 2010
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
10 Feb 2012 - R. Yantosca - Extend #if statement for SOIL_EMIS_FAC in order
                            to get the code to compile w/o error.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
11 Apr 2012 - R. Yantosca - Replace lai_mod.F with modis_lai_mod.F90
```

1.64.5 read_nasa_transp

Subroutine READ_NASA_TRANSP reads monthly average transpiration [m/s] from NASA: for input into the vegetation emissions.

INTERFACE:

```
SUBROUTINE READ_NASA_TRANSP
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_TAU0,   READ_BPCH2
USE BPCH2_MOD,      ONLY : GET_RES_EXT
USE DIRECTORY_MOD,  ONLY : DATA_DIR
USE TIME_MOD,       ONLY : GET_MONTH,  ITS_A_NEW_MONTH
USE TRANSFER_MOD,   ONLY : TRANSFER_2D

USE CMN_SIZE_MOD       ! Size parameters
```

REMARKS:

```
Data source:
 http://gcmd.nasa.gov/records/GCMD_MINTZ_WALKER_SOIL_AND_EVAPO.html
References:
-----------
Mintz, Y and G.K. Walker (1993). "Global fields of soil moisture
 and land surface evapotranspiration derived from observed
 precipitation and surface air temperature." J. Appl. Meteorol. 32 (8),
1305-1334.
```

REVISION HISTORY:

```
15 Sep 2006 - N. E. Selin - Initial version
30 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.64.6 snowpack_mercury_flux

Subroutine SNOWPACK_MERCURY_FLUX calculates emission of Hg(0) from snow and ice.

INTERFACE:

```
SUBROUTINE SNOWPACK_MERCURY_FLUX( FLUX, LHGSNOW )
```

USES:

```
USE TRACERID_MOD,     ONLY : N_Hg_CATS
USE TIME_MOD,         ONLY : GET_TS_EMIS
USE DAO_MOD,          ONLY : T, SUNCOS
USE DEPO_MERCURY_MOD, ONLY : SNOW_HG

USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
      LOGICAL, INTENT(IN)   :: LHGSNOW                      ! Use Hg from snow?
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT)  :: FLUX(IIPAR,JJPAR,N_Hg_CATS)  ! Hg0 flux [kg/s]
```

REMARKS:

```
    Emissions are a linear function of Hg mass stored in the snowpack. The
    Hg lifetime in snow is assumed to be 180 d when T< 270K and 7 d when T>270K
       E = k * SNOW_HG     : k = 6D-8 if T<270K, 1.6D-6 otherwise
    These time constants reflect the time scales of emission observed in the
    Arctic and in field studies. Holmes et al 2010
```

REVISION HISTORY:

```
    15 Sep 2009 - C. Holmes, S. Carouge - Initial version
    30 Aug 2010 - R. Yantosca - Added ProTex headers
    12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
```

1.64.7 gtmm_dr

GTMM_DR is a driver to call GTMM from GEOS-Chem.

INTERFACE:

```
      SUBROUTINE GTMM_DR( Hg0gtm )
```

USES:

```
      USE BPCH2_MOD
      USE DAO_MOD,           ONLY : IS_LAND
      USE FILE_MOD,          ONLY : IU_FILE, IOERROR
      USE TIME_MOD,          ONLY : EXPAND_DATE, YMD_EXTRACT
      USE TIME_MOD,          ONLY : GET_NYMD, GET_NHMS
      USE DIRECTORY_MOD,     ONLY : DATA_DIR
      USE DEPO_MERCURY_MOD,  ONLY : CHECK_DIMENSIONS
      USE DEPO_MERCURY_MOD,  ONLY : WD_Hg2, WD_HgP, DD_HgP, DD_Hg2
      USE DEPO_MERCURY_MOD,  ONLY : READ_GTMM_RESTART

      USE CMN_SIZE_MOD          ! Size parameters
```

INPUT PARAMETERS:

```
      ! Emission of Hg0 calculated by GTMM for the month [kg/s]
      REAL*8, INTENT(OUT)   :: Hg0gtm(IIPAR, JJPAR)
```

REVISION HISTORY:

```
    15 Sep 2009 - C. Carouge  - Initial version
```

1.64.8 init_land_mercury

Subroutine INIT_LAND_MERCURY allocates and zeroes all module arrays.

INTERFACE:

```
      SUBROUTINE INIT_LAND_MERCURY
```

USES:

```
      USE ERROR_MOD,    ONLY : ALLOC_ERR
      USE TRACERID_MOD, ONLY : N_Hg_CATS

      USE CMN_SIZE_MOD     ! Size parameters
```

REVISION HISTORY:

```
    14 Sep 2009 - C. Carouge  - Initial version
```

1.64.9 cleanup_land_mercury

Subroutine CLEANUP_LAND_MERCURY deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_LAND_MERCURY
```

REVISION HISTORY:

```
    14 Sep 2009 - C. Carouge  - Initial version
```

1.65 Fortran: Module Interface lightning_nox_mod

Module LIGHTNING_NOx_MOD contains variables and routines for emitting NOx from lightning into the atmosphere. Original code comes from the old GISS-II CTM's of Yuhang Wang, Gerry Gardner, & Larry Horowitz.

INTERFACE:

```
      MODULE LIGHTNING_NOx_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: LIGHTNING
PUBLIC  :: EMLIGHTNING
PUBLIC  :: CLEANUP_LIGHTNING_NOX
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: LIGHTDIST
PRIVATE :: FLASHES_CTH
PRIVATE :: GET_IC_CG_RATIO
PRIVATE :: READ_LOCAL_REDIST
PRIVATE :: GET_OTD_LIS_SCALE
PRIVATE :: INIT_LIGHTNING_NOX
```

PUBLIC DATA MEMBERS:

```
! Lightning NOx emissions [molec/cm3/s]
REAL*8, ALLOCATABLE, PUBLIC :: EMIS_LI_NOx(:,:,:)
```

REMARKS:

```
%%% NOTE: MFLUX and PRECON methods are now deprecated (ltm, bmy, 7/9/09)
                                                                             .
References:
============================================================================
(1 ) Price & Rind (1992), JGR, vol. 97, 9919-9933.
(2 ) Price & Rind (1994), M. Weather Rev, vol. 122, 1930-1939.
(3 ) Allen & Pickering (2002), JGR, 107, D23, 4711, doi:10.1029/2002JD002066
(4 ) Hudman et al (2007), JGR, 112, D12S05, doi:10.1029/2006JD007912
(5 ) Sauvage et al, 2007, ACP,
      http://www.atmos-chem-phys.net/7/815/2007/acp-7-815-2007.pdf
(6 ) Ott et al., (2010), JGR
(7 ) Allen et al., (2010), JGR
(8 ) Murray et al., (2011), in prep.
```

REVISION HISTORY:

```
14 Apr 2004 - L. Murray, R. Hudman - Initial version
(1 ) Based on "lightning_nox_mod.f", but updated for near-land formulation
      and for CTH, MFLUX, PRECON parameterizations (ltm, bmy, 5/10/06)
(2 ) Now move computation of IC/CG flash ratio out of routines FLASHES_CTH,
      FLASHES_MFLUX, FLASHES_PRECON, and into routine GET_IC_CG_RATIO.
      Added a fix in LIGHTDIST for pathological grid boxes.  Set E_IC_CG=1
      according to Allen & Pickering [2002].  Rename OTDSCALE array to
      OTD_REG_REDIST, and also add OTD_LOC_REDIST array.  Now scale
      lightning to 6 Tg N/yr for both 2x25 and 4x5.  Rename routine
      GET_OTD_LIS_REDIST to GET_REGIONAL_REDIST.  Add similar routine
      GET_LOCAL_REDIST.  Removed GET_OTD_LOCp AL_REDIST.  Bug fix: divide
      A_M2 by 1d6 to get A_KM2. (rch, ltm, bmy, 2/22/07)
(3 ) Rewritten for separate treatment of LNOx emissions at tropics &
```

```
      midlatitudes, based on Hudman et al 2007.  Removed obsolete
      variable E_IC_CG. (rch, ltm, bmy, 3/27/07)
(4 ) Changes implemented in this version (ltm, bmy, 10/3/07)
      * Revert to not classifying near-land as land
      * Eliminate NOx emisisons per path length entirely
      * Scale tropics to 260 mol/fl constraint from Randall Martin's
         4.4 Tg and OTD-LIS avg ann flash rate
      * Remove top-down scaling (remove the three functions)
      * Allow option of mid-level scaling to match global avg ann flash
         rate between G-C and OTD-LIS 11-year climatology (new function)
      * Local Redist now a la Murray et al, 2007 in preparation (monthly)
      * Replace GEMISNOX (from CMN_NOX) with module variable EMIS_LI_NOx
(5 ) Added MFLUX, PRECON redistribution options (ltm, bmy, 11/29/07)
(6 ) Updated OTD/LIS scaling for GEOS-5 to get more realistic totals
      (ltm, bmy, 2/20/08)
(7 ) Now add the proper scale factors for the GEOS-5 0.5 x 0.666 grid
      and the GEOS-3 1x1 nested N. America grid in routine
      GET_OTD_LIS_SCALE. (yxw, dan, ltm, bmy, 11/14/08)
(8 ) Added quick fix for GEOS-5 reprocessed met fields (ltm, bmy, 2/18/09)
(9 ) Added quick fix for GEOS-5 years 2004, 2005, 2008 (ltm, bmy, 4/29/09)
(10) Updated OTD/LIS scaling for GEOS-5 reprocessed data (ltm, bmy, 7/10/09)
(11) Updated for GEOS-4 1 x 1.25 grid (lok, ltm, bmy, 1/13/10)
(12) Reprocessed for CLDTOPS calculation error; Updated Ott vertical
      profiles; Removal of depreciated options, e.g., MFLUX and PRECON;
      GEOS5 5.1.0 vs. 5.2.0 special treatment; MERRA; Other changes.
      Please see PDF on wiki page for full description of lightning
      changes to v9-01-01. (ltm, 1/25/11)
13 Aug 2010 - R. Yantosca - Add modifications for MERRA
10 Nov 2010 - L. Murray   - Updated OTD/LIS local scaling for MERRA 4x5
10 Nov 2010 - R. Yantosca - Added ProTeX headers
02 Feb 2012 - R. Yantosca - Added modifications for GEOS-5.7.x met fields
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
```

1.65.1 lightning

Subroutine LIGHTNING uses Price & Rind's formulation for computing NOx emission from lightning (with various updates).

INTERFACE:

```
SUBROUTINE LIGHTNING
```

USES:

```
USE DAO_MOD,      ONLY : BXHEIGHT,  CLDTOPS,    PRECON,   T, ZMMU
USE DIAG56_MOD,   ONLY : AD56,      ND56
USE GRID_MOD,     ONLY : GET_YMID,  GET_XMID,   GET_AREA_M2
USE LOGICAL_MOD,  ONLY : LOTDLOC
```

```
      USE PRESSURE_MOD, ONLY : GET_PEDGE, GET_PCENTER
      USE TIME_MOD,     ONLY : GET_MONTH, GET_YEAR

      USE CMN_SIZE_MOD     ! Size parameters
      USE CMN_GCTM_MOD     ! Physical constants
```

REMARKS:

```
Output Lightning NOX [molec/cm3/s] is stored in the EMIS_NOX_LI array.
```

REVISION HISTORY:

```
10 May 2006 - L. Murray - Initial version
(1 ) Now recompute the cold cloud thickness according to updated formula
     from Lee Murray.  Rearranged argument lists to routines FLASHES_CTH,
     FLASHES_MFLUX, FLASHES_PRECON.  Now call READ_REGIONAL_REDIST and
     READ_LOCAL_REDIST. Updated comments accordingly.  Now apply
     FLASH_SCALE to scale the total lightning NOx to 6 Tg N/yr.  Now apply
     OTD/LIS regional or local redistribution (cf. B. Sauvage) to the ND56
     diagnostic. lightning redistribution to the ND56 diag.  Renamed
     REGSCALE variable to REDIST.  Bug fix: divide A_M2 by 1d6 to get
     A_KM2. (rch, ltm, bmy, 2/14/07)
(2 ) Rewritten for separate treatment of LNOx emissions at tropics &
     midlatitudes (rch, ltm, bmy, 3/27/07)
(3 ) Remove path-length algorithm.  Renamed from LIGHTNING_NL to LIGHTNING.
     Other improvements. (ltm, bmy, 9/24/07)
(4 ) Remove depreciated options; Update to new Ott et al vertical profiles;
     Reprocessed for bug in CLDTOPS calculation. See PDF on wiki for
     full description of changes for v9-01-01. (ltm, bmy, 1/25,11)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
```

1.65.2 lightdist

Subroutine LIGHTDIST reads in the CDF used to partition the column lightning NOx into the GEOS-Chem vertical layers.

INTERFACE:

```
      SUBROUTINE LIGHTDIST( I, J, LTOP, H0, XLAT, TOTAL, VERTPROF )
```

USES:

```
      USE DAO_MOD,       ONLY : BXHEIGHT, IS_ICE,  IS_LAND
      USE DAO_MOD,       ONLY : IS_NEAR,  IS_WATER
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE ERROR_MOD,     ONLY : GEOS_CHEM_STOP
      USE FILE_MOD,      ONLY : IU_FILE,  IOERROR
      USE GRID_MOD,      ONLY : GET_YMID
```

```
      USE TIME_MOD,      ONLY : GET_MONTH

      USE CMN_SIZE_MOD                        ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: I                ! Longitude index
      INTEGER, INTENT(IN)  :: J                ! Latitude index
      INTEGER, INTENT(IN)  :: LTOP             ! Level of conv cloud top
      REAL*8,  INTENT(IN)  :: H0               ! Conv cloud top height [m]
      REAL*8,  INTENT(IN)  :: XLAT             ! Latitude value [degrees]
      REAL*8,  INTENT(IN)  :: TOTAL            ! Column Total # of LNOx molec
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: VERTPROF(LLPAR)   ! Vertical profile of LNOx
```

REMARKS:

```
    References:
    ============================================================================
    (1 ) Pickering et al., JGR 103, 31,203 - 31,316, 1998.
    (2 ) Ott et al., JGR, 2010
    (3 ) Allen et al., JGR, 2010
```

REVISION HISTORY:

```
    18 Sep 2002 - M. Evans - Initial version (based on Yuhang Wang's code)
    (1 ) Use functions IS_LAND and IS_WATER to determine if the given grid
         box is over land or water.  These functions work for all DAO met
         field data sets. (bmy, 4/2/02)
    (2 ) Renamed M2 to LTOP and THEIGHT to H0 for consistency w/ variable names
         w/in "lightning.f".  Now read the "light_dist.dat.geos3" file for
         GEOS-3 directly from the DATA_DIR/lightning_NOx_200203/ subdirectory.
         Now read the "light_dist.dat" file for GEOS-1, GEOS-STRAT directly
         from the DATA_DIR/lightning_NOx_200203/ subdirectory.  Added
         descriptive comment header.  Now trap I/O errors across all
         platforms with subroutine "ioerror.f".  Updated comments, cosmetic
         changes.  Redimension FRAC(NNLIGHT) to FRAC(LLPAR). (bmy, 4/2/02)
    (3 ) Deleted obsolete code from April 2002.  Now reference IU_FILE and
         IOERROR from "file_mod.f".  Now use IU_FILE instead of IUNIT as the
         file unit number. (bmy, 6/27/02)
    (4 ) Now reference BXHEIGHT from "dao_mod.f" (bmy, 9/18/02)
    (5 ) Bug fix: add GEOS_4 to the #if block (bmy, 3/4/04)
    (6 ) Now bundled into "lightning_mod.f".  CDF's are now read w/in
         routine INIT_LIGHTNING to allow parallelization (bmy, 4/14/04)
    (7 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
    (8 ) Now uses near-land formulation (ltm, bmy, 5/10/06)
    (9 ) Added extra safety check for pathological boxes (bmy, 12/11/06)
    (10) Remove the near-land formulation, except for PRECON (ltm, bmy, 9/24/07)
```

```
(11) Now use the Ott et al. [2010] profiles, and apply consistently with
     GMI model [Allen et al., 2010] (ltm, bmy, 1/25/11).
10 Nov 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.65.3 flashes_cth

Subroutine FLASHES_CTH determines the rate of lightning flashes per minute based on the height of convective cloud tops, and the intra-cloud to cloud-ground strike ratio.

INTERFACE:

```
      SUBROUTINE FLASHES_CTH( I, J, HEIGHT, FLASHRATE )
```

USES:

```
#     include "define.h"

      USE DAO_MOD, ONLY : IS_ICE
      USE DAO_MOD, ONLY : IS_LAND
      USE DAO_MOD, ONLY : IS_WATER
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: I           ! Longitude index
      INTEGER, INTENT(IN)  :: J           ! Latitude index
      REAL*8,  INTENT(IN)  :: HEIGHT      ! Height of conv cloud top [m]
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: FLASHRATE   ! Lightning flash rate [flashes/min]
```

REVISION HISTORY:

```
10 May 2006 - L. Murray - Initial version
(1  ) Subroutine renamed from FLASHES (ltm, bmy, 5/10/06)
(2  ) Remove CCTHICK, IC_CG_RATIO as arguments.  Remove computation of
      IC_CG_RATIO and move that to GET_IC_CG_RATIO. (ltm, bmy, 12/11/06)
(3  ) Remove the near-land formulation (i.e. use function IS_LAND
      instead of IS_NEAR).(ltm, bmy, 9/24/07)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
```

1.65.4 get_ic_cg_ratio

Function GET_IC_CG_RATIO calculates the Intra-Cloud (IC) and Cloud-to-Ground (CG) lightning flash ratio based on the method of Price and Rind 1993, which is calculated from the cold-cloud depth (CCTHICK).

INTERFACE:

```
FUNCTION GET_IC_CG_RATIO( CCTHICK ) RESULT( IC_CG_RATIO )
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN)  :: CCTHICK       ! Cold cloud thickness [m]
```

RETURN VALUE:

```
REAL*8               :: IC_CG_RATIO   ! Intra-cloud/cloud-ground ratio
```

REVISION HISTORY:

```
11 Dec 2006 - R. Yantosca - Initial version
(1 ) Split off from FLASHES_CTH, FLASHES_MFLUX, FLASHES_PRECON into this
     separate function (ltm, bmy, 12/11/06)
(2 ) Bug fix for XLF compiler (morin, bmy, 7/8/09)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
```

1.65.5 read_local_redist

Subroutine READ_LOCAL_REDIST reads in seasonal factors in order to redistribute GEOS-Chem flash rates according the "local redistribution" method of Bastien Sauvage. This helps to make sure that the lightning flashes occur according to the distribution of observed convection.

INTERFACE:

```
SUBROUTINE READ_LOCAL_REDIST( MONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT
USE BPCH2_MOD,     ONLY : GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0
USE BPCH2_MOD,     ONLY : READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE ERROR_MOD,     ONLY : ALLOC_ERR
USE TIME_MOD,      ONLY : GET_TAU
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD               ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: MONTH   ! Current month
```

REVISION HISTORY:

```
26 Jan 2007 - B. Sauvage - Initial version
(1 ) Change from seasonal to monthly.  Rename all filenames from "v2"
     to "v3". (ltm, bmy, 9/24/07)
```

```
(2 ) Change all filenames from "v2" to "v3".  Also now read from the
     directory lightning_NOx_200709. (ltm, bmy, 9/24/07)
(3 ) Added "quick fix" for reprocessed GEOS-5 met fields to be used when
     the IN_CLOUD_OD switch is turned on. (ltm, bmy, 2/18/09)
(4 ) Now read from lightning_NOx_200907 directory for GEOS-4 and
     GEOS-5 CTH parameterizations.  Updated OTD/LIS for GEOS-5 based on
     4+ years of data; removed temporary fixes. (ltm, bmy, 7/10/09)
(5 ) Remove depreciated options and update to v5 of redist files in
     new data directory. Special handling for GEOS5.1.0 and 5.2.0 added.
     (ltm, bmy, 1/25/11)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
02 Feb 2012 - R. Yantosca - Added modifications for GEOS-5.7.x met
```

1.65.6 emlightning

Subroutine EMLIGHTNING converts lightning emissions to [molec/cm3/s] and stores them in the GEMISNOX array, which gets passed to SMVGEAR.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMLIGHTNING( EMISS )
```

USES:

```
      USE DAO_MOD,  ONLY : BXHEIGHT
      USE DIAG_MOD, ONLY : AD32_li

      USE CMN_SIZE_MOD         ! Size parameters
      USE CMN_DIAG_MOD         ! ND32

      REAL*8, INTENT(INOUT) :: EMISS(:,:,:)

      INTEGER             :: I,J,L
      REAL*8              :: TMP

      ! External functions
      REAL*8, EXTERNAL    :: BOXVL

      !=================================================================
      ! EMLIGHTNING begins here!
      !=================================================================
      DO I = 1, IIPAR
         DO J = 1,JJPAR
            DO L = 1, LLCONVM

  SLBASE(I,J,L) has units [molec NOx/6h/box], convert units:
```

```
   [molec/6h/box] * [6h/21600s] * [box/BOXVL cm3] = [molec/cm3/s]
               TMP         = SLBASE(I,J,L) / ( 21600.d0 * BOXVL(I,J,L) )

               EMIS_LI_NOx(I,J,L) = TMP
               EMISS      (I,J,L) = TMP

   ND32 Diagnostic: Lightning NOx [molec NOx/cm2/s]
               IF ( ND32 > 0 ) THEN
                  AD32_li(I,J,L) = AD32_li(I,J,L) +
     &                 ( TMP * BXHEIGHT(I,J,L) * 1d2 )
               ENDIF
            ENDDO
         ENDDO
      ENDDO
#else
      SUBROUTINE EMLIGHTNING( I, J )
```

USES:

```
      USE DAO_MOD,  ONLY : BXHEIGHT
      USE DIAG_MOD, ONLY : AD32_li

      USE CMN_SIZE_MOD         ! Size parameters
      USE CMN_DIAG_MOD         ! ND32
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I   ! Longitude index
      INTEGER, INTENT(IN) :: J   ! Latitude index
```

REVISION HISTORY:

```
    09 Oct 1997 - R. Yantosca - Initial version
    (1 ) Remove IOFF, JOFF from the argument list.  Also remove references
         to header files "CMN_O3" and "comtrid.h" (bmy, 3/16/00)
    (2 ) Now use allocatable array for ND32 diagnostic (bmy, 3/16/00)
    (3 ) Now reference BXHEIGHT from "dao_mod.f".  Updated comments, cosmetic
         changes.  Replace LCONVM with the parameter LLCONVM. (bmy, 9/18/02)
    (4 ) Removed obsolete reference to "CMN".  Now bundled into
         "lightning_mod.f" (bmy, 4/14/04)
    (5 ) Renamed from EMLIGHTNING_NL to EMLIGHTNING.  Now replace GEMISNOX
         (from CMN_NOX) with module variable EMIS_LI_NOx. (ltm, bmy, 10/3/07)
    10 Nov 2010 - R. Yantosca - Added ProTeX headers
```

1.65.7 get_otd_lis_scale

Function GET_OTD_LIS_SCALE returns a met-field dependent scale factor which is to be applied to the lightning flash rate to bring the annual average flash rate to match that

of the OTD-LIS climatology (45.9 flashes/sec). Computed by running the model over the 11-year OTD-LIS campaign window and comparing the average flash rates, or as many years as are available.

INTERFACE:

```
      FUNCTION GET_OTD_LIS_SCALE() RESULT( BETA )
```

USES:

```
#     include "define.h"

      USE BPCH2_MOD,   ONLY : GET_TAU0
      USE ERROR_MOD,   ONLY : GEOS_CHEM_STOP
      USE TIME_MOD,    ONLY : GET_TAU, GET_MONTH, GET_YEAR
```

RETURN VALUE:

```
      REAL*8 :: BETA    ! Scale factor
```

REMARKS:

REVISION HISTORY:

```
    24 Sep 2007 - L. Murray - Initial version
    (1 ) Added MFLUX, PRECON scaling for GEOS-4.  Also write messages for met
         field types/grids where scaling is not defined. (ltm, bmy, 11/29/07)
    (2 ) Now use different divisor for local redist (ltm, bmy, 2/20/08)
    (3 ) Now compute the proper scale factor for GEOS-5 0.5 x 0.666 grids
         and the GEOS-3 1x1 nested NA grid (yxw, dan, ltm, bmy, 11/14/08)
    (4 ) Added "quick fix" for reprocessed GEOS-5 met fields to be used when
         the IN_CLOUD_OD switch is turned on. (ltm, bmy, 2/18/09)
    (5 ) Added "quick fix" for 2004, 2005, 2008 OTD/LIS (ltm, bmy, 4/29/09)
    (6 ) Updated scale factors for GEOS-5 based on 4+ years of data.  Remove
         temporary fixes. (bmy, 7/10/09)
    (7 ) Modification for GEOS-4 1 x 1.25 grid (lok, ltm, bmy, 1/13/10)
    (8 ) Reprocessed for error in CLDTOPS field; Updated for GEOS
         5.1.0 vs. 5.2.0; MERRA added; (ltm, bmy, 1/25/11)
    10 Nov 2010 - R. Yantosca - Added ProTeX headers
    02 Feb 2012 - R. Yantosca - Compute BETA for MERRA 2 x 2.5
    02 Feb 2012 - R. Yantosca - Compute BETA for GEOS-5.7.x
```

1.65.8 init_lightning_NOx

Subroutine INIT_LIGHTNING_NOx allocates all module arrays. It also reads the lightning CDF data from disk before the first lightning timestep.

INTERFACE:

```
SUBROUTINE INIT_LIGHTNING_NOx
```

USES:

```
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE ERROR_MOD,     ONLY : ALLOC_ERR
USE FILE_MOD,      ONLY : IOERROR
USE FILE_MOD,      ONLY : IU_FILE
USE GRID_MOD,      ONLY : GET_AREA_M2
USE LOGICAL_MOD,   ONLY : LOTDLOC

USE CMN_SIZE_MOD      ! Size parameters
```

REVISION HISTORY:

```
14 Apr 2004 - R. Yantosca - Initial version
(1 ) Now reference DATA_DIR from "directory_mod.f"
(2 ) Now call GET_MET_FIELD_SCALE to initialize the scale factor for
     each met field type and grid resolution (bmy, 8/25/05)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now get the box area at 30N for MFLUX, PRECON (lth, bmy, 5/10/06)
(5 ) Rename OTDSCALE to OTD_REG_REDIST.  Also add similar array
     OTD_LOC_REDIST.  Now call GET_FLASH_SCALE_CTH, GET_FLASH_SCALE_MFLUX,
     GET_FLASH_SCALE_PRECON depending on the type of lightning param used.
     Updated comments.  (ltm, bmy, 1/31/07)
(6 ) Removed near-land stuff.  Renamed from INIT_LIGHTNING_NOX_NL to
     INIT_LIGHTNING_NOX.  Now allocate EMIS_LI_NOx. (ltm, bmy, 10/3/07)
(7 ) Also update location of PDF file to lightning_NOx_200709 directory.
     (bmy, 1/24/08)
(8 ) Read in new Ott profiles from lightning_NOx_201101. Remove
     depreciated options. (ltm, bmy, 1/25/11)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Removed reference to GET_YEDGE
```

1.65.9 cleanup_lightning_NOx

Subroutine CLEANUP_LIGHTNING_NOx deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_LIGHTNING_NOx
```

REVISION HISTORY:

```
14 Apr 2004 - R. Yantosca - Initial version
(1 ) Now deallocates OTDSCALE (ltm, bmy, 5/10/06)
(2 ) Rename OTDSCALE to OTD_REG_REDIST.  Now deallocate OTD_LOC_REDIST.
```

```
      (bmy, 1/31/07)
(3 ) Renamed from CLEANUP_LIGHTNING_NOX_NL to CLEANUP_LIGHTNING_NOX.
      Now deallocate EMIS_LI_NOx. (ltm, bmy, 10/3/07)
(4 ) Remove depreciated options. (ltm, bmy, 1/25/11)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
```

1.66 Fortran: Module Interface linoz_mod

Module LINOZ_MOD contains routines to perform the Linoz stratospheric ozone chemistry.

INTERFACE:

```
      MODULE LINOZ_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

DEFINED PARAMETERS:

```
      INTEGER, PARAMETER  :: NFIELDS_LINOZ = 7   ! # of Linoz fields
      INTEGER, PARAMETER  :: NLEVELS_LINOZ = 25  ! # of levels in Linoz fields
      INTEGER, PARAMETER  :: NLAT_LINOZ    = 18  ! # latitudes in Linoz fields
      INTEGER, PARAMETER  :: NMONTHS_LINOZ = 12  ! # of months in Linoz fields
  !PRIVATE DATA MEMBERS:
      REAL*8, ALLOCATABLE :: TPARM(:,:,:,:)
      REAL*8, ALLOCATABLE :: TLSTT(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_LINOZ
      PUBLIC  :: DO_LINOZ
      PUBLIC  :: LINOZ_READ
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: INIT_LINOZ
      PRIVATE :: LINOZ_CHEM3
      PRIVATE :: LINOZ_STRATL
      PRIVATE :: LINOZ_STRT2M
      PRIVATE :: LINOZ_SOMLFQ
      PRIVATE :: LINOZ_INTPL
      PRIVATE :: STRAT_INIT
```

REMARKS:

```
   Dylan Jones (dbj@atmosp.physics.utoronto.ca) wrote:

     Testing this code [in v8-02-04] was more difficult that I thought.
```

```
   I began by trying to compare the output of v8-02-04 with our previous
   runs with v8-02-01.  I accounted for the changes in the transport_mod.f
   and I tried to undo the changes in when the diagnostics are archived in
   v8-02-04, but I was still getting large differences between v8-02-04
   and v8-02-01. I finally gave up on this since I may have made a mistake
   in reverting to the old way of doing the diagnostics in v8-02-04.  In
   the end I took the new linoz code from v8-02-04 and used it in v8-02-01.
   I ran two GEOS-5 full chemistry simulations for 2007 and the output
   were consistent over the full year.

   I think that it is safe to release [Linoz in v8-02-04].  However, we
   should acknowledge that it was [only] tested in v8-02-01, since I was
   not able to assess the quality of the output in v8-02-04.
REVISION HISTORY:
 23 Mar 2000 - P. Cameron-Smith    - Initial version adapted heavily
                                     from McLinden's original file.
 24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
 28 May 2009 - D. Jones            - Further modifications
 18 Nov 2009 - D. Jones            - Further modifications
 01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
```

1.66.1 do_linoz

Subroutine DO_LINOZ is the main driver for the Linoz stratospheric Ozone chemistry package.

INTERFACE:

```
      SUBROUTINE DO_LINOZ
```

USES:

```
      USE TIME_MOD

      USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
   24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
   10 Jun 2012 - L. Murray - Move call to DO_LINOZ from transport code to
                 chemistry code, so the use of DT_TS_CHEM is now correct.
```

1.66.2 linoz_chem3

Subroutine LINOZ_CHEM3 applies linearized chemistry based on tables from PRATMO model using climatological T, O3, time of year

INTERFACE:

```
SUBROUTINE LINOZ_CHEM3( DTCHEM )
```

USES:

```
USE DAO_MOD
USE GRID_MOD,       ONLY : GET_AREA_CM2
USE TRACER_MOD
USE TRACERID_MOD
USE TROPOPAUSE_MOD, ONLY : GET_TPAUSE_LEVEL
USE TROPOPAUSE_MOD, ONLY : GET_MAX_TPAUSE_LEVEL
USE PRESSURE_MOD,   ONLY : GET_PEDGE
USE PRESSURE_MOD,   ONLY : GET_PCENTER

USE CMN_SIZE_MOD
USE CMN_MOD
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: DTCHEM    ! Time step [seconds]
```

REVISION HISTORY:

```
24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
18 Nov 2009 - D. Jones            - For now, set tagged stratospheric
                                    tracer to total O3 in the overworld
                                    to avoid issues with spin ups
08 Feb 2010 - R. Yantosca         - Deleted obsolete local variables
22 Oct 2010 - R. Yantosca         - Added OMP parallel loop
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.66.3 linoz_stratl

Subroutine LINOZ_STRATL performs a monthly fixup of chemistry parameters for the Linoz stratospheric ozone chemistry.

INTERFACE:

```
SUBROUTINE LINOZ_STRATL
```

USES:

```
USE GRID_MOD,       ONLY : GET_YMID
USE TIME_MOD,       ONLY : GET_MONTH
USE PRESSURE_MOD

USE CMN_SIZE_MOD
USE CMN_MOD
```

REVISION HISTORY:

```
24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
```

1.66.4 linoz_strt2m

Subroutine LINOZ_STRT2M sets up a std z* atmosphere: p = 1000 * 10**(-z*/16 km).

INTERFACE:

```
SUBROUTINE LINOZ_STRT2M(STRTX,NX,STRT0L,STRT1L,STRT2L,P0L,NSTRT)
```

USES:

```
USE CMN_SIZE_MOD
```

DEFINED PARAMETERS:

```
! Parameter (ncbox=25)
! Now use nlevels_linoz for all routines. {PJC}
INTEGER, PARAMETER   :: NL = NLEVELS_LINOZ+5
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: NX
INTEGER, INTENT(IN)  :: NSTRT
REAL*8,  INTENT(IN)  :: STRTX(NLEVELS_LINOZ)
REAL*8,  INTENT(IN)  :: P0L(LLPAR+1)
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: STRT0L(LLPAR+1)
REAL*8,  INTENT(OUT) :: STRT1L(LLPAR+1)
REAL*8,  INTENT(OUT) :: STRT2L(LLPAR+1)
```

REVISION HISTORY:

```
24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
```

1.66.5 linoz_somlfq

subroutine LINOZ_SOMLFQ calculates loss freq moments from a set of loss frequencies at std z*, given a CTM model interval pressure range: P1 ¿ P2 (decreasing up)

INTERFACE:

```
SUBROUTINE LINOZ_SOMLFQ(P1,P2,F0,F1,F2,PS,F,NL)
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: NL
REAL*8,  INTENT(IN)  :: F(NL)
REAL*8,  INTENT(IN)  :: PS(NL+1)
REAL*8,  INTENT(OUT) :: P1
REAL*8,  INTENT(OUT) :: P2
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: F0
      REAL*8,  INTENT(OUT) :: F1
      REAL*8,  INTENT(OUT) :: F2
  REMARKS:
  The pressure levels BETWEEN z* values are:
       PS(i) > PS(i+1) bounds z*(i)

  NL:  z* levels, ==> PS(NL+1) = 0  (extrapolate chemical loss to top)
       Z1 = 16.D0*LOG10(1000.D0/P1)
       Z2 = 16.D0*LOG10(1000.D0/P2)

  The MOMENTS for a square-wave or 'bar': F(x)=f0  b<=x<=c, =0.0 else
       S0 =   f0 (x)                      [from x=b to x=c]
       S1 = 3 f0 (x^2 - x)                [from x=b to x=c]
       S2 = 5 f0 (2x^3 - 3x^2 + x)        [from x=b to x=c]
```

REVISION HISTORY:

```
  24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
```

1.66.6 linoz_read

Subroutine LINOZ_READ reads the input data file for the Linoz stratospheric ozone chemistry.

INTERFACE:

```
      SUBROUTINE LINOZ_READ
```

USES:

```
      USE FILE_MOD,      ONLY : IU_FILE        ! Logical unit #
      USE FILE_MOD,      ONLY : IOERROR        ! I/O error subroutine
      USE DIRECTORY_MOD, ONLY : DATA_DIR_1x1   ! Data directory path

      USE CMN_SIZE_MOD
```

REMARKS:

```
  LINOZ_READ is called from "main.f" at the start of the simulation.
  LINOZ_READ will also call INIT_LINOZ to initialize the arrays.
```

REVISION HISTORY:

```
  24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
  16 Oct 2009 - R. Yantosca         - Now use IU_FILE instead of IU_LINOZ
  16 Oct 2009 - R. Yantosca         - Read file from DATA_DIR_1x1
```

1.66.7 linoz_intpl

Subroutine LINOZ_INTPL does some kind of interpolation.

INTERFACE:

```
SUBROUTINE LINOZ_INTPL(KE,IE,ND,NE,XI,XN,YI,YN)
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: KE
INTEGER, INTENT(IN)  :: IE
INTEGER, INTENT(IN)  :: ND
INTEGER, INTENT(IN)  :: NE
REAL*8,  INTENT(IN)  :: XI(IE)
REAL*8,  INTENT(IN)  :: XN(ND)
REAL*8,  INTENT(IN)  :: YI(KE,IE)
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: YN(KE,ND)
```

REVISION HISTORY:

```
24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
```

1.66.8 strat_init

Subroutine STRAT_INIT copies the ozone computed by the Linoz stratospheric chemistry algorithm back into the GEOS-Chem tracer array.

INTERFACE:

```
SUBROUTINE STRAT_INIT
```

USES:

```
USE TRACERID_MOD
USE TRACER_MOD

USE CMN_SIZE_MOD
USE CMN_MOD
```

REVISION HISTORY:

```
24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
```

1.66.9 init_linoz

Subroutine INIT_LINOZ allocates and zeroes the module arrays used in the Linoz stratospheric ozone algorithm.

INTERFACE:

```
      SUBROUTINE INIT_LINOZ
```

USES:

```
      USE ERROR_MOD, ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
    16 Oct 2009 - R. Yantosca - Initial version
```

1.66.10 cleanup_linoz

Subroutine CLEANUP_LINOZ deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_LINOZ
```

REVISION HISTORY:

```
    16 Oct 2009 - R. Yantosca - Initial version
```

1.67 Fortran: Module Interface logical_mod.f

Module LOGICAL_MOD contains all of the logical switches used by GEOS-Chem.

INTERFACE:

```
      MODULE LOGICAL_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
```

REVISION HISTORY:

```
    05 Nov 2004 - R. Yantosca - Added LNEI99 switch to toggle EPA/NEI emissions
    20 Dec 2004 - R. Yantosca - Added LAVHRRLAI switch for AVHRR LAI fields
    20 Oct 2005 - T-M Fu.     - Added LMEGAN switch for MEGAN biogenics
    01 Nov 2005 - B. Field    - Added LEMEP switch
    26 Feb 2006 - R. Yantosca - Added LDYNOCEAN switch for online ocean Hg model
```

```
05 Apr 2006 - R. Yantosca - Added LGFED2BB switch for GFED2 BIOMASS BURNING
05 May 2006 - L. Murray   - Added LCTH, LMFLUX, LPRECON for lightning
30 May 2006 - S. Wu       - Added LFUTURE
26 Jun 2006 - R. Park     - Added LBRAVO
06 Jul 2006 - Aaron van D.- Added LEDGAR, LEDGARNOx, LEDGARCO, LEDGARSHIP,
                            LEDGARSOx switches for EDGAR emissions
17 Aug 2006 - R. Yantosca - Added LSTREETS for David Streets' emissions
21 Aug 2006 - P. Le Sager - Added LVARTROP for variable tropopause
31 Jan 2007 - L. Murray   - Added LOTDREG, LOTDLOC for regional or local
                            OTD-LIS redistribution of lightning flashes
31 Jan 2007 - L. Murray   - Added LOTDSCALE
08 Mar 2008 - Aaron van D.- Added LCAC, LARCSHIP, LEMEPSHIP
24 Nov 2008 - Aaron van D.- Added LVISTAS
16 Oct 2009 - Y. Chen     - Added L8DAYBB, L3HRBB and LSYNOPBB for
                            8-day and 3-hr GFED BB emissions
26 Jan 2009 - P. Le Sager - Added LICARTT to account for Hudman
                            corrections to EPA/NEI99
12 Feb 2009 - D. Henze    - Added LSVCSPEC
10 Mar 2009 - T-M Fu      - Added LMEGANMONO
10 Mar 2009 - T-M Fu      - Added LDICARB
29 May 2009 - J. Lin      - Add LNLPBL, LARPBLH and LDEPBCK (non-local PBL)
18 May 2009 - P. Le Sager - Added LCOOKE
28 May 2009 - P. Le Sager - Added LKPP
16 Oct 2009 - C. Lee      - Added LICOADSSHIP
18 Aug 2009 - K. Wecht    - Added switches for CH4 emissions & budget
16 Oct 2009 - R. Yantosca - Added LLINOZ switch for Linoz O3 strat chem
16 Oct 2009 - R. Yantosca - Added ProTeX header
30 Oct 2009 - Aaron van D - Added LNEI2005
19 Nov 2009 - M. Barkley  - Added LMODISLAI and LPECCA
18 Dec 2009 - Aaron van D - Added HDF5 logical switches
18 Dec 2009 - Aaron van D - Added logicals for NA, EU, CH, CU nested grids
18 Dec 2009 - Aaron van D - Added logical for 2 x 2.5 TPCORE BC's
29 Jan 2009 - F. Paulot   - Added LFERTILIZERNOX.
26 Feb 2010 - R. Yantosca - Remove obsolete LEMBED flag
18 May 2010 - R. Nassar   - Add logical flags for CO2 offline simulation
20 Jul 2010 - C. Carouge  - Add LPREINDHG and LGTMM for updated mercury.
24 Jan 2011 - L. Murray   - Remove LOTDREG, LCTH, LMFLUX, LPRECON,
                             and LOTDSCALE for lightning
07 Sep 2011 - P. Kasibhatla - Modified to include GFED3
26 Mar 2012 - R. Yantosca - Add USE_OLSON_2001 switch, which will use the
                            newer Olson 2001 land map & drydep inputs
```

1.68 Fortran: Module Interface mapping_mod

Module MAPPING_MOD contains a derived-type object to compute and save the mapping weight (i.e. fraction of each "fine" grid box that fits into the "coarse" grid box") and areal mapping (i.e. the area of each "fine" grid box contained within a "coarse" grid box).

INTERFACE:

```
MODULE Mapping_Mod
```

USES:

```
  USE CMN_SIZE_MOD                    ! Size parameters
  USE ERROR_MOD                       ! Error handling routines
  USE LOGICAL_MOD                     ! Logical switches

  IMPLICIT NONE
  PRIVATE
```

PUBLIC DATA MEMBERS:

```
  PUBLIC :: MapWeight
  TYPE MapWeight
     INTEGER          :: count        ! # of "fine" boxes per "coarse" box
     INTEGER, POINTER :: II(:)        ! Longitude indices,  "fine"   grid
     INTEGER, POINTER :: JJ(:)        ! Latitude  indices,  "fine"   grid
     INTEGER, POINTER :: olson(:)     ! Olson land type,    "fine"   grid
     INTEGER, POINTER :: ordOlson(:)  ! Ordering of Olson land types
     REAL*4,  POINTER :: area(:)      ! Surface areas,      "fine"   grid
     REAL*4           :: sumarea      ! Total surface area, "coarse" grid
  END TYPE MapWeight
```

PUBLIC MEMBER FUNCTIONS:

```
  PUBLIC  :: Init_Mapping
  PUBLIC  :: Get_Map_Wt
  PUBLIC  :: Cleanup_Mapping
```

REMARKS:

```
  The mapping weights and areal mapping are initialized when the Olson
  land map is read from disk (in olson_landmap_mod.F90).  They are used
  again when the MODIS leaf area index data is prepared for input into
  GEOS-Chem's (legacy) dry deposition module.

  Also, we do not define the mapping weight object within this module.
  This allows you to create more than one mapping weight object for
  different native grids (e.g. 0.5 x 0.5 and 0.25 x 0.25, etc.)
```

REVISION HISTORY:

```
  03 Apr 2012 - R. Yantosca - Initial version
  05 Apr 2012 - R. Yantosca - Comment out mapwt field of MapWeight type,
                              leave this for future expansion
  17 Apr 2012 - R. Yantosca - Rename pointer object "map" to "mapping,
                              to remove confusion w/ F90 intrinsic
```

1.68.1 init_mapping

Subroutine INIT_MAPPING allocates and initializes a derived-type object containing grid mapping information.

INTERFACE:

```
SUBROUTINE Init_Mapping( I_FINE, J_FINE, I_COARSE, J_COARSE, mapping )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I_FINE    ! # of longitudes on the "fine" grid
INTEGER, INTENT(IN) :: J_FINE    ! # of latitudes  on the,"fine" grid
INTEGER, INTENT(IN) :: I_COARSE  ! # of longitudes on the "coarse" grid
INTEGER, INTENT(IN) :: J_COARSE  ! # of latitudes  on the "coarse" grid
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MapWeight), POINTER, INTENT(INOUT) :: mapping(:,:) !"fine" -> "coarse"
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
10 Apr 2012 - R. Yantosca - Now add a different # to FINE_PER_COARSE
                            depending on which Olson map we are using
17 Apr 2012 - R. Yantosca - Rename to "map" to "mapping" to avoid confusion
                            with a F90 intrinsic function
17 Apr 2012 - R. Yantosca - Add error check for mapping object
18 Apr 2012 - R. Yantosca - Improve error check for sub-fields of mapping
                            object so as not to interfere w/ parallel loop
```

1.68.2 get_map_wt

Subroutine GET_MAP_Wt returns the "mapping weight", that is, the fraction that each "fine" grid box fits into each "coarse" grid box.

INTERFACE:

```
SUBROUTINE Get_Map_Wt( xedge_w, xedge_e, xedgeC_w, xedgeC_e,   &
                       yedge_s, yedge_n, yedgeC_s, yedgeC_n,   &
                       mapWt                                  )
```

INPUT PARAMETERS:

```
REAL*4, INTENT(IN)  :: xedge_w,  xedge_e    ! Lon edges, fine grid
REAL*4, INTENT(IN)  :: xedgeC_w, xedgeC_e   ! Lon edges, coarse grid
REAL*4, INTENT(IN)  :: yedge_s,  yedge_n    ! Lat edges, fine grid
REAL*4, INTENT(IN)  :: yedgeC_s, yedgeC_n   ! Lat edges, coarse grid
REAL*4, INTENT(OUT) :: mapWt                ! Mapping weight
```

REMARKS:

```
Follows the algorithm from GAMAP routine ctm_getweight.pro
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
21 Mar 2012 - R. Yantosca - Typo: set xOverLap to zero if it is out of the
                            range of 0-1.  (We had set yOverLap=0 before)
21 Mar 2012 - R. Yantosca - Now use REAL*4 for computations to avoid
                            roundoff errors at hi-res grids
03 Apr 2012 - R. Yantosca - Moved from "olson_landmap_mod.F90" to here;
                            renamed "Get_Mapping"
```

1.68.3 cleanup_mapping

Subroutine CLEANUP_MAPPING deallocates memory from a derived-type object containing mapping information.

INTERFACE:

```
SUBROUTINE Cleanup_Mapping( mapping )
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MapWeight), POINTER, INTENT(INOUT) :: mapping(:,:)
```

REVISION HISTORY:

```
03 Mar 2012 - R. Yantosca - Initial version
17 Apr 2012 - R. Yantosca - Rename to "map" to "mapping to avoid name
                            confusion with a F90 intrinsic function
```

1.69 Fortran: Module Interface megan_mod

Module MEGAN_MOD contains variables and routines specifying the algorithms that control the MEGAN inventory of biogenic emissions.

References:

- Guenther, A., et al., *A global model of natural volatile organic compound emissions*, J.Geophys. Res., **100**, 8873-8892, 1995.
- Wang, Y., D. J. Jacob, and J. A. Logan, *Global simulation of tropospheric O3-Nox-hydrocarbon chemistry: 1. Model formulation*, J. Geophys. Res., **103**, D9, 10713-10726, 1998.
- Guenther, A., B. Baugh, G. Brasseur, J. Greenberg, P. Harley, L. Klinger, D. Serca, and L. Vierling, *Isoprene emission estimates and uncertanties for the Central African EXPRESSO study domain*, J. Geophys. Res., **104**, 30,625-30,639, 1999.

- Guenther, A. C., T. Pierce, B. Lamb, P. Harley, and R. Fall, *Natural emissions of non-methane volatile organic compounds, carbon monoxide, and oxides of nitrogen from North America*, Atmos. Environ., **34**, 2205-2230, 2000.
- Guenther, A., and C. Wiedinmyer, *User's guide to Model of Emissions of Gases and Aerosols from Nature*. http://cdp.ucar.edu. (Nov. 3, 2004)
- Guenther, A., *AEF for methyl butenol*, personal commucation. (Nov, 2004)

INTERFACE:

```
      MODULE MEGAN_MOD
```

USES:

```
      USE CMN_SIZE_MOD                                  ! Size parameters
      USE CMN_GCTM_MOD                                  ! Physical constants
      USE ERROR_MOD                                     ! Error trapping

      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

DEFINED PARAMETERS:

```
      ! Scalars
#if   defined( MERRA ) || defined( GEOS_57 )
      INTEGER, PARAMETER  :: DAY_DIM        = 24       ! # of 1-hr periods/day
#else
      INTEGER, PARAMETER  :: DAY_DIM        = 8        ! # of 3-hr periods/day
#endif
      INTEGER, PARAMETER  :: NUM_DAYS       = 10       ! # of days to avg
      REAL*8,  PARAMETER  :: WM2_TO_UMOLM2S = 4.766d0  ! W/m2 -> umol/m2/s

      REAL*8, PARAMETER   :: D2RAD =  PI_180           ! Degrees to radians
      REAL*8, PARAMETER   :: RAD2D =  1d0 / PI_180     ! Radians to degrees
```

PRIVATE TYPES:

```
      ! Past light & temperature conditions (mpb,2009)
      ! (1) Temperature at 2m (TS):
      REAL*8, ALLOCATABLE :: T_DAILY(:,:)       ! Daily averaged sfc temp
      REAL*8, ALLOCATABLE :: T_DAY(:,:,:)       ! Holds 1 day of sfc temp data
      REAL*8, ALLOCATABLE :: T_15(:,:,:)        ! Holds 15 days of daily avg T
      REAL*8, ALLOCATABLE :: T_15_AVG(:,:)      ! Sfc temp avg'd over NUM_DAYS

      ! (2) PAR Direct:
      REAL*8, ALLOCATABLE :: PARDR_DAILY(:,:)   ! Average daily PARDR
      REAL*8, ALLOCATABLE :: PARDR_DAY(:,:,:)   ! Holds 1 day of PARDR data
      REAL*8, ALLOCATABLE :: PARDR_15(:,:,:)    ! 10 days of daily avg'd PARDR
      REAL*8, ALLOCATABLE :: PARDR_15_AVG(:,:)  ! PARDR averaged over NUM_DAYS
```

```
! (3) PAR Diffuse:
REAL*8, ALLOCATABLE :: PARDF_DAILY(:,:)   ! Average daily PARDR
REAL*8, ALLOCATABLE :: PARDF_DAY(:,:,:)   ! Holds 1-day of PARDR data
REAL*8, ALLOCATABLE :: PARDF_15(:,:,:)    ! 10 days of daily avg'd PARDR
REAL*8, ALLOCATABLE :: PARDF_15_AVG(:,:)  ! PARDF averaged over NUM_DAYS

! Annual emission factor arrays (mpb,2009)
REAL*8, ALLOCATABLE :: AEF_ISOP(:,:)      ! Isoprene
REAL*8, ALLOCATABLE :: AEF_MONOT(:,:)     ! Total monoterpenes
REAL*8, ALLOCATABLE :: AEF_MBO(:,:)       ! Methyl butenol
REAL*8, ALLOCATABLE :: AEF_OVOC(:,:)      ! Other biogenic VOC's
REAL*8, ALLOCATABLE :: AEF_APINE(:,:)     ! Alpha-pinene
REAL*8, ALLOCATABLE :: AEF_BPINE(:,:)     ! Beta-pinene
REAL*8, ALLOCATABLE :: AEF_LIMON(:,:)     ! Limonene
REAL*8, ALLOCATABLE :: AEF_SABIN(:,:)     ! Sabine
REAL*8, ALLOCATABLE :: AEF_MYRCN(:,:)     ! Myrcene
REAL*8, ALLOCATABLE :: AEF_CAREN(:,:)     ! 3-Carene
REAL*8, ALLOCATABLE :: AEF_OCIMN(:,:)     ! Ocimene
REAL*8, ALLOCATABLE :: AEF_ACET(:,:)      ! Acetone

! Path to MEGAN emission factors
CHARACTER(LEN=20)   :: MEGAN_SUBDIR = 'MEGAN_200909/'
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: ACTIVITY_FACTORS
PUBLIC  :: CLEANUP_MEGAN
PUBLIC  :: GET_EMACET_MEGAN
PUBLIC  :: GET_EMISOP_MEGAN
PUBLIC  :: GET_EMMBO_MEGAN
PUBLIC  :: GET_EMMONOG_MEGAN
PUBLIC  :: GET_EMMONOT_MEGAN
PUBLIC  :: GET_AEF
PUBLIC  :: GET_AEF_05x0666
PUBLIC  :: INIT_MEGAN
PUBLIC  :: UPDATE_T_DAY
PUBLIC  :: UPDATE_T_15_AVG
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: GET_GAMMA_LAI
PRIVATE :: GET_GAMMA_LEAF_AGE
PRIVATE :: GET_GAMMA_P
PRIVATE :: GET_GAMMA_T_ISOP
PRIVATE :: GET_GAMMA_T_NISOP
PRIVATE :: GET_GAMMA_P_PECCA
PRIVATE :: SOLAR_ANGLE
```

REVISION HISTORY:

```
(1 ) Original code (biogen_em_mod.f) by Dorian Abbot (6/2003).  Updated to
     latest algorithm and modified for the standard code by May Fu
     (11/2004).
(2 ) All emission are currently calculated using TS from DAO met field.
     TS is the surface air temperature, which should be carefully
     distinguished from TSKIN. (tmf, 11/20/2004)
(3 ) In GEOS4, the TS used here are the T2M in the A3 files, read in
     'a3_read_mod.f'.
(4 ) Bug fix: change #if block to also cover GCAP met fields (bmy, 12/6/05)
(5 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(6 ) Bug fix: Skip Feb 29th if GCAP in INIT_MEGAN (phs, 9/18/07)
(7 ) Added routine GET_AEF_05x0666 to read hi-res AEF data for the GEOS-5
     0.5 x 0.666 nested grid simulations (yxw, dan, bmy, 11/6/08)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
09 Mar 2010 - R. Yantosca - Minor bug fix in GET_EMMONOT_MEGAN
17 Mar 2010 - H. Pye      - AEF_SPARE must be a scalar local variable
                            in GET_EMMONOT_MEGAN for parallelization.
20 Aug 2010 - R. Yantosca - Move CMN_SIZE to top of module
20 Aug 2010 - R. Yantosca - Now set DAY_DIM = 24 for MERRA, since the
                            surface temperature is now an hourly field.
01 Sep 2010 - R. Yantosca - Bug fix in INIT_MEGAN: now only read in
                            NUM_DAYS (instead of 15) days of sfc temp data
22 Nov 2011 - R. Yantosca - Do not use erroneous AEF's for nested grids
06 Dec 2011 - E. Fischer  - Added Acetone emissions
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
01 Mar 2012 - R. Yantosca - Use updated GET_LOCALTIME from time_mod.F
11 Apr 2012 - R. Yantosca - Replace lai_mod.F with modis_lai_mod.F90
```

1.69.1 get_emisop_megan

Subroutine GET_EMISOP_MEGAN computes isoprene emissions in units of [atoms C/box] using the MEGAN inventory.

INTERFACE:

```
      FUNCTION GET_EMISOP_MEGAN( I,  J,     SUNCOS,
     &                           TS, Q_DIR, Q_DIFF, XNUMOL )
     &         RESULT( EMISOP )
```

USES:

```
      USE LOGICAL_MOD,   ONLY : LPECCA                    ! Use PCEEA model?
      USE MODIS_LAI_MOD, ONLY : ISOLAI     => GC_LAI      ! Daily LAI
      USE MODIS_LAI_MOD, ONLY : PMISOLAI   => GC_LAI_PM   ! Prev month's LAI
      USE MODIS_LAI_MOD, ONLY : MISOLAI    => GC_LAI_CM   ! Curr month's LAI
```

```
      USE MODIS_LAI_MOD, ONLY : NMISOLAI   => GC_LAI_NM    ! Next month's LAI
      USE MODIS_LAI_MOD, ONLY : DAYS_BTW_M => DAYS_BTW_MON ! LAI month interval
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I, J     ! GEOS-Chem lon & lat indices
      REAL*8,  INTENT(IN) :: SUNCOS   ! Solar zenith angle [unitless]
      REAL*8,  INTENT(IN) :: TS       ! Surface temperature [K]
      REAL*8,  INTENT(IN) :: Q_DIR    ! Flux of direct PAR above canopy [W/m2]
      REAL*8,  INTENT(IN) :: Q_DIFF   ! Flux of diffuse PAR above canopy [W/m2]
      REAL*8,  INTENT(IN) :: XNUMOL   ! Number of atoms C / kg C
```

RETURN VALUE:

```
      REAL*8              :: EMISOP   ! Isoprene emissions [atoms C/box]
```

REMARKS:

```
    References (see above for full citations):
    ============================================================================
    (1 ) Guenther et al, 1995, 1999, 2000, 2004, 2006
    (2 ) Wang,    et al, 1998
    (3 ) Guenther et al, 2007, MEGAN v2.1 User mannual
```

REVISION HISTORY:

```
    (1 ) Original code by Dorian Abbot (9/2003).  Updated to the latest
         algorithm and modified for the standard code by May Fu (11/20/04)
    (2 ) All MEGAN biogenic emission are currently calculated using TS from DAO
         met field. TS is the surface air temperature, which should be
         carefully distinguished from TSKIN. (tmf, 11/20/04)
    (3 ) Restructing of function & implementation of activity factors (mpb,2009)
    17 Dec 2009 - R. Yantosca - Added ProTeX headers
    11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
    11 Apr 2012 - R. Yantosca - Cosmetic changes
```

1.69.2 get_emmbo_megan

Subroutine GET_EMMBO_MEGAN computes methylbutenol emissions in units of [atoms C/box] using the MEGAN inventory.

INTERFACE:

```
      FUNCTION GET_EMMBO_MEGAN( I,  J,      SUNCOS,
     &                          TS, Q_DIR,  Q_DIFF, XNUMOL )
     &         RESULT( EMMBO )
```

USES:

```
USE LOGICAL_MOD,   ONLY : LPECCA                    ! Use PCEEA model?
USE MODIS_LAI_MOD, ONLY : ISOLAI     => GC_LAI      ! Daily LAI
USE MODIS_LAI_MOD, ONLY : PMISOLAI   => GC_LAI_PM   ! Prev month's LAI
USE MODIS_LAI_MOD, ONLY : MISOLAI    => GC_LAI_CM   ! Curr month's LAI
USE MODIS_LAI_MOD, ONLY : NMISOLAI   => GC_LAI_NM   ! Next month's LAI
USE MODIS_LAI_MOD, ONLY : DAYS_BTW_M => DAYS_BTW_MON ! LAI month interval
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J    ! GEOS-Chem lon & lat indices
REAL*8,  INTENT(IN) :: SUNCOS  ! Solar zenith angle [unitless]
REAL*8,  INTENT(IN) :: TS      ! Surface temperature [K]
REAL*8,  INTENT(IN) :: Q_DIR   ! Flux of direct PAR above canopy [W/m2]
REAL*8,  INTENT(IN) :: Q_DIFF  ! Flux of diffuse PAR above canopy [W/m2]
REAL*8,  INTENT(IN) :: XNUMOL  ! Number of atoms C / kg C
```

RETURN VALUE:

```
REAL*8              :: EMMBO   ! Methylbutenol emissions [atoms C/box]
```

REMARKS:

```
References (see above for full citations):
==============================================================================
(1 ) Guenther et al, 1995, 1999, 2000, 2004, 2006
(2 ) Wang,    et al, 1998
(3 ) Guenther et al, 2007, MEGAN v2.1 User mannual
```

REVISION HISTORY:

```
(1 ) Original code by Dorian Abbot (9/2003).  Updated to the latest
     algorithm and modified for the standard code by May Fu (11/20/04)
(2 ) All MEGAN biogenic emission are currently calculated using TS from DAO
     met field. TS is the surface air temperature, which should be
     carefully distinguished from TSKIN. (tmf, 11/20/04)
(3 ) Restructing of function & implementation of activity factors (mpb,2009)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
```

1.69.3 get_emmonog_megan

Subroutine GET_EMMONOG_MEGAN computes generic ('G') monoterpene emissions for individual monoterpene species in units of [atoms C/box] using the new v2.1 MEGAN inventory emission factor maps.

INTERFACE:

```
 FUNCTION GET_EMMONOG_MEGAN( I,     J,      SUNCOS, TS,
&                            Q_DIR, Q_DIFF, XNUMOL, MONO_SPECIES )
&            RESULT( EMMONOT )
```

USES:

```
USE LOGICAL_MOD,   ONLY : LPECCA                    ! Use PCEEA model?
USE MODIS_LAI_MOD, ONLY : ISOLAI     => GC_LAI      ! Daily LAI
USE MODIS_LAI_MOD, ONLY : PMISOLAI   => GC_LAI_PM   ! Prev month's LAI
USE MODIS_LAI_MOD, ONLY : MISOLAI    => GC_LAI_CM   ! Curr month's LAI
USE MODIS_LAI_MOD, ONLY : NMISOLAI   => GC_LAI_NM   ! Next month's LAI
USE MODIS_LAI_MOD, ONLY : DAYS_BTW_M => DAYS_BTW_MON ! LAI month interval
```

INPUT PARAMETERS:

```
INTEGER,          INTENT(IN) :: I, J          ! Lon & lat indices
REAL*8,           INTENT(IN) :: SUNCOS        ! Cos(solar zenith angle)
REAL*8,           INTENT(IN) :: TS            ! Surface temperature [K]
REAL*8,           INTENT(IN) :: Q_DIR         ! Direct PAR [W/m2]
REAL*8,           INTENT(IN) :: Q_DIFF        ! Diffuse PAR [W/m2]
REAL*8,           INTENT(IN) :: XNUMOL        ! Number of atoms C / kg C
CHARACTER(LEN=5), INTENT(IN) :: MONO_SPECIES  ! Monoterpene species name
```

RETURN VALUE:

```
REAL*8                       :: EMMONOT       ! Emissions [atoms C/box]
```

REMARKS:

```
References (see above for full citations):
==============================================================================
(1 ) Guenther et al, 1995, 1999, 2004, 2006
(2 ) Guenther et al, 2007, MEGAN v2.1 User Manual
```

REVISION HISTORY:

```
(1 ) Written by Michael Barkley (2008), based on old monoterpene code by
     dsa,tmf.
(2 ) Uses gamma factors instead of exchange factors, this includes
      calling of a new temperature algorithm which use a beta factor.
      (mpb,2008)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
```

1.69.4 get_emacet_megan

Subroutine GET_EMACET_MEGAN computes acetone emissions in units of [atomsC/box] using the MEGAN inventory.

INTERFACE:

```
 FUNCTION GET_EMACET_MEGAN( I,     J ,     SUNCOS , TS,
&                           Q_DIR, Q_DIFF, XNUMOL )
&            RESULT( EMACET )
```

USES:

```
USE LOGICAL_MOD,   ONLY : LMEGAN                    ! Is MEGAN used?
USE LOGICAL_MOD,   ONLY : LPECCA                    ! Use PCEEA model?
USE MODIS_LAI_MOD, ONLY : ISOLAI     => GC_LAI      ! Daily LAI
USE MODIS_LAI_MOD, ONLY : PMISOLAI   => GC_LAI_PM   ! Prev month's LAI
USE MODIS_LAI_MOD, ONLY : MISOLAI    => GC_LAI_CM   ! Curr month's LAI
USE MODIS_LAI_MOD, ONLY : NMISOLAI   => GC_LAI_NM   ! Next month's LAI
USE MODIS_LAI_MOD, ONLY : DAYS_BTW_M => DAYS_BTW_MON ! LAI month interval
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I,  J   ! GEOS-Chem lon & lat indices
REAL*8,  INTENT(IN) :: SUNCOS  ! Solar zenith angle [unitless]
REAL*8,  INTENT(IN) :: TS      ! Surface temperature [K]
REAL*8,  INTENT(IN) :: Q_DIR   ! Flux of direct PAR above canopy [W/m2]
REAL*8,  INTENT(IN) :: Q_DIFF  ! Flux of diffuse PAR above canopy [W/m2]
REAL*8,  INTENT(IN) :: XNUMOL  ! Number of atoms C / kg C
```

RETURN VALUE:

```
REAL*8              :: EMACET  ! Acetone emissions [atoms C/box]
```

REMARKS:

```
References (see above for full citations):
==============================================================================
(1 ) Guenther et al, 1995, 1999, 2004, 2006
(2 ) Guenther et al, 2007, MEGAN v2.1 User Manual
```

REVISION HISTORY:

```
(1 ) Written by Michael Barkley (2008), based on old monoterpene code by
     dsa,tmf.
(2 ) Uses gamma factors instead of exchange factors, this includes
      calling of a new temperature algorithm which use a beta factor.
      (mpb,2008)
24 May 2011 - E. Fischer  - Modified for acetone. Function GET_EMACET_MEGAN
                            is called from "acetone_mod.f"
06 Dec 2011 - M. Payer    - Added ProTeX headers
27 Mar 2012 - R. Yantosca - Avoid segfault errors if LMEGAN=.FALSE.
11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
```

1.69.5 get_emmonot_megan

Subroutine GET_EMMONOT_MEGAN computes the total monoterpene emissions in units of [atoms C/box] using the MEGAN v2.1 inventory.

INTERFACE:

```
      FUNCTION GET_EMMONOT_MEGAN( I,  J,     SUNCOS,
     &                            TS, Q_DIR, Q_DIFF, XNUMOL )
     &            RESULT( EMMONOT )
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I, J      ! Lon & lat indices
      REAL*8,  INTENT(IN) :: SUNCOS    ! Cos( solar zenith angle )
      REAL*8,  INTENT(IN) :: TS        ! Local surface air temperature [K]
      REAL*8,  INTENT(IN) :: Q_DIR     ! Direct PAR above canopy [W/m2]
      REAL*8,  INTENT(IN) :: Q_DIFF    ! Diffuse PAR above canopy [W/m2]
      REAL*8,  INTENT(IN) :: XNUMOL    ! Number of atoms C / kg C
```

RETURN VALUE:

```
      REAL*8              :: EMMONOT   ! Monoterpene emissions [atoms C/box]
```

REMARKS:

```
    References (see above for full citations):
    ============================================================================
    (1 ) Guenther et al, 1995, 1999, 2000, 2006
    (2 ) Guenther et al, 2007, MEGAN v2.1 User Manual
```

REVISION HISTORY:

```
    (1 ) Original code by Michael Barkley (mpb,2009).
    17 Dec 2009 - R. Yantosca - Added ProTeX headers
    09 Mar 2010 - H.O.T. Pye  - Change order of arguments in call to
                                routine GET_EMMONOG_MEGAN
    11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
```

1.69.6 activity_factors

Subroutine ACTIVITY_FACTORS computes the gamma activity factors which adjust the emission factors to the current weather and vegetation conditions. Here they are calculated by (default) for isoprene.

INTERFACE:

```
      SUBROUTINE ACTIVITY_FACTORS( I,              J,       TS,
     &                             SUNCOS,         Q_DIR,   Q_DIFF,
     &                             XNUMOL,         SPECIES, GAMMA_LAI,
     &                             GAMMA_LEAF_AGE, GAMMA_P, GAMMA_T,
     &                             GAMMA_SM )
```

USES:

```
USE LOGICAL_MOD,   ONLY : LPECCA                    ! Use PCEEA model?
USE MODIS_LAI_MOD, ONLY : ISOLAI     => GC_LAI      ! Daily LAI
USE MODIS_LAI_MOD, ONLY : PMISOLAI   => GC_LAI_PM   ! Prev month's LAI
USE MODIS_LAI_MOD, ONLY : MISOLAI    => GC_LAI_CM   ! Curr month's LAI
USE MODIS_LAI_MOD, ONLY : NMISOLAI   => GC_LAI_NM   ! Next month's LAI
USE MODIS_LAI_MOD, ONLY : DAYS_BTW_M => DAYS_BTW_MON ! LAI month interval
```

INPUT PARAMETERS:

```
INTEGER,          INTENT(IN)   :: I, J     ! Lon & lat indices
REAL*8,           INTENT(IN)   :: SUNCOS   ! Cos( solar zenith angle )
REAL*8,           INTENT(IN)   :: TS       ! Surface air temperature [K]
REAL*8,           INTENT(IN)   :: XNUMOL   ! Number of atoms C / kg C
REAL*8,           INTENT(IN)   :: Q_DIR    ! Direct PAR [W/m2]
REAL*8,           INTENT(IN)   :: Q_DIFF   ! Diffuse PAR [W/m2]
CHARACTER(LEN=4), INTENT(IN)   :: SPECIES  ! Species (ISOP,MONO,MBOT)
```

OUTPUT PARAMETERS:

```
! GAMMA factors for:
REAL*8,           INTENT(OUT)  :: GAMMA_LAI       ! LAI
REAL*8,           INTENT(OUT)  :: GAMMA_LEAF_AGE  ! Leaf age
REAL*8,           INTENT(OUT)  :: GAMMA_P         ! Light
REAL*8,           INTENT(OUT)  :: GAMMA_T         ! Temperature
REAL*8,           INTENT(OUT)  :: GAMMA_SM        ! Soil moisture
```

REVISION HISTORY:

```
(1 ) Original code written by Michael Barkley (mpb,2009).
17 Dec 2009 - R. Yantosca - Added ProTeX headers
11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
```

1.69.7 get_gamma_p_pecca

Computes the PECCA gamma activity factor with sensitivity to LIGHT.

INTERFACE:

```
FUNCTION GET_GAMMA_P_PECCA( I , J , Q_DIR_2, Q_DIFF_2 ,
&                           PARDR_AVG_SIM ,  PARDF_AVG_SIM  )
&             RESULT( GAMMA_P_PECCA )
```

USES:

```
USE TIME_MOD,   ONLY : GET_DAY_OF_YEAR
USE TIME_MOD,   ONLY : GET_LOCALTIME
USE GRID_MOD,   ONLY : GET_YMID
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I,  J             ! Lon & lat indices
REAL*8,  INTENT(IN) :: PARDR_AVG_SIM     ! Average direct PAR [W/m2]
REAL*8,  INTENT(IN) :: PARDF_AVG_SIM     ! Average diffuse PAR [W/m2]
REAL*8,  INTENT(IN) :: Q_DIR_2           ! Direct PAR [umol/m2/s]
REAL*8,  INTENT(IN) :: Q_DIFF_2          ! Diffuse PAR [umol/m2/s]
```

RETURN VALUE:

```
REAL*8              :: GAMMA_P_PECCA     ! GAMMA factor for light
```

REMARKS:

```
References (see above for full citations):
==============================================================================
(1 ) Guenther et al, 2006
(2 ) Guenther et al, 2007, MEGAN v2.1 user guide
```

REVISION HISTORY:

```
(1 ) Here PAR*_AVG_SIM is the average light conditions over the simulation
     period. I've set this = 10 days to be consistent with temperature & as
     outlined in Guenther et al, 2006. (mpb,2009)
(2 ) Code was taken & adapted directly from the MEGAN v2.1 source code.
     (mpb,2009)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_LOCALTIME(I,J,L) from time_mod.F90
```

1.69.8 solar_angle

Function SOLAR_ANGLE computes the local solar angle for a given day of year, latitude and longitude (or local time). Called from routine GAMMA_P_PECCA.

INTERFACE:

```
FUNCTION SOLAR_ANGLE( DOY, SHOUR, LAT ) RESULT( SINbeta )
```

INPUT PARAMETERS:

```
! Arguments
INTEGER, INTENT(IN) :: DOY       ! Day of year
REAL*8,  INTENT(IN) :: SHOUR     ! Local time
REAL*8,  INTENT(IN) :: LAT       ! Latitude
```

RETURN VALUE:

```
REAL*8              :: SINbeta   ! Sin of the local solar angle
```

REMARKS:

```
References (see above for full citations):
(1 ) Guenther et al, 2006
(2 ) Guenther et al, MEGAN v2.1 user mannual 2007-09
```

REVISION HISTORY:

```
(1 ) This code was taken directly from the MEGAN v2.1 source code.(mpb,2009)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.69.9 get_gamma_t_isop

Function GET_GAMMA_T_ISOP computes the temperature sensitivity for ISOPRENE ONLY.

INTERFACE:

```
FUNCTION GET_GAMMA_T_ISOP( T, PT_15, PT_1 ) RESULT( GAMMA_T )
```

INPUT PARAMETERS:

```
! Current leaf temperature, the surface air temperature field (TS)
! is assumed equivalent to the leaf temperature over forests.
REAL*8,  INTENT(IN) :: T


! Average leaf temperature over the past 15 days
REAL*8,  INTENT(IN) :: PT_15

! Average leaf temperature over the past arbitray day(s).
! This is not used at present (but might be soon!).
REAL*8,  INTENT(IN) :: PT_1
```

RETURN VALUE:

```
! GAMMA factor for temperature (isoprene only)
REAL*8              :: GAMMA_T
```

REMARKS:

```
References (see above for full citations):
=============================================================================
(1 ) Guenther et al, 1995
(2 ) Guenther et al, 2006
(3 ) Guenther et al, MEGAN v2.1 user mannual 2007-08
```

REVISION HISTORY:

```
(1 ) Includes the latest MEGAN v2.1 temperature algorithm (mpb, 2009).
     Note, this temp-dependence is the same for the PECCA & hybrid models.
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.69.10 get_gamma_t_nisop

Function GET_GAMMA_T_NISOP computes the temperature activity factor (GAMMA_T) for BVOCs OTHER than isoprene. Called from routines GET_EMMONOG_MEGAN and GET_EMMBO_MEGAN.

INTERFACE:

```
FUNCTION GET_GAMMA_T_NISOP( T, BETA ) RESULT( GAMMA_T )
```

INPUT PARAMETERS:

```
! Current leaf temperature [K], the surface air temperature field (TS)
! is assumed equivalent to the leaf temperature over forests.
REAL*8, INTENT(IN) :: T

! Temperature factor per species (from MEGAN user manual).
! Beta = 0.09 for MBO and for monoterpene species (APINE, BPINE, LIMON,
! SABIN, MYRCN, CAREN, OCIMN). Pass as an argument in case this changes.
REAL*8, INTENT(IN) :: BETA
```

RETURN VALUE:

```
REAL*8             :: GAMMA_T  !
```

REMARKS:

```
GAMMA_T =  exp[BETA*(T-Ts)]

                                                                              .
           where BETA   = temperature dependent parameter
                 Ts     = standard temperature (normally 303K, 30C)
                                                                              .
References (see above for full citations):
================================================================================
(1 ) Guenther et al, 2006
(2 ) Guenther et al, MEGAN user mannual 2007-08
```

REVISION HISTORY:

```
(1 ) Original code by Michael Barkley (2009).
     Note: If T = Ts  (i.e. standard conditions) then GAMMA_T = 1
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.69.11 get_gamma_p

Function GET_GAMMA_P computes the gamma activity factor with sensitivity to LIGHT (aka 'PAR'). Called by the functions ! GET_EMISOP_MEGAN, GET_EMMBO_MEGAN, and GET_EMMONOG_MEGAN.

INTERFACE:

```
      FUNCTION GET_GAMMA_P( LAI, SUNCOS1, Q_DIR_2, Q_DIFF_2 )
     &              RESULT( GAMMA_P )
```

INPUT PARAMETERS:

```
      REAL*8,  INTENT(IN) :: LAI        ! Cumulative leaf area index
      REAL*8,  INTENT(IN) :: SUNCOS1    ! Cosine of solar zenith angle
      REAL*8,  INTENT(IN) :: Q_DIR_2    ! Direct PAR above canopy [umol/m2/s]
      REAL*8,  INTENT(IN) :: Q_DIFF_2   ! Diffuse PAR above canopy [umol/m2/s]
```

RETURN VALUE:

```
      REAL*8              :: GAMMA_P    ! Gamma activity factor w/r/t light
```

REMARKS:

```
    *** REVAMPED FUNCTION ***
                                                                             .
    C_PPFD: Effect of increasing PPFD up to a saturation point, where emission
            level off, based on Eq 4abc from Guenther et al. (1999)
            In addition, a 5 layered canopy model based on Eqs 12-16
            from Guenther et al. (1995) is included to correct for light
            attenuation in the canopy.
                                                                             .
    References (see above for full citations):
    ============================================================================
    (1 ) Guenther et al, 1995
    (2 ) Wang     et al, 1998
    (3 ) Guenther et al, 1999
    (5 ) Guenther et al, 2004
```

REVISION HISTORY:

```
    (1 ) Original code by Dorian Abbot and by May Fu.
    (2 ) This code was extracted from the previous GET_HEA_TL function.
         (mpb,2009)
    17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.69.12 get_gamma_leaf_age

Function GET_GAMMA_LEAF_AGE computes the gamma exchange activity factor which is sensitive to leaf age (= GAMMA_LEAF_AGE). Called from GET_EMISOP_MEGAN, GET_EMMBO_MEGAN, and GET_EMMONOG_MEGAN.

INTERFACE:

```
      FUNCTION GET_GAMMA_LEAF_AGE( CMLAI, PMLAI, T, SPECIES, TT )
     &         RESULT( GAMMA_LEAF_AGE )
```

INPUT PARAMETERS:

```
REAL*8,           INTENT(IN) :: T        ! Number of days between
                                         !  current and previous LAI.
REAL*8,           INTENT(IN) :: CMLAI    ! Current month's LAI [cm2/cm2]
REAL*8,           INTENT(IN) :: PMLAI    ! Previous months LAI [cm2/cm2]
CHARACTER(LEN=4), INTENT(IN) :: SPECIES  ! BVOC species name
REAL*8,           INTENT(IN) :: TT       ! Daily average temperature [K]
```

RETURN VALUE:

```
REAL*8                       :: GAMMA_LEAF_AGE   ! Activity factor
```

REMARKS:

```
References (see above for full citations):
==========================================================================
(3 ) Guenther et al, 2006
(5 ) Guenther et al, MEGAN user mannual 2007-08
```

REVISION HISTORY:

```
(1 ) Original code by Dorian Abbot (9/2003). Modified for the standard
     code by May Fu (11/2004)
(2 ) Update to publically released (as of 11/2004) MEGAN algorithm and
     modified for the standard code by May Fu (11/2004).
(3 ) Algorithm is based on the latest User's Guide (tmf, 11/19/04)
(4 ) Renamed & now includes specific relative emission activity factors for
    each BVOC based on MEGAN v2.1 algorithm (mpb,2008)
(5 ) Now calculate TI (number of days after budbreak required to induce
    iso. em.) and TM (number of days after budbreak required to reach
    peak iso. em. rates) using the daily average temperature, instead
    of using fixed values (mpb,2008)
    NOTE: Can create 20% increases in tropics (Guenther et al 2006)
(6 ) Implemented change for the calculation of FGRO if ( CMLAI > PMLAI ),
    i.e. if LAI has increased with time, and used new values for
    all foilage fractions if ( CMLAI = PMLAI ). Also removed TG variable
    as not now needed. (mpb,2000)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.69.13 get_gamma_lai

Function GET_GAMMA_LAI computes the gamma exchange activity factor which is sensitive to leaf area (= GAMMA_LAI). Called from GET_EMISOP_MEGAN, GET_EMMBO_MEGAN, and GET_EMMONOG_MEGAN.

INTERFACE:

```
FUNCTION GET_GAMMA_LAI( CMLAI ) RESULT( GAMMA_LAI )
```

INPUT PARAMETERS:

```
      REAL*8, INTENT(IN)  :: CMLAI       ! Current month's LAI [cm2/cm2]
```

RETURN VALUE:

```
      REAL*8              :: GAMMA_LAI
```

REMARKS:

```
    References (see above for full citations):
    ============================================================================
    (1 ) Guenther et al, 2006
    (2 ) Guenther et al, MEGAN user mannual 2007-08
```

REVISION HISTORY:

```
    (1 ) Original code by Dorian Abbot (9/2003).  Modified for the standard
         code by May Fu (11/2004)
    (2 ) Update to publically released (as of 11/2004) MEGAN algorithm and
         modified for the standard code by May Fu (11/2004).
    (3 ) Algorithm is based on the latest MEGAN v2.1 User's Guide (mpb,2009)
    17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.69.14 get_aef

Subroutine GET_AEF reads Annual Emission Factor for all biogenic VOC species from disk. Called from GET_AEF is called from "main.f".

INTERFACE:

```
      SUBROUTINE GET_AEF
```

USES:

```
      USE BPCH2_MOD,      ONLY : GET_RES_EXT, READ_BPCH2
      USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
      USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
      USE TIME_MOD,       ONLY : GET_TS_EMIS
      USE GRID_MOD,       ONLY : GET_AREA_M2
```

REMARKS:

```
    Reference: (5 ) Guenther et al, 2004
```

REVISION HISTORY:

```
    (1 ) Original code by Dorian Abbot (9/2003).  Modified for the standard
         code by May Fu (11/2004)
    (2 ) AEF detailed in the latest MEGAN User's Guide (tmf, 11/19/04)
    (3 ) Bug fix (tmf, 11/30/04)
    (4 ) Now reads 1x1 files and regrids to current resolution (bmy, 10/24/05)
```

```
(5 ) Uses new v2.1 emission factors maps for isoprene, MBO and 7 monoterpene
      species, download in 2009. (mpb,2009)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.69.15 get_aef_05x0666

Subroutine GET_AEF_05x0666 reads Annual Emission Factor for all biogenic VOC species from disk. Called from "main.f". Specially constructed to read 0.5 x 0.666 nested grid data for the GEOS-5 nested grid simulations.

INTERFACE:

```
SUBROUTINE GET_AEF_05x0666
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_RES_EXT, READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE TIME_MOD,       ONLY : GET_TS_EMIS
USE GRID_MOD,       ONLY : GET_AREA_M2
USE DIRECTORY_MOD,  ONLY : DATA_DIR
```

REMARKS:

```
Reference: (5 ) Guenther et al, 2004
```

REVISION HISTORY:

```
(1) Specially constructed to read 0.5 x 0.666 nested grid data for the
    GEOS-5 nested grid simulations. (yxw, dan, bmy, 11/6/08)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
02 Jul 2012 - R. Yantosca - Rename the input file latlon_nested.txt to
                            latlon_geos05x0666.txt to avoid confusion
```

1.69.16 update_t_day

Subroutine UPDATE_T_DAY must be called every time the A-3 fields are updated. Each 3h TS value for each gridbox is moved up one spot in the matrix and the current value is put in the last spot.

INTERFACE:

```
SUBROUTINE UPDATE_T_DAY
```

USES:

```
USE MEGANUT_MOD     ! We use all functions from the module
```

REVISION HISTORY:

```
(1 ) All MEGAN biogenic emission are currently calculated using TS from DAO
     met field. TS is the surface air temperature, which should be
     carefully distinguished from TSKIN. (tmf, 11/20/04)
(2 ) In GEOS4, TS are originally T2M in the A3 files, read in
     'a3_read_mod.f'.
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.69.17 update_t_15_avg

Subroutine UPDATE_T_15_AVG should be called at the beginning of each day. It loops through the gridboxes doing the following:

1. Average T_DAY over the 8 TS values during the day.
2. Push the daily average TS values through T_15, throwing out the oldest and putting the newest (the T_DAY average) in the last spot
3. Get T_15_AVG by averaging T_15 over the 15 day period.

INTERFACE:

```
SUBROUTINE UPDATE_T_15_AVG
```

REVISION HISTORY:

```
01 Oct 1995 - M. Prather  - Initial version
(1 ) All MEGAN biogenic emission are currently calculated using TS from DAO
     met field. TS is the surface air temperature, which should be
     carefully distinguished from TSKIN. (tmf, 11/20/04)
(2 ) In GEOS4, TS are originally T2M in the A3 files, read in
     'a3_read_mod.f'.
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.69.18 init_megan

Subroutine INIT_MEGAN allocates and initializes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_MEGAN
```

USES:

```
USE A3_READ_MOD
USE GEOS57_READ_MOD, ONLY : GEOS57_READ_A1
USE MERRA_A1_MOD
USE FILE_MOD,         ONLY : IU_A3
USE JULDAY_MOD,       ONLY : CALDATE
USE ERROR_MOD,        ONLY : ALLOC_ERR
USE LOGICAL_MOD,      ONLY : LUNZIP
USE TIME_MOD,         ONLY : GET_FIRST_A3_TIME, GET_JD
USE TIME_MOD,         ONLY : ITS_A_LEAPYEAR,    YMD_EXTRACT
```

REVISION HISTORY:

```
(1 ) Change the logic in the #if block for G4AHEAD. (bmy, 12/6/05)
(2 ) Bug fix: skip Feb 29th if GCAP (phs, 9/18/07)
(3 ) Now call GET_AEF_05x0666 for GEOS-5 nested grids (yxw,dan,bmy, 11/6/08)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
26 Aug 2010 - R. Yantosca - Now reference merra_a1_mod.f
01 Sep 2010 - R. Yantosca - Now read in NUM_DAYS of sfc temp data (this had
                            been hardwired to 15 days previously)
07 Feb 2011 - R. Yantosca - Fix typos: make sure to zero out the proper
                            PARDF_* and PARDR_* arrays after allocation
22 Nov 2011 - R. Yantosca - Do not use erroneous AEF's for nested grids
08 Feb 2012 - R. Yantosca - Now read surface temperature for GEOS-5.7.x
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
11 Apr 2012 - R. Yantosca - Now remove the call to INIT_LAI; we shall
                            initialize the LAI arrays from main.F
```

1.69.19 cleanup_megan

Subroutine CLEANUP_MEGAN deallocates all allocated arrays at the end of a GEOS-Chem model run.

INTERFACE:

```
SUBROUTINE CLEANUP_MEGAN
```

REVISION HISTORY:

```
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.70 Fortran: Module Interface meganut_mod

Module MEGANUT_MOD contains functions used by MEGAN.

INTERFACE:

```
      MODULE MEGANUT_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: XLTMMP
      PUBLIC :: XLPARDF
      PUBLIC :: XLPARDR
  !REVISION HISTORY
   20 Nov 2009 - C. Carouge - Create the module with xltmmp, xlpardf and
                              xlpardr functions.
```

1.70.1 xltmmp

Function XLTMMP passes the value of the DAO meterological field TS(IIPAR,JJPAR) back to the calling subroutine. This preserves the functionality of the H/G/I CTM function XLTMMP. XLTMMP is written in Fixed-Form Fortran 90. I, J are the long/lat indices of the grid box. IJLOOP is passed in order to maintain compatibility with the H/G/I subroutines, but is not used.

INTERFACE:

```
      FUNCTION XLTMMP( I, J, IJLOOP ) RESULT( VALUE )
```

USES:

```
      USE DAO_MOD, ONLY : TS

      USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)           :: I, J
      INTEGER, INTENT(IN), OPTIONAL :: IJLOOP
```

RETURN VALUE:

```
      REAL*8                        :: VALUE
```

REVISION HISTORY:

```
                              Use C-preprocessor #include statement to
                              include CMN_SIZE, which has IIPAR, JJPAR,
                              LLPAR, IIPAR, JJPAR, LGLOB.
    23 Jun 2000 - R. Yantosca - Now reference TS from "dao_mod.f" instead of
                              from common block header file "CMN_TS".
    31 Aug 2000 - R. Yantosca - Eliminated obsolete code from 6/23/00
    26 Sep 2001 - R. Yantosca - Now declare XLTMMP as REAL*8 w/in program body.
                              Also updated comments.
    24 Oct 2001 - R. Yantosca - Remove obsolete commented out code from 9/01
    20 Jul 2004 - R. Yantosca - IJLOOP is now not declared optional...this
                              facilitates compiling with -C on Altix
    04 Aug 2005 - R. Yantosca - Now make IJLOOP an optional argument; it's only
                              kept for backwards compatibility w/ older code
  ------------------------------------------------------------------------------
  BOC
       VALUE = TS(I,J)

       END FUNCTION XLTMMP
  EOC
  ------------------------------------------------------------------------------
            Harvard University Atmospheric Chemistry Modeling Group            !
  ------------------------------------------------------------------------------
%//////////////////////////////////////////////////////////
```

\mbox{}\hrulefill\

  \subsubsection{xlpardr }

  Function XLPARDR passes the value of the DAO meterological
    field PARDR(IIPAR,JJPAR) back to the calling subroutine. This preserves
    the functionality of the H/G/I CTM function PARDR. I, J are the long/lat
    indices of the grid box. IJLOOP is passed in order to maintain compatibility
    with the H/G/I subroutines, but is not used.
  \\
  \\{\bf INTERFACE:}

```
\begin{verbatim}       FUNCTION XLPARDR( I, J, IJLOOP ) RESULT( VALUE )
   !USES
       USE DAO_MOD, ONLY : PARDR

       USE CMN_SIZE_MOD
   !INPUT PARAMETERS
       INTEGER, INTENT(IN)           :: I, J
       INTEGER, INTENT(IN), OPTIONAL :: IJLOOP
```

RETURN VALUE:

```
       REAL*8                        :: VALUE
```

```
   !REVISION HISTORY
   20 Nov 2009 - M. Barkley - Original version
```

1.70.2 xlpardf

Function XLPARDF passes the value of the DAO meterological field PARDF(IIPAR,JJPAR) back to the calling subroutine. This preserves the functionality of the H/G/I CTM function PARDF. I, J are the long/lat indices of the grid box. IJLOOP is passed in order to maintain compatibility with the H/G/I subroutines, but is not used.

INTERFACE:

```
       FUNCTION XLPARDF( I, J, IJLOOP ) RESULT( VALUE )
   !USES
       USE DAO_MOD, ONLY : PARDF

       USE CMN_SIZE_MOD
   !INPUT PARAMETERS
       INTEGER, INTENT(IN)           :: I, J
       INTEGER, INTENT(IN), OPTIONAL :: IJLOOP
```

RETURN VALUE:

```
       REAL*8                        :: VALUE

   !REVISION HISTORY
    20 Nov 2009 - M. Barkley - Original version
  !EOP
  ------------------------------------------------------------------------------
  BOC
       VALUE = PARDF(I,J)

       END FUNCTION XLPARDF
  EOC
       END MODULE MEGANUT_MOD
\markboth{Left}{Source File: merra\_a1\_mod.F,  Date: Tue Jul 24 15:01:14 EDT 2012
}


  ------------------------------------------------------------------------------
           Harvard University Atmospheric Chemistry Modeling Group            !
  ------------------------------------------------------------------------------
%//////////////////////////////////////////////////////////

\mbox{}\hrulefill\


  \subsection{Fortran:  Module Interface merra\_a1\_mod }
```

```
  Module MERRA\_A1\_MOD contains subroutines for reading the
    1-hour time averaged (aka "A1") fields from the MERRA data archive.
  \\
  \\{\bf INTERFACE:}
\begin{verbatim}       MODULE MERRA_A1_MOD
```

USES:

```
       IMPLICIT NONE
 #     include "define.h"
       PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
       PUBLIC  :: GET_MERRA_A1_FIELDS
       PUBLIC  :: OPEN_MERRA_A1_FIELDS
```

PRIVATE MEMBER FUNCTIONS:

```
       PRIVATE :: A1_CHECK
       PRIVATE :: DO_OPEN_A1
       PRIVATE :: READ_A1
```

REMARKS:

```
    Don't bother with the file unzipping anymore.
```

REVISION HISTORY:

```
    19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
```

1.70.3 do_open_a1

Function DO_OPEN_A1 returns TRUE if is time to open the A1 met field file or FALSE otherwise. This prevents us from opening a file which has already been opened.

INTERFACE:

```
       FUNCTION DO_OPEN_A1( NYMD, NHMS, RESET ) RESULT( DO_OPEN )
```

INPUT PARAMETERS:

```
       INTEGER, INTENT(IN)           :: NYMD     ! YYYYMMDD and hhmmss to test
       INTEGER, INTENT(IN)           :: NHMS     !  if it's time to open file
       LOGICAL, INTENT(IN), OPTIONAL :: RESET    ! Reset the
```

RETURN VALUE:

```
       LOGICAL                       :: DO_OPEN  ! =T if it's time to open file
```

REVISION HISTORY:

```
    19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
    21 Sep 2010 - R. Yantosca - Add RESET via the argument list to reset
                                the FIRST flag if so desired.
```

1.70.4 open_merra_a1_fields

Subroutine OPEN_MERRA_A1_FIELDS opens the A1 met fields file for date NYMD and time NHMS.

INTERFACE:

```
SUBROUTINE OPEN_MERRA_A1_FIELDS( NYMD, NHMS, RESET )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_RES_EXT
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE DIRECTORY_MOD, ONLY : MERRA_DIR
USE ERROR_MOD,     ONLY : ERROR_STOP
USE FILE_MOD,      ONLY : FILE_EXISTS
USE FILE_MOD,      ONLY : IU_A1
USE FILE_MOD,      ONLY : IOERROR
USE TIME_MOD,      ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)           :: NYMD    ! YYYYMMDD date
INTEGER, INTENT(IN)           :: NHMS    ! hhmmss time
LOGICAL, INTENT(IN), OPTIONAL :: RESET   ! Reset first-time A1 flag?
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
```

1.70.5 get_merra_a1_fields

Subroutine GET_MERRA_A1_FIELDS is a wrapper for routine READ_A1.

INTERFACE:

```
SUBROUTINE GET_MERRA_A1_FIELDS( NYMD, NHMS )
```

USES:

```
USE DAO_MOD, ONLY : ALBD,     CLDFRC,   EFLUX,    EVAP
USE DAO_MOD, ONLY : FRSEAICE, FRSNO,    GRN,      GWETROOT
USE DAO_MOD, ONLY : GWETTOP,  HFLUX,    LAI,      LWI
USE DAO_MOD, ONLY : PARDF,    PARDR,    PBL,      PREANV
USE DAO_MOD, ONLY : PREACC,   PRECON,   PRELSC,   PRECSNO
USE DAO_MOD, ONLY : RADLWG,   RADSWG,   SEAICE00, SEAICE10
USE DAO_MOD, ONLY : SEAICE20, SEAICE30, SEAICE40, SEAICE50
USE DAO_MOD, ONLY : SEAICE60, SEAICE70, SEAICE80, SEAICE90
USE DAO_MOD, ONLY : SLP,      SNODP,    SNOMAS,   TROPP
USE DAO_MOD, ONLY : TS,       TSKIN,    U10M,     USTAR
```

```
      USE DAO_MOD, ONLY : V10M,     Z0

      USE CMN_SIZE_MOD            ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: NYMD   ! YYYYMMDD
      INTEGER, INTENT(IN) :: NHMS   !  and hhmmss of data to read from disk
```

REVISION HISTORY:

```
    19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
    25 Aug 2010 - R. Yantosca - Now pass LWI down to READ_A1
```

1.70.6 read_a1

Subroutine READ_A1 reads MERRA 1-hour time averaged ("A1") met fields from disk.

INTERFACE:

```
      SUBROUTINE READ_A1( NYMD,     NHMS,
     &                    ALBEDO,   CLDTOT,   EFLUX,    EVAP,
     &                    FRSEAICE, FRSNO,    GRN,      GWETROOT,
     &                    GWETTOP,  HFLUX,    LAI,      LWGNT,
     &                    LWI,      PARDF,    PARDR,    PBLH,
     &                    PRECANV,  PRECTOT,  PRECCON,  PRECLSC,
     &                    PRECSNO,  SEAICE00, SEAICE10, SEAICE20,
     &                    SEAICE30, SEAICE40, SEAICE50, SEAICE60,
     &                    SEAICE70, SEAICE80, SEAICE90, SLP,
     &                    SNODP,    SNOMAS,   SWGNT,    TROPPT,
     &                    T2M,      TS,       U10M,     USTAR,
     &                    V10M,     Z0M                           )
```

USES:

```
      USE DIAG_MOD,     ONLY : AD67
      USE FILE_MOD,     ONLY : IOERROR
      USE FILE_MOD,     ONLY : IU_A1
      USE TIME_MOD,     ONLY : SET_CT_A1
      USE TIME_MOD,     ONLY : TIMESTAMP_STRING
      USE TRANSFER_MOD, ONLY : TRANSFER_2D
      USE TRANSFER_MOD, ONLY : TRANSFER_TO_1D

      USE CMN_SIZE_MOD                          ! Size parameters
      USE CMN_DIAG_MOD                          ! ND67 flag
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: NYMD                ! YYYYMMDD and hhmmss
      INTEGER, INTENT(IN)  :: NHMS                !  of data to read
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: ALBEDO  (IIPAR,JJPAR)  ! Sfc albedo [unitless]
REAL*8,  INTENT(OUT) :: CLDTOT  (IIPAR,JJPAR)  ! Column cld fraction
REAL*8,  INTENT(OUT) :: EFLUX   (IIPAR,JJPAR)  ! Latent heat flux [W/m2]
REAL*8,  INTENT(OUT) :: EVAP    (IIPAR,JJPAR)  ! Surface evap [kg/m2/s]
REAL*8,  INTENT(OUT) :: FRSEAICE(IIPAR,JJPAR)  ! Sfc sea ice fraction
REAL*8,  INTENT(OUT) :: FRSNO   (IIPAR,JJPAR)  ! Sfc snow fraction
REAL*8,  INTENT(OUT) :: GRN     (IIPAR,JJPAR)  ! Greenness fraction
REAL*8,  INTENT(OUT) :: GWETROOT(IIPAR,JJPAR)  ! Root soil wetness [frac]
REAL*8,  INTENT(OUT) :: GWETTOP (IIPAR,JJPAR)  ! Topsoil wetness [frac]
REAL*8,  INTENT(OUT) :: HFLUX   (IIPAR,JJPAR)  ! Sensible H-flux [W/m2]
REAL*8,  INTENT(OUT) :: LAI     (IIPAR,JJPAR)  ! Leaf area index [m2/m2]
REAL*8,  INTENT(OUT) :: LWI     (IIPAR,JJPAR)  ! Leaf area index [m2/m2]
REAL*8,  INTENT(OUT) :: LWGNT   (IIPAR,JJPAR)  ! Net LW rad @ sfc [W/m2]
REAL*8,  INTENT(OUT) :: PARDF   (IIPAR,JJPAR)  ! Diffuse PAR [W/m2]
REAL*8,  INTENT(OUT) :: PARDR   (IIPAR,JJPAR)  ! Direct PAR [W/m2]
REAL*8,  INTENT(OUT) :: PBLH    (IIPAR,JJPAR)  ! PBL height [m]
REAL*8,  INTENT(OUT) :: PRECANV (IIPAR,JJPAR)  ! Anv prec @ sfc [kg/m2/s]
REAL*8,  INTENT(OUT) :: PRECTOT (IIPAR,JJPAR)  ! Tot prec @ sfc [kg/m2/s]
REAL*8,  INTENT(OUT) :: PRECCON (IIPAR,JJPAR)  ! CV prec @ sfc [kg/m2/s]
REAL*8,  INTENT(OUT) :: PRECLSC (IIPAR,JJPAR)  ! LS prec @ sfc [kg/m2/s]
REAL*8,  INTENT(OUT) :: PRECSNO (IIPAR,JJPAR)  ! Snow precip [kg/m2/s]
REAL*8,  INTENT(OUT) :: SEAICE00(IIPAR,JJPAR)  ! Sea ice coverage 00-10%
REAL*8,  INTENT(OUT) :: SEAICE10(IIPAR,JJPAR)  ! Sea ice coverage 10-20%
REAL*8,  INTENT(OUT) :: SEAICE20(IIPAR,JJPAR)  ! Sea ice coverage 20-30%
REAL*8,  INTENT(OUT) :: SEAICE30(IIPAR,JJPAR)  ! Sea ice coverage 30-40%
REAL*8,  INTENT(OUT) :: SEAICE40(IIPAR,JJPAR)  ! Sea ice coverage 40-50%
REAL*8,  INTENT(OUT) :: SEAICE50(IIPAR,JJPAR)  ! Sea ice coverage 50-60%
REAL*8,  INTENT(OUT) :: SEAICE60(IIPAR,JJPAR)  ! Sea ice coverage 60-70%
REAL*8,  INTENT(OUT) :: SEAICE70(IIPAR,JJPAR)  ! Sea ice coverage 70-80%
REAL*8,  INTENT(OUT) :: SEAICE80(IIPAR,JJPAR)  ! Sea ice coverage 80-90%
REAL*8,  INTENT(OUT) :: SEAICE90(IIPAR,JJPAR)  ! Sea ice coverage 90-100%
REAL*8,  INTENT(OUT) :: SLP     (IIPAR,JJPAR)  ! Sea level pressure [hPa]
REAL*8,  INTENT(OUT) :: SNODP   (IIPAR,JJPAR)  ! Snow depth [m]
REAL*8,  INTENT(OUT) :: SNOMAS  (IIPAR,JJPAR)  ! Snow mass [kg/m2]
REAL*8,  INTENT(OUT) :: SWGNT   (IIPAR,JJPAR)  ! SW rad @ sfc [W/m2]
REAL*8,  INTENT(OUT) :: TROPPT  (IIPAR,JJPAR)  ! T'pause pressure [hPa]
REAL*8,  INTENT(OUT) :: T2M     (IIPAR,JJPAR)  ! T @ 2m height [K]
REAL*8,  INTENT(OUT) :: TS      (IIPAR,JJPAR)  ! Sfc skin T [K]
REAL*8,  INTENT(OUT) :: U10M    (IIPAR,JJPAR)  ! U-wind @ 10m [m/s]
REAL*8,  INTENT(OUT) :: USTAR   (IIPAR,JJPAR)  ! Friction velocity [m/s]
REAL*8,  INTENT(OUT) :: V10M    (IIPAR,JJPAR)  ! V-wind @ 10m [m/s]
REAL*8,  INTENT(OUT) :: Z0M     (IIPAR,JJPAR)  ! Roughness height [m]
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
```

```
25 Aug 2010 - R. Yantosca - Now read LWI (land/water/ice) from disk
15 Aug 2011 - R. Yantosca - Now save SWGDN in 2nd slot of ND67 diagnostic
25 Mar 2011 - R. Yantosca - Bug fix: make local SWGDN array for ND67 diag
```

1.70.7 a1_check

Subroutine A1_CHECK prints an error message if not all of the A-3 met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE A1_CHECK( NFOUND, N_A1 )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! Number of met fields read in from disk
INTEGER, INTENT(IN) :: N_A1     ! Number of expected met fields
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
```

1.71 Fortran: Module Interface merra_a3_mod

Module MERRA_A3_MOD contains subroutines for reading the 3-hour time averaged (aka "A3") fields from the MERRA data archive.

INTERFACE:

```
MODULE MERRA_A3_MOD
```

USES:

```
IMPLICIT NONE
#include "define.h"
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: GET_MERRA_A3_FIELDS
PUBLIC  :: OPEN_MERRA_A3_FIELDS
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: A3_CHECK
PRIVATE :: DO_OPEN_A3
PRIVATE :: READ_A3
```

REMARKS:

```
Don't bother with the file unzipping anymore.
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.71.1 do_open_a3

unction DO_OPEN_A3 returns TRUE if is time to open the A3 met field file or FALSE otherwise. This prevents us from opening a file which has already been opened.

INTERFACE:

```
FUNCTION DO_OPEN_A3( NYMD, NHMS ) RESULT( DO_OPEN )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NYMD      ! YYYYMMDD and hhmmss to be tested
INTEGER, INTENT(IN) :: NHMS      !  to see if it's time to open A3 file
```

RETURN VALUE:

```
LOGICAL             :: DO_OPEN   ! = T if it is time to open the file
```

REVISION HISTORY:

```
20 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
```

1.71.2 open_merra_a3_fields

Subroutine OPEN_MERRA_A3_FIELDS opens the A3 met fields file for date NYMD and time NHMS.

INTERFACE:

```
SUBROUTINE OPEN_MERRA_A3_FIELDS( NYMD, NHMS )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_RES_EXT
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE DIRECTORY_MOD, ONLY : MERRA_DIR
USE ERROR_MOD,     ONLY : ERROR_STOP
USE FILE_MOD,      ONLY : FILE_EXISTS
USE FILE_MOD,      ONLY : IU_A3
USE FILE_MOD,      ONLY : IOERROR
USE TIME_MOD,      ONLY : EXPAND_DATE

USE CMN_SIZE_MOD      ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NYMD   ! YYYYMMDD and
INTEGER, INTENT(IN) :: NHMS   !  hhmmss to test for A3 file open
```

REVISION HISTORY:

```
20 Aug 2010 - R. Yantosca - Initial version, based on a6_read_mod.f
```

1.71.3 get_merra_a3_fields

Subroutine GET_MERRA_A3_FIELDS is a wrapper for routine READ_A3.

INTERFACE:

```
SUBROUTINE GET_MERRA_A3_FIELDS( NYMD, NHMS )
```

USES:

```
USE DAO_MOD, ONLY : CLDF,    CLDTOPS,  CMFMC,    DQRCU
USE DAO_MOD, ONLY : DQRLSAN, DQIDTMST, DQLDTMST, DQVDTMST
USE DAO_MOD, ONLY : DTRAIN,  MOISTQ,   OPTDEP,   PFICU
USE DAO_MOD, ONLY : PFILSAN, PFLCU,    PFLLSAN,  QI
USE DAO_MOD, ONLY : QL,      SPHU,     REEVAPCN, REEVAPLS
USE DAO_MOD, ONLY : T,       TAUCLI,   TAUCLW,   UWND
USE DAO_MOD, ONLY : VWND

USE CMN_SIZE_MOD            ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NYMD   ! YYYYMMDD and
INTEGER, INTENT(IN) :: NHMS   !  hhmmss of desired data fields
```

REVISION HISTORY:

```
20 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
```

1.71.4 read_a3

Subroutine READ_A3 reads the MERRA 3-hour time-averaged (aka "A3") met fields from disk.

INTERFACE:

```
 SUBROUTINE READ_A3( NYMD,     NHMS,
&                    CLOUD,    CLDTOPS,  CMFMC,    DQRCU,
```

```
&                    DQRLSAN,  DQIDTMST, DQLDTMST, DQVDTMST,
&                    DTRAIN,   MOISTQ,   OPTDEPTH, PFICU,
&                    PFILSAN,  PFLCU,    PFLLSAN,  QI,
&                    QL,       QV,       REEVAPCN, REEVAPLS,
&                    T,        TAUCLI,   TAUCLW,   U,
&                    V                                    )
```

USES:

```
      USE DIAG_MOD,     ONLY : AD66
      USE DIAG_MOD,     ONLY : AD67
      USE FILE_MOD,     ONLY : IOERROR
      USE FILE_MOD,     ONLY : IU_A3
      USE TIME_MOD,     ONLY : SET_CT_A3
      USE TIME_MOD,     ONLY : TIMESTAMP_STRING
      USE TRANSFER_MOD, ONLY : TRANSFER_A6
      USE TRANSFER_MOD, ONLY : TRANSFER_3D_Lp1
      USE TRANSFER_MOD, ONLY : TRANSFER_3D
      USE TRANSFER_MOD, ONLY : TRANSFER_G5_PLE

      USE CMN_SIZE_MOD                                  ! Size parameters
      USE CMN_DIAG_MOD                                  ! ND66, LD66, ND67
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: NYMD                        ! YYYYMMDD & hhmmss
      INTEGER, INTENT(IN)  :: NHMS                        !  of desired data
```

OUTPUT PARAMETERS:

```
      ! Fields dimensioed as (I,J)
      INTEGER, INTENT(OUT) :: CLDTOPS (IIPAR,JJPAR       )

      ! Fields dimensioned as (I,J,L)
      REAL*8,  INTENT(OUT) :: CMFMC   (IIPAR,JJPAR,LLPAR+1)
      REAL*8,  INTENT(OUT) :: DQRCU   (IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: DQRLSAN (IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: DQIDTMST(IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: DQLDTMST(IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: DQVDTMST(IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: DTRAIN  (IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: PFICU   (IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: PFILSAN (IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: PFLCU   (IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: PFLLSAN (IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: QI      (IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: QL      (IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: QV      (IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: REEVAPCN(IIPAR,JJPAR,LLPAR  )
      REAL*8,  INTENT(OUT) :: REEVAPLS(IIPAR,JJPAR,LLPAR  )
```

```
REAL*8,  INTENT(OUT) :: T       (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: TAUCLI  (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: TAUCLW  (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: U       (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: V       (IIPAR,JJPAR,LLPAR  )

! Fields dimensioned as (L,I,J)
REAL*8,  INTENT(OUT) :: CLOUD   (LLPAR,IIPAR,JJPAR  )
REAL*8,  INTENT(OUT) :: MOISTQ  (LLPAR,IIPAR,JJPAR  )
REAL*8,  INTENT(OUT) :: OPTDEPTH(LLPAR,IIPAR,JJPAR  )
```

REVISION HISTORY:

```
20 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
20 Aug 2010 - R. Yantosca - Now save CLDTOPS to ND67 diagnostic
```

1.71.5 a3_check

Subroutine A3_CHECK prints an error message if not all of the A-6 met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE A3_CHECK( NFOUND, N_A3 )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! # of fields found in file
INTEGER, INTENT(IN) :: N_A3     ! # of expected fields
```

REVISION HISTORY:

```
20 Aug 2010 - R. Yantosca - Initial version, based on a6_read_mod.f
```

1.72 Fortran: Module Interface merra_cn_mod

Module MERRA_CN_MOD contains subroutines for reading the constant (aka "CN") fields from the MERRA data archive.

INTERFACE:

```
MODULE MERRA_CN_MOD
```

USES:

```
      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! NDxx flags
      USE CMN_GCTM_MOD             ! g0

      IMPLICIT NONE
#     include "define.h"

      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: GET_MERRA_CN_FIELDS
      PUBLIC  :: OPEN_MERRA_CN_FIELDS
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: CN_CHECK
      PRIVATE :: READ_CN
```

REMARKS:

```
   Don't bother with the file unzipping anymore.
```

REVISION HISTORY:

```
   19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
   20 Aug 2010 - R. Yantosca - Moved include files to top of module
```

1.72.1 open_merra_cn_fields

Subroutine OPEN_MERRA_CN_FIELDS opens the MERRA "CN" met fields file for date NYMD and time NHMS.

INTERFACE:

```
      SUBROUTINE OPEN_MERRA_CN_FIELDS( NYMD, NHMS )
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_RES_EXT
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE DIRECTORY_MOD, ONLY : MERRA_DIR
      USE ERROR_MOD,     ONLY : ERROR_STOP
      USE FILE_MOD,      ONLY : FILE_EXISTS
      USE FILE_MOD,      ONLY : IU_CN
      USE FILE_MOD,      ONLY : IOERROR
      USE TIME_MOD,      ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: NYMD   ! YYYYMMDD date
      INTEGER, INTENT(IN) :: NHMS   ! hhmmss time
```

REVISION HISTORY:

```
    19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.72.2 get_merra_cn_fields

Subroutine GET_MERRA_CN_FIELDS is a wrapper for routine READ_CN.

INTERFACE:

```
      SUBROUTINE GET_MERRA_CN_FIELDS( NYMD, NHMS )
```

USES:

```
      USE DAO_MOD, ONLY : FRLAKE     ! Fraction of grid box that is lake
      USE DAO_MOD, ONLY : FRLAND     ! Fraction of grid box that is land
      USE DAO_MOD, ONLY : FRLANDIC   ! Fraction of grid box that is land ice
      USE DAO_MOD, ONLY : FROCEAN    ! Fraction of grid box that is ocean
      USE DAO_MOD, ONLY : PHIS       ! Surface geopotential height
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: NYMD    ! YYYYMMDD date
      INTEGER, INTENT(IN) :: NHMS    !  and hhmmss time of desired data
```

REVISION HISTORY:

```
    19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.72.3 read_cn

Subroutine READ_CN reads the MERRA CN (constant) fields from disk.

INTERFACE:

```
      SUBROUTINE READ_CN( NYMD,   NHMS,
     &                    FRLAKE, FRLAND, FRLANDIC, FROCEAN, PHIS )
```

USES:

```
      USE DIAG_MOD,     ONLY : AD67
      USE FILE_MOD,     ONLY : IOERROR
      USE FILE_MOD,     ONLY : IU_CN
      USE TIME_MOD,     ONLY : TIMESTAMP_STRING
      USE TRANSFER_MOD, ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: NYMD   ! YYYYMMDD and
INTEGER, INTENT(IN)  :: NHMS   !  hhmmss time of desired data
```

OUTPUT PARAMETERS:

```
! Fraction of grid box covered by lakes [unitless]
REAL*8,  INTENT(OUT) :: FRLAKE  (IIPAR,JJPAR)

! Fraction of grid box covered by land ice [unitless]
REAL*8,  INTENT(OUT) :: FRLAND  (IIPAR,JJPAR)

! Fraction of grid box covered by land ice [unitless]
REAL*8,  INTENT(OUT) :: FRLANDIC(IIPAR,JJPAR)

! Fraction of grid box covered by ocean [unitless]
REAL*8,  INTENT(OUT) :: FROCEAN (IIPAR,JJPAR)

! Surface geopotential height [m2/s2]
REAL*8,  INTENT(OUT) :: PHIS    (IIPAR,JJPAR)
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.72.4 cn_check

Subroutine CN_CHECK prints an error message if not all of the CN met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE CN_CHECK( NFOUND, N_CN )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! Number of met fields read in from disk
INTEGER, INTENT(IN) :: N_CN     ! Number of expected met fields
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.73 Fortran: Module Interface merra_i6_mod

Module MERRA_I6_MOD contains subroutines for reading the 6-hour instantaneous (aka "I6") fields from the MERRA data archive.

INTERFACE:

```
      MODULE MERRA_I6_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: GET_MERRA_I6_FIELDS_1
      PUBLIC  :: GET_MERRA_I6_FIELDS_2
      PUBLIC  :: OPEN_MERRA_I6_FIELDS
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: I6_CHECK
      PRIVATE :: READ_I6
```

REMARKS:

Don't bother with the file unzipping anymore.

REVISION HISTORY:

19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f

---

1.73.1 open_merra_i6_fields

Subroutine OPEN_MERRA_I6_FIELDS opens the MERRA "I6" met fields file for date NYMD and time NHMS.

INTERFACE:

```
      SUBROUTINE OPEN_MERRA_I6_FIELDS( NYMD, NHMS )
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_RES_EXT
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE DIRECTORY_MOD, ONLY : MERRA_DIR
      USE ERROR_MOD,     ONLY : ERROR_STOP
      USE FILE_MOD,      ONLY : FILE_EXISTS
      USE FILE_MOD,      ONLY : IU_I6
      USE FILE_MOD,      ONLY : IOERROR
      USE TIME_MOD,      ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NYMD   ! YYYYMMDD date
INTEGER, INTENT(IN) :: NHMS   ! hhmmss time
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.73.2 get_merra_i6_fields_1

Subroutine GET_MERRA_I6_FIELDS_1 is a wrapper for routine READ_I6. It reads the initial data at the start of a GEOS-Chem simulation.

INTERFACE:

```
SUBROUTINE GET_MERRA_I6_FIELDS_1( NYMD, NHMS )
```

USES:

```
USE DAO_MOD, ONLY : PS1       ! Surface pressure  [hPa]
USE DAO_MOD, ONLY : RH1       ! Relative humidity [fraction]
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NYMD   ! YYYYMMDD date
INTEGER, INTENT(IN) :: NHMS   !  and hhmmss time of desired data
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.73.3 get_merra_i6_fields_2

Subroutine GET_MERRA_I6_FIELDS_2 is a wrapper for routine READ_I6. It reads the data every 6 hours during a GEOS-Chem simulation.

INTERFACE:

```
SUBROUTINE GET_MERRA_I6_FIELDS_2( NYMD, NHMS )
```

USES:

```
USE DAO_MOD, ONLY : PS2       ! Surface pressure  [hPa]
USE DAO_MOD, ONLY : RH2       ! Relative humidity [fraction]
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NYMD   ! YYYYMMDD date
INTEGER, INTENT(IN) :: NHMS   !  and hhmmss time of desired data
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.73.4 read_i6

Subroutine READ_I6 reads GEOS-Chem I-6 (instantaneous 6-hour) met fields from disk.

INTERFACE:

```
SUBROUTINE READ_I6( NYMD, NHMS, PS, RH )
```

USES:

```
USE FILE_MOD,     ONLY : IOERROR
USE FILE_MOD,     ONLY : IU_I6
USE TIME_MOD,     ONLY : SET_CT_I6
USE TIME_MOD,     ONLY : TIMESTAMP_STRING
USE TRANSFER_MOD, ONLY : TRANSFER_2D
USE TRANSFER_MOD, ONLY : TRANSFER_3D

USE CMN_SIZE_MOD                              ! Size parameters
USE CMN_DIAG_MOD                              ! NDxx flags
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: NYMD                    ! YYYYMMDD and hhmmss
INTEGER, INTENT(IN)  :: NHMS                    !  time of desired data
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: PS(IIPAR,JJPAR      )  ! Surface pressure [hPa]
REAL*8,  INTENT(OUT) :: RH(IIPAR,JJPAR,LLPAR)  ! Rel. humidity [unitless]
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.73.5 i6_check

Subroutine I6_CHECK prints an error message if not all of the I6 met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE I6_CHECK( NFOUND, N_I6 )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! Number of met fields read in from disk
INTEGER, INTENT(IN) :: N_I6     ! Number of expected met fields
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.74 Fortran: Module Interface modis_lai_mod

Module MODIS_LAI_MOD reads the MODIS LAI data at native resolution (either 0.25 x 0.25 or 0.5 x 0.5, in netCDF format) and rebins it to the proper GEOS-Chem LAI arrays. This module eliminates the need for the following GEOS-Chem modules, routines, and data files:

- lai_mod.F
- readlai.F
- rdlai.F
- findmon.F
- The `lai*.global` input files
- CMN_VEL_mod.F

INTERFACE:

```
MODULE Modis_Lai_Mod
```

USES:

```
  USE CMN_SIZE_Mod                                  ! Size parameters
  USE CMN_DEP_Mod                                   ! IREG, ILAND, IUSE, FRCLND
  USE Directory_Mod                                 ! Disk directory paths
  USE Error_Mod                                     ! Error checking routines
  USE Logical_Mod                                   ! Logical switches
  USE Mapping_Mod                                   ! Mapping weights & areas
  USE Time_Mod                                      ! EXPAND_DATE

  IMPLICIT NONE
  PRIVATE
```

PUBLIC DATA MEMBERS:

```
  INTEGER, PUBLIC              :: DAYS_BTW_MON    ! Days btw LAI midmonths
  REAL*8,  PUBLIC, ALLOCATABLE :: GC_LAI   (:,:)  ! Daily        LAI, G-C grid
  REAL*8,  PUBLIC, ALLOCATABLE :: GC_LAI_PM(:,:)  ! Prev month's LAI, G-C grid
  REAL*8,  PUBLIC, ALLOCATABLE :: GC_LAI_CM(:,:)  ! Curr month's LAI, G-C grid
  REAL*8,  PUBLIC, ALLOCATABLE :: GC_LAI_NM(:,:)  ! Next month's LAI, G-C grid
```

PUBLIC MEMBER FUNCTIONS:

```
  PUBLIC  :: Compute_Modis_Lai
  PUBLIC  :: Read_Modis_Lai
  PUBLIC  :: Find_Lai_Month
  PUBLIC  :: Init_Modis_Lai
  PUBLIC  :: Cleanup_Modis_Lai
```

PRIVATE MEMBER FUNCTIONS:

```
  PRIVATE :: RoundOff
```

REMARKS:

```
  Functionality of this module:
  ============================================================================
  If you are using the Olson 1992 land map, then this module will pick the
  MODIS LAI data at 0.5 x 0.5 native resolution.  This is because the legacy
  code assumed a direct correspondence between the Olson 1992 land map and
  the MODIS LAI data.  Similarly, if you are using the Olson 2001 land map,
  then this module will pick the MODIS LAI data at 0.25 x 0.25 resolution.
                                                                             .
  Follows the same algorithm as in the IDL codes used to regrid MODIS LAI
  data (regridmodis_lai_v5.pro; contact GEOS-Chem Support team).
                                                                             .
                                                                             .
  Historical background of how LAI data have been used in GEOS-Chem:
  ============================================================================
  Note that GEOS-Chem (as of April 2012) uses LAI data from two separate
  sources.  The dry deposition and soil NOx modules rely on the data from
  "lai*.global" ASCII files.  These files (which are pre-processed offline
  by IDL codes) are generated for each specific GEOS-Chem grid configuration
  (e.g. 4x5, 2x25, 0.5x0.666 nested grids).  These files are read from disk
  by routine RDLAI, which saves the LAI data into the XLAI and XYLAI arrays.
  XLAI and XYLAI store the leaf area index as a function of Olson land type
  (cf Olson 1992 land map).
                                                                             .
  However, the MEGAN biogenic emissions code relies on LAI data stored at
  1x1 resolution stored in bpch format.  These binary files are read by
  routine RDISOLAI (and other underlying routines in lai_mod.F), and are
  regridded on-the-fly to the current GEOS-Chem grid resolution.
                                                                             .
  Therefore, these two sources of LAI data present an inconsistency that
  should be resolved.  Also, for the Grid-Indpendent GEOS-Chem project,
  we must move away from ASCII files (which prevent interfacing with
  external GCMs).  We also cannot assume any particular horizontal grid,
  since that is now to be specified at the start of the simulation.
                                                                             .
  Also, to facilitate simulations at ultra-fine horizontal resolution, we
  will eventually adopt the Olson 2001 land map, which has a native
  resolution of 0.25 x 0.25 degrees, and likewise use an updated version
  of the MODIS LAI data at 0.25 x 0.25 resolution.
                                                                             .
  To resolve these issues, we have created a new module (modis_lai_mod.F90)
  which reads from the MODIS LAI data in netCDF format at the native
  resolution and then regrids the LAI data to GEOS-Chem resolution on-the-
  fly.  The XLAI array is populated for backwards compatibility with the
  existing legacy codes.  The LAI arrays used for MEGAN (ISOLAI, PMISOLAI,
  MISOLAI, and NMISOLAI) are now replaced by arrays GC_LAI, GC_LAI_PM,
```

```
GC_LAI_CM, and GC_LAI_NM) from modis_lai_mod.F.

.

We have validated that the new scheme generates identical XLAI arrays
w/r/t the old scheme.  The arrays GC_LAI etc. differ from the ISOLAI etc.
arrays slightly (but generally agree to within 0.001).  This is due to
the fact that the ISOLAI arrays were regridded from 1 x 1 native
resolution, but now we are regridding from much finer resolution
(either 0.5 x 0.5 or 0.25 x 0.25).

.

NOTES:
(1) At the present time, we have removed all references to the obsolete
    XYLAI array and its parent module CMN_VEL_mod.F.
(2) At the present time, we have not yet disabled the RDISOLAI function.
    We will do so in the future, and will validate this with a separate
    benchmark.
    -- Bob Yantosca (geos-chem-support@as.harvard.edu), 09 Apr 2012

.

.

LAI arrays and where they are (or will be) used in GEOS-Chem:
===============================================================================
(1) XLAI      --> Used in Soil NOx module
(2) XLAI2     --> Used to compute XLAI
(3) XYLAI     --> %%% OBSOLETE: REMOVED, NOW REPLACED BY XLAI %%%
(4) GC_LAI    --> Intended replacement for ISOLAI   (from lai_mod.F)
(5) GC_LAI_PM --> Intended replacement for PMISOLAI (from lai_mod.F)
(6) GC_LAI_CM --> Intended replacement for MISOLAI  (from lai_mod.F)
(7) GC_LAI_NM --> Intended replacement for NMISOLAI (from lai_mod.F)
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
05 Apr 2012 - R. Yantosca - Added descriptive comments
09 Apr 2012 - R. Yantosca - Fixed error in ROUNDOFF function that caused
                            numbers to be rounded up incorrectly.
09 Apr 2012 - R. Yantosca - Changed variables to REAL*8
09 Apr 2012 - R. Yantosca - Now set MODIS_START and MODIS_END depending
                            on which version of MODIS LAI we are using
```

1.74.1 compute_modis_lai

Subroutine COMPUTE_MODIS_LAI computes the daily MODIS leaf area indices for GEOS-Chem directly from the native grid resolution (0.25 x 0.25 or 0.5 x 0.5). The XLAI array (used in the legacy soil NOx and dry deposition routines) are populated accordingly. The XYLAI array is now obsolete and has been replaced by XLAI.

INTERFACE:

```
SUBROUTINE Compute_Modis_Lai( doy, mm, mapping, wasModisRead )
```

INPUT PARAMETERS:

```
INTEGER,         INTENT(IN) :: doy           ! Day of year
INTEGER,         INTENT(IN) :: mm            ! Month for LAI data
TYPE(MapWeight), POINTER    :: mapping(:,:)  ! "fine" -> "coarse" grid map
LOGICAL,         INTENT(IN) :: wasModisRead  ! Was LAI data just read in?
```

REMARKS:

```
Uses same algorithm as RDISOLAI in the existing lai_mod.F.
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
05 Apr 2012 - R. Yantosca - Renamed arg "doMonthly" to "wasModisRead"
09 Apr 2012 - R. Yantosca - Changed variables to REAL*8
09 Apr 2012 - R. Yantosca - Now follows same algorithm as rdlai.F for
                            populating XLAI array
09 Apr 2012 - R. Yantosca - Remove refs to CMN_VEL_mod.F and XYLAI array;
                            these are now obsolete
17 Apr 2012 - R. Yantosca - Now rename "map" object to "mapping" to avoid
                            name confusion w/ an F90 intrinsic function
```

1.74.2 read_modis_lai

Subroutine READ_MODIS_LAI reads the MODIS LAI from disk (in netCDF format) for the current month, and for next month.

INTERFACE:

```
SUBROUTINE Read_Modis_Lai( yyyy, mm, wasModisRead )
```

USES:

```
USE m_netcdf_io_open                    ! netCDF file open
USE m_netcdf_io_read                    ! netCDF read
USE m_netcdf_io_readattr                ! netCDF attribute reads
USE m_netcdf_io_close                   ! netCDF file close

#  include "netcdf.inc"                 ! netCDF settings & parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: yyyy            ! Year for LAI data
INTEGER, INTENT(IN)  :: mm              ! Month for LAI data
```

OUTPUT PARAMETERS:

```
LOGICAL, INTENT(OUT) :: wasModisRead    ! Was LAI data just read in?
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
05 Apr 2012 - R. Yantosca - Renamed arg "doMonthly" to "wasModisRead"
```

1.74.3 find_lai_month

Function FIND_LAI_MONTH returns the corresponding LAI month and year for the current calendar date. Note that the LAI data starts at mid-month.

INTERFACE:

```
SUBROUTINE Find_Lai_Month( doy, month, year, mm, yyyy )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: doy       ! Current day of year
INTEGER, INTENT(IN)  :: month     ! Current month
INTEGER, INTENT(IN)  :: year      ! Current year
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: mm        ! Output month for LAI data
INTEGER, INTENT(OUT) :: yyyy      ! Output year  for LAI data
```

REVISION HISTORY:

```
05 Jan 1994 - Y. H. Wang, G.M. Gardner, D. Jacob - Initial version
(1 ) Updated comments, cosmetic changes (bmy, 4/4/03)
(2 ) Add the current simulation year as input & the current LAI as output.
     This is necessary for reading in MODIS LAI (mpb,2009).
08 Dec 2009 - R. Yantosca - Added ProTeX headers
03 Apr 2012 - R. Yantosca - Renamed to FIND_LAI_MONTH; made PUBLIC
```

1.74.4 RoundOff

Rounds a number X to N decimal places of precision.

INTERFACE:

```
FUNCTION RoundOff( X, N ) RESULT( Y )
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: X   ! Number to be rounded
INTEGER, INTENT(IN) :: N   ! Number of decimal places to keep
```

RETURN VALUE:

```
REAL*8              :: Y   ! Number rounded to N decimal places
```

REMARKS:

```
The algorithm to round X to N decimal places is as follows:
(1) Multiply X by 10**(N+1)
(2) If X < 0, then add -5 to X; otherwise add 5 to X
(3) Take the integer part of X
```

```
(4) Divide X by 10**(N+1)
(5) Truncate X to N decimal places: INT( X * 10**N ) / 10**N
                                                                              .
Rounding algorithm from: Hultquist, P.F, "Numerical Methods for Engineers
 and Computer Scientists", Benjamin/Cummings, Menlo Park CA, 1988, p. 20.
                                                                              .
Truncation algorithm from: http://en.wikipedia.org/wiki/Truncation
                                                                              .
The two algorithms have been merged together for efficiency.
```

REVISION HISTORY:

```
06 Apr 2012 - R. Yantosca - Initial version
09 Apr 2012 - R. Yantosca - Changed all variables & arguments to REAL*8
```

1.74.5 init_modis

Subroutine INIT_MODIS_LAI initializes and allocates all module variables.

INTERFACE:

```
SUBROUTINE Init_Modis_Lai()
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
```

1.74.6 cleanup_modis_lai

Subroutine CLEANUP_MODIS_LAI deallocates all previously-allocated module variables.

INTERFACE:

```
SUBROUTINE Cleanup_Modis_Lai
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
```

1.75 Fortran: Module Interface nei2005_anthro_mod

Module NEI2005_ANTHRO_MOD contains variables and routines to read the NEI2005 anthropogenic emissions.

INTERFACE:

```
MODULE NEI2005_ANTHRO_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      REAL*8, PUBLIC, ALLOCATABLE :: USA_MASK(:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_NEI2005_ANTHRO
      PUBLIC  :: EMISS_NEI2005_ANTHRO
      PUBLIC  :: EMISS_NEI2005_ANTHRO_05x0666
      PUBLIC  :: GET_NEI2005_ANTHRO
      !-------------------------------------
      ! Leave for future use (bmy, 12/3/09)
      !PUBLIC  :: GET_NEI2005_MASK
      !-------------------------------------
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: NEI2005_SCALE_FUTURE
      PRIVATE :: INIT_NEI2005_ANTHRO
      PRIVATE :: TOTAL_ANTHRO_TG
      PRIVATE :: READ_NEI2005_MASK
      PRIVATE :: GET_NEI99_SEASON
      PRIVATE :: GET_NEI99_SEASON_05x0666
      PRIVATE :: GET_VISTAS_SEASON
      PRIVATE :: GET_VISTAS_SEASON_05x0666
      PRIVATE :: GET_NEI99_WKSCALE
      PRIVATE :: GET_NEI99_WKSCALE_05x0666
```

REMARKS:

```
(1) NIT is available in the data file but not read here (it is not
    emitted in GEOS-Chem).
(2) The algorithms in routines EMISS_NEI2005_ANTHRO and
    EMISS_NEI2005_ANTHRO_05x0666 may cause the code to die
    when running offline simulations.  We will add a fix later.
```

REVISION HISTORY:

```
07 Oct 2009 - A. van Donkelaar - initial version
20 Oct 2009 - P. Le Sager - added handling of VOC & masks
02 Nov 2009 - A. van Donkelaar - added seasonality, weekday factors
02 Dec 2009 - R. Yantosca - Added GET_NEI2005_MASK function
02 Dec 2009 - R. Yantosca - Updated comments etc.
10 Dec 2009 - D. Millet - Fix scaling, which is by ozone season
11 Dec 2009 - L. Zhang, A. Van Donkelaar - Add seasonality for NH3
```

```
21 Dec 2009 - R. Yantosca - Added support for 0.5 x 0.666 nested grids
13 Aug 2010 - R. Yantosca - Add modifications for MERRA (treat like GEOS-5)
27 Jul 2011 - R. Yantosca - Removed typo in EMISS_NEI2005_ANTHRO_05x0666
08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
 2 Mar 2012 - R. Yantosca - Remove A_CM2 array, use GET_AREA_CM2 instead
22 Mar 2012 - M. Payer    - C2H6 emissions are too low. Use Yaping
                            Xiao's C2H6 emissions instead.
24 May 2012 - R. Yantosca - Make all module arrays targets for pointers
```

1.75.1 get_nei2005_anthro

Function GET_NEI2005_ANTHRO returns the NEI2005 emission for GEOS-Chem grid box (I,J,L) and tracer N. Emissions can be returned in units of [kg/s] or [molec/cm2/s].

INTERFACE:

```
FUNCTION GET_NEI2005_ANTHRO( I,    J,     L, N, WEEKDAY,
&                          MOLEC_CM2_S, KG_S ) RESULT( VALUE )
```

USES:

```
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TRACER_MOD,   ONLY : XNUMOL
USE TRACERID_MOD, ONLY : IDTACET, IDTALK4, IDTC2H6, IDTC3H8
USE TRACERID_MOD, ONLY : IDTALD2, IDTCH2O, IDTPRPE, IDTMEK
USE TRACERID_MOD, ONLY : IDTNOx,  IDTCO,   IDTSO2,  IDTNH3
USE TRACERID_MOD, ONLY : IDTSO4
```

INPUT PARAMETERS:

```
! Longitude, latitude, and tracer indices
INTEGER, INTENT(IN)           :: I, J, L, N

! OPTIONAL -- return emissions in [molec/cm2/s]
LOGICAL, INTENT(IN), OPTIONAL :: WEEKDAY, MOLEC_CM2_S

! OPTIONAL -- return emissions in [kg/s] or [kg C/s]
LOGICAL, INTENT(IN), OPTIONAL :: KG_S
```

RETURN VALUE:

```
! Emissions output
REAL*8                        :: VALUE
```

REVISION HISTORY:

```
07 Oct 2009 - A. van Donkelaar - initial version
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

```
   01 Mar 2012 - R. Yantosca - Remove A_CM2 array, use GET_AREA_CM2 instead
   22 Mar 2012 - M. Payer    - C2H6 emissions are too low. Use Yaping
                               Xiao's C2H6 emissions instead.
```

1.75.2 emiss_nei2005_anthro

Subroutine EMISS_NEI2005_ANTHRO reads the NEI2005 emission fields at 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISS_NEI2005_ANTHRO( EMISS )
#else
      SUBROUTINE EMISS_NEI2005_ANTHRO
#endif
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
      USE LOGICAL_MOD,        ONLY : LFUTURE
      USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A
      USE TIME_MOD,           ONLY : GET_YEAR, GET_MONTH
      USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR_1x1
      USE TRACER_MOD,         ONLY : ITS_A_FULLCHEM_SIM
      USE TRACERID_MOD,       ONLY : IDTACET, IDTALK4, IDTC2H6, IDTC3H8
      USE TRACERID_MOD,       ONLY : IDTALD2, IDTCH2O, IDTPRPE, IDTMEK
      USE TRACERID_MOD,       ONLY : IDTNOx,  IDTCO,   IDTSO2,  IDTNH3
      USE TRACERID_MOD,       ONLY : IDTSO4,  IDTOCPI, IDTBCPI

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_O3_MOD               ! FSCALYR

#if defined( DEVEL )
      USE TRACERID_MOD, ONLY : IDTACET, IDTALK4, IDTC2H6, IDTC3H8
      USE TRACERID_MOD, ONLY : IDTALD2, IDTCH2O, IDTPRPE, IDTMEK
      USE TRACERID_MOD, ONLY : IDTNOx,  IDTCO,   IDTSO2,  IDTNH3
      USE TRACERID_MOD, ONLY : IDTSO4,  IDTOCPI, IDTBCPI
      USE TRACER_MOD,   ONLY : N_TRACERS
      USE TIME_MOD,     ONLY : GET_DAY_OF_WEEK
#endif
```

REVISION HISTORY:

```
   07 Oct 2009 - A. van Donkelaar - initial version
   20 Oct 2009 - P. Le Sager - added VOC, account for mask to get better total
   12 Jul 2010 - R. Yantosca - Now point to NEI2005_201007 directory, to read
```

```
                              in updated files (by Aaron van Donkelaar) to
                              fix a problem in the VOC emissions.
   13 Aug 2010 - R. Yantosca - Treat MERRA like GEOS-5
   08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
   28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
   13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
   24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.75.3 emiss_nei2005_anthro_05x0666

Subroutine EMISS_NEI2005_ANTHRO reads the NEI2005 emission fields at 1/2 x 2.3 resolution

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISS_NEI2005_ANTHRO_05x0666( EMISS )
#else
      SUBROUTINE EMISS_NEI2005_ANTHRO_05x0666
#endif
```

USES:

```
      USE BPCH2_MOD,         ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,     ONLY : DATA_DIR
      USE LOGICAL_MOD,       ONLY : LFUTURE
      USE TIME_MOD,          ONLY : GET_YEAR, GET_MONTH
      USE SCALE_ANTHRO_MOD,  ONLY : GET_ANNUAL_SCALAR_05x0666_NESTED
      USE TRACER_MOD,        ONLY : ITS_A_FULLCHEM_SIM
      USE TRACERID_MOD, ONLY : IDTACET, IDTALK4, IDTC2H6, IDTC3H8
      USE TRACERID_MOD, ONLY : IDTALD2, IDTCH2O, IDTPRPE, IDTMEK
      USE TRACERID_MOD, ONLY : IDTNOx,  IDTCO,   IDTSO2,  IDTNH3
      USE TRACERID_MOD, ONLY : IDTSO4,  IDTOCPI, IDTBCPI

      USE CMN_SIZE_MOD          ! Size parameters
      USE CMN_O3_MOD            ! FSCALYR

#if defined( DEVEL )
      USE TRACERID_MOD, ONLY : IDTACET, IDTALK4, IDTC2H6, IDTC3H8
      USE TRACERID_MOD, ONLY : IDTALD2, IDTCH2O, IDTPRPE, IDTMEK
      USE TRACERID_MOD, ONLY : IDTNOx,  IDTCO,   IDTSO2,  IDTNH3
      USE TRACERID_MOD, ONLY : IDTSO4,  IDTOCPI, IDTBCPI
      USE TRACER_MOD,   ONLY : N_TRACERS
      USE TIME_MOD,     ONLY : GET_DAY_OF_WEEK
#endif
```

REVISION HISTORY:

```
03 Nov 2009 - A. van Donkelaar - initial version
12 Jul 2010 - R. Yantosca - Now point to NEI2005_201007 directory, to read
                            in updated files (by Aaron van Donkelaar) to
                            fix a problem in the VOC emissions.
13 Aug 2010 - R. Yantosca - Treat MERRA like GEOS-5 (leave for future use)
27 Jul 2011 - R. Yantosca - Fixed typo: now *really* point to the NEI2005
                            data directory NEI2005_101007/
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x like MERRA
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.75.4 get_nei99_season

Subroutine GET_NEI99_SEASON returns monthly scale factors from EPA 1999

INTERFACE:

```
SUBROUTINE GET_NEI99_SEASON( TRACER, AS )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_TAU0,    READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR_1x1
USE TIME_MOD,      ONLY : GET_MONTH
USE TRACERID_MOD,  ONLY : IDTACET, IDTALK4, IDTC2H6, IDTC3H8
USE TRACERID_MOD,  ONLY : IDTALD2, IDTCH2O, IDTPRPE, IDTMEK
USE TRACERID_MOD,  ONLY : IDTNOx,  IDTCO,   IDTSO2,  IDTNH3
USE TRACERID_MOD,  ONLY : IDTSO4

USE CMN_SIZE_MOD                         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: TRACER   ! Tracer number
```

INPUT/OUTPUT PARAMETERS:

```
REAL*4,  INTENT(OUT)   :: AS(I1x1,J1x1,5)  ! Scale factor array
```

REVISION HISTORY:

```
30 Oct 2009 - A. van Donkelaar - Initial Version
 3 Nov 2009 - P. Le Sager      - update handling of boxes w/ zero emissions
10 Dec 2009 - D. Millet        - Now scale to August, not an annual average
11 Dec 2009 - L. Zhang, A. van Donkelaar - Add seasonality for NH3
```

1.75.5 get_nei99_season_05x0666

Subroutine GET_NEI_SEASON returns monthly scale factors from EPA 1999, for the 0.5 x 0.666 nested grids.

INTERFACE:

```
SUBROUTINE GET_NEI99_SEASON_05x0666( TRACER, AS )
```

USES:

```
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)     :: TRACER   ! Tracer number
```

INPUT/OUTPUT PARAMETERS:

```
REAL*4,  INTENT(INOUT)  :: AS(IIPAR,JJPAR,5)  ! Scale factor array
```

REVISION HISTORY:

```
30 Oct 2009 - A. van Donkelaar - Initial Version
13 Mar 2012 - M. Cooper        - Changed regrid algorithm to map_a2a
07 Jun 2012 - M. Payer         - Fix minor bugs in map_a2a implementation
```

1.75.6 get_vistas_season

Subroutine GET_VISTAS_SEASON returns monthly scale factors to account for monthly variations in NOx emissions on 1x1 resolution grid (amv, 11/02/09)

INTERFACE:

```
SUBROUTINE GET_VISTAS_SEASON( AS )
```

USES:

```
USE BPCH2_MOD,         ONLY : GET_TAU0,      READ_BPCH2
USE DIRECTORY_MOD,     ONLY : DATA_DIR_1x1
USE TIME_MOD,          ONLY : GET_MONTH,     GET_YEAR

USE CMN_SIZE_MOD                          ! Size parameters
USE CMN_O3_MOD           ! FSCALYR
```

INPUT/OUTPUT PARAMETERS:

```
REAL*4,  INTENT(INOUT) :: AS(I1x1,J1x1,5)  ! Scale factor array
```

REVISION HISTORY:

```
30 Oct 2009 - A. van Donkelaar - Initial Version
 3 Nov 2009 - P. Le Sager      - update handling of boxes w/ zero emissions
10 Dec 2009 - D. Millet        - Now scale to August, not an annual average
```

1.75.7 get_vistas_season_05x0666

Subroutine GET_VISTAS_SEASON_05x0666 returns monthly scale factors to account for monthly variations in NOx emissions for the 0.5 x 0.666 nested grids. (amv, 11/02/09)

INTERFACE:

```
SUBROUTINE GET_VISTAS_SEASON_05x0666( AS )
```

USES:

```
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1

USE CMN_SIZE_MOD         ! Size parameters
```

INPUT/OUTPUT PARAMETERS:

```
REAL*4,  INTENT(INOUT)  :: AS(IIPAR,JJPAR,5)  ! Scale factor array
```

REVISION HISTORY:

```
03 Nov 2009 - A. van Donkelaar - Initial Version
13 Mar 2012 - M. Cooper        - Changed regrid algorithm to map_a2a
07 Jun 2012 - M. Payer         - Fix minor bugs in map_a2a implementation
```

1.75.8 get_nei99_wkscale

Subroutine GET_NEI99_WKSCALE returns the scale factors to convert weekday to weekend emissions based on the NEI99.

INTERFACE:

```
SUBROUTINE GET_NEI99_WKSCALE( TRACER, AS )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
USE TIME_MOD,           ONLY : GET_MONTH
USE TRACERID_MOD, ONLY : IDTACET, IDTALK4, IDTC2H6, IDTC3H8
USE TRACERID_MOD, ONLY : IDTALD2, IDTCH2O, IDTPRPE, IDTMEK
USE TRACERID_MOD, ONLY : IDTNOx,  IDTCO,   IDTSO2,  IDTNH3
USE TRACERID_MOD, ONLY : IDTSO4

USE CMN_SIZE_MOD                        ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)       :: TRACER   ! Tracer number
```

INPUT/OUTPUT PARAMETERS:

```
REAL*4,  INTENT(INOUT) :: AS(I1x1,J1x1,5)  ! Scale factor array
```

REVISION HISTORY:

```
30 Oct 2009 - A. van Donkelaar - Initial Version
 3 Nov 2009 - P. Le Sager - update handling of boxes w/ zero emissions
```

1.75.9 get_nei99_wkscale_05x0666

Subroutine GET_NEI99_WKSCALE_05x0666 returns the scale factors (for 0.5 x 0.666 nested grids) to convert weekday to weekend emissions based on the NEI99.

INTERFACE:

```
SUBROUTINE GET_NEI99_WKSCALE_05x0666( TRACER, AS )
```

USES:

```
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)     :: TRACER   ! Tracer number
```

INPUT/OUTPUT PARAMETERS:

```
REAL*4,  INTENT(INOUT)  :: AS(IIPAR,JJPAR,5)  ! Scale factor array
```

REVISION HISTORY:

```
30 Oct 2009 - A. van Donkelaar - Initial Version
13 Mar 2012 - M. Cooper        - Changed regrid algorithm to map_a2a
07 Jun 2012 - M. Payer         - Fix minor bugs in map_a2a implementation
```

1.75.10 read_nei2005_mask

Subroutine READ_NEI2005_MASK reads the mask for NEI data

INTERFACE:

```
SUBROUTINE READ_NEI2005_MASK
```

USES:

```
! Reference to F90 modules
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE LOGICAL_MOD,    ONLY : LCAC,            LBRAVO
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
```

```
      USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
      USE TRANSFER_MOD,   ONLY : TRANSFER_2D

      USE CMN_SIZE_MOD         ! Size parameters
```

REMARKS:

```
      temporary mask: same as EPA 99
```

REVISION HISTORY:

```
     20 Oct 2009 - P. Le Sager - init
     26 Oct 2009 - P. Le Sager - new masks
     13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
     24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.75.11 nei2005_scale_future

Subroutine NEI2005_SCALE_FUTURE applies the IPCC future scale factors to the NEI2005 anthropogenic emissions.

INTERFACE:

```
      SUBROUTINE NEI2005_SCALE_FUTURE
```

USES:

```
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_COff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NH3an
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_OCff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_BCff

      USE CMN_SIZE_MOD             ! Size parameters
```

REMARKS:

```
     VOC are not scaled, however scale factors are available (see
      epa_nei_mod.f for procedure)
```

REVISION HISTORY:

```
      7 Oct 2009 - A. van Donkelaar - initial version
     20 Oct 2009 - P. Le Sager - set L OpenMP private, put L loop first
```

1.75.12 total_anthro_Tg

Subroutine TOTAL_ANTHRO_TG prints the totals for the anthropogenic emissions of NOx, CO, SO2 and NH3.

INTERFACE:

```
SUBROUTINE TOTAL_ANTHRO_TG( YEAR )
```

USES:

```
USE CMN_SIZE_MOD            ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: YEAR   ! Year of data to compute totals
```

REVISION HISTORY:

```
 7 Oct 2009 - A. van Donkelaar - initial version
22 Mar 2012 - M. Payer         - Remove print for C2H6 emissions.
```

1.75.13 init_nei2005_anthro

Subroutine INIT_NEI2005_ANTHRO allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_NEI2005_ANTHRO
```

USES:

```
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE LOGICAL_MOD, ONLY : LNEI05

USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
02 Mar 2012 - R. Yantosca - Remove A_CM2 array
```

1.75.14 cleanup_nei2005_anthro

Subroutine CLEANUP_NEI2005_ANTHRO deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_NEI2005_ANTHRO
```

REVISION HISTORY:

```
01 Mar 2012 - R. Yantosca - Remove reference to A_CM2 array
```

1.76 Fortran: Module Interface olson_landmap_mod

Module OLSON_LANDMAP_MOD reads the Olson land map and computes the IREG, ILAND, and IUSE arrays. This module was written to facilitate Grid-Independent GEOS-Chem development while still keeping backwards compatibility with existing legacy code. It replaces the old routine rdland.F.

INTERFACE:

```
MODULE Olson_LandMap_Mod
```

USES:

```
  USE CMN_GCTM_MOD                    ! Physical constants
  USE CMN_DEP_MOD                     ! IREG, ILAND, IUSE, FRCLND arrays
  USE CMN_SIZE_MOD                    ! Size parameters
  USE DIRECTORY_MOD                   ! Disk directory paths
  USE ERROR_MOD                       ! Error checking routines
  USE GRID_MOD                        ! Horizontal grid definition
  USE LOGICAL_MOD                     ! Logical switches
  USE MAPPING_MOD                     ! Mapping weights & areas

  IMPLICIT NONE
  PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
  PUBLIC  :: Init_Olson_Landmap
  PUBLIC  :: Compute_Olson_Landmap
  PUBLIC  :: Cleanup_Olson_LandMap
```

REMARKS:

```
   The Olson land types are as follows:
   ============================================================================
    0 Water              25 Deciduous           50 Desert
    1 Urban              26 Deciduous           51 Desert
    2 Shrub              27 Conifer             52 Steppe
    3 ---                28 Dwarf forest        53 Tundra
    4 ---                29 Trop. broadleaf     54 rainforest
    5 ---                30 Agricultural        55 mixed wood/open
    6 Trop. evergreen    31 Agricultural        56 mixed wood/open
    7 ---                32 Dec. woodland       57 mixed wood/open
    8 Desert             33 Trop. rainforest    58 mixed wood/open
    9 ---                34 ---                 59 mixed wood/open
   10 ---                35 ---                 60 conifers
   11 ---                36 Rice paddies        61 conifers
   12 ---                37 agric               62 conifers
   13 ---                38 agric               63 Wooded tundra
   14 ---                39 agric.              64 Moor
   15 ---                40 shrub/grass         65 coastal
```

```
16 Scrub              41 shrub/grass         66 coastal
17 Ice                42 shrub/grass         67 coastal
18 ---                43 shrub/grass         68 coastal
19 ---                44 shrub/grass         69 desert
20 Conifer            45 wetland             70 ice
21 Conifer            46 scrub               71 salt flats
22 Conifer            47 scrub               72 wetland
23 Conifer/Deciduous  48 scrub               73 water
24 Deciduous/Conifer  49 scrub
                                                                              .
                                                                              .
Arrays computed by olson_landmap_mod.F90
================================================================================
(1) IREG   (in CMN_DEP_mod.F): # of Olson land types per G-C grid box
(2) ILAND  (in CMN_DEP_mod.F): List of all Olson land types in G-C grid box
(3) IUSE   (in CMN_DEP_mod.F): Coverage of each Olson type in G-C grid box
(4) IJREG  (in CMN_VEL_mod.F): %%%%% OBSOLETE: NOW REPLACED BY IREG  %%%%%
(5) IJLAND (in CMN_VEL_mod.F): %%%%% OBSOLETE: NOW REPLACED BY ILAND %%%%%
(6) IJUSE  (in CMN_VEL_mod.F): %%%%% OBSOLETE: NOW REPLACED BY IUSE  %%%%%
(7) FRCLND (in CMN_DEP_mod.F): Fraction of G-C grid box that is not water
                                                                              .
NOTES:
(1) IREG,  ILAND,  IUSE  are used by the soil NOx emissions routines
(2) IJREG, IJLAND, IJUSE are used by the drydep routines (legacy code)
(3) FRCLND               is  used by various GEOS-Chem routines
                                                                              .
                                                                              .
BUG IN THE OLD "rdland.F" FOR 2 X 2.5 DEGREE RESOLUTION
================================================================================
This module ("olson_landmap_mod.F") replaces the old routine "rdland.F",
which previously read in the Olson landtype data from the ASCII format
file named "vegtype.global".  There used to be a different "vegtype.global"
file for each different horizontal grid resolution.
                                                                              .
The "vegtype.global" stored the following quantities, such that values
for a single grid box were saved on a single line:
                                                                              .
  I, J, IREG(I,J), ILAND(I,J,K), IUSE(I,J,K)  (where K=1,IREG(I,J))
                                                                              .
Routine "rdland.F" reads these quantities from "vegtype.global" assuming
there were 20 integer characters on a single line (i.e. using Fortran
FORMAT '(20i4)').   However, ~ 12 lines of the 2 x 2.5 "vegtype.global"
file contained more than 20 integer values.  This caused "rdland.F",
to read in the values from these lines improperly, which in turn caused
the IREG, ILAND, IUSE, IJREG, IJLAND, IJUSE, and FRCLND arrays to be
improperly initialized for the grid boxes corresponding to these
lines in the "vegtype.global" file.
                                                                              .
```

```
Bob Yantosca has validated that "olson_landmap_mod.F" returns results
100% identical to the "vegtype.global" file.  Therefore, if you want
to compare the output of model simulations using "olson_landmap_mod.F"
the output of simulations using "rdland.F", you will see a slight
difference in the MCL lifetime and tracer concentrations.
                                                                      .
If you need to run a GEOS-Chem simulation with an older version of the
code using "rdland.F", then this bug may be corrected by changing the
line of code:
                                                                      .
    101  FORMAT(20I4)
                                                                      .
to:
                                                                      .
   #if   defined( GRID2x25 )
    101  FORMAT(25I4)
   #else
    100  FORMAT(20I4)
   #endif
                                                                      .
This is more or less a moot point, as "olson_landmap_mod.F" will be
installed into GEOS-Chem v9-01-03 and higher versions.
                                                                      .
                                                                      .
NOTE FOR 0.5 x 0.666 grids
=============================================================================
As of 21 Mar 2012, the IUSE values computed by "olson_landmap_mod.F90"
may slightly differ from those specified in the "vegtype.global" files
for 0.5 x 0.666 nested grids.  We attribute this to roundoff error caused
by the the longitude spacing being an irrational number (0.6666666...).
We are still investigating.
```

REVISION HISTORY:

```
13 Mar 2012 - R. Yantosca - Initial version
19 Mar 2012 - R. Yantosca - Minor last-minute bug fixes
21 Mar 2012 - R. Yantosca - Now use REAL*4 for computations
22 Mar 2012 - R. Yantosca - Now read surface area from the file
22 Mar 2012 - R. Yantosca - Now make lon, lat, OLSON, A_CM2 allocatable
22 Mar 2012 - R. Yantosca - Now define I_OLSON, J_OLSON, N_OLSON, D_LON,
                            and D_LAT in routine Init_Olson_LandMap
27 Mar 2012 - R. Yantosca - Now reference USE_OLSON_2001 from logical_mod.F
02 Apr 2012 - R. Yantosca - Now reference mapping_mod.F90
02 Apr 2012 - R. Yantosca - Moved routine GET_MAP_WT to mapping_mod.F90
02 Apr 2012 - R. Yantosca - Now Save mapping info for later use
09 Apr 2012 - R. Yantosca - Removed IJREG, IJUSE, IJLAND; these are now
                            replaced by IREG, IUSE, ILAND arrays
09 Apr 2012 - R. Yantosca - Removed reference to CMN_VEL_mod.F
```

1.76.1 compute_olson_landmap

Subroutine COMPUTE_OLSON_LANDMAP computes the GEOS-Chem arrays IREG, ILAND, IUSE (and corresponding 1-D arrays IJREG, IJLAND, IJUSE) on-the-fly from the Olson Land map file. This routine, which is intended to facilitate the Grid-Independent GEOS-Chem, replaces the old rdland.F, which read from pre-computed "vegtype.global" files.

INTERFACE:

```
SUBROUTINE Compute_Olson_LandMap( mapping )
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MapWeight), POINTER :: mapping(:,:)   ! "fine" -> "coarse" mapping
```

REMARKS:

```
This routine supplies arrays that are required for legacy code routines:
(1) IREG,  ILAND,  IUSE are used by the Soil NOx routines
(2) IJREG, IJLAND, IJUSE are used by the dry deposition routines
```

REVISION HISTORY:

```
13 Mar 2012 - R. Yantosca - Initial version
19 Mar 2012 - R. Yantosca - Reorder ILAND, IUSE, IJLAND, IJUSE to be
                            consistent w/ the leaf area indices
19 Mar 2012 - R. Yantosca - Compute the FRCLND array (from CMN_DEP_mod.F)
21 Mar 2012 - R. Yantosca - Now use REAL*4 for computation, to reduce
                            roundoff errors at high-resolution
22 Mar 2012 - R. Yantosca - Now get surface area directly from variable
                            A_CM2 (read from disk) instead of computing it
02 Apr 2012 - R. Yantosca - Now pass MAP (mapping weight object) via the
                            arg list, to save the mapping info for later
09 Apr 2012 - R. Yantosca - Remove IJLOOP variable
09 Apr 2012 - R. Yantosca - Now do not compute IJREG, IJLAND, IJUSE; these
                            are replaced by IREG, ILAND, IUSE arrays
17 Apr 2012 - R. Yantosca - Rename "map" object to "mapping" to avoid name
                            confusion with an F90 intrinsic function
```

1.76.2 init_olson_landmap

Subroutine INIT_OLSON_LANDMAP reads Olson land map information from disk (in netCDF format).

INTERFACE:

```
SUBROUTINE Init_Olson_LandMap()
```

USES:

```
      USE m_netcdf_io_open
      USE m_netcdf_io_read
      USE m_netcdf_io_readattr
      USE m_netcdf_io_close

      IMPLICIT NONE

#     include "netcdf.inc"
```

REMARKS:

```
    Assumes that you have:
    (1) A netCDF library (either v3 or v4) installed on your system
    (2) The NcdfUtilities package (from Bob Yantosca) source code
```

REVISION HISTORY:

```
    13 Mar 2012 - R. Yantosca - Initial version
    22 Mar 2012 - R. Yantosca - Also read in surface areas [m2] from file
    27 Mar 2012 - R. Yantosca - Now read the "units" attribute of each variable
    27 Mar 2012 - R. Yantosca - Now echo file I/O status info to stdout
    27 Mar 2012 - R. Yantosca - Now can read Olson 1992 or Olson 2001 land map
```

1.76.3 cleanup_olson_landmap

Subroutine CLEANUP_OLSON_LANDMAP deallocates all allocated global module variables.

INTERFACE:

```
   SUBROUTINE Cleanup_Olson_LandMap
```

REVISION HISTORY:

```
    22 Mar 2012 - R. Yantosca - Initial version
```

1.77 Fortran: Module Interface optdepth_mod

Module OPTDEPTH_MOD contains routines to return optical depths and update the ND21 diagnostic.

INTERFACE:

```
      MODULE OPTDEPTH_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
INTERFACE OPTDEPTH
   MODULE PROCEDURE OD_GEOS3_GEOS4
END INTERFACE

PUBLIC  :: OPTDEPTH
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: OD_GEOS3_GEOS4
```

REVISION HISTORY:

```
15 Aug 2001 - R. Yantosca - Initial version
(1 ) Now add parallel DO-loops (bmy, 8/15/01)
(2 ) Removed obsolete code from 9/01 (bmy, 10/24/01)
(3 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
     MODULE ROUTINES sections.  Also add MODULE INTERFACES section,
     since we have an interface here. (bmy, 5/28/02)
(4 ) Renamed OD_GEOS2_GEOS_3 to OD_GEOS3_GEOS4.  (bmy, 4/20/05)
(5 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
14 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.77.1 od_geos3_geos4

Subroutine OD_GEOS3_GEOS4 copies the DAO grid box optical depth from the OPTDEP met field array into the OPTD array. Diagnostics are also archived.

INTERFACE:

```
SUBROUTINE OD_GEOS3_GEOS4( NVERT, CLDF, OPTDEP, OPTD )
```

USES:

```
USE DIAG_MOD, ONLY: AD21

USE CMN_SIZE_MOD   ! Size parameters
USE CMN_DIAG_MOD   ! ND21
```

INPUT PARAMETERS:

```
! Number of levels for which optical depth is desired
INTEGER, INTENT(IN)  :: NVERT

! 3/D cloud fraction from met fields  [unitless]
REAL*8,  INTENT(IN)  :: CLDF  (LLPAR,IIPAR,JJPAR)

! Optical depths from met fields [unitless]
REAL*8,  INTENT(IN)  :: OPTDEP(LLPAR,IIPAR,JJPAR)
```

OUTPUT PARAMETERS:

```
! Optical depth output array [unitless]
REAL*8,  INTENT(OUT) :: OPTD  (LLPAR,IIPAR,JJPAR)
```

REMARKS:

```
The optical depths in the GEOS-5 met field archives are in-cloud optical
depths instead of grid-box optical depths (as was reported in the file
specification documents erroneously).

Also, the name "OD_GEOS3_GEOS4" is historical.  Once upon a time this was
used to denote the difference between the optical depths in GEOS-3 and
GEOS-4 (which come directly from the met fields) and GEOS-1 and GEOS-STRAT
(which were computed as functions of temperature).  The GEOS-5 and MERRA
optical depths are also provided in the met field archive, so the
algorithms in this routine are also equally applicable.
```

REVISION HISTORY:

```
15 Aug 2001 - R. Yantosca - Initial version
(1 ) Now parallelize I-J DO loops (bmy, 8/15/01)
(2 ) Renamed to OD_GEOS3_GEOS4.  Also now saves CLDF in AD21(I,J,L,2)
      for the ND21 diagnostic (bmy, 4/20/05)
14 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.78 Fortran: Module Interface paranox_mod

Module PARANOX_MOD contains subroutines for reading and interpolating look up tables necessary for the PARANOX (PARAmeterization of emitted NOX) ship plume model developed by G.C.M. Vinken.

INTERFACE:

```
MODULE PARANOX_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: READ_PARANOX_LUT
PUBLIC  :: INTERPOLATE_LUT
PUBLIC  :: INTERPOLATE_LUT2

!REMARKS
 References:
```

```
=============================================================================
(1 ) Vinken, G.C.M., Boersma, K.F., Jacob, D.J., and Meijer, E.W.:
     Accounting for non-linear chemistry of ship plumes in the GEOS-Chem
     global chemistry transport model, Atmos. Chem. Phys., 11, 11707-11722,
     doi:10.5194/acp-11-11707-2011, 2011.
```

REVISION HISTORY:

```
06 Feb 2012 - M. Payer    - Initial version
01 Mar 2012 - R. Yantosca - Use updated GET_LOCALTIME from time_mod.F
```

1.78.1 read_paranox_lut

Subroutine READ_PARANOX_LUT reads look up tables for use in the PARANOX ship plume model (G.C.M. Vinken)

INTERFACE:

```
SUBROUTINE READ_PARANOX_LUT
```

USES:

```
USE DIRECTORY_MOD, ONLY : DATA_DIR_1x1
USE FILE_MOD,      ONLY : IOERROR, IU_FILE

USE CMN_O3_MOD          ! FRACNOX, INTOPE
```

REVISION HISTORY:

```
06 Feb 2012 - M. Payer    - Initial version modified from code provided by
                            G.C.M. Vinken
```

1.78.2 interpolate_lut

Subroutine INTERPOLATE_LUT returns FracNOx or IntOPE from the lookup table (G.C.M. Vinken, KNMI, June 2010)

INTERFACE:

```
SUBROUTINE INTERPOLATE_LUT( I, J, fraction_nox, int_ope )
```

USES:

```
USE DAO_MOD,      ONLY : TS,   AD
USE DAO_MOD,      ONLY : SUNCOS_MID,  SUNCOS_MID_5hr
USE TRACERID_MOD, ONLY : IDO3, IDTOX, IDTCO
USE TRACER_MOD,   ONLY : STT,  TCVV
USE TIME_MOD,     ONLY : GET_LOCALTIME
USE ERROR_MOD,    ONLY : ERROR_STOP

USE CMN_FJ_MOD         ! Photolysis parameters
USE CMN_O3_MOD         ! fracnox, intope, jvalues
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)        :: I, J
```

OUTPUT PARAMETERS:

```
      REAL,    INTENT(OUT)       :: fraction_nox, int_ope
```

REVISION HISTORY:

```
      Jun 2010 - G.C.M. Vinken - Initial version
   06 Feb 2012 - M. Payer      - Moved from emissions_mod.F to paranox_mod.F;
                                 Added ProTeX headers
   15 Feb 2012 - M. Payer      - Add error trap to ensure 0 < fracnox < 1.
```

1.78.3 interpolate_lut2

Subroutine INTERPOLATE_LUT2 returns FracNOx or IntOPE from the lookup tables (G.C.M. Vinken, KNMI, June 2010)

INTERFACE:

```
      SUBROUTINE INTERPOLATE_LUT2( I, J, o3, no, no2, dens,
     &                             fraction_nox, int_ope )
```

USES:

```
      USE DAO_MOD,   ONLY : TS
      USE DAO_MOD,   ONLY : SUNCOS_MID,  SUNCOS_MID_5hr
      USE TIME_MOD,  ONLY : GET_LOCALTIME
      USE ERROR_MOD, ONLY : ERROR_STOP

      USE CMN_FJ_MOD      ! Photolysis parameters
      USE CMN_O3_MOD      ! fracnox, intope, jvalues
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)        :: I, J
      REAL*8,  INTENT(IN)        :: o3, no, no2, dens
```

OUTPUT PARAMETERS:

```
      REAL,    INTENT(OUT)       :: fraction_nox, int_ope
```

REVISION HISTORY:

```
      Jun 2010 - G.C.M. Vinken - Initial version
   21 Feb 2011 - G.C.M. Vinken - Updated for NOx in LUT
   06 Feb 2012 - M. Payer      - Moved from emissions_mod.F to paranox_mod.F;
                                 Added ProTeX headers
   15 Feb 2012 - M. Payer      - Add error trap to ensure 0 < fracnox < 1.
```

1.79 Fortran: Module Interface pbl_mix_mod

Module PBL_MIX_MOD contains routines and variables used to compute the planetary boundary layer (PBL) height and to mix tracers underneath the PBL top.

INTERFACE:

```
      MODULE PBL_MIX_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_PBL_MIX
      PUBLIC  :: DO_PBL_MIX
      PUBLIC  :: GET_FRAC_OF_PBL
      PUBLIC  :: GET_FRAC_UNDER_PBLTOP
      PUBLIC  :: GET_PBL_MAX_L
      PUBLIC  :: GET_PBL_TOP_hPa
      PUBLIC  :: GET_PBL_TOP_L
      PUBLIC  :: GET_PBL_TOP_m
      PUBLIC  :: GET_PBL_THICK
      PUBLIC  :: INIT_PBL_MIX
      PUBLIC  :: COMPUTE_PBL_HEIGHT

#if defined ( DEVEL )
      PUBLIC :: PBL_TOP_L, PBL_TOP_m
#endif
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: TURBDAY
```

REVISION HISTORY:

```
   11 Feb 2005 - R. Yantosca - Initial version
   (1 ) Now modified for GCAP and GEOS-5 met fields (bmy, 5/24/05)
   (2 ) Remove reference to "CMN" and XTRA2. (bmy, 8/30/05)
   (3 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
   (4 ) Add INIT_PBL_MIX and COMPUTE_PBL_HEIGHT as PUBLIC routines
        (lin, 5/29/09)
   (5 ) Extend tracers for APM simulation (GanLuo, 2010)
   28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
   28 Feb 2012 - R. Yantosca - Added ProTeX headers
   01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
```

1.79.1 do_pbl_mix

Subroutine DO_PBL_MIX is the driver routine for planetary boundary layer mixing. The PBL layer height and related quantities are always computed. Complete mixing of tracers underneath the PBL top is toggled by the DO_TURBDAY switch.

INTERFACE:

```
      SUBROUTINE DO_PBL_MIX( DO_TURBDAY )
```

USES:

```
      USE LOGICAL_MOD, ONLY : LTURB
      USE TRACER_MOD,  ONLY : N_TRACERS, STT, TCVV
#if   defined( APM )
      USE TRACER_MOD,  ONLY : N_APMTRA
#endif
```

INPUT PARAMETERS:

```
      LOGICAL, INTENT(IN) :: DO_TURBDAY   ! =T means call TURBDAY
                                          !    for full PBL mixing
```

REVISION HISTORY:

```
   11 Feb 2005 - R. Yantosca - Initial version
   07 Sep 2011 - G. Luo    - Add modifications for APM
   28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.79.2 compute_pbl_height

Subroutine COMPUTE_PBL_HEIGHT computes the PBL height and other related quantities.

INTERFACE:

```
      SUBROUTINE COMPUTE_PBL_HEIGHT
```

USES:

```
      USE DAO_MOD,      ONLY : BXHEIGHT, PBL
      USE ERROR_MOD,    ONLY : ERROR_STOP
      USE PRESSURE_MOD, ONLY : GET_PEDGE

      USE CMN_SIZE_MOD       ! Size parameters
      USE CMN_GCTM_MOD       ! Scale height
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
(1 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(2 ) Remove reference to "CMN" and XTRA2 -- they're obsolete.  Also do not
      force BLTOP, BLTHIK to minimum values for GEOS-STRAT met fields.
      (bmy, 8/30/05)
(3 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.79.3 turbday

! Subroutine TURBDAY executes the GEOS-Chem boundary layer mixing algorithm (full PBL mixing).

INTERFACE:

```
SUBROUTINE TURBDAY( NTRC, TC, TCVV )
```

USES:

```
USE DAO_MOD,     ONLY : AD
USE DIAG_MOD,    ONLY : TURBFLUP
USE TIME_MOD,    ONLY : GET_TS_CONV

USE CMN_SIZE_MOD      ! Size parameters
USE CMN_DIAG_MOD      ! ND15
```

INPUT PARAMETERS:

```
! Number of tracers used in computation
INTEGER,  INTENT(IN)    :: NTRC

! MW air (g/mol) / MW tracer (g/mol)     [ unitless ]
REAL*8,   INTENT(IN)    :: TCVV(NTRC)
```

INPUT/OUTPUT PARAMETERS:

```
! Tracer concentration [v/v]
REAL*8,   INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR,NTRC)
```

REMARKS:

```
Original subroutine by Dale Allen, Univ of MD.
```

REVISION HISTORY:

```
30 Jan 1998 - I. Bey, R. Yantosca - Initial version
(1 ) TURBDAY is written in Fixed-Form Fortran 90.  Also use F90
      syntax for declarations (bmy, 4/1/99).
(2 ) New tracer concentrations are returned in TC.
```

```
(3 ) PS(I,J) is ACTUAL surface pressure and not Psurface - PTOP
(4 ) Change in tracer in kg is now stored in DTC(I,J,L,N).  This makes
     it easier to compute diagnostic quantities.  The new mixing ratio
     is computed as TC(I,J,L,N) = TC(I,J,L,N) + DTC(I,J,L,N) / AD(I,J,L).
(5 ) XTRA2(*,*,5) is the height of the PBL in # of layers.  So if the
     PBL top is located in the middle of the 3rd sigma layer at (I,J)
     the value of XTRA2(I,J,5) would be 2.5.  The XTRA2 variable is
     used by the HCTM drydep subroutines...it really is a historical
     holdover.
(6 ) Restore the following NDxx diagnostics: (a) ND63 : Mass balance
     (CNVUPP) (b) ND15 : Mass change due to mixing in the boundary layer
(7 ) Now pass TCVV and NCONV for the mass flux diagnostics.  Also
     updated comments and cleaned up a few things. (bey, bmy, 11/10/99)
(8 ) Remove PTOP and XNUMOL from the arg list.  PTOP is now a parameter
     in "CMN_SIZE".  XNUMOL is no longer used in TURBDAY. (bmy, 2/10/00)
(9 ) Also removed obsolete ND63 diagnostics and updated comments.
     (bmy, 4/12/00)
(10) Now use NTRC instead of NNPAR to dimension variables TC, TCVV, DTC,
     and DTCSUM (bmy, 10/17/00).
(11) Removed obsolete code from 10/17/00 (bmy, 12/21/00)
(12) If the PBL depth is very small (or zero), then assume a PBL depth
     of 2 mb -- this prevents NaN's from propagating throughout the
     code.  Also updated comments & made cosmetic changes. (bmy, 3/9/01)
(13) DTCSUM was declared twice but wasn't used.  Elminate declarations
     to DTCSUM. (bmy, 7/16/01)
(14) XTRA2(IREF,JREF,5) is now XTRA2(I,J).  Also updated comments.
     Also remove IREF, JREF and some debug output. (bmy, 9/25/01)
(15) Removed obsolete commented out code from 9/01 (bmy, 10/24/01)
(16) Now takes in P=PS-PTOP instead of PS.  Redimension SIGE to
     (1:LLPAR+1).
(17) Renamed PS to PZ so as not to conflict w/ the existing P variable.
     Now pass P-PTOP thru PZ, in order to ensure that P and AD are
     consistent w/ each other.  Added parallel DO-loops. Updated comments,
     cosmetic changes.  Now print a header to stdout on the first call,
     to confirm that TURBDAY has been called. (bmy, 4/11/02)
(18) Now use GET_PEDGE from "pressure_mod.f" to compute the pressure
     at the bottom edge of grid box (I,J,L).  Deleted obsolete code from
     4/02.  Removed PZ, SIGE from the argument list, since we now compute
     pressure from GET_PEDGE. (dsa, bdf, bmy, 8/22/02)
(19) Now reference AD, PBL from "dao_mod.f".  Now removed DXYP from the
     arg list, use GET_AREA_M2 from "grid_mod.f" instead.  Now removed
     NCONV, ALPHA_d, ALPHA_n from the arg list.  Now no longer reference
     SUNCOS.  Now set A(:,:)=1 day & nite; we assume full mixing all the
     time regardless of SUNCOS.  Updated comments, cosmetic changes.
     (bmy, 2/11/03)
(20) Now can handle PBL field in meters for GEOS-4/fvDAS.  Also the
     atmospheric scale height from CMN_GCTM. (bmy, 6/23/03)
(21) Now bundled into "pbl_mix_mod.f".  Broke off the part which computes
```

```
      PBL height and related quantities into COMPUTE_PBL_HEIGHT.
      (bmy, 2/15/05)
28 Feb 2012 - R. Yantosca - Added ProTeX headers
 2 Mar 2012 - R. Yantosca - Remove reference to GET_AREA_M2
```

1.79.4 get_frac_of_pbl

Function GET_FRAC_OF_PBL returns the fraction of grid box (I,J,L) that lies within the planetary boundary layer.

INTERFACE:

```
FUNCTION GET_FRAC_OF_PBL( I, J, L ) RESULT( FRAC )
```

USES:

```
USE CMN_SIZE_MOD   ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L    ! Lon, lat, lev indices
```

RETURN VALUE:

```
REAL*8              :: FRAC       ! Fraction of box (I,J,L) in the PBL
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.79.5 get_frac_under_pbltop

Function GET_FRAC_UNDER_PBLTOP returns the fraction of grid box (I,J,L) that lies underneath the planetary boundary layer top.

INTERFACE:

```
FUNCTION GET_FRAC_UNDER_PBLTOP( I, J, L ) RESULT( FRAC )
```

USES:

```
USE CMN_SIZE_MOD                ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L   ! Lon, lat, level indices
```

RETURN VALUE:

```
      REAL*8              :: FRAC      ! Fraction of box (I,J,L) below PBL top
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.79.6 get_pbl_max_l

Function GET_PBL_MAX_L returns the model level at the highest part of the planetary boundary layer.

INTERFACE:

```
      FUNCTION GET_PBL_MAX_L() RESULT( TOP )
```

RETURN VALUE:

```
      INTEGER  :: TOP   ! Highest extent of PBL [model levels]
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.79.7 get_pbl_top_hpa

Function GET_PBL_TOP_hPa returns the planetary boundary layer top [hPa] at a given GEOS-Chem surface location (I,J).

INTERFACE:

```
      FUNCTION GET_PBL_TOP_hPa( I, J ) RESULT( TOP )
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I, J   ! Lon and lat indices
```

RETURN VALUE:

```
      REAL*8              :: TOP    ! PBL top [hPa]
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.79.8 get_pbl_top_l

Function GET_PBL_TOP_L returns the planetary boundary layer top [model levels] at a given GEOS-Chem surface location (I,J).

INTERFACE:

```
FUNCTION GET_PBL_TOP_L( I, J ) RESULT( TOP )
```

USES:

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J   ! Lon and lat indices
```

RETURN VALUE:

```
REAL*8              :: TOP    ! PBL top [model levels]
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.79.9 get_pbl_top_m

Function GET_PBL_TOP_m returns the planetary boundary layer top [m] at a given GEOS-CHEM surface location (I,J).

INTERFACE:

```
FUNCTION GET_PBL_TOP_m( I, J ) RESULT( TOP )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J   ! Lon and lat indices
```

RETURN VALUE:

```
REAL*8              :: TOP    ! PBL top [m]
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.79.10

Function GET_PBL_THICK returns the thickness of the PBL at a given surface location (I,J).

INTERFACE:

```
FUNCTION GET_PBL_THICK( I, J ) RESULT( THICK )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J    ! Lon and lat indices
```

RETURN VALUE:

```
REAL*8              :: THICK   ! PBL thickness [hPa]
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.79.11 init_pbl_mix

Subroutine INIT_PBL_MIX allocates and zeroes module arrays

INTERFACE:

```
SUBROUTINE INIT_PBL_MIX
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR
USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.79.12 cleanup_pbl_mix

Subroutine CLEANUP_PBL_MIX allocates and zeroes module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_PBL_MIX
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.80 Fortran: Module Interface Pjc_Pfix_Mod

Module Pjc_Pfix_Mod contains routines which implements the Philip Cameron-Smith pressure fixer for the new fvDAS transport scheme. (bdf, bmy, 5/8/03, 10/27/03)

INTERFACE:

```
      MODULE Pjc_Pfix_Mod
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: Do_Pjc_Pfix
      PUBLIC  :: Cleanup_Pjc_Pfix
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: Calc_Pressure
      PRIVATE :: Calc_Advection_Factors
      PRIVATE :: Adjust_Press
      PRIVATE :: Init_Press_Fix
      PRIVATE :: Do_Press_Fix_LLNL
      PRIVATE :: Average_Press_Poles
      PRIVATE :: Convert_Winds
      PRIVATE :: Calc_Horiz_Mass_Flux
      PRIVATE :: Calc_Divergence
      PRIVATE :: Set_Press_Terms
      PRIVATE :: Do_Divergence_Pole_Sum
      PRIVATE :: Xpavg
      PRIVATE :: Init_Pjc_Pfix
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
Brendan Field and Bob Yantosca (5/8/03)
Modified for new GMI TPCORE by Claire Carouge (ccarouge@seas.harvard.edu)
```

REVISION HISTORY:

```
(1 ) Bug fix for Linux/PGI compiler in routines ADJUST_PRESS and
      INIT_PRESS_FIX. (bmy, 6/23/03)
(2 ) Now make P1, P2 true surface pressure in DO_PJC_PFIX (bmy, 10/27/03)
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
```

1.80.1 Do_Pjc_Pfix

Subroutine Do_Pjc_Pfix is the driver routine for the Philip Cameron-Smith pressure fixer for the fvDAS transport scheme. (bdf, bmy, 5/8/03, 3/5/07)

We assume that the winds are on the A-GRID, since this is the input that the fvDAS transport scheme takes. (bdf, bmy, 5/8/03)

INTERFACE:

```
SUBROUTINE Do_Pjc_Pfix( D_DYN, P1, P2, UWND, VWND, XMASS, YMASS )
```

USES:

```
USE CMN_SIZE_MOD    ! Size parameters
USE CMN_GCTM_MOD    ! Physical constants
```

INPUT PARAMETERS:

```
! Dynamic timestep [s]
REAL*8,  INTENT(IN)  :: D_DYN

! True PSurface at middle of dynamic timestep [hPa]
REAL*8,  INTENT(IN)  :: P1(IIPAR,JJPAR)

! True PSurface at end    of dynamic timestep [hPa]
REAL*8,  INTENT(IN)  :: P2(IIPAR,JJPAR)

! Zonal (E-W) wind [m/s]
REAL*8,  INTENT(IN)  :: UWND(IIPAR,JJPAR,LLPAR)

! Meridional (N-S) wind [m/s]
REAL*8,  INTENT(IN)  :: VWND(IIPAR,JJPAR,LLPAR)
```

OUTPUT PARAMETERS:

```
! E-W mass fluxes [mixing ratio]
REAL*8,  INTENT(OUT) :: XMASS(IIPAR,JJPAR,LLPAR)

! N-S mass fluxes [mixing ratio]
REAL*8,  INTENT(OUT) :: YMASS(IIPAR,JJPAR,LLPAR)
```

AUTHOR:

```
Brendan Field and Bob Yantosca (5/8/03)
```

REMARKS:

```
(1 ) Now P1 and P2 are "true" surface pressures, and not PS-PTOP.  If using
     this P-fixer w/ GEOS-3 winds, pass true surface pressure to this
     routine. (bmy, 10/27/03)
(2 ) Now define P2_TMP array for passing to ADJUST_PRESS (yxw, bmy, 3/5/07)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.80.2 Calc_Pressure

Subroutine Calc_Pressure recalculates the new surface pressure from the adjusted air masses XMASS and YMASS. This is useful for debugging purposes. (bdf, bmy, 5/8/03)

INTERFACE:

```
SUBROUTINE Calc_Pressure( XMASS, YMASS, RGW_FV, PS_NOW, PS_AFTER )
```

USES:

```
USE CMN_SIZE_MOD  ! Size parameters
USE CMN_MOD       ! STT, NTRACE, LPRT, LWINDO
```

INPUT PARAMETERS:

```
! E-W mass flux from pressure fixer
REAL*8, INTENT(IN)  :: XMASS(IIPAR,JJPAR,LLPAR)

! N-S mass flux from pressure fixer
REAL*8, INTENT(IN)  :: YMASS(IIPAR,JJPAR,LLPAR)

! Surface pressure - PTOP at current time
REAL*8, INTENT(IN)  :: PS_NOW(IIPAR,JJPAR)

! 1 / ( SINE(J+1) - SINE(J) ) -- latitude factor
REAL*8, INTENT(IN)  :: RGW_FV(JJPAR)
```

OUTPUT PARAMETERS:

```
! Surface pressure - PTOP adjusted by P-fixer
REAL*8, INTENT(OUT) :: PS_AFTER(IIPAR,JJPAR)
```

AUTHOR:

```
Brendan Field and Bob Yantosca (5/8/03)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.80.3 Calc_Advection_Factors

Subroutine Calc_Advection_Factors calculates the relative area of each grid box, and the geometrical factors used by this modified version of TPCORE. These geomoetrical DO assume that the space is regularly gridded, but do not assume any link between the surface area and the linear dimensions.

INTERFACE:

```
 SUBROUTINE Calc_Advection_Factors
&  (mcor, rel_area, geofac, geofac_pc)
```

USES:

```
USE CMN_SIZE_MOD   ! Size parameters
USE CMN_GCTM_MOD   ! Physical constants
```

INPUT PARAMETERS:

```
! Area of grid box (m^2)
REAL*8, INTENT(IN)  :: mcor(i1_gl :i2_gl, ju1_gl:j2_gl)
```

OUTPUT PARAMETERS:

```
! relative surface area of grid box (fraction)
REAL*8, INTENT(OUT) :: rel_area(i1_gl :i2_gl, ju1_gl:j2_gl)

! Geometrical factor for meridional advection; geofac uses
! correct spherical geometry, and replaces acosp as the
! meridional geometrical factor in tpcore
REAL*8, INTENT(OUT) :: geofac(ju1_gl:j2_gl)

! Special geometrical factor (geofac) for Polar cap
REAL*8, INTENT(OUT) :: geofac_pc
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REMARKS:

```
Now reference PI from "CMN_GCTM" for consistency.  Also force
double-precision with the "D" exponent. (bmy, 5/6/03)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.80.4 Adjust_Press

Subroutine Adjust_Press initializes and calls the pressure fixer code.

INTERFACE:

```
 SUBROUTINE Adjust_Press
&  (metdata_name_org, do_timinterp_winds, new_met_rec,
&   met_grid_type, advec_consrv_opt, pmet2_opt, press_fix_opt,
&   tdt, geofac_pc, geofac, cose, cosp, rel_area, dap, dbk,
&   pctm1, pctm2, pmet2, uu, vv, xmass, ymass)
```

INPUT PARAMETERS:

```
! First  part of metdata_name, e.g., "NCAR"
CHARACTER(LEN=*) :: metdata_name_org

! Time interpolate wind fields?
LOGICAL :: do_timinterp_winds

! New met record?
LOGICAL :: new_met_rec

! Met grid type, A or C
INTEGER :: met_grid_type

! Advection_conserve option
INTEGER :: advec_consrv_opt

! pmet2 option
INTEGER :: pmet2_opt

! pressure fixer option
INTEGER :: press_fix_opt

! Model time step [s]
REAL*8  :: tdt

! Special geometrical factor (geofac) for Polar cap
REAL*8  :: geofac_pc

! Geometrical factor for meridional advection; geofac uses
! correct spherical geometry, and replaces acosp as the
! meridional geometrical factor in tpcore
REAL*8  :: geofac  (ju1_gl:j2_gl)

! Cosines of grid box edges and centers
REAL*8  :: cose    (ju1_gl:j2_gl)
REAL*8  :: cosp    (ju1_gl:j2_gl)
```

```
! Pressure difference across layer from (ai * pt) term [hPa]
REAL*8  :: dap     (k1:k2)

! Difference in bi across layer - the dSigma term
REAL*8  :: dbk     (k1:k2)

! Relative surface area of grid box (fraction)
REAL*8  :: rel_area( i1_gl:i2_gl,   ju1_gl:j2_gl)

! Metfield surface pressure at t1+tdt [hPa]
REAL*8  :: pmet2(ilo_gl:ihi_gl, julo_gl:jhi_gl)

! CTM surface pressure at t1 [hPa]
REAL*8  :: pctm1(ilo_gl:ihi_gl, julo_gl:jhi_gl)

! CTM surface pressure at t1+tdt [hPa]
REAL*8  :: pctm2(ilo_gl:ihi_gl, julo_gl:jhi_gl)

! Wind velocity, x direction at t1+tdt/2 [m/s]
REAL*8  :: uu(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)

! Wind velocity, y direction at t1+tdt/2 [m/s]
REAL*8  :: vv(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)
```

INPUT/OUTPUT PARAMETERS:

```
! Horizontal mass flux in E-W direction [hPa]
REAL*8  :: xmass(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)

! Horizontal mass flux in N-S direction [hPa]
REAL*8  :: ymass(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)
```

AUTHOR:

Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.80.5 Init_Press_Fix

Subroutine Init_Press_Fix initializes the pressure fixer.

INTERFACE:

```
SUBROUTINE Init_Press_Fix
```

```
&  (metdata_name_org, met_grid_type, tdt, geofac_pc, geofac,
&   cose, cosp, dap, dbk, dps, dps_ctm, rel_area, pctm1, pmet2,
&   uu, vv, xmass, ymass)
```

INPUT PARAMETERS:

```
! Model Time step [s]
REAL*8 :: tdt

! First part of metdata_name, e.g., "NCAR"
CHARACTER(LEN=*) :: metdata_name_org

! Met grid type, A or C
INTEGER          :: met_grid_type

! Special geometrical factor (geofac) for Polar cap
REAL*8           :: geofac_pc

! Cosine of grid box edges and centers
REAL*8           :: cose(ju1_gl:j2_gl)
REAL*8           :: cosp(ju1_gl:j2_gl)

! Geometrical factor for meridional advection; geofac uses
! correct spherical geometry, and replaces acosp as the
! meridional geometrical factor in tpcore
REAL*8           :: geofac(ju1_gl:j2_gl)

! Pressure difference across layer from (ai * pt) term [hPa]
REAL*8           :: dap(k1:k2)

! Difference in bi across layer - the dSigma term
REAL*8           :: dbk(k1:k2)

! relative surface area of grid box (fraction)
REAL*8           :: rel_area( i1_gl:i2_gl, ju1_gl:j2_gl)

! Metfield surface pressure at t1 [hPa]
REAL*8           :: pmet2(ilo_gl:ihi_gl, julo_gl:jhi_gl)

! CTM surface pressure at t1 [hPa]
REAL*8           :: pctm1(ilo_gl:ihi_gl, julo_gl:jhi_gl)

! CTM surface pressure at t1+tdt [hPa]
REAL*8           :: pctm2(ilo_gl:ihi_gl, julo_gl:jhi_gl)

! Wind velocity, x direction at t1+tdt/2 [m/s]
REAL*8           :: uu(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)

! Wind velocity, y direction at t1+tdt/2 [m/s]
```

```
REAL*8           :: vv(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)
```

OUTPUT PARAMETERS:

```
! Horizontal mass flux in E-W direction [hPa]
REAL*8  :: xmass(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)

! Horizontal mass flux in N-S direction [hPa]
REAL*8  :: ymass(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)

! Change of surface pressure from met field pressure [hPa]
REAL*8  :: dps(i1_gl:i2_gl, ju1_gl:j2_gl)

! CTM surface pressure tendency [hPa]
REAL*8  :: dps_ctm(i1_gl:i2_gl, ju1_gl:j2_gl)
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.80.6 Do_Press_Fix_Llnl

Subroutine Do_Press_Fix_Llnl fixes the mass fluxes to match the met field pressure tendency.

INTERFACE:

```
 SUBROUTINE Do_Press_Fix_Llnl
&  (geofac_pc, geofac, dbk, dps, dps_ctm, rel_area,
&   xmass, ymass, xmass_fixed, ymass_fixed)
```

INPUT PARAMETERS:

```
! Special geometrical factor (geofac) for Polar cap
REAL*8, INTENT(IN)   :: geofac_pc

! Geometrical factor for meridional advection; geofac uses
! correct spherical geometry, and replaces acosp as the
!  meridional geometrical factor in tpcore
REAL*8, INTENT(IN)   :: geofac(ju1_gl:j2_gl)

! Difference in bi across layer - the dSigma term
REAL*8, INTENT(IN)   :: dbk(k1:k2)

! Change of surface pressure from met field pressure [hPa]
```

```
      REAL*8, INTENT(IN)   :: dps(i1:i2, ju1:j2)

      ! Relative surface area of grid box (fraction)
      REAL*8, INTENT(IN)   :: rel_area(i1:i2, ju1:j2)

      ! Horizontal mass fluxes in E-W and N-S directions [hPa]
      REAL*8, INTENT(IN)   :: xmass(ilo:ihi, julo:jhi, k1:k2)
      REAL*8, INTENT(IN)   :: ymass(ilo:ihi, julo:jhi, k1:k2)
```

OUTPUT PARAMETERS:

```
      ! Sum over vertical of dpi calculated from original mass fluxes [hPa]
      REAL*8,  INTENT(OUT) :: dps_ctm(i1:i2, ju1:j2)

      ! Horizontal mass flux in E-W and N-S directions after fixing [hPa]
      REAL*8,  INTENT(OUT) :: xmass_fixed(ilo:ihi, julo:jhi, k1:k2)
      REAL*8,  INTENT(OUT) :: ymass_fixed(ilo:ihi, julo:jhi, k1:k2)
```

AUTHOR:

```
   Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REVISION HISTORY:

```
    02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                                Declare all REAL variables as REAL*8.
```

1.80.7 Average_Press_Poles

Subroutine Average_Press_Poles averages pressure at the Poles when the Polar cap is enlarged. It makes the last two latitudes equal.

INTERFACE:

```
      SUBROUTINE Average_Press_Poles
     &  (rel_area, press)
```

INPUT PARAMETERS:

```
      ! Relative surface area of grid box (fraction)
      REAL*8, INTENT(IN)    :: rel_area(i1:i2, ju1:j2)
```

OUTPUT PARAMETERS:

```
      ! Surface pressure [hPa]
      REAL*8, INTENT(INOUT) :: press   (ilo:ihi, julo:jhi)
```

AUTHOR:

```
    Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REVISION HISTORY:

```
    02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                                Declare all REAL variables as REAL*8.
```

1.80.8 Convert_Winds

Subroutine Convert_Winds converts winds on A or C grid to Courant # on C grid.

INTERFACE:

```
      SUBROUTINE Convert_Winds
     &  (igd, tdt, cosp, crx, cry, uu, vv)
```

USES:

```
      USE CMN_SIZE_MOD ! Size parameters
      USE CMN_GCTM_MOD ! Re, PI
```

INPUT PARAMETERS:

```
      ! A or C grid
      INTEGER, INTENT(IN)  :: igd

      ! Model time step [s]
      REAL*8,  INTENT(IN)  :: tdt

      ! Cosine of grid box centers
      REAL*8,  INTENT(IN)  :: cosp(ju1_gl:j2_gl)

      ! Wind velocity in E-W (UU) and N-S (VV) directions at t1+tdt/2 [m/s]
      REAL*8,  INTENT(IN)  :: uu  (ilo:ihi, julo:jhi, k1:k2)
      REAL*8,  INTENT(IN)  :: vv  (ilo:ihi, julo:jhi, k1:k2)
```

OUTPUT PARAMETERS:

```
      ! Courant number in E-W (CRX) and N-S (CRY) directions
      REAL*8,  INTENT(OUT) :: crx (ilo:ihi, julo:jhi, k1:k2)
      REAL*8,  INTENT(OUT) :: cry (ilo:ihi, julo:jhi, k1:k2)
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REMARKS:

```
Use GEOS-CHEM physical constants Re, PI to be consistent with other
usage everywhere (bmy, 5/5/03)
```

REVISION HISTORY:

```
 02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                             Declare all REAL variables as REAL*8.
```

1.80.9 Calc_Horiz_Mass_Flux

Subroutine Calc_Horiz_Mass_Flux calculates the horizontal mass flux for non-GISS met data.

INTERFACE:

```
      SUBROUTINE Calc_Horiz_Mass_Flux
     &  (cose, delpm, uu, vv, xmass, ymass, tdt, cosp)
```

USES:

```
      USE CMN_SIZE_MOD ! Size parameters
      USE CMN_GCTM_MOD ! Re, Pi
```

INPUT PARAMETERS:

```
      ! Timestep [s]
      REAL*8, INTENT(IN)   :: tdt

      ! Cosine of grid box edges
      REAL*8, INTENT(IN)   :: cose (ju1_gl:j2_gl)

      ! Cosine of grid box centers
      REAL*8, INTENT(IN)   :: cosp (ju1_gl:j2_gl)

      ! Pressure thickness, the pseudo-density in a
      ! hdrostatic system  at t1+tdt/2 (approximate) [hPa]
      REAL*8, INTENT(IN)   :: delpm(ilo:ihi, julo:jhi, k1:k2)

      ! E-W (UU) and N-S (VV) winds [m/s]
      REAL*8, INTENT(IN)   :: uu  (ilo:ihi, julo:jhi, k1:k2)
      REAL*8, INTENT(IN)   :: vv  (ilo:ihi, julo:jhi, k1:k2)
```

OUTPUT PARAMETERS:

```
      ! Horizontal mass flux in E-W and N-S directions [hPa]
      REAL*8, INTENT(OUT)  :: xmass(ilo:ihi, julo:jhi, k1:k2)
      REAL*8, INTENT(OUT)  :: ymass(ilo:ihi, julo:jhi, k1:k2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REMARKS:

```
Use GEOS-CHEM physical constants Re, PI to be consistent with other
usage everywhere (bmy, 5/5/03)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.80.10 Calc_Divergence

Subroutine Calc_Divergence calculates the divergence.

INTERFACE:

```
  SUBROUTINE Calc_Divergence
 &  (do_reduction, geofac_pc, geofac, dpi, xmass, ymass)
```

INPUT PARAMETERS:

```
  ! Set to F if called on Master; set to T if called by Slaves
  ! (NOTE: this doesn't seem to be used!)
  LOGICAL, INTENT(IN)    :: do_reduction

  ! Special geometrical factor (geofac) for Polar cap
  REAL*8,  INTENT(IN)    :: geofac_pc

  ! geometrical factor for meridional advection; geofac uses
  ! correct spherical geometry, and replaces acosp as the
  ! meridional geometrical factor in tpcore
  REAL*8,  INTENT(IN)    :: geofac(ju1_gl:j2_gl)

  ! horizontal mass fluxes in E-W and N-S directions [hPa]
  REAL*8,  INTENT(IN)    :: xmass (ilo:ihi, julo:jhi, k1:k2)
  REAL*8,  INTENT(IN)    :: ymass (ilo:ihi, julo:jhi, k1:k2)
```

INPUT/OUTPUT PARAMETERS:

```
  ! Divergence at a grid point; used to calculate vertical motion [hPa]
  REAL*8,  INTENT(INOUT) :: dpi   (i1:i2, ju1:j2, k1:k2)
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.80.11 Set_Press_Terms

Subroutine Set_Press_Terms sets the pressure terms.

INTERFACE:

```
      SUBROUTINE Set_Press_Terms
     &  (dap, dbk, pres1, pres2, delp1, delpm, pu)
```

INPUT PARAMETERS:

```
      ! Pressure difference across layer from (ai * pt) term [hPa]
      REAL*8, INTENT(IN)  :: dap  (k1:k2)

      ! Difference in bi across layer - the dSigma term
      REAL*8, INTENT(IN)  :: dbk  (k1:k2)

      ! Surface pressure at t1 [hPa]
      REAL*8, INTENT(IN)  :: pres1(ilo:ihi, julo:jhi)

      ! Surface pressure at t1+tdt [hPa]
      REAL*8, INTENT(IN)  :: pres2(ilo:ihi, julo:jhi)
```

OUTPUT PARAMETERS:

```
      ! Pressure thickness, the psudo-density in a
      ! hydrostatic system at t1 [hPa]
      REAL*8, INTENT(OUT) :: delp1(ilo:ihi, julo:jhi, k1:k2)

      ! Pressure thickness, the psudo-density in a
      ! hydrostatic system at t1+tdt/2 (approximate)  [hPa]
      REAL*8, INTENT(OUT) :: delpm(ilo:ihi, julo:jhi, k1:k2)

      ! Pressure at edges in "u" [hPa]
      REAL*8, INTENT(OUT) :: pu   (ilo:ihi, julo:jhi, k1:k2)
```

AUTHOR:

```
    Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REVISION HISTORY:

```
     02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                                 Declare all REAL variables as REAL*8.
```

1.80.12 Do_Divergence_Pole_Sum

Do_Divergence_Pole_Sum sets the divergence at the Poles.

INTERFACE:

```
      SUBROUTINE Do_Divergence_Pole_Sum
     &  (do_reduction, geofac_pc, dpi, ymass)
```

INPUT PARAMETERS:

```
      ! Set to T if called on Master; set to F if called by Slaves
      ! (NOTE: This does not seem to be used!)
      LOGICAL :: do_reduction

      ! Special geometrical factor (geofac) for Polar cap
      REAL*8  :: geofac_pc

      ! horizontal mass flux in N-S direction [hPa]
      REAL*8  :: ymass(ilo:ihi, julo:jhi, k1:k2)
```

OUTPUT PARAMETERS:

```
      ! Divergence at a grid point; used to calculate vertical motion [hPa]
      REAL*8  :: dpi  ( i1:i2,   ju1:j2,  k1:k2)
```

AUTHOR:

```
   Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REVISION HISTORY:

```
    02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                                Declare all REAL variables as REAL*8.
```

1.80.13 Xpavg

!description: Subroutine Xpavg replaces each element of a vector with the average of the entire array. (bmy, 5/7/03)

INTERFACE:

```
      SUBROUTINE Xpavg( P, IM )
```

USES:

```
      ! References to F90 modules
      USE ERROR_MOD, ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
      ! Dimension of P
      INTEGER, INTENT(IN)    :: IM
```

INPUT/OUTPUT PARAMETERS:

```
      ! 1-D vector to be averaged
      REAL*8,  INTENT(INOUT) :: P(IM)
```

AUTHOR:

Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)

REVISION HISTORY:

02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
Now make all REAL variables REAL*8.

1.80.14 Init_Pjc_Pfix

Subroutine Init_Pjc_Pfix allocates and initializes module arrays and variables. GMI dimension variables will be used for compatibility with the Phil Cameron-Smith P-fixer. (bdf, bmy, 5/8/03)

INTERFACE:

```
SUBROUTINE Init_Pjc_Pfix
```

USES:

```
! References to F90 modules
USE GRID_MOD,     ONLY : GET_AREA_M2, GET_YMID_R
USE ERROR_MOD,    ONLY : ALLOC_ERR,   ERROR_STOP
USE PRESSURE_MOD, ONLY : GET_AP,      GET_BP

USE CMN_SIZE_MOD  ! Size parameters
USE CMN_GCTM_MOD  ! Re, PI, etc...
```

AUTHOR:

Brendan Field and Bob Yantosca (5/8/03)

REVISION HISTORY:

02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R(I,J,L) from grid_mod.F90

1.80.15 Cleanup_Pjc_Pfix

Subroutine Cleanup_Pjc_Pfix deallocates all module arrays (bmy, 5/8/03)

INTERFACE:

```
SUBROUTINE Cleanup_Pjc_Pfix
```

REVISION HISTORY:

02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.

1.81 Fortran: Module Interface planeflight_mod

Module PLANEFLIGHT_MOD contains variables and routines which are used to "fly" a plane through the GEOS-Chem model simulation. This is useful for comparing model results with aircraft observations.

INTERFACE:

```
      MODULE PLANEFLIGHT_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: ARCHIVE_RXNS_FOR_PF
      PUBLIC  :: CLEANUP_PLANEFLIGHT
      PUBLIC  :: PLANEFLIGHT
      PUBLIC  :: SETUP_PLANEFLIGHT
      PUBLIC  :: SET_PLANEFLIGHT
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: AN_SETUP
      PRIVATE :: INIT_PLANEFLIGHT
      PRIVATE :: NOY_SETUP
      PRIVATE :: READ_VARIABLES
      PRIVATE :: READ_POINTS
      PRIVATE :: RO2_SETUP
      PRIVATE :: TEST_VALID
      PRIVATE :: WRITE_VARS_TO_FILE
```

REMARKS:

```
    The quantities that are saved to disk by the planeflight diagnostic were
    requested by GEOS-Chem users.  If you would like to save out a new quantity,
    then you will have to make your own modifications in this module.
```

REVISION HISTORY:

```
    (1 ) Now references "pressure_mod.f" (dsa, bdf, bmy, 8/21/02)
    (2 ) Now reference AD from "dao_mod.f".  Now also references "error_mod.f".
         (bmy, 10/15/02)
    (3 ) Bug fix: replace missing commas in FORMAT statement (bmy, 3/23/03)
    (4 ) Now references "time_mod.f". (bmy, 3/27/03)
    (5 ) Renamed PRATE to PRRATE to avoid conflict w/ SMVGEAR II (bmy, 4/1/03)
    (6 ) Bug fix: use NAMEGAS instead of NAMESPEC (lyj, bmy, 7/9/03)
    (7 ) Bug fix: avoid referencing JLOP for non-SMVGEAR runs (bmy, 7/18/03)
    (8 ) Bug fix: Use T instead of T3 for GMAO temperature.  Also replace
```

```
      NAMESPEC w/ NAMEGAS in RO2_SETUP.  Now locate reordered rxn
      numbers for SMVGEAR II.(tdf, mje, bmy, 8/1/03)
(9 ) Now print out N2O5 hydrolysis rxn as a special case.   Also rename
      output file. (bmy, 8/8/03)
(10) Changed "DAO" to "GMAO" for met field variable names.  Now can save
      aerosol optical depths.  Bug fix in TEST_VALID. (bmy, 4/23/03)
(11) Now references "tracer_mod.f" (bmy, 7/20/04)
(12) Bug fix in READ_VARIABLES (1/7/05)
(13) Modified the plane flight diagnostic so that it writes output files
      for each day where flight track files are defined. (bmy, 3/24/05)
(14) Minor bug fix in ARCHIVE_RXNS_FOR_PF (bmy, 5/20/05)
(15) Now split AOD's into column AOD's and AOD's below plane.  Also scale
      AOD's to 400nm. (bmy, 10/25/05)
(16) Bug fixes in READ_VARIABLES (bmy, 10/16/06)
(17) Bug fix in PLANEFLIGHT (cdh, bmy, 12/12/06)
(18) Bug fix in RO2_SETUP (tmf, bmy, 4/23/07)
(19) Set very small values to zero.  (tmf, 1/7/09)
(20) Add new RO2 species according to 'globchem.dat' (tmf, 1/7/09)
(21) Make sure we have 3 spaces in the exponential format (phs, 7/13/09)
(22) Output the grid cell indexes (kjw, 8/18/09)
(23) Add AN and NOy species. (fp, 3/10/10)
(24) Now scale AODs to wavelength specified in jv_spec_aod.dat(clh, 5/14/09)
29 Jul 2011 - R. Yantosca - Now also archive MERRA SEAICExx fields
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.81.1 setup_planeflight

Subroutine SETUP_PLANEFLIGHT reads information from the input file in order to initialize the planeflight diagnostic. Also calls INIT_PLANEFLIGHT to allocate and zero module arrays.

INTERFACE:

```
SUBROUTINE SETUP_PLANEFLIGHT
```

USES:

```
USE FILE_MOD,   ONLY : FILE_EXISTS
USE FILE_MOD,   ONLY : IOERROR
USE FILE_MOD,   ONLY : IU_FILE
USE FILE_MOD,   ONLY : IU_PLANE
USE TIME_MOD,   ONLY : EXPAND_DATE
USE TIME_MOD,   ONLY : GET_NYMD
USE TIME_MOD,   ONLY : GET_NHMS
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM
```

REMARKS:

```
For SMVGEAR or KPP simulations, the call to SETUP_PLANEFLIGHT is made from
routine "chemdr.f", after the "chem.dat" file is read.  This is necessary
since we have to reference the SMVGEAR rxn rate and species numbers.

For offline simulations, the call to SETUP_PLANEFLIGHT can be made
at the start of the GEOS-Chem run (in "ndxx_setup.f" or similar routine).
```

REVISION HISTORY:

```
30 Jul 2002 - M. Evans    - Initial version
(1 ) Rename from "plane.dat" to "plane.log", since "*.dat" implies an input
      file name. (bmy, 8/8/03)
(2 ) Add fancy output string (bmy, 4/26/04)
(3 ) Now references GET_NYMD, GET_NHMS, and EXPAND_DATE from "time_mod.f".
      Now also replaces date & time tokens in the filenames. (bmy, 7/20/04)
(4 ) Now references FILE_EXISTS from "file_mod.f".  Modified so that we
      check if a flight track file exists on each day.  Open file for
      output on each day and write header. (bmy, 3/25/05)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.81.2 read_variables

Subroutine READ_VARIABLES reads the list of variables (SMVGEAR/KPP chemical species, SMVGEAR/KPP rxn rates, GMAO met fields, or GEOS-Chem tracers) to be printed out and sorts the information into the appropriate module variables.

INTERFACE:

```
SUBROUTINE READ_VARIABLES
```

USES:

```
USE ERROR_MOD,  ONLY : GEOS_CHEM_STOP
USE FILE_MOD,   ONLY : IU_FILE
USE FILE_MOD,   ONLY : IOERROR
USE TRACER_MOD, ONLY : N_TRACERS
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM

USE CMN_SIZE_MOD     ! Size parameters
USE COMODE_LOOP_MOD  ! NAMEGAS, NSPEC
```

REVISION HISTORY:

```
30 Jul 2002 - M. Evans    - Initial version
(1 ) Now references GEOS_CHEM_STOP from "error_mod.f", which frees all
      allocated memory before stopping the run. (bmy, 10/15/02)
(2 ) Bug fix: replace missing commas in FORMAT statement (bmy, 3/23/03)
```

```
(3 ) Bug fix: replace NAMESPEC w/ NAMEGAS for SMVGEAR II (lyj, bmy, 7/9/09)
(4 ) Now locate reordered rxn numbers for SMVGEAR II. (mje, bmy, 8/1/03)
(5 ) Now flag N2O5 hydrolysis rxn as a special case (bmy, 8/8/03)
(6 ) Changed variable name prefix "DAO" to "GMAO".  Also added aerosol
     optical depths w/ tracer offset 2000. (bmy, 4/23/04)
(7 ) Now references N_TRACERS & ITS_A_FULLCHEM_SIM from "tracer_mod.f"
     (bmy, 7/20/04)
(8 ) Bug fix: extract tracer # when reading rxn rates (bmy, 1/7/05)
(9 ) Now computes column AOD's and AOD's below plane (bmy, 10/24/05)
(10) We need to trim NAMEGAS before comparing to LINE so that comparisons
     for species like "O3" will work.  Also set NCS=NCSURBAN at the top
     of the subroutine, to avoid out of bounds error. (dbm, bmy, 10/16/06)
29 Jul 2011 - R. Yantosca - Also search for MERRA SEAICExx met fields
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.81.3 read_points

Subroutine READ_POINTS reads the information (ID, date, time, lat, lon, pressure) for each measurement listed in the input file, and sorts these into the appropriate module variables.

INTERFACE:

```
SUBROUTINE READ_POINTS
```

USES:

```
USE BPCH2_MOD, ONLY : GET_TAU0
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
USE FILE_MOD,  ONLY : IU_FILE, IOERROR
```

REVISION HISTORY:

```
30 Jul 2002 - M. Evans    - Initial version
(1 ) Now references GEOS_CHEM_STOP from "error_mod.f", which frees all
     allocated memory before stopping the run. (bmy, 10/15/02)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.81.4 ro2_setup

Subroutine RO2_SETUP saves the SMVGEAR species indices of RO2 constituents in the PRO2 array. Also computes the count NPRO2.

INTERFACE:

```
SUBROUTINE RO2_SETUP
```

USES:

```
USE ERROR_MOD,  ONLY : GEOS_CHEM_STOP
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM

USE CMN_SIZE_MOD     ! Size parameters
USE COMODE_LOOP_MOD  ! NAMEGAS, NSPEC
```

REVISION HISTORY:

```
01 Aug 2003 - M. Evans    - Initial version
(1 ) Now references GEOS_CHEM_STOP from "error_mod.f", which frees all
     allocated memory before stopping the run. (bmy, 10/15/02)
(2 ) Now replace NAMESPEC w/ NAMEGAS for SMVGEAR II (bmy, 8/1/03)
(3 ) Now references ITS_A_FULLCHEM_SIM from "tracer_mod.f" (bmy, 7/20/04)
(4 ) Bug fix: PO3 should be PO2 (tmf, bmy, 4/23/07)
(5 ) NOTE: PO3 was a bug, that should have been PO2 (tmf, 2/10/09)
(6 ) Add new RO2 species according to 'globchem.dat' (tmf, 3/10/09)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.81.5 noy_setup

Subroutine NOY_SETUP saves the SMVGEAR species indices of NOy constituents in the PNOY array. Also computes the count NPNOY.

INTERFACE:

```
SUBROUTINE NOY_SETUP
```

USES:

```
USE ERROR_MOD,  ONLY : GEOS_CHEM_STOP
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM

USE CMN_SIZE_MOD   ! Size parameters
USE COMODE_LOOP_MOD       ! NSPEC, NAMEGAS, NCS
```

REVISION HISTORY:

```
01 Jun 2009 - F. Paulot   - Initial version
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.81.6 an_setup

Subroutine AN_SETUP saves the SMVGEAR species indices of AN constituents in the P_AN array. Also computes the count NPAN.

INTERFACE:

```
SUBROUTINE AN_SETUP
```

USES:

```
USE ERROR_MOD,  ONLY : GEOS_CHEM_STOP
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM

USE CMN_SIZE_MOD   ! Size parameters
USE COMODE_LOOP_MOD       ! NSPEC, NAMEGAS, NCS
```

REVISION HISTORY:

```
04 Jan 2010 - F. Paulot   - Initial version
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.81.7 planeflight

Subroutine PLANEFLIGHT saves concentrations to disk at locations corresponding to a flight track.

INTERFACE:

```
SUBROUTINE PLANEFLIGHT
```

USES:

```
USE COMODE_MOD,   ONLY : AIRDENS,        CSPEC,       JLOP
USE COMODE_MOD,   ONLY : T3,             VOLUME,      ABSHUM
USE COMODE_MOD,   ONLY : TAREA
USE DAO_MOD,      ONLY : AD,             SEAICE00,    SEAICE10
USE DAO_MOD,      ONLY : SEAICE20,       SEAICE30,    SEAICE40
USE DAO_MOD,      ONLY : SEAICE50,       SEAICE60,    SEAICE70
USE DAO_MOD,      ONLY : SEAICE80,       SEAICE90,    T
USE DAO_MOD,      ONLY : UWND,           VWND
USE ERROR_MOD,    ONLY : GEOS_CHEM_STOP
USE PRESSURE_MOD, ONLY : GET_PEDGE
USE TIME_MOD,     ONLY : GET_TAU,        GET_TS_DIAG
USE TRACER_MOD,   ONLY : STT,            TCVV

USE JV_CMN_MOD         ! ODAER, QAA, QAA_AOD
USE COMODE_LOOP_MOD    ! CSPEC, etc.
```

REVISION HISTORY:

```
08 Jul 2002 - M. Evans    - Initial version
(1 ) Now reference AD from "dao_mod.f".  Now references GEOS_CHEM_STOP from
     "error_mod.f", which frees memory before stopping. (bmy, 10/15/02)
(2 ) Now uses functions GET_TAU, GET_TS_CHEM from "time_mod.f".
```

```
      (bmy, 3/27/03)
(3 ) Updated comments, cosmetic changes (bmy, 7/18/03)
(4 ) Now references T from "dao_mod.f", so that we can save out temperature
      for non-SMVGEAR runs. (bmy, 8/1/03)
(5 ) Now references UWND and VWND from "dao_mod.f".  Now references
      GET_PEDGE from "pressure_mod.f".  Added CASEs for surface pressure,
      UWND, VWND to the CASE statement (bmy, 4/23/04)
(6 ) Now references STT & TCVV from "tracer_mod.f" (bmy, 7/20/04)
(7 ) Now return if DO_PF = .FALSE. (bmy, 3/24/05)
(8 ) Now compute column AOD's and AOD's below plane.  Also now scale
      AOD's to 400nm. (bmy, 10/24/05)
(9 ) Bug fix: exit if PTAU(M) == PTAUE, so that we write out on the next !
      planeflight timestep (cdh, bmy, 12/12/06)
(10) Change planeflight output time step. (ccc, 8/27/09)
(11) Now scale AOD's to jv_spec_aod.dat wavelength. (clh, 5/14/09)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
09 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
```

1.81.8 test_valid

Subroutine TEST_VALID tests to see if we are w/in the tropopause, which is where SMVGEAR chemistry is done.

INTERFACE:

```
SUBROUTINE TEST_VALID( IND, PCHEM, JLOOP, I, J, L )
```

USES:

```
USE COMODE_MOD,     ONLY : JLOP
USE PRESSURE_MOD,   ONLY : GET_PEDGE
USE TRACER_MOD,     ONLY : ITS_A_FULLCHEM_SIM
USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_TROP
USE GRID_MOD,       ONLY : GET_XOFFSET
USE GRID_MOD,       ONLY : GET_YOFFSET

USE CMN_SIZE_MOD               ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: IND     ! # of the flight track point
```

OUTPUT PARAMETERS:

```
LOGICAL, INTENT(OUT) :: PCHEM   ! =T if chemistry is done here
INTEGER, INTENT(OUT) :: JLOOP   ! 1-D grid box index for SMVGEAR/KPP
INTEGER, INTENT(OUT) :: I       ! GEOS-Chem longitude index
INTEGER, INTENT(OUT) :: J       ! GEOS-Chem latitude index
INTEGER, INTENT(OUT) :: L       ! GEOS-Chem level index
```

REVISION HISTORY:

```
08 Jul 2002 - M. Evans    - Initial version
(1 ) Now use GET_PEDGE of "pressure_mod.f" to return the pressure at the
     bottom edge of box (I,J,L), for hybrid grid. (dsa, bdf, bmy, 8/21/02)
(2 ) Since JLOP is not allocated for non-SMVGEAR runs, set PCHEM=F and
     JLOOP=0 even if we are in the troposphere. (bmy, 7/18/03)
(3 ) Bug fix: add 0.5 in expression for I so that the rounding will
     be done correctly.  Also make sure that I is computed correctly
for points near the date line.  (bmy, 4/23/04)
(4 ) Now references ITS_A_FULLCHEM_SIM from "tracer_mod.f" (bmy, 7/20/04)
(5 ) Now references ITS_IN_THE_TROP from "tropopause_mod.f" (bmy, 8/22/05)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
08 Sep 2011 - L. Schiferl - Added correct definitions for I and J
                            based on nested regions
```

1.81.9 write_vars_to_file

Subroutine WRITE_VARS_TO_FILE writes the values of all the variables for a given flight track point to the output file.

INTERFACE:

```
SUBROUTINE WRITE_VARS_TO_FILE( IND, VARI )
```

USES:

```
USE FILE_MOD, ONLY : IU_PLANE
USE FILE_MOD, ONLY : IOERROR
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: IND           ! # of the flight track point
REAL*8,  INTENT(IN) :: VARI(NPVAR)   ! Values to print to file
```

REVISION HISTORY:

```
08 Jul 2002 - M. Evans    - Initial version
(1 ) The max line length for output seems to be 1024 characters.  Adjust
     MAXVARS accordingly so that we don't exceed this. (bmy, 7/8/02)
(2 ) Now do not write file header -- this is now done in subroutine
     SETUP_PLANEFLIGHT at the start of each day (bmy, 3/25/05)
(3 ) Bug fix: make sure we have 3 spaces in exponential (phs, 7/13/09)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.81.10 archive_rxns_for_PF

Subroutine ARCHIVE_RXNS_FOR_PF is called from "calcrate.f" to pass reaction rates from the SMVGEAR solver for the planeflight diagnostic.

INTERFACE:

```
SUBROUTINE ARCHIVE_RXNS_FOR_PF( JO1D, N2O5 )
```

USES:

```
USE COMODE_MOD, ONLY : IXSAVE
USE COMODE_MOD, ONLY : IYSAVE
USE COMODE_MOD, ONLY : IZSAVE
USE ERROR_MOD,  ONLY : GEOS_CHEM_STOP

USE CMN_SIZE_MOD                    ! Size parameters
USE COMODE_LOOP_MOD                 ! RRATE, JLOOPLO, KBLOOP
USE CMN_DIAG_MOD                    ! ND40 switch
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN)  :: JO1D(KBLOOP)  ! JO1D photolysis rate [1/s]
REAL*8, INTENT(IN)  :: N2O5(KBLOOP)  ! N2O5 hydrolysis rate [molec/cm3/s]
```

REVISION HISTORY:

```
08 Jul 2002 - M. Evans    - Initial version
(1 ) Now avoid overflow/underflow errors in PRATE (bmy, 7/8/02)
(2 ) Now reference GEOS_CHEM_STOP from "error_mod.f", which frees all
     allocated memory before stopping the run (bmy, 10/15/02)
(3 ) Renamed PRATE to PRRATE to avoid conflict w/ SMVGEAR II (bmy, 4/1/03)
(4 ) Now also pass N2O5 hydrolysis rxn rate array via the arg list.
     Also bug fix: replace TMP with RATE in under/overflow checking
     for JO1D and N2O5. (bmy, 8/8/03)
(5 ) Bug fix: Replace with DO_PF since this variable is reset to either T
     or F each day depending on whether there is plane flight data
     available (bmy, 5/20/05)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.81.11 set_planeflight

Subroutine SET_PLANEFLIGHT is used to pass values read in from the GEOS-Chem input file to "planeflight_mod.f".

INTERFACE:

```
SUBROUTINE SET_PLANEFLIGHT( PF, IN_FILE, OUT_FILE )
```

INPUT PARAMETERS:

```
LOGICAL,            INTENT(IN) :: PF         ! Turn on planeflight diag?
CHARACTER(LEN=255), INTENT(IN) :: IN_FILE    ! Input file to read
CHARACTER(LEN=255), INTENT(IN) :: OUT_FILE   ! Output file to write
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.81.12 init_planeflight

Subroutine INIT_PLANEFLIGHT reads the input file to compute the number of variables and flight track points to print out. Also allocates all module arrays.

INTERFACE:

```
SUBROUTINE INIT_PLANEFLIGHT
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
USE FILE_MOD,  ONLY : IU_FILE
USE FILE_MOD,  ONLY : IOERROR

USE CMN_SIZE_MOD    ! Size Parameters
USE COMODE_LOOP_MOD ! ITLOOP
```

REVISION HISTORY:

```
08 Jul 2002 - M. Evans    - Initial version
(1 ) Now reference GEOS_CHEM_STOP from "error_mod.f", which frees all
      allocated memory before stopping the run.  Also reference ALLOC_ERR
      from "error_mod.f" (bmy, 10/15/02)
(2 ) Renamed PRATE to PRRATE to avoid conflict w/ SMVGEAR II (bmy, 4/1/03)
(3 ) INIT_PLANEFLIGHT is now called each day but the arrays are only
      allocated once.  Arrays are now allocated to the maximum size.
      (bmy, 3/25/05)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.81.13 cleanup_planeflight

Subroutine CLEANUP_PLANEFLIGHT deallocates all allocatable module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_PLANEFLIGHT
```

REVISION HISTORY:

```
01 Jul 2001 - M. Evans    - Initial version
(1 ) Renamed PRATE to PRRATE to avoid conflict w/ SMVGEAR II (bmy, 4/1/03)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.82 Fortran: Module Interface retro_mod

Module RETRO_MOD reads emissions from the RETRO emissions inventory

INTERFACE:

```
MODULE RETRO_MOD

IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
REAL*4, ALLOCATABLE :: RETRO_ALK4(:,:)
REAL*4, ALLOCATABLE :: RETRO_ACET(:,:)
REAL*4, ALLOCATABLE :: RETRO_MEK(:,:)
REAL*4, ALLOCATABLE :: RETRO_ALD2(:,:)
REAL*4, ALLOCATABLE :: RETRO_PRPE(:,:)
REAL*4, ALLOCATABLE :: RETRO_C3H8(:,:)
REAL*4, ALLOCATABLE :: RETRO_C2H6(:,:)
REAL*4, ALLOCATABLE :: RETRO_CH2O(:,:)
REAL*4, ALLOCATABLE :: RETRO_BENZ(:,:)
REAL*4, ALLOCATABLE :: RETRO_TOLU(:,:)
REAL*4, ALLOCATABLE :: RETRO_XYLE(:,:)
REAL*4, ALLOCATABLE :: RETRO_C2H4(:,:)
REAL*4, ALLOCATABLE :: RETRO_C2H2(:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_RETRO
PUBLIC  :: EMISS_RETRO
PUBLIC  :: GET_RETRO_ANTHRO
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: INIT_RETRO
PRIVATE :: READ_RETRO
PRIVATE :: TOTAL_ANTHRO_Tg
```

REVISION HISTORY:

```
08 Mar 2011 - W. Reinhart - Initial version
18 Aug 2011 - D. Millet   - Partition ketones into 25% MEK and 75% ACET
18 Aug 2011 - D. Millet   - Remove call to GET_ANNUAL_SCALAR
22 Aug 2011 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
22 Mar 2012 - M. Payer    - RETRO C2H6 emissions are too low. Use
                            Yaping Xiao's C2H6 emissions instead.
```

1.82.1 read_retro

Subroutine READ_RETRO reads a BPCH file created from RETRO data. The data has units of [atoms C/cm2/s].

INTERFACE:

```
 SUBROUTINE READ_RETRO( FILENAME, ALK4, ACET, MEK,  ALD2, PRPE,
&                       C3H8,     C2H6, CH2O, BENZ, TOLU, XYLE,
&                       C2H4,     C2H2                          )
```

USES:

```
USE BPCH2_MOD,         ONLY : OPEN_BPCH2_FOR_READ
USE FILE_MOD,          ONLY : IU_FILE, IOERROR
USE TRANSFER_MOD,      ONLY : TRANSFER_2D
USE SCALE_ANTHRO_MOD, ONLY : GET_ANNUAL_SCALAR
USE TIME_MOD,          ONLY : GET_YEAR
USE CMN_SIZE_MOD            ! Size parameters
USE CMN_O3_MOD              ! FSCLYR
```

INPUT PARAMETERS:

```
! Name of file to read
CHARACTER(LEN=*), INTENT(IN)    :: FILENAME
```

INPUT/OUTPUT PARAMETERS:

```
! RETRO emissions for various VOC species [molec/cm2/s]
REAL*4,           INTENT(INOUT) :: ALK4(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: ACET(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: MEK (IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: ALD2(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: PRPE(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: C3H8(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: CH2O(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: C2H6(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: BENZ(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: TOLU(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: XYLE(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: C2H4(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: C2H2(IIPAR,JJPAR)
```

REVISION HISTORY:

```
08 Mar 2011 - W. Reinhart - Initial Version
18 Aug 2011 - D. Millet   - Remove call to GET_ANNUAL_SCALAR
22 Aug 2011 - R. Yantosca - Added ProTeX headers
```

1.82.2 TOTAL_ANTHRO_Tg

Subroutine TOTAL_ANTHRO_Tg to print total RETRO anthropogenic VOC emissions each month in [Tg C].

INTERFACE:

```
SUBROUTINE TOTAL_ANTHRO_Tg( THISMONTH )
```

USES:

```
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TRACER_MOD,   ONLY : TRACER_MW_KG
USE TRACERID_MOD, ONLY : IDTALK4, IDTMEK,  IDTPRPE, IDTC3H8
USE TRACERID_MOD, ONLY : IDTCH2O, IDTC2H6, IDTBENZ, IDTTOLU
USE TRACERID_MOD, ONLY : IDTXYLE, IDTC2H4, IDTC2H2
USE TRACERID_MOD, ONLY : IDTACET, IDTALD2
USE CMN_SIZE_MOD       ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH   ! Current month
```

REVISION HISTORY:

```
08 Mar 2011 - W. Reinhart - Initial Version
22 Aug 2011 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
22 Mar 2012 - M. Payer    - Remove print for C2H6 emissions
```

1.82.3 get_retro_anthro

Function GET_RETRO_ANTHRO returns the monthly average anthropogenic VOC emissions at GEOS-Chem grid box (I,J). Data will be returned in units of [atoms C/cm2/s].

INTERFACE:

```
FUNCTION GET_RETRO_ANTHRO( I, J, N ) RESULT( RETRO )
```

USES:

```
USE TRACERID_MOD, ONLY : IDTALK4, IDTMEK,  IDTPRPE, IDTC3H8
USE TRACERID_MOD, ONLY : IDTCH2O, IDTC2H6, IDTBENZ, IDTTOLU
USE TRACERID_MOD, ONLY : IDTXYLE, IDTC2H4, IDTC2H2
USE TRACERID_MOD, ONLY : IDTACET, IDTALD2
USE CMN_SIZE_MOD       ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I   ! GEOS-Chem longitude index
INTEGER, INTENT(IN) :: J   ! GEOS-Chem latitude index
INTEGER, INTENT(IN) :: N   ! GEOS-Chem tracer index
```

RETURN VALUE:

```
REAL*8              :: RETRO   ! RETRO emissions [mole
```

REVISION HISTORY:

```
08 Mar 2011 - W. Reinhart - Initial Version
18 Aug 2011 - D. Millet   - Partition RETRO ketones into 75% acetone
                            and 25% MEK
22 Mar 2012 - M. Payer    - RETRO C2H6 emissions are too low. Use
                            Yaping Xiao's C2H6 emissions instead.
```

1.82.4 init_retro

Subroutine INIT_RETRO allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_RETRO
```

USES:

```
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE LOGICAL_MOD, ONLY : LRETRO
USE CMN_SIZE_MOD      ! Size parameters
```

REVISION HISTORY:

```
08 Mar 2011 - W. Reinhart - Initial Version
22 Aug 2011 - R. Yantosca - Added ProTeX headers
```

1.82.5 cleanup_retro

Subroutine CLEANUP_RETRO deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_RETRO
```

REVISION HISTORY:

```
08 Mar 2011 - W. Reinhart - Initial Version
22 Aug 2011 - R. Yantosca - Added ProTeX headers
```

1.83 Fortran: Module Interface RnPbBe_mod

Module RnPbBe_MOD contains variables and routines used for the 222Rn-210Pb-7Be simulation. (hyl, swu, bmy, 6/14/01, 8/4/06)

INTERFACE:

```
MODULE RnPbBe_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: EMISSRnPbBe
      PUBLIC  :: CHEMRnPbBe
      PUBLIC  :: SLQ
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: READ_7Be
      PRIVATE :: CORRECT_STE
```

REMARKS:

```
References:
============================================================================
(1 ) Liu,H., D.Jacob, I.Bey, and R.M.Yantosca, Constraints from 210Pb
      and 7Be on wet deposition and transport in a global three-dimensional
      chemical tracer model driven by assimilated meteorological fields,
      JGR, 106, D11, 12,109-12,128, 2001.
(2 ) Jacob et al.,Evaluation and intercomparison of global atmospheric
      transport models using Rn-222 and other short-lived tracers,
      JGR, 1997 (102):5953-5970
(3 ) Dorothy Koch, JGR 101, D13, 18651, 1996.
(4 ) Lal, D., and B. Peters, Cosmic ray produced radioactivity on the
      Earth. Handbuch der Physik, 46/2, 551-612, edited by K. Sitte,
      Springer-Verlag, New York, 1967.
```

REVISION HISTORY:

```
14 Jun 2001 - H. Liu      - Initial version
(1 ) Added existing routines to this module (bmy, 6/14/01)
(2 ) Updated comments (bmy, 9/4/01)
(3 ) Eliminate AVGF; redimensioned XTRA2 (bmy, 9/25/01)
(4 ) Replace references to PW(I,J) with P(I,J) (bmy, 10/3/01)
(5 ) Remove obsolete code from 9/01 and 10/01 (bmy, 10/23/01)
(6 ) Removed duplicate variable declarations (bmy, 11/15/01)
(7 ) Now read files from DATA_DIR/RnPbBe_200203/ directory.
      Also updated comments. (bmy, 3/29/02)
(8 ) Incorporated latest changes from Hongyu Liu.  Also split off the
      code to read in the 7Be emissions into a separate routine.
      Add parallel DO-loops in several places.  Cleaned up DRYFLXRnPbBe,
      and now make sure ND44 accurately represents the drydep fluxes
      of 210Pb and 7Be. (hyl, bmy, 8/7/02)
(9 ) Now reference AD from "dao_mod.f".  Now references "error_mod.f".
      Moved routine DRYFLXRnPbBe into "drydep_mod.f".  (bmy, 1/27/03)
(10) Now references the new "time_mod.f" (bmy, 2/11/03)
(11) Bug fix in EMISSRnPbBe -- take abs( lat) for 7Be emiss. (bmy, 6/10/03)
(12) Bug fix in EMISSRnPbBe -- shut off 222Rn emissions in polar regions
      (swu, bmy, 10/28/03)
(13) Now references "directory_mod.f", "logical_mod.f", and "tracer_mod.f"
      (bmy, 7/20/04)
(14) Now modified for GCAP and GEOS-5 met fields (swu, bmy, 5/24/05)
(15) Now references "tropopause_mod.f"
(16) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
19 Nov 2010 - R. Yantosca - Added ProTeX headers
08 Nov 2011 - R. Yantosca - Prevent out-of-bounds errors in diagnostics
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use routines from the new grid_mod.F90
```

1.83.1 read_7Be

Subroutine READ_7Be reads the 7Be emissions from Lal & Peters on 33 pressure levels. This only needs to be done on the very first timestep.

INTERFACE:

```
SUBROUTINE READ_7BE
```

USES:

```
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IU_FILE, IOERROR

USE CMN_SIZE_MOD      ! Size parameters
```

REVISION HISTORY:

```
07 Aug 2002 - H. Liu - Initial version
(1 ) This code was split off from routine EMISSRnPbBe below. (bmy, 8/7/02)
(2 ) Now reference DATA_DIR from "directory_mod.f" (bmy, 7/19/04)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.83.2 correct_ste

Subroutine CORRECT_STE reduces the emission of 210Pb and/or 7Be in the stratosphere, to correct for too fast STE in the GEOS-CHEM model.

INTERFACE:

```
SUBROUTINE CORRECT_STE( EMISSION )
```

USES:

```
#     include "define.h"    ! Switches
```

INPUT PARAMETERS:

```
! Arguments
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8, INTENT(INOUT) :: EMISSION   ! Emissions to be corrected [kg]
```

REVISION HISTORY:

```
07 Aug 2002 - H. Liu - Initial version
(1 ) Now updated for GCAP met fields (swu, bmy, 5/24/05)
(2 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.83.3 emissRnPbBe

Subroutine EMISSRnPbBe emits 222Rn and 7Be into the tracer array STT.

INTERFACE:

```
SUBROUTINE EMISSRnPbBe
```

USES:

```
USE DAO_MOD,        ONLY : AD, TS
USE DIAG_MOD,       ONLY : AD01
USE GRID_MOD,       ONLY : GET_AREA_CM2
USE GRID_MOD,       ONLY : GET_YMID
USE GRID_MOD,       ONLY : GET_YEDGE
```

```
      USE LOGICAL_MOD,    ONLY : LEMIS
      USE TIME_MOD,       ONLY : GET_TS_EMIS
      USE TRACER_MOD,     ONLY : STT, N_TRACERS
      USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_STRAT
      USE PRESSURE_MOD,   ONLY : GET_PCENTER

      USE CMN_SIZE_MOD       ! Size parameters
      USE CMN_DIAG_MOD       ! ND02
      USE CMN_DEP_MOD        ! FRCLND
```

REVISION HISTORY:

```
28 May 1999 - I. Bey - Initial version
(1 ) Also added Hongyu's code for emission of Be7 (bmy, 3/22/99)
(2 ) Now trap I/O errors with subroutine IOERROR (bmy, 5/28/99)
(3 ) Eliminate obsolete code and ND63 diagnostic (bmy, 4/12/00)
(4 ) Now reference TS from "dao_mod.f" instead of from common block
     header file "CMN_TS". (bmy, 6/23/00)
(5 ) Cosmetic changes (bmy, 7/12/00)
(6 ) Now use IOS /= 0 criterion to trap both I/O errors and EOF
     condition. (bmy, 9/13/00)
(7 ) Added to module "RnPbBe_mod.f".  Also updated comments and made
     cosmetic changes. (bmy, 6/14/01)
(8 ) Replace PW(I,J) with P(I,J) (bmy, 10/3/01)
(9 ) Now reference DATA_DIR from "CMN_SETUP".  Added FILENAME variable.
     Now read "7Be.Lal" file from DATA_DIR/RnPbBe_200203/ directory.
     (bmy, 3/29/02)
(10) Add diagnostics for Rn/Be emissions.  Also cleaned up some old code
     and added parallel DO-loops.  Correct for S-T exchange for 7Be
     emissions. Updated comments, cosmetic changes. (hyl, 8/6/02)
(11) Now reference routine GET_PCENTER from "pressure_mod.f", which
     returns the correct "floating" pressure. (dsa, bdf, bmy, 8/20/02)
(12) Now reference AD from "dao_mod.f".  Now make FIRSTEMISS a local SAVEd
     variable instead of an argument.  (bmy, 1/27/03)
(13) Now use routine GET_YMID from "grid_mod.f" instead of common block
     variable YLMID.  Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2
     of "grid_mod.f".  Now use routine GET_TS_EMIS from time_mod.
     (bmy, 2/11/03)
(14) Bug fix: take the absolute value of latitude -- this was a bug when
     implementing the GET_YMID function from v5-04. (bmy, 6/10/03)
(15) Now reference GET_YEDGE from "grid_mod.f".
(16) Bug fix: the Rn emission in antarctic area in the original code would
     lead to enormously hight Rn concentrations there, esp. after boundary
     layer mixing.  Now apply different emissions over land and water,
     and also shut off emissions poleward of 70 deg. (swu, bmy, 10/28/03)
(17) Now reference LEMIS from "logical_mod.f".  Now reference STT and
     N_TRACERS from "tracer_mod.f" (bmy, 7/20/04)
(18) Remove reference to CMN; it's obsolete.  Now use inquiry functions
```

```
      from "tropopause_mod.f" to diagnose strat boxes. (bmy, 8/15/05)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
08 Nov 2011 - R. Yantosca - Prevent out-of-bounds errors in diagnostics
01 Mar 2012 - R. Yantosca - Now use functions GET_AREA_CM2(I,J,L) and
                            GET_YEDGE(I,J,L) from the new grid_mod.F90
```

1.83.4 chemRnPbBe

Subroutine CHEMRnPbBe performs loss chemistry on 222Rn, 210Pb, and 7Be.

INTERFACE:

```
SUBROUTINE CHEMRnPbBe
```

USES:

```
USE DIAG_MOD,       ONLY : AD01, AD02
USE TIME_MOD,       ONLY : GET_TS_CHEM
USE TRACER_MOD,     ONLY : STT, N_TRACERS
USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_STRAT

USE CMN_SIZE_MOD       ! Size parameters
USE CMN_DIAG_MOD       ! ND01, ND02
```

REVISION HISTORY:

```
31 Oct 1999 - H. Liu - Initial version
(1 ) Now use F90 syntax (bmy, hyl, 3/22/99)
(2 ) Add FIRSTCHEM as an argument.  Only compute the exponential terms
     when FIRSTCHEM = .TRUE., and save the values for later use
     (bmy, 3/24/99)
(3 ) Cosmetic changes (bmy, 10/13/99)
(4 ) Eliminate obsolete code and ND63 diagnostic (bmy, 4/12/00)
(5 ) Cosmetic changes (bmy, 7/12/00)
(6 ) Added to module "RnPbBe_mod.f".  Also updated comments
     and made cosmetic changes. (bmy, 6/14/01)
(7 ) Add diagnostics for Rn/Be emissions.  Also cleaned up some old code
     and added parallel DO-loops.  Updated comments. (hyl, 8/6/02)
(8 ) Now make FIRSTCHEM a local SAVEd variable.  (bmy, 1/27/03)
(9 ) Now use function GET_TS_CHEM from "time_mod.f" (bmy, 2/11/03)
(10) Now references STT and N_TRACERS from "tracer_mod.f" (bmy, 7/20/04)
(11) Remove reference to CMN; it's obsolete.  Now use inquiry functions
     from "tropopause_mod.f" to diagnose strat boxes. (bmy, 8/15/05)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
08 Nov 2011 - R. Yantosca - Prevent out-of-bounds errors in diagnostics
```

1.83.5 slq

Subroutine SLQ is an interpolation subroutine from a Chinese reference book (says Hongyu Liu).

INTERFACE:

```
SUBROUTINE SLQ( X, Y, Z, N, M, U, V, W )
```

INPUT PARAMETERS:

```
INTEGER :: N        ! First dimension of Z
INTEGER :: M        ! Second dimension of Z
REAL*8  :: X(N)     ! X-axis coordinate on original grid
REAL*8  :: Y(M)     ! Y-axis coordinate on original grid
REAL*8  :: Z(N,M)   ! Array of data on original grid
REAL*8  :: U        ! X-axis coordinate for desired interpolated value
REAL*8  :: V        ! Y-axis coordinate for desired interpolated value
```

OUTPUT PARAMETERS:

```
REAL*8  :: W        ! Interpolated value of Z array, at coords (U,V)
```

REMARKS:

REVISION HISTORY:

```
17 Mar 1998 - H. Liu      - Initial version
(1 ) Added to "RnPbBe_mod.f" (bmy, 7/16/01)
(2 ) Removed duplicate definition of IQ.  Added comments. (bmy, 11/15/01)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.84 Fortran: Module Interface scale_anthro_mod

Module SCALE_ANTHRO_MOD contains routines to scale anthropogenic emissions from a base year to a simulation year.

INTERFACE:

```
MODULE SCALE_ANTHRO_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: GET_ANNUAL_SCALAR
      PUBLIC  :: GET_ANNUAL_SCALAR_1x1
      PUBLIC  :: GET_ANNUAL_SCALAR_05x0666_NESTED
```

REVISION HISTORY:

```
   28 Jan 2009 - A. v. Donkelaar and P. Le Sager - Initial Version
```

REMARKS:

```
   (1 ) Add GET_ANNUAL_SCALAR_05x0666_NESTED_CH for nested grid simulations
        over China. (tmf, 12/3/09)
   (2 ) Renamed consistently variables: name depends on relation of variable
        to BASE or TARGET year. New data directory to account for updated
        scale factors for 1985-1989 (phs, 5/7/09)
   (3 ) Adjusted GET_ANNUAL_SCALAR_05x0666_CH for new scalar format and
        renamed to GET_ANNUAL_SCALAR_05x0666 (amv, 10/29/2009)
   18 Dec 2009 - Aaron van D - Updated scale factors thru 2006
   18 Dec 2009 - Aaron van D - Updated routine GET_ANNUAL_SCALAR_05x0666_NESTED
   10 Aug 2011 - D. Millet   - Now use updated scale factor file for CO, which
                               corrects a problem over Botswana/S. Africa
```

1.84.1 get_annual_scalar

Subroutine GET_ANNUAL_SCALAR returns annual scale factors to convert B_YEAR (base year) to T_YEAR (simulation year), on the current model resolution.

INTERFACE:

```
      SUBROUTINE GET_ANNUAL_SCALAR( TRACER, B_YEAR, T_YEAR, AS )
```

USES:

```
      USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
      USE FILE_MOD,       ONLY : IOERROR, IU_FILE
      USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1

      USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)     :: TRACER           ! Tracer number
      INTEGER, INTENT(IN)     :: B_YEAR           ! Base year of emissions
      INTEGER, INTENT(IN)     :: T_YEAR           ! Target year of emissions
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*4,  INTENT(INOUT)  :: AS(IIPAR,JJPAR)  ! Scale factor array
```

REVISION HISTORY:

```
   28 Jan 2009 - A. v. Donkelaar and P. Le Sager - Initial Version
   13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
   07 Jun 2012 - M. Payer    - Fixed minor bugs in map_a2a calls (M. Cooper)
```

1.84.2 get_annual_scalar_1x1

Subroutine GET_ANNUAL_SCALAR_1x1 returns annual scale factors to convert B_YEAR (base year) to T_YEAR (target year), on the 1x1 GEOS-Chem grid.

INTERFACE:

```
SUBROUTINE GET_ANNUAL_SCALAR_1x1( TRACER, B_YEAR, T_YEAR, AS_1x1 )
```

USES:

```
USE DIRECTORY_MOD, ONLY : DATA_DIR_1x1
USE BPCH2_MOD,     ONLY : GET_TAU0, READ_BPCH2

USE CMN_SIZE_MOD                          ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: TRACER            ! Tracer number
INTEGER, INTENT(IN)    :: B_YEAR            ! Base year of emissions
INTEGER, INTENT(IN)    :: T_YEAR            ! Target year of emissions
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,   INTENT(OUT)  :: AS_1x1(I1x1,J1x1)  ! Scale factor array
```

REVISION HISTORY:

```
28 Jan 2009 - A. v. Donkelaar and P. Le Sager - Initial Version
```

REMARKS:

```
(1) Scaling factors are for years between 1985 and 2005, on the GEOS-Chem
     1x1 grid (phs, 3/10/08)
18 Dec 2009 - Aaron van D - Updated scale factors through 2006,
                            changed to new, directory, reset year limits
18 Dec 2009 - Aaron van D - Reformated scale factors to a single file for
                            all years, made necessary input changes
10 Aug 2011 - D. Millet   - Now use updated scale factor file for CO, which
                            corrects a problem over Botswana/S. Africa
25 Apr 2012 - M. Payer    - Add kludge to set TARG_YEAR=1985 for 1986 thru
                            1989 (B. Yantosca)
```

1.84.3 get_annual_scalar_05x0666_nested

Subroutine GET_ANNUAL_SCALAR_05x0666_NESTED returns annual scale factors to convert B_YEAR (base year) to T_YEAR (target year), on the 0.5x0.666 GEOS-Chem grid for nested China domain.

INTERFACE:

```
      SUBROUTINE GET_ANNUAL_SCALAR_05x0666_NESTED
     &                     ( TRACER, B_YEAR, T_YEAR, AS )
```

USES:

```
      USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
      USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

      USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)     :: TRACER
      INTEGER, INTENT(IN)     :: B_YEAR
      INTEGER, INTENT(IN)     :: T_YEAR
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*4,   INTENT(INOUT) :: AS(IIPAR,JJPAR)
```

REVISION HISTORY:

```
    28 Jan 2009 - A. v. Donkelaar and P. Le Sager - Initial Version
    12 Mar 2009 - T-M. Fu     - Initial Version
    03 Nov 2009 - Aaron van D - rewritten to employ GET_ANNUAL_SCALAR_1x1
                                and regrid.
    18 Dec 2009 - Aaron van D - Renamed to GET_ANNUAL_SCALAR_05x0666_NESTED
    18 Dec 2009 - Aaron van D - Rewrote GET_ANNUAL_SCALAR_05x0666_NESTED to
                                retrieve and regrid scale factors by calling
                                GET_ANNUAL_SCALAR_1x1 and regridding on fly
    06 Apr 2012 - M. Payer    - Changed regrid algorithm to map_a2a (M. Cooper)
    07 Jun 2012 - M. Payer    - Fixed minor bugs in map_a2a calls (M. Cooper)
```

REMARKS:

```
    (1) Scaling factors are for years between 1985 and 2005, on the GEOS-Chem
        0.5x0.666 grid for China domain (tmf, 3/5/09)
```

1.85 Fortran: Module Interface seasalt_mod

Module SEASALT_MOD contains arrays and routines for performing either a coupled chemistry/aerosol run or an offline seasalt aerosol simulation. Original code taken from Mian Chin's GOCART model and modified accordingly. (bec, rjp, bmy, 6/22/00, 11/23/09)

INTERFACE:

```
      MODULE SEASALT_MOD
```

USES:

```
      USE LOGICAL_MOD,     ONLY : LNLPBL ! (Lin, 03/31/09)

      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CHEMSEASALT
      PUBLIC :: EMISSSEASALT
      PUBLIC :: CLEANUP_SEASALT
      PUBLIC :: GET_ALK
```

PUBLIC DATA MEMBERS:

```
      PUBLIC :: SALT_V
      PUBLIC :: DMID
```

REMARKS:

```
   Seasalt aerosol species: (1) Accumulation mode (usually 0.1 -  0.5 um)
                            (2) Coarse mode       (usually 0.5 - 10.0 um)
                                                                          .
   NOTE: You can change the bin sizes for accumulation mode and coarse
         mode seasalt in the "input.geos" file in v7-yy-zz and higher.
   References:
   ============================================================================
   (1 ) Chin, M., P. Ginoux, S. Kinne, B. Holben, B. Duncan, R. Martin,
         J. Logan, A. Higurashi, and T. Nakajima, "Tropospheric aerosol
         optical thickness from the GOCART model and comparisons with
         satellite and sunphotometers measurements", J. Atmos Sci., 2001.
   (2 ) Gong, S., L. Barrie, and J.-P. Blanchet, "Modeling sea-salt
         aerosols in the atmosphere. 1. Model development", J. Geophys. Res.,
         v. 102, 3805-3818, 1997.
```

REVISION HISTORY:

```
   (1 ) Now references "logical_mod.f" and "tracer_mod.f".  Comment out
         SS_SIZE, this has been replaced by SALA_REDGE_um and SALC_REDGE_um
         from "tracer_mod.f".  Increased NR_MAX to 200. (bmy, 7/20/04)
   (2 ) Added error check in EMISSSEASALT (bmy, 1/20/05)
   (3 ) Now references "pbl_mix_mod.f" (bmy, 2/22/05)
   (4 ) Added routine GET_ALK to account for alkalinity. (bec, bmy, 4/13/05)
   (5 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
   (6 ) Now only call dry deposition routine if LDRYD=T (bec, bmy, 5/23/06)
   (7 ) Remove unused variables from GET_ALK.  Also fixed variable declaration
         bug in WET_SETTLING. (bec, bmy, 9/5/06)
   (8 ) Extra error check for low RH in WET_SETTLING (phs, 6/11/08)
   (9 ) Bug fix to remove a double-substitution in GET_ALK (bec, bmy, 7/18/08)
   (10) Save surface emissions separately (emis_save) for non-local scheme.
         (ccc, 5/14/09)
```

```
(11) Bug fixes in GET_ALK and SRCSALT (bec, lyj, bmy, 11/23/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
```

1.85.1 chemseasalt

Subroutine CHEMSEASALT is the interface between the GEOS-CHEM main program and the seasalt chemistry routines that mostly calculates seasalt dry deposition (rjp, bmy, 1/24/02, 5/23/06)

INTERFACE:

```
SUBROUTINE CHEMSEASALT
```

USES:

```
USE DRYDEP_MOD,   ONLY : DEPNAME, NUMDEP
USE ERROR_MOD,    ONLY : DEBUG_MSG
USE LOGICAL_MOD,  ONLY : LPRT,    LDRYD
USE TRACER_MOD,   ONLY : STT
USE TRACERID_MOD, ONLY : IDTSALA, IDTSALC

USE CMN_SIZE_MOD       ! Size parameters
```

REVISION HISTORY:

```
(1 ) Now reference STT from "tracer_mod.f".  Now references LPRT from
     "logical_mod.f" (bmy, 7/20/04)
(2 ) Now only call DRY_DEPOSITION if LDRYD=T (bec, bmy, 5/23/06)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.85.2 wet_settling

Subroutine WET_SETTLING performs wet settling of sea salt. (bec, rjp, bmy, 4/20/04, 6/11/08)

INTERFACE:

```
SUBROUTINE WET_SETTLING( TC, N )
```

USES:

```
USE DAO_MOD,       ONLY : T, BXHEIGHT, RH
USE DIAG_MOD,      ONLY : AD44
USE DRYDEP_MOD,    ONLY : DEPSAV
USE PRESSURE_MOD,  ONLY : GET_PCENTER
USE TRACER_MOD,    ONLY : SALA_REDGE_um, SALC_REDGE_um, XNUMOL
```

```
      USE TRACERID_MOD,  ONLY : IDTSALA,       IDTSALC
      USE TIME_MOD,      ONLY : GET_TS_CHEM
      USE GRID_MOD,      ONLY : GET_AREA_CM2
      ! add (jaegle 5/11/11)
      USE ERROR_MOD,     ONLY : DEBUG_MSG, ERROR_STOP

      USE CMN_SIZE_MOD        ! Size parameters
      USE CMN_DIAG_MOD        ! ND44
      USE CMN_GCTM_MOD        ! g0
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: N  ! N=1 is accum mode; N=2 is coarse mode
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! Sea salt tracer [kg]
```

REVISION HISTORY:

```
(1 ) Now references SALA_REDGE_um and SALC_REDGE_um from "tracer_mod.f"
     (bmy, 7/20/04)
(2 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(3 ) Bug fix: DTCHEM has to be REAL*8, not integer. (bmy, 9/7/06)
(4 ) Now limit relative humidity to [tiny(real*8),0.99] range for DLOG
      argument (phs, 5/1/08)
(5 ) Update sea salt density calculation using Tang et al. (1997) (bec,
     jaegle 5/11/11)
(6 ) Update hygroscopic growth for sea salt using Lewis and Schwartz (2006)
     and and density calculation based on Tang et al. (1997) (bec, jaegle
     5/11/11)
(7 ) Itegrate settling velocity over entire size distribution (jaegle
     5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.85.3 dry_deposition

Subroutine DRY_DEPOSITION computes the loss of sea salt by dry deposition at the surface, using an implicit method (bec, rjp, bmy, 4/20/04)

INTERFACE:

```
      SUBROUTINE DRY_DEPOSITION( TC, N )
```

USES:

```
      USE DIAG_MOD,     ONLY : AD44
      USE DRYDEP_MOD,   ONLY : DEPSAV
      USE TRACER_MOD,   ONLY : XNUMOL
```

```
      USE TRACERID_MOD, ONLY : IDTSALA,   IDTSALC
      USE TIME_MOD,     ONLY : GET_MONTH, GET_TS_CHEM
      USE GRID_MOD,     ONLY : GET_AREA_CM2
      ! Add PBL variables (jaegle  5/5/11)
      USE PBL_MIX_MOD, ONLY : GET_FRAC_UNDER_PBLTOP, GET_PBL_MAX_L

      USE CMN_SIZE_MOD       ! Size parameters
      USE CMN_DIAG_MOD       ! ND44
      USE CMN_GCTM_MOD       ! g0
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: N   ! N=1 is accum mode; N=2 is coarse mode
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! Sea salt tracer [kg]
```

REVISION HISTORY:

```
   (1 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
   (2 ) Update to calculate the drydep throughout the entire PBL instead of
        just at the surface. This is more in line with what is done in
        dry_dep.f. This is only used if LNLPBL is turned off (or for GEOS-4 and
        prior met fields). (jaegle 5/11/11)
   22 Dec 2011 - M. Payer    - Added ProTeX headers
   01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.85.4 emissseasalt

Subroutine EMISSSEASALT is the interface between the GEOS-Chem model and the SEASALT emissions routines in "seasalt_mod.f". (bec, rjp, bmy, 3/24/03, 2/22/05)

INTERFACE:

```
 #if defined( DEVEL )
      SUBROUTINE EMISSSEASALT( SFLX, SSA_Br2 )
 #else
      SUBROUTINE EMISSSEASALT( SSA_Br2 )
 #endif
```

USES:

```
      USE ERROR_MOD,    ONLY : DEBUG_MSG
      USE LOGICAL_MOD,  ONLY : LPRT
      USE TRACER_MOD,   ONLY : STT
      USE TRACERID_MOD, ONLY : IDTSALA, IDTSALC
      USE VDIFF_PRE_MOD,ONLY : emis_save ! (Lin, 03/31/09)
 #if defined( DEVEL )
      USE TRACER_MOD,   ONLY : N_TRACERS
```

```
#endif

      USE CMN_SIZE_MOD       ! Size parameters
```

OUTPUT PARAMETERS:

```
      REAL*8, INTENT(OUT), OPTIONAL :: SSA_Br2(IIPAR, JJPAR)
  !INPUT/OUTPUT PARAMETERS
#if defined( DEVEL )
      REAL*8, INTENT(INOUT) :: SFLX(IIPAR,JJPAR,LLPAR,N_TRACERS+1)
#endif
```

REVISION HISTORY:

```
   (1 ) Now references LPRT from "logical_mod.f" and STT from "tracer_mod.f".
        (bmy, 7/20/04)
   (2 ) Now make sure IDTSALA, IDTSALC are nonzero before calling SRCSALT.
        (bmy, 1/26/05)
   (3 ) Remove reference to header file "CMN" (bmy, 2/22/05)
   (4 ) Now call INIT_SEASALT on the first timestep.  Also initialize ALK_EMIS
        and N_DENS on each timestep. (bec, bmy, 4/13/05)
   22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.85.5 srcsalt

Subroutine SRCSALT is based on the sea salt source function of Gong (2003) with the empirical sea surface temperature (SST) dependence of Jaegle et al. (2011). This SST dependence was derived based on comparisons to cruise observations of coarse mode sea salt mass concentrations.
Contact: Lyatt Jaegle (jaegle@uw.edu)

INTERFACE:

```
      SUBROUTINE SRCSALT( TC, SSA_Br2, N )
```

USES:

```
      USE DAO_MOD,       ONLY : PBL, AD, IS_WATER, AIRVOL
      ! Add TSKIN (jaegle 5/11/11)
      USE DAO_MOD,       ONLY : TSKIN ! jaegle
      USE DIAG_MOD,      ONLY : AD08
      USE ERROR_MOD,     ONLY : DEBUG_MSG, ERROR_STOP
      USE GRID_MOD,      ONLY : GET_AREA_M2
      USE PBL_MIX_MOD,   ONLY : GET_FRAC_OF_PBL, GET_PBL_TOP_L
      USE TIME_MOD,      ONLY : GET_TS_EMIS
      USE TRACER_MOD,    ONLY : SALA_REDGE_um, SALC_REDGE_um, XNUMOL
      USE SSA_BROMINE_MOD, ONLY : EMISS_SSA_BROMINE

      USE CMN_SIZE_MOD        ! Size parameters
      USE CMN_DIAG_MOD        ! ND44, ND08
      USE CMN_GCTM_MOD        ! PI
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: N  ! N=1 is accum mode; N=2 is coarse mode
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,  INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! Sea salt tracer [v/v]
```

OUTPUT PARAMETERS:

```
!jpp, 3/2/10
REAL*8,  INTENT(OUT)   :: SSA_Br2(IIPAR,JJPAR)  ! Br2 sea salt emissions
```

REMARKS:

References:

(1) Chin, M., P. Ginoux, S. Kinne, B. Holben, B. Duncan, R. Martin, J. Logan, A. Higurashi, and T. Nakajima, "Tropospheric aerosol optical thickness from the GOCART model and comparisons with satellite and sunphotometers measurements", J. Atmos Sci., 2001.

(2) Gong, S., L. Barrie, and J.-P. Blanchet, "Modeling sea-salt aerosols in the atmosphere. 1. Model development", J. Geophys. Res., v. 102, 3805-3818, 1997.

(3) Gong, S. L., "A parameterization of sea-salt aerosol source function for sub- and super-micron particles", Global Biogeochem. Cy., 17(4), 1097, doi:10.1029/2003GB002079, 2003.

(4) Jaegle, L., P.K. Quinn, T.S. Bates, B. Alexander, J.-T. Lin, "Global distribution of sea salt aerosols: New constraints from in situ and remote sensing observations", Atmos. Chem. Phys., 11, 3137-3157, doi:10.5194/acp-11-3137-2011.

REVISION HISTORY:

(1) Now references SALA_REDGE_um and SALC_REDGE_um from "tracer_mod.f" (bmy, 7/20/04)

(2) Now references GET_FRAC_OF_PBL and GET_PBL_TOP_L from "pbl_mix_mod.f". Removed reference to header file CMN. Removed reference to "pressure_mod.f". (bmy, 2/22/05)

(3) Now also compute alkalinity and number density of seasalt emissions. (bec, bmy, 4/13/05)

(4) Now references XNUMOL & XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)

(5) The source function is for wet aerosol radius (RH=80%, with a radius twice the size of dry aerosols) so BETHA should be set to 2 instead of 1. Also now use LOG10 instead of LOG in the expressions for the seasalt base source, since we need the logarithm to the base 10. (jaegle, bec, bmy, 11/23/09)

(6) Update to use the Gong (2003) source function (jaegle 5/11/11)

(7) Apply an empirical sea surface temperature dependence to Gong (2003) (jaegle 5/11/11)

22 Dec 2011 - M. Payer - Added ProTeX headers

01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90

1.85.6 get_alk

Subroutine GET_ALK returns the seasalt alkalinity emitted at each timestep to sulfate_mod.f for chemistry on seasalt aerosols. (bec, 12/7/04, 11/23/09)

INTERFACE:

```
SUBROUTINE GET_ALK( I, J, L, ALK1, ALK2, Kt1, Kt2, Kt1N, Kt2N )
```

USES:

```
USE DAO_MOD,      ONLY : AD, RH
USE ERROR_MOD,    ONLY : IT_IS_NAN
USE TRACER_MOD,   ONLY : SALA_REDGE_um, SALC_REDGE_um
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: I, J, L
```

OUTPUT PARAMETERS:

```
REAL*8, INTENT(OUT)  :: ALK1, ALK2           ! [kg]
REAL*8, INTENT(OUT)  :: Kt1, Kt2, Kt1N, Kt2N ! [s-1]
```

REVISION HISTORY:

```
(1 ) Becky Alexander says we can remove AREA1, AREA2 (bec, bmy, 9/5/06)
(2 ) Bug fix to remove a double-substitution.  Replace code lines for
     TERM{123}A, TERM{123}B, TERM{123}AN, TERM{123}BN. (bec, bmy, 7/18/08)
(3 ) Updated hygroscopic growth parameters (bec, bmy, 11/23/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.85.7 init_seasalt

Subroutine INIT_SEASALT initializes and zeroes all module arrays (bmy, 4/26/04, 4/13/05)

INTERFACE:

```
SUBROUTINE INIT_SEASALT
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
(1 ) Now exit if we have allocated arrays before.  Now also allocate
     ALK_EMIS & N_DENS.  Now reference CMN_SIZE. (bec, bmy, 4/13/05)
(2 ) Added SALT_V and DMID (jaegle 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.85.8 cleanup_seasalt

Subroutine CLEANUP_SEASALT deallocates all module arrays (bmy, 4/26/04, 4/13/05)

INTERFACE:

```
SUBROUTINE CLEANUP_SEASALT
```

REVISION HISTORY:

```
(1 ) Now deallocates ALK_EMIS, N_DENS, SRC_N (bec, bmy, 4/13/05)
(2 ) Deallocated SALT_V and DMID (jaegle 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.86 Fortran: Module Interface ssa_bromine_mod

Module SSA_BROMINE_MOD contains variables and routines for emissions of Br2.

INTERFACE:

```
MODULE SSA_BROMINE_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: EMISS_SSA_BROMINE
PUBLIC :: EMIT_Br2
```

REVISION HISTORY:

```
02 Mar 2010 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
```

1.86.1 emiss_ssa_bromine

Subroutine EMISS_SSA_BROMINE calculates aerosol emissions of Br2.

INTERFACE:

```
SUBROUTINE EMISS_SSA_BROMINE( ilat, rmid, p_kgsalt, br2_emiss_kg )
```

USES:

```
USE TIME_MOD, ONLY : GET_MONTH
USE GRID_MOD, ONLY : GET_YMID
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: ilat         ! Grid latitude index
      REAL*8,  INTENT(IN) :: rmid         ! Dry radius of aerosol
      REAL*8,  INTENT(IN) :: p_kgsalt     ! Seasalt aerosol production [kgNaCl]
```

OUTPUT PARAMETERS:

```
      REAL*8, INTENT(OUT) :: br2_emiss_kg ! Br2 emissions [kg NaCl]
```

REVISION HISTORY:

```
    02 Mar 2010 - J. Parrella - Initial version
    22 May 2012 - M. Payer    - Added ProTeX headers
```

1.86.2 emit_br2

Subroutine EMIT_BR2 takes the mass flux of Br2 [kg] emitted from sea-salt and distributes it through the the boundary layer.

INTERFACE:

```
      SUBROUTINE EMIT_BR2(SSA_Br2)
```

USES:

```
      USE BROMOCARB_MOD,  ONLY : Br_SCALING
      USE GRID_MOD,       ONLY : GET_AREA_M2
      USE LOGICAL_MOD,    ONLY : LSSABr2
      USE TRACERID_MOD,   ONLY : IDEBr2
      USE TIME_MOD,       ONLY : GET_TS_EMIS
      USE DIAG_MOD,       ONLY : AD46

      USE CMN_SIZE_MOD         ! Size parameters
      USE COMODE_LOOP_MOD      ! AVG(avagadro's #)
      USE CMN_DIAG_MOD         ! Diagnostic integers...
      USE CMN_O3_MOD           ! for EMISRR array
```

INPUT PARAMETERS:

```
      REAL*8, INTENT(INOUT)   :: SSA_Br2(IIPAR, JJPAR)
```

REVISION HISTORY:

```
    02 Mar 2010 - J. Parrella - Initial version
    22 May 2012 - M. Payer    - Added ProTeX headers
```

1.87 Fortran: Module Interface strat_chem_mod

Module STRAT_CHEM_MOD contains variables and routines for performing a simple linearized chemistry scheme in the stratosphere, using archived 3D monthly climatological production rates and loss frequencies are applied from the GMI combo model.
In the original schem code (schem.F), only the following species were destroyed by photolysis in the stratosphere: PAN, H2O2, ACET, MEK, ALD2, RCHO, MVK, MACR, R4N2, CH2O, N2O5, HNO4, MP and by reaction with OH: ALK4, ISOP, H2O2, ACET, MEK, ALD2, RCHO, MVK, MACR, PMN, R4N2, PRPE, C3H8, CH2O, C2H6, HNO4, MP
The updated code includes at least all of these, and many more. The code is flexible enough to automatically apply the rate to any new tracers for future simulations that share the name in tracer_mod with the GMI name. (See Documentation on wiki).

INTERFACE:

```
MODULE STRAT_CHEM_MOD
```

USES:

```
  IMPLICIT NONE
  PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
  PUBLIC  :: Init_Strat_Chem
  PUBLIC  :: Do_Strat_Chem
  PUBLIC  :: Cleanup_Strat_Chem
  PUBLIC  :: Calc_STE
```

PRIVATE MEMBER FUNCTIONS:

```
  PRIVATE :: Get_Rates
  PRIVATE :: Get_Rates_Interp
  PRIVATE :: Do_Synoz
```

PUBLIC DATA MEMBERS:

REMARKS:

```
   References:
=============================================================================
   (1 )
```

REVISION HISTORY:

```
   01 Feb 2011 - L. Murray   - Initial version
   20 Jul 2012 - R. Yantosca - Reorganized declarations for clarity
   20 Jul 2012 - R. Yantosca - Correct compilation error in GET_RATES_INTERP
```

1.87.1 do_strat_chem

Function DO_STRAT_CHEM is the driver routine for computing the simple linearized stratospheric chemistry scheme.

INTERFACE:

```
SUBROUTINE DO_STRAT_CHEM
```

USES:

```
    USE DAO_MOD,         ONLY : AD, CONVERT_UNITS, T, SUNCOS
    USE ERROR_MOD,       ONLY : DEBUG_MSG, GEOS_CHEM_STOP
    USE LOGICAL_MOD,     ONLY : LLINOZ, LPRT
    USE LINOZ_MOD,       ONLY : DO_LINOZ
    USE TIME_MOD,        ONLY : GET_MONTH, TIMESTAMP_STRING
    USE TRACER_MOD,      ONLY : ITS_A_FULLCHEM_SIM, ITS_A_TAGOX_SIM
    USE TRACER_MOD,      ONLY : ITS_A_H2HD_SIM
    USE TRACER_MOD,      ONLY : N_TRACERS, STT, TCVV, TRACER_MW_KG, XNUMOLAIR
    USE TRACERID_MOD,    ONLY : IDTOX, IDTCHBr3, IDTCH2Br2, IDTCH3Br
    USE TROPOPAUSE_MOD, ONLY : GET_MIN_TPAUSE_LEVEL, GET_TPAUSE_LEVEL
    USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_TROP

    USE CMN_SIZE_MOD

    IMPLICIT NONE

#include "define.h"
```

REMARKS:

REVISION HISTORY:

```
    01 Feb 2011 - L. Murray   - Initial version
    18 Jul 2012 - R. Yantosca - For compatibility w/ the GEOS-5/GCM, we cannot
                                assume a minimum tropopause level anymore
    18 Jul 2012 - R. Yantosca - Make sure I is the innermost DO loop
                                wherever expedient
    20 Jul 2012 - R. Yantosca - Reorganized declarations for clarity
```

1.87.2 get_rates

Function GET_RATES reads from disk the chemical production and loss rates for the species of interest

INTERFACE:

```
SUBROUTINE GET_RATES( THISMONTH )
```

USES:

```
USE BPCH2_MOD,       ONLY : GET_NAME_EXT, GET_RES_EXT, GET_TAU0, READ_BPCH2
USE DIRECTORY_MOD,   ONLY : DATA_DIR
USE LOGICAL_MOD,     ONLY : LLINOZ
USE TIME_MOD,        ONLY : GET_MONTH
USE TRACER_MOD,      ONLY : N_TRACERS, TRACER_NAME
USE TRANSFER_MOD,    ONLY : TRANSFER_3D

USE m_netcdf_io_open
USE m_netcdf_io_read
USE m_netcdf_io_close

USE CMN_SIZE_MOD

IMPLICIT NONE
```

INPUT PARAMETERS:

```
INTEGER,INTENT(IN) :: THISMONTH
```

REVISION HISTORY:

```
01 Feb 2011 - L. Murray   - Initial version
20 Jul 2012 - R. Yantosca - Reorganized declarations for clarity
```

1.87.3 get_rates_interp

Function GET_RATES_INTERP reads from disk the chemical production and loss rates for the species of interest to resolutions finer than 2 x 2.5 (e.g., nested simluations) via simple nearest-neighbor mapping.

INTERFACE:

```
SUBROUTINE GET_RATES_INTERP( THISMONTH )
```

USES:

```
USE BPCH2_MOD,       ONLY : GET_NAME_EXT
USE BPCH2_MOD,       ONLY : GET_RES_EXT
USE BPCH2_MOD,       ONLY : GET_TAU0
USE BPCH2_MOD,       ONLY : READ_BPCH2
USE DIRECTORY_MOD,   ONLY : DATA_DIR_1x1
USE GRID_MOD,        ONLY : GET_XMID
USE GRID_MOD,        ONLY : GET_YMID
USE LOGICAL_MOD,     ONLY : LLINOZ
USE TIME_MOD,        ONLY : GET_MONTH
USE TRACER_MOD,      ONLY : N_TRACERS, TRACER_NAME
USE TRANSFER_MOD,    ONLY : TRANSFER_3D
USE TRANSFER_MOD,    ONLY : TRANSFER_3D_Bry
```

```
      USE m_netcdf_io_open
      USE m_netcdf_io_read
      USE m_netcdf_io_close

      USE CMN_SIZE_MOD

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      INTEGER,INTENT(IN) :: THISMONTH
```

REVISION HISTORY:

```
    01 Feb 2011 - L. Murray   - Initial version
    18 Jul 2012 - R. Yantosca - Make sure that I is the innermost DO loop
                                (wherever expedient)
    20 Jul 2012 - R. Yantosca - Now call routine TRANSFER_3D_Bry, which takes
                                arrays of size (144,91,:) as input & output
    20 Jul 2012 - R. Yantosca - Reorganized declarations for clarity
```

1.87.4 calc_ste

Subroutine CALC_STE estimates what the stratosphere-to- troposphere exchange flux must have been since the last time it was reset

INTERFACE:

```
   SUBROUTINE Calc_STE
```

USES:

```
      USE TRACER_MOD, ONLY : STT, TRACER_MW_KG, N_TRACERS, TRACER_NAME
      USE TIME_MOD,   ONLY : GET_TAU, GET_NYMD, GET_NHMS, EXPAND_DATE

      USE CMN_SIZE_MOD

      IMPLICIT NONE

 #include "define.h"
```

REVISION HISTORY:

```
    28 Apr 2012 - L. Murray   - Initial version
    18 Jul 2012 - R. Yantosca - Make sure I is the innermost DO loop
                                (wherever expedient)
    20 Jul 2012 - R. Yantosca - Reorganized declarations for clarity
```

1.87.5 init_strat_chem

Subroutine INIT_STRAT_CHEM allocates all module arrays. It also opens the necessary rate files.

INTERFACE:

```
SUBROUTINE INIT_STRAT_CHEM
```

USES:

```
USE ERROR_MOD,     ONLY : ALLOC_ERR
USE LOGICAL_MOD,   ONLY : LLINOZ
USE TRACER_MOD,    ONLY : ITS_A_FULLCHEM_SIM, ITS_A_TAGOX_SIM
USE TRACER_MOD,    ONLY : N_TRACERS, TRACER_NAME, STT
USE TRACERID_MOD,  ONLY : IDTCHBr3, IDTCH2Br2, IDTCH3Br
USE TRACERID_MOD,  ONLY : IDTBr2,IDTBr,IDTBrO,IDTHOBr,IDTHBr,IDTBrNO3
USE TIME_MOD,      ONLY : GET_TAU, GET_NYMD, GET_NHMS, GET_TS_CHEM

USE m_netcdf_io_open
USE m_netcdf_io_read
USE m_netcdf_io_close

USE CMN_SIZE_MOD

IMPLICIT NONE
```

REVISION HISTORY:

```
1 Feb 2011 - L. Murray - Initial version
```

1.87.6 cleanup_strat_chem

Subroutine CLEANUP_STRAT_CHEM deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_STRAT_CHEM
```

USES:

```
IMPLICIT NONE
```

REVISION HISTORY:

```
1 Feb 2011 - L. Murray - Initial version
```

1.87.7 do_synoz

Subroutine Do_Synoz establishes the flux boundary condition for Ozone coming down from the stratosphere, using the Synoz algorithm of McLinden et al, 2000.

INTERFACE:

```
   SUBROUTINE Do_Synoz
```

USES:

```
     USE DAO_MOD,         ONLY : AD, BXHEIGHT, T, TROPP
     USE ERROR_MOD,       ONLY : ERROR_STOP
     USE LOGICAL_MOD,     ONLY : LVARTROP
     USE PRESSURE_MOD,    ONLY : GET_PEDGE, GET_PCENTER
     USE TAGGED_OX_MOD,   ONLY : ADD_STRAT_POX
     USE TIME_MOD,        ONLY : GET_TS_CHEM, GET_YEAR
     USE TRACER_MOD,      ONLY : STT, ITS_A_TAGOX_SIM
     USE TRACERID_MOD,    ONLY : IDTOX, IDTOxStrt
     USE TROPOPAUSE_MOD, ONLY : GET_TPAUSE_LEVEL

     USE CMN_SIZE_MOD       ! Size parameters
     USE CMN_GCTM_MOD       ! Rdg0

     IMPLICIT NONE
 #include "define.h"
```

REMARKS:

```
    Reference:
    ============================================================================
    C. A. McLinden, S. Olsen, B. Hannegan, O. Wild, M. J. Prather, and
    J. Sundet, "Stratospheric Ozone in 3-D models: A simple chemistry
    and the cross-tropopause flux".

                                                                              .
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %%%% NOTE: This SYNOZ scheme is now obsolete, replaced by LINOZ   %%%%
    %%%% We keep this for backwards compatibility w/ older met fields %%%%
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
    13 Dec 1999 - Q. Li, R. Martin - Initial version
    (1 ) The parameter Rdg0 from "CMN_GCTM" = R / g0 = 28.97.
    (2 ) Pass PW = PS - PTOP to UPBDFLX via "CMN".
    (3 ) Now pass IORD, JORD, KORD as arguments (bmy, 12/6/00)
    (4 ) Now compute the proper value of PO3_vmr that will yield 475 Tg O3/yr
         for various settings of IORD, JORD, KORD (rvm, bey, bmy, 12/5/00)

                                                                              .
         ************************************************************
```

```
      ***** You must use this version of UPBDFLX_O3 if you are *****
      ***** using the Parallel Processor TPCORE v. 7.1         *****
      ************************************************************
```

.

```
(5 ) Added to "upbdflx_mod.f".  Also updated comments and made some
     cosmetic changes. (bmy, 6/28/01)
(6 ) Now reference CMN_SETUP for LSPLIT.  Also store strat O3 into
     tracer #11 for multi-tracer Ox run. (amf, bmy, 7/3/01)
(7 ) Removed IREF, JREF -- these are obsolete.  Also T(IREF,JREF,L) is
     now T(I,J,L). (bmy, 9/27/01)
(8 ) Also replace PW(I,J) with P(I,J) (bmy, 10/3/01)
(9 ) Removed obsolete commented out code from 9/01 (bmy, 10/24/01)
(10) Removed obsolete commented out code from 7/01 (bmy, 11/26/01)
(11) Now write file names to stdout (bmy, 4/3/02)
(12) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(13) Now use GET_PEDGE and GET_PCENTER from "pressure_mod.f" to compute
     the pressure at the bottom edge and center of grid box (I,J,L).
     Also removed obsolete, commented-out code.  Removed G_SIG and
     G_SIGE from the arg list. (dsa, bdf, bmy, 8/21/02)
(14) Now reference BXHEIGHT and T from "dao_mod.f".  Also reference routine
     ERROR_STOP from "error_mod.f".  Now references IDTOX from F90 module
     "tracerid_mod.f" instead of from "comtrid.h". (bmy, 11/6/02)
(15) Now define J30S and J30N for 1x1 nested grid (bmy, 3/11/03)
(16) Make sure to pass AD via "dao_mod.f" for GEOS-1 (bnd, bmy, 4/14/03)
(17) On the first timestep, print how much O3 flux is coming down from the
     stratosphere in Tg/yr. (mje, bmy, 8/15/03)
(18) Change O3 flux to 500 Tg/yr for GEOS-3 (mje, bmy, 9/15/03)
(19) Now calls routine ADD_STRAT_POX from "tagged_ox_mod.f" in order to
     pass stratospheric flux of Ox to the proper tagged tracer w/o
     resorting to hardwiring w/in this routine. (bmy, 8/18/03)
(20) Add GEOS_4 to the #if defined block. (bmy, 1/29/04)
(21) Activated parallel DO-loops.  Now made STFLUX a local array
     in order to facilitate parallelization. (bmy, 4/15/04)
(22) Removed IORD, JORD, KORD from the arg list.  Now reference STT and
     ITS_A_TAGOX_SIM from "tracer_mod.f".  (bmy, 7/20/04)
(23) Use an #ifdef block to comment out an EXIT statement from w/in a
     parallel loop for COMPAQ compiler.  COMPAQ seems to have some
     problems with this.  Now supports 1x125 grid. (auvray, bmy, 12/1/04)
(24) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(25) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(26) Now set J30S and J30N for GEOS-5 nested grid (yxw, dan, bmy, 11/6/08)
(27) Remove support for COMPAQ compiler (bmy, 7/8/09)
(28) Now do not call ADD_STRAT_POx for tagged Ox (dbj, bmy, 10/16/09)
13 Aug 2010 - R. Yantosca - Treat MERRA like GEOS-5 (bmy, 8/13/10)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.2 in the same way as MERRA
10 Feb 2012 - R. Yantosca - Modified for 0.25 x 0.3125 grids
```

```
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
28 Apr 2012 - L. Murray - Moved from upbdflx_mod.F to here, modified to
              F90, renamed from UPBDFLX_O3 to DO_SYNOZ. Use chem timestep
              now. Also, removed INIT_UPBDFLX, which was last used for
              GEOS-3.
```

1.87.8 upbdflx_hd

Subroutine UPBDFLX_HD establishes the flux boundary condition for HD coming down from the stratosphere. This is adapted from the UPBDFLX_O3 routine.

INTERFACE:

```
SUBROUTINE UPBDFLX_HD
```

USES:

```
USE DAO_MOD,      ONLY : AD, BXHEIGHT, T
USE ERROR_MOD,    ONLY : ERROR_STOP
USE PRESSURE_MOD, ONLY : GET_PEDGE, GET_PCENTER
USE TIME_MOD,     ONLY : GET_TS_CHEM
USE TRACER_MOD,   ONLY : STT
USE TRACERID_MOD, ONLY : IDTHD, IDTH2

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_GCTM_MOD     ! Rdg0
```

REMARKS:

```
Instead of calculating the fractionation of H2 in the stratosphere
(where we would have to take into account fractionation of CH4),
we simply set the HD tracer concentrations in the stratosphere to
reproduce observed profiles in the UT/LS.

References:
============================================================================
(1) "Global Budget of Molecular Hydrogen and its Deuterium Content:
     Constraints from Ground Station, Cruise, and Aircraft Observations"
     Price, H., L. Jaegl, A. Rice, P. Quay, P.C. Novelli, R. Gammon,
     submitted to J. Geophys. Res., 2007.
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager - Initial version
(1 ) First adapted from UPBDFLX_O3 (G-C v5-05-03) then merged w/ v7-04-12.
      Added parallel DO loops. (phs, 9/18/07)
(26) Now set J30S and J30N for GEOS-5 nested grid (yxw, dan, bmy, 11/6/08)
(27) Remove support for COMPAQ compiler (bmy, 7/8/09)
```

```
13 Aug 2010 - R. Yantosca - Treat MERRA like GEOS-5
02 Dec 2010 - R. Yantosca - Added ProTeX headers
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.2 in the same way as MERRA
10 Feb 2012 - R. Yantosca - Modified for 0.25 x 0.3125 grids
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
20 Jun 2012 - L. Murray - Moved from upbdflx_mod.F to here.
```

1.88 Fortran: Module Interface sulfate_mod

Module SULFATE_MOD contains arrays and routines for performing either a coupled chemistry/aerosol run or an offline sulfate aerosol simulation. Original code taken from Mian Chin's GOCART model and modified accordingly. (rjp, bdf, bmy, 6/22/00, 8/26/10)

INTERFACE:

```
      MODULE SULFATE_MOD
```

USES:

```
      USE LOGICAL_MOD,   ONLY : LNLPBL ! (Lin, 03/31/09)
      USE VDIFF_PRE_MOD, ONLY : emis_save ! (Lin, 03/31/09)

      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CHEMSULFATE
      PUBLIC :: EMISSSULFATE
      PUBLIC :: CLEANUP_SULFATE
```

REMARKS:

```
References:
============================================================================
(1 ) Andreae, M.O. & P. Merlet, "Emission of trace gases and aerosols from
      biomass burning", Global Biogeochem. Cycles, 15, 955-966, 2001.
(2 ) Nightingale et al [2000a], J. Geophys. Res, 14, 373-387
(3 ) Nightingale et al [2000b], Geophys. Res. Lett, 27, 2117-2120
(4 ) Wanninkhof, R., "Relation between wind speed and gas exchange over
      the ocean", J. Geophys. Res, 97, 7373-7382, 1992.
```

REVISION HISTORY:

```
(1 ) All module variables are declared PRIVATE (i.e., they can only
      be seen from within this module (bmy, 6/2/00)
(2 ) The routines in "sulfate_mod.f" assume that we are doing chemistry
```

```
      over the global region (e.g. IIPAR=IIPAR, JJPAR=JJPAR). (bmy, 6/8/00)
(3 ) Removed obsolete code from DRYDEP_SULFATE (bmy, 12/21/00)
(4 ) Removed obsolete commented-out code from module routines (bmy, 4/23/01)
(5 ) Now read data files from DATA_DIR/sulfate_sim_200106/ (bmy, 6/19/01)
(6 ) Updated comments (bmy, 9/4/01)
(7 ) XTRA2(IREF,JREF,5) is now XTRA2(I,J).  Now reference COSSZA from
      "dao_mod.f". (bmy, 9/27/01)
(8 ) Removed obsolete commented out code from 9/01 (bmy, 10/24/01)
(9 ) Minor fixes to facilitate compilation on ALPHA (bmy, 11/15/01)
(11) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
      MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(12) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
      to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(13) Now reference "file_mod.f" (bmy, 6/27/02)
(14) Now references GET_PEDGE from "pressure_mod.f", which computes P at
      the bottom edge of grid box (I,J,L).  Also deleted obsolete,
      commented-out code. (dsa, bdf, bmy, 8/21/02)
(15) Added updated code from Rokjin Park and Brendan Field, in order to
      perform coupled chemistry-aerosol simulations.  Also added parallel
      DO-loops in several subroutines.  Updated comments, cosmetic
      changes.  Now reference "error_mod.f" and "wetscav_mod.f".
      Now only do chemistry below the tropopause. (rjp, bdf, bmy, 12/6/02)
(16) Added ENH3_na array to hold natural source NH3 emissions.  Also now
      facilitate passing DMS, SO2, SO4, NH3 to SMVGEAR for fullchem
      simulations.  Added subroutine READ_NATURAL_NH3. (rjp, bmy, 3/23/03)
(17) Now references "grid_mod.f" and "time_mod.f".  Also made other minor
      cosmetic changes. (bmy, 3/27/03)
(18) Updated chemistry routines to apply drydep losses throughout the
      entire PBL. (rjp, bmy, 8/1/03)
(19) Now accounts for GEOS-4 PBL being in meters (bmy, 1/15/04)
(20) Fix ND44 diag so that we get same results for sp or mp (bmy, 3/24/04)
(21) Added COSZM array.  Now use diurnal varying JH2O2 in CHEM_H2O2.
      (rjp, bmy, 3/39/04)
(22) Added more parallel DO-loops (bmy, 4/14/04)
(23) Now add SO2 from ships (bec, bmy, 5/20/04)
(24) Now references "directory_mod.f", "logical_mod.f" and "tracer_mod.f".
      Now removed IJSURF. (bmy, 7/20/04)
(25) Can overwrite USA with EPA/NEI99 emissions (rjp, rch, bmy, 11/16/04)
(26) Modified for AS, AHS, LET, SO4aq, NH4aq (cas, bmy, 1/11/05)
(27) Now also references "pbl_mix_mod.f".  NOTE: Comment out phase
      transition  code for now since it is still under development and
      will take a while to be rewritten. (bmy, 3/15/05)
(28) Modified for SO4s, NITs chemistry (bec, 4/13/05)
(29) Now reads updated files for SST and offline chemistry.  Now read data
      for both GCAP and GEOS grids.  Now references "tropopause_mod.f".
      (bmy, 8/22/05)
(30) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(31) Now references XNUMOL & XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
```

```
(32) Now read int'annual SST data on GEOS 1x1 grid (bmy, 11/17/05)
(33) Bug fix for offline aerosol sim in SEASALT_CHEM (bec, bmy, 3/29/06)
(34) Bug fix in INIT_DRYDEP (bmy, 5/23/06)
(35) Now references "bravo_mod.f" (rjp, kfb, bmy, 6/26/06)
(36) Now references "streets_anthro_mod.f" (yxw, bmy, 8/17/06)
(37) Now references "biomass_mod.f" (bmy, 9/27/06)
(38) Now prevent seg fault error in READ_BIOFUEL_SO2 (bmy, 11/3/06)
(39) Bug fix in SEASALT_CHEM (havala, bec, bmy, 12/8/06)
(40) Extra error check for low RH in GRAV_SETTLING (phs, 6/11/08)
(41) Now references "cac_anthro_mod.f".  And apply SO2 yearly scale factor
     to SO2 from GEIA (amv, phs, 3/11/08)
(41) Bug fixes in reading EDGAR data w/ the right tracer number,
     when we are doing offline or nonstd simulations (dkh, 10/31/08)
(42) Bug fix for AD13_SO2_sh in SRCSO2 (phs, 2/27/09)
(43) Bug fix: need to add CAC_AN to PRIVATE statements (bmy, 5/27/09)
(44) Constrain surface emissions to the first level and save them into
     emis_save (lin, 5/29/09)
(45) Last year of SST data is now 2008 (see READ_SST) (bmy, 7/13/09)
(46) Updated rxns in CHEM_DMS and CHEM_SO2 to JPL 2006 (jaf, bmy, 10/15/09)
(47) Added new volcanic emissions of SO2 (jaf, bmy, 10/15/09)
(48) Now accounts for NEI 2005 emissions, and multilevels SOxan emissions
     (amv, phs, 10/15/2009)
(49) Fixes in SRCSO2 for SunStudio compiler (bmy, 12/3/09)
(50) Standardized patch in READ_ANTHRO_NH3 (dkh, bmy, 3/5/10)
(51) Use LWC from GEOS-5 met fields (jaf, bmy, 6/30/10)
(52) Add module parameters MNYEAR_VOLC and MXYEAR_VOLC to define the 1st
     and last year with data for volcanic emissions. (ccc, 9/30/10)
(53) Use updated volcanic emissions from 1979 to 2009
26 Aug 2010 - R. Yantosca   - Add modifications for MERRA
12 Nov 2010 - R. Yantosca   - Avoid div-by-zero when computing L2S, L3S
07 Sep 2011 - P. Kasibathla - Modified to include GFED3
22 Dec 2011 - M. Payer      - Added ProTeX headers
08 Feb 2012 - R. Yantosca   - Add modifications for GEOS-5.7.2 met
01 Mar 2012 - R. Yantosca   - Now reference new grid_mod.F90
13 Mar 2012 - M. Cooper     - Changed regrid algorithm to map_a2a
```

1.88.1 get_vcldf

Subroutine GET_VCLDF computes the volume cloud fraction for SO2 chemistry. (rjp, bdf, bmy, 9/23/02)

INTERFACE:

```
SUBROUTINE GET_VCLDF
```

USES:

```
USE DAO_MOD,      ONLY : RH
```

```
      USE PRESSURE_MOD, ONLY : GET_PCENTER, GET_PEDGE

      USE CMN_SIZE_MOD       ! Size parameters
```

REMARKS:

```
    References:
    ============================================================================
    (1) Sundqvist et al. [1989]
```

REVISION HISTORY:

```
    14 Jan 2011 - R. Yantosca - Return if VCLDF is not allocated
    22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.2 get_lwc

Function GET_LWC returns the cloud liquid water content [m3 H2O/m3 air] at a GEOS-CHEM grid box as a function of temperature. (rjp, bmy, 10/31/02, 1/14/03)

INTERFACE:

```
      FUNCTION GET_LWC( T ) RESULT( LWC )
```

INPUT PARAMETERS:

```
      REAL*8, INTENT(IN) :: T ! Temperature value at a GEOS-CHEM grid box [K]
```

RETURN VALUE:

```
      REAL*8             :: LWC
```

REVISION HISTORY:

```
    18 Jan 2011 - R. Yantosca - Updated comments
    22 Dec 2011 - M. Payer    - Added ProTeX header
```

1.88.3 chemsulfate

Subroutine CHEMSULFATE is the interface between the GEOS-CHEM main program and the sulfate chemistry routines. The user has the option of running a coupled chemistry-aerosols simulation or an offline aerosol simulation. (rjp, bdf, bmy, 5/31/00, 3/16/06)

INTERFACE:

```
      SUBROUTINE CHEMSULFATE
```

USES:

```
      USE DAO_MOD,         ONLY : AD,     AIRDEN,  CLDF
      USE DAO_MOD,         ONLY : CONVERT_UNITS
      USE DRYDEP_MOD,      ONLY : DEPSAV
      USE ERROR_MOD,       ONLY : DEBUG_MSG
      USE GLOBAL_OH_MOD,   ONLY : GET_GLOBAL_OH
      USE GLOBAL_NO3_MOD, ONLY : GET_GLOBAL_NO3
      USE LOGICAL_MOD,     ONLY : LCRYST,          LPRT
      USE TIME_MOD,        ONLY : GET_MONTH,       GET_TS_CHEM
      USE TIME_MOD,        ONLY : GET_ELAPSED_SEC, ITS_A_NEW_MONTH
      USE TRACER_MOD,      ONLY : STT,             TCVV
      USE TRACER_MOD,      ONLY : N_TRACERS,       ITS_AN_AEROSOL_SIM
      USE TRACERID_MOD,    ONLY : IDTNITs,         IDTSO4s

      USE CMN_SIZE_MOD          ! Size parameters
```

REVISION HISTORY:

```
(1 ) Now reference all arguments except FIRSTCHEM and RH from either F90
     modules or from common block header files.  Updated comments,
     cosmetic changes.  Added NH3, NH4, NITRATE chemistry routines.
     Also call MAKE_RH and CONVERT_UNITS from "dao_mod.f".  Now references
     IDTDMS, IDTSO2 etc. from "tracerid_mod.f".  Now make FIRSTCHEM a
     local SAVEd variable.  Now reference DEPSAV from "drydep_mod.f".
     Also get rid of extraneous dimensions of DEPSAV.  Added NTIME,
     NHMSb arrays for OHNO3TIME.  (rjp, bdf, bmy, 12/16/02)
(2 ) CHEM_DMS is now only called for offline sulfate simulations.
     (rjp, bmy, 3/23/03)
(3 ) Now remove NTIME, NHMSb from the arg list and call to OHNO3TIME.
     Now references functions GET_MONTH, GET_TS_CHEM, and GET_ELAPSED_SEC
     from the new "time_mod.f". (bmy, 3/27/03)
(4 ) Now reference STT, TCVV, N_TRACERS, ITS_AN_AEROSOL_SIM from
     "tracer_mod.f".  Now reference ITS_A_NEW_MONTH from "time_mod.f".
     Now references LPRT from "logical_mod.f". (bmy, 7/20/04)
(5 ) Updated for AS, AHS, LET, SO4aq, NH4aq.  Now references LCRYST from
     logical_mod.f.  Now locate species in the DEPSAV array w/in
     INIT_SULFATE. (bmy, 12/21/04)
(6 ) Now handle gravitational settling of SO4s, NITs (bec, bmy, 4/13/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Remove reference to MAKE_RH, it's not needed here (bmy, 3/16/06)
05 Oct 2011 - R. Yantosca - SUNCOS is no longer needed here
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.4 grav_settling

Subroutine GRAV_SETTLING performs gravitational settling of sulfate and nitrate in coarse sea salt (SO4S and NITS). (bec, rjp, bmy, 4/20/04, 7/20/04, 10/25/05)

INTERFACE:

```
SUBROUTINE GRAV_SETTLING( TC, N )
```

USES:

```
USE DAO_MOD,       ONLY : T, BXHEIGHT, RH
USE DIAG_MOD,      ONLY : AD44
USE DRYDEP_MOD,    ONLY : DEPSAV
USE PRESSURE_MOD,  ONLY : GET_PCENTER
USE TRACER_MOD,    ONLY : SALA_REDGE_um,   SALC_REDGE_um,  XNUMOL
USE TRACERID_MOD,  ONLY : IDTSO4s,         IDTNITs
USE TIME_MOD,      ONLY : GET_ELAPSED_SEC, GET_TS_CHEM
USE GRID_MOD,      ONLY : GET_AREA_CM2

USE CMN_SIZE_MOD        ! Size parameters
USE CMN_DIAG_MOD        ! ND44
USE CMN_GCTM_MOD        ! g0
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: N  ! N=1 is SO4S; N=2 is NITS
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,  INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! Tracer [kg]
```

REVISION HISTORY:

```
(1 ) Now references SALA_REDGE_um and SALC_REDGE_um from "tracer_mod.f"
     (bmy, 7/20/04)
(2 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(3 ) Now limit relative humidity to [tiny(real*8),0.99] range for DLOG
     argument (phs, 5/1/08)
(4 ) Bug fixes to the Gerber hygroscopic growth for sea salt aerosols
     (jaegle, 5/5/11)
(5 ) Update hygroscopic growth to Lewis and Schwartz formulation (2006) and
     density calculation based on Tang et al. (1997) (bec, jaegle 5/5/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.5 chem_dms

Subroutine CHEM_DMS is the DMS chemistry subroutine from Mian Chin's GOCART model, modified for use with the GEOS-CHEM model. (rjp, bdf, bmy, 5/31/00, 10/15/09)

INTERFACE:

```
SUBROUTINE CHEM_DMS
```

USES:

```
      USE DAO_MOD,         ONLY : AD, AIRDEN, SUNCOS, T
      USE DIAG_MOD,        ONLY : AD05
      USE DRYDEP_MOD,      ONLY : DEPSAV
      USE TIME_MOD,        ONLY : GET_TS_CHEM
      USE TRACER_MOD,      ONLY : STT, ITS_A_FULLCHEM_SIM, XNUMOL
      USE TRACERID_MOD,    ONLY : IDTDMS
      USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_STRAT

      USE CMN_SIZE_MOD          ! Size parameters
      USE CMN_DIAG_MOD          ! ND05, LD05
      USE CMN_GCTM_MOD          ! AIRMW
```

REMARKS:

```
    Reaction List (by Mian Chin, chin@rondo.gsfc.nasa.gov)
    ============================================================================
                                                                              .
    R1:    DMS + OH  -> a*SO2 + b*MSA                OH addition channel
           k1 = { 1.7e-42*exp(7810/T)*[O2] / (1+5.5e-31*exp(7460/T)*[O2] }
           a = 0.75, b = 0.25
                                                                              .
    R2:    DMS + OH  ->   SO2 + ...                  OH abstraction channel
           k2 = 1.2e-11*exp(-260/T)
                                                                              .
           DMS_OH = DMS0 * exp(-(r1+r2)* NDT1)
           where DMS0 is the DMS concentration at the beginning,
           r1 = k1*[OH], r2 = k2*[OH].
                                                                              .
    R3:    DMS + NO3 ->   SO2 + ...
           k3 = 1.9e-13*exp(500/T)
                                                                              .
           DMS = DMS_OH * exp(-r3*NDT1)
           where r3 = k3*[NO3].
                                                                              .
    R4:    DMS + X   ->   SO2 + ...
           assume to be at the rate of DMS+OH and DMS+NO3 combined.
                                                                              .
    The production of SO2 and MSA here, PSO2_DMS and PMSA_DMS, are saved
    for use in CHEM_SO2 and CHEM_MSA subroutines as a source term.  They
    are in unit of [v/v/timestep].
```

REVISION HISTORY:

```
    (1 ) Now reference AD, AIRDEN, and SUNCOS from "dao_mod.f".  Added
         parallel DO-loops.  Also now extract OH and NO3 from SMVGEAR
         for coupled chemistry-aerosol runs. (rjp, bdf, bmy, 9/16/02)
    (2 ) Bug fix: remove duplicate definition of RK3 (bmy, 3/23/03)
    (3 ) Now use function GET_TS_CHEM from "time_mod.f".  (bmy, 3/27/03)
```

```
(4 ) Now reference STT and ITS_A_FULLCHEM_SIM from "tracer_mod.f"
     Now replace IJSURF w/ an analytic function. (bmy, 7/20/04)
(5 ) Shift rows 8,9 in AD05 to 9,10 in to make room for P(SO4) from O3
     oxidation in sea-salt aerosols (bec, bmy, 4/13/05)
(6 ) Now remove reference to CMN, it's obsolete.  Now reference
     ITS_IN_THE_STRAT from "tropopause_mod.f". (bmy, 8/22/05)
(7 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(8 ) Now correctly records P(SO2) from OH in AD05 (pjh)
(9 ) Update reaction rate to match JPL06 and full chem (jaf, bmy, 10/15/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.6 chem_h2o2

Subroutine CHEM_H2O2 is the H2O2 chemistry subroutine for offline sulfate simulations. For coupled runs, H2O2 chemistry is already computed by the SMVGEAR module. (rjp, bmy, 11/26/02, 10/25/05)

INTERFACE:

```
SUBROUTINE CHEM_H2O2
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,     READ_BPCH2
USE DAO_MOD,        ONLY : AD, AIRDEN,   OPTD,     SUNCOS, T
USE DIAG_MOD,       ONLY : AD44
USE DIRECTORY_MOD,  ONLY : DATA_DIR
USE DRYDEP_MOD,     ONLY : DEPSAV
USE GRID_MOD,       ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,    ONLY : GET_FRAC_UNDER_PBLTOP
USE TIME_MOD,       ONLY : GET_MONTH, GET_TS_CHEM, ITS_A_NEW_MONTH
USE TRACER_MOD,     ONLY : STT,       TCVV,        XNUMOL
USE TRACERID_MOD,   ONLY : IDTH2O2
USE TRANSFER_MOD,   ONLY : TRANSFER_3D_TROP
USE UVALBEDO_MOD,   ONLY : UVALBEDO
USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_STRAT

USE CMN_SIZE_MOD
USE CMN_FJ_MOD, ONLY     : JPMAX, JPPJ
USE CMN_DIAG_MOD         ! ND44
USE CMN_GCTM_MOD         ! AIRMW
```

REVISION HISTORY:

```
(1 ) Bug fix: need to multiply DXYP by 1d4 for cm2 (bmy, 3/23/03)
(2 ) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid_mod.f"
```

```
      Now use functions GET_MONTH and GET_TS_CHEM from "time_mod.f".
      (bmy, 3/27/03)
(3 ) Now references PBLFRAC from "drydep_mod.f".  Now apply dry deposition
      throughout the entire PBL.  Added FREQ variable. (bmy, 8/1/03)
(4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
      sum into AD44 array.  This preents numerical differences when using
      multiple processors. (bmy, 3/24/04)
(5 ) Now use diurnally-varying JO1D.  Now use new unit conversion for
      the ND44 diagnostic. (rjp, bmy, 3/30/04)
(6 ) Now use parallel DO-loop to zero ND44_TMP.  Now uses ITS_A_NEW_MONTH
      from time_mod.f. (bmy, 4/14/04)
(7 ) Now reference STT & TCVV from "tracer_mod.f".  Also replace IJSURF
      with an analytic function.  Now references DATA_DIR from
      "directory_mod.f". (bmy, 7/20/04)
(8 ) Now suppress output from READ_BPCH with QUIET keyword (bmy, 1/25/05)
(9 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP
      from "pbl_mix_mod.f" (bmy, 2/22/05)
(10) Now read offline files from "sulfate_sim_200508/offline".  Now remove
      reference to CMN, it's obsolete.  Now reference ITS_IN_THE_STRAT from
      "tropopause_mod.f". (bmy, 8/22/05)
(11) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(12) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.7 chem_so2

Subroutine CHEM_SO2 is the SO2 chemistry subroutine. (rjp, bmy, 11/26/02, 8/26/10)

INTERFACE:

```
SUBROUTINE CHEM_SO2
```

USES:

```
USE DAO_MOD,          ONLY : AD,      AIRDEN, T
USE DIAG_MOD,         ONLY : AD05,    AD44
USE DRYDEP_MOD,       ONLY : DEPSAV
USE DIRECTORY_MOD,    ONLY : DATA_DIR
USE ERROR_MOD,        ONLY : IS_SAFE_EXP
USE ERROR_MOD,        ONLY : SAFE_DIV
USE GLOBAL_HNO3_MOD, ONLY : GET_GLOBAL_HNO3
USE GRID_MOD,         ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,      ONLY : GET_FRAC_UNDER_PBLTOP
USE PRESSURE_MOD,     ONLY : GET_PCENTER
USE TIME_MOD,         ONLY : GET_TS_CHEM, GET_MONTH
USE TIME_MOD,         ONLY : ITS_A_NEW_MONTH
USE TRACER_MOD,       ONLY : STT,     TCVV,  ITS_AN_AEROSOL_SIM
```

```
      USE TRACER_MOD,      ONLY : XNUMOL
      USE TRACERID_MOD,    ONLY : IDTH2O2, IDTSO2
      USE SEASALT_MOD,     ONLY : GET_ALK
      USE WETSCAV_MOD,     ONLY : H2O2s,   SO2s
      USE TROPOPAUSE_MOD,  ONLY : ITS_IN_THE_STRAT

      ! For LWC from met fields in GEOS-5 (jaf, 6/30/10)
      USE DAO_MOD,         ONLY : AIRDEN, QL, CLDF

      USE CMN_SIZE_MOD          ! Size parameters
      USE CMN_DIAG_MOD          ! LD05, ND05, ND44
      USE CMN_GCTM_MOD          ! AIRMW
```

REMARKS:

```
      Reaction List (by Rokjin Park, rjp@io.harvard.edu)
      ============================================================================
      (1 ) SO2 production:
           DMS + OH, DMS + NO3 (saved in CHEM_DMS)

                                                                                .
      (2 ) SO2 loss:
           (a) SO2 + OH  -> SO4
           (b) SO2       -> drydep
           (c) SO2 + H2O2 or O3 (aq) -> SO4

                                                                                .
      (3 ) SO2 = SO2_0 * exp(-bt) +  PSO2_DMS/bt * [1-exp(-bt)]

                                                                                .
           where b is the sum of the reaction rate of SO2 + OH and the dry
           deposition rate of SO2, PSO2_DMS is SO2 production from DMS in
           MixingRatio/timestep.

                                                                                .
      If there is cloud in the gridbox (fraction = fc), then the aqueous
      phase chemistry also takes place in cloud. The amount of SO2 oxidized
      by H2O2 in cloud is limited by the available H2O2; the rest may be
      oxidized due to additional chemistry, e.g, reaction with O3 or O2
      (catalyzed by trace metal).
```

REVISION HISTORY:

```
      (1 ) Removed duplicate definition of Ki (bmy, 11/15/01)
      (2 ) Eliminate duplicate HPLUS definition.  Make adjustments to facilitate
           SMVGEAR chemistry for fullchem runs (rjp, bmy, 3/23/03)
      (3 ) Now replace DXYP(J+J0)*1d4 with routine GET_AREA_CM2 of "grid_mod.f"
           Now use function GET_TS_CHEM from "time_mod.f".
      (4 ) Now apply dry deposition to entire PBL.  Now references PBLFRAC array
           from "drydep_mod.f". (bmy, 8/1/03)
      (5 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
           sum into AD44 array.  This preents numerical differences when using
```

```
      multiple processors. (bmy, 3/24/04)
(6 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
(7 ) Now reference STT, TCVV, & ITS_AN_AEROSOL_SIM from "tracer_mod.f".
      Now reference DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(8 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
      "pbl_mix_mod.f" (bmy, 2/22/05)
(9 ) Modified for SO4s, NITs.  Also modified for alkalinity w/in the
      seasalt chemistry. (bec, bmy, 4/13/05)
(10) Now remove reference to CMN, it's obsolete.  Now reference
      ITS_IN_THE_STRAT from "tropopause_mod.f" (bmy, 8/22/05)
(11) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(12) Updated to match JPL 2006 + full chem (jaf, bmy, 10/15/09)
(13) Now prevent floating-point exceptions when taking the exponential
      terms. (win, bmy, 1/4/10)
(14) Added extra error checks to prevent negative L2S, L3S (bmy, 4/28/10)
(15) Use liq. water content from met fields in GEOS-5 (jaf, bmy, 6/30/10)
26 Aug 2010 - R. Yantosca - Use liquid water content from MERRA
12 Nov 2010 - R. Yantosca - Prevent div-by-zero when computing L2S and L3S
27 May 2011 - L. Zhang    - Divide LWC by cloud fraction for GEOS/MERRA
                            and adjust the L2S and L3S rates accordingly
22 Dec 2011 - M. Payer    - Added ProTeX headers
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.2 in the same way as MERRA
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.8 seasalt_chem

Subroutine SEASALT_CHEM computes SO4 formed from S(IV) + O3 on seasalt aerosols as a function of seasalt alkalinity. (bec, bmy, 4/13/05, 10/7/08)

INTERFACE:

```
      SUBROUTINE SEASALT_CHEM ( I,      J,     L,   ALK1, ALK2,
     &                          SO2_cd, Kt1,   Kt2, Kt1N, Kt2N,
     &                          SO2_ss, PSO4E, PSO4F )
```

USES:

```
      USE COMODE_MOD,      ONLY : CSPEC, JLOP, VOLUME
      USE DAO_MOD,         ONLY : AD, AIRDEN, AIRVOL
      USE TRACERID_MOD
      !-----------------------------------------------------------------
      ! DIAGNOSTIC -- leave commented out for now (bec, bmy, 4/13/05)
      !USE DIAG_MOD,        ONLY : AD09
      !-----------------------------------------------------------------
      USE ERROR_MOD,       ONLY : GEOS_CHEM_STOP
      USE TIME_MOD,        ONLY : GET_TS_CHEM,        GET_ELAPSED_SEC
      USE ERROR_MOD,       ONLY : IT_IS_NAN
      USE TRACER_MOD,      ONLY : ITS_A_FULLCHEM_SIM, STT
```

```
      USE TRACER_MOD,      ONLY : TCVV,               XNUMOLAIR
      USE GLOBAL_HNO3_MOD, ONLY : GET_HNO3_UGM3
      USE TIME_MOD,        ONLY : GET_ELAPSED_SEC,    GET_MONTH
      USE TIME_MOD,        ONLY : ITS_A_NEW_MONTH

      ! Add these for GET_GNO3 fix (lyj, bmy, 10/7/08)
      USE GLOBAL_HNO3_MOD, ONLY : GET_HNO3_UGM3
      USE DAO_MOD,         ONLY : AIRVOL

      USE CMN_SIZE_MOD          ! Size parameters
 ------------------------------------------------------------------
  DIAGNOSTIC -- leave commented out for now (bec, bmy, 4/13/05)
       USE CMN_DIAG_MOD          ! ND19
 ------------------------------------------------------------------
      USE CMN_GCTM_MOD          ! AIRMW
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: I, J, L
      REAL*8,  INTENT(IN)  :: SO2_cd     ! SO2 mixing ratio [v/v] after gas
                                         ! phase chemistry and dry deposition
      REAL*8,  INTENT(IN)  :: Kt1, Kt2   ! Rate constant [s-1] for sulfate
                                         ! formation on seasalt aerosols from
                                         ! GET_ALK (1=fine; 2=course)
      REAL*8,  INTENT(IN)  :: Kt1N, Kt2N
      REAL*8,  INTENT(IN)  :: ALK1, ALK2 ! Alkalinity [kg] from seasalt_mod
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: SO2_ss     ! SO2 mixing ratio [v/v] after SS chem
      REAL*8,  INTENT(OUT) :: PSO4E      ! SO4E (sulfate produced by S(IV)+O3
                                         ! on fine seasalt) mixing ratio [v/v]
      REAL*8,  INTENT(OUT) :: PSO4F      ! SO4F (sulfate produced by S(IV)+O3
                                         ! on coarse seasalt) mixing ratio[v/v]
```

REMARKS:

```
    Chemical reactions:
    ===================================================================================
    (R1) SO2 + O3 + ALK => SO4 + O2
         Modeled after Chamedies and Stelson, 1992?
```

REVISION HISTORY:

```
    (1 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
    (2 ) Bug fix: now avoid seg fault error if IDTHNO3 is zero, as it would
          be for an offline aerosol simulation. (bmy, 3/29/06)
    (3 ) Fixed typo in FALK_A_SO2 equation: C_FLUX_C should be C_FLUX_A.
          (havala, bec, bmy, 12/8/06)
    (4 ) Bug fix for mass balance, replace TITR_HNO3 w/ HNO3_SSC in the
          expression for HNO3_ss.  Bug fix: now do equivalent computation
```

```
      for GET_GNO3, which is now no longer called because it's in
      "isoropia_mod.f". (bec, bmy, 7/30/08)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.9 aqchem_so2

Subroutine AQCHEM_SO2 computes the reaction rates for aqueous SO2 chemistry. (rjp, bmy, 10/31/02, 12/12/02)

INTERFACE:

```
  SUBROUTINE AQCHEM_SO2( LWC, T,     P,       SO2, H2O2,
 &                       O3,  Hplus, KaqH2O2, KaqO3 )
```

INPUT PARAMETERS:

```
  REAL*8, INTENT(IN)  :: LWC     ! Liq water content [m3/m3]=1.E-6*L [g/m3]
  REAL*8, INTENT(IN)  :: T       ! Temperature [K]
  REAL*8, INTENT(IN)  :: P       ! Pressure [atm]
  REAL*8, INTENT(IN)  :: SO2     ! SO2  mixing ratio [v/v]
  REAL*8, INTENT(IN)  :: H2O2    ! H2O2 mixing ratio [v/v]
  REAL*8, INTENT(IN)  :: O3      ! O3   mixing ratio [v/v]
  REAL*8, INTENT(IN)  :: HPLUS   ! Concentration of H+ ion (i.e. pH) [v/v]
```

OUTPUT PARAMETERS:

```
  REAL*8, INTENT(OUT) :: KaqH2O2 ! Reaction rate for H2O2
  REAL*8, INTENT(OUT) :: KaqO3   ! Reaction rate for O3
```

REMARKS:

```
Chemical Reactions:
================================================================================
(R1) HSO3- + H2O2(aq) + H+ => SO4-- + 2H+ + H2O [Jacob, 1986]
                                                                              .
    d[S(VI)]/dt = k[H+][H2O2(aq)][HSO3-]/(1 + K[H+])
    [Seinfeld and Pandis, 1998, page 366]
                                                                              .
(R2) SO2(aq) + O3(aq) =>
     HSO3-   + O3(aq) =>
     SO3--   + O3(aq) =>
     [Jacob, 1986; Jacobson, 1999]
                                                                              .
     d[S(VI)]/dt = (k0[SO2(aq)] + k1[HSO3-] + K2[SO3--])[O3(aq)]
     [Seinfeld and Pandis, 1998, page 363]
                                                                              .
Reaction rates can be given as
     Ra     = k [H2O2(ag)] [S(IV)]  [mole/liter*s]  OR
     Krate  = Ra LWC R T / P        [1/s]
```

```
.
Where:
     LWC = Liquid water content(g/m3)*10-6 [m3(water)/m3(gas)]
     R   = 0.08205  (atm L / mol-K), Universal gas const.
     T   = Temperature (K)
     P   = Pressure (atm)
.
Procedure:
=============================================================================
(a ) Given [SO2] which is assumed to be total SO2 (gas+liquid) in
      equilibrium between gas and liquid phase.
.
(b ) We can compute SO2(g) using Henry's law
        P(so2(g)) = Xg * [SO2]
        Xg = 1/(1 + Faq), Fraction of SO2 in gas
     where:
        Faq   = Kheff * R * T * LWC,
        KHeff = Effective Henry's constant
.
(c ) Then Calculate Aquous phase, S[IV] concentrations
      S[IV] = Kheff * P(so2(g) in atm) [M]
.
(d ) The exact same procedure is applied to calculate H2O2(aq)
```

REVISION HISTORY:

```
(1 ) Updated by Rokjin Park (rjp, bmy, 12/12/02)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.10 chem_so4

Subroutine CHEM_SO4 is the SO4 chemistry subroutine from Mian Chin's GOCART model, modified for the GEOS-CHEM model. Now also modified to account for production of crystalline and aqueous sulfur tracers. (rjp, bdf, cas, bmy, 5/31/00, 5/23/06)

INTERFACE:

```
SUBROUTINE CHEM_SO4
```

USES:

```
USE DAO_MOD,         ONLY : AD
USE DIAG_MOD,        ONLY : AD44
USE DRYDEP_MOD,      ONLY : DEPSAV
USE GRID_MOD,        ONLY : GET_AREA_CM2
USE LOGICAL_MOD,     ONLY : LCRYST, LSSALT
USE PBL_MIX_MOD,     ONLY : GET_FRAC_UNDER_PBLTOP
USE TIME_MOD,        ONLY : GET_TS_CHEM
```

```
      USE TRACER_MOD,     ONLY : STT,    TCVV,     XNUMOL
      USE TRACERID_MOD,   ONLY : IDTSO4, IDTSO4s,  IDTAS,   IDTAHS
      USE TRACERID_MOD,   ONLY : IDTLET, IDTSO4aq, IDTNH4aq
      USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_STRAT

      USE CMN_SIZE_MOD         ! Size parameters
      USE CMN_DIAG_MOD         ! ND44
```

REMARKS:

```
Reaction List (by Mian Chin, chin@rondo.gsfc.nasa.gov)
============================================================================
The Only production is from SO2 oxidation (save in CHEM_SO2), and the only
loss is dry depsition here.  Wet deposition will be treated in "wetdep.f".
                                                                            .
SO4 = SO4_0 * exp(-kt) + PSO4_SO2/kt * (1.-exp(-kt))
  where k = dry deposition.
                                                                            .
```

REVISION HISTORY:

```
(1 ) Now reference AD from "dao_mod.f".  Added parallel DO-loops.
     Updated comments, cosmetic changes. (rjp, bdf, bmy, 9/16/02)
(2 ) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid_mod.f"
     Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(3 ) Now reference PBLFRAC from "drydep_mod.f".  Now apply dry deposition
     to the entire PBL. (rjp, bmy, 8/1/03)
(4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
     sum into AD44 array.  This preents numerical differences when using
     multiple processors. (bmy, 3/24/04)
(5 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
(6 ) Now reference STT & TCVV from "tracer_mod.f" (bmy, 7/20/04)
(7 ) Now references LCRYST from "logical_mod.f".  Modified for crystalline
     and aqueous sulfate2 tracers: AS, AHS, LET, SO4aq.  Also changed name
     of ND44_TMP to T44 to save space. (cas, bmy, 12/21/04)
(8 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
     "pbl_mix_mod.f" (bmy, 2/22/05)
(9 )  Now remove reference to CMN, it's obsolete.  Now reference
      ITS_IN_THE_STRAT from "tropopause_mod.f" (bmy, 8/22/05)
(10) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(11) Rearrange error check to avoid SEG FAULTS (bmy, 5/23/06)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.11 chem_msa

Subroutine CHEM_MSA is the SO4 chemistry subroutine from Mian Chin's GOCART model, modified for the GEOS-CHEM model. (rjp, bdf, bmy, 5/31/00, 10/25/05)

INTERFACE:

```
SUBROUTINE CHEM_MSA
```

USES:

```
USE DAO_MOD,         ONLY : AD
USE DIAG_MOD,        ONLY : AD44
USE DRYDEP_MOD,      ONLY : DEPSAV
USE GRID_MOD,        ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,     ONLY : GET_FRAC_UNDER_PBLTOP, GET_PBL_MAX_L
USE TIME_MOD,        ONLY : GET_TS_CHEM
USE TRACER_MOD,      ONLY : STT, TCVV, XNUMOL
USE TRACERID_MOD,    ONLY : IDTMSA
USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_STRAT

USE CMN_SIZE_MOD          ! Size parameters
USE CMN_DIAG_MOD          ! ND44
USE CMN_GCTM_MOD          ! AIRMW
```

REMARKS:

```
Reaction List (by Mian Chin, chin@rondo.gsfc.nasa.gov)
============================================================================
The Only production is from DMS oxidation (saved in CHEM_DMS), and the only
loss is dry depsition here.  Wet deposition will be treated in "wetdep.f".
                                                                            .
MSA = MSA_0 * exp(-dt) + PMSA_DMS/kt * (1.-exp(-kt))
  where k = dry deposition.
```

REVISION HISTORY:

```
(1 ) Now reference AD from "dao_mod.f".  Added parallel DO-loops.
     Updated comments, cosmetic changes. (rjp, bmy, bdf, 9/16/02)
(2 ) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid_mod.f"
     Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(3 ) Now reference PBLFRAC from "drydep_mod.f".  Now apply dry deposition
     to the entire PBL. (rjp, bmy, 8/1/03)
(4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
     sum into AD44 array.  This preents numerical differences when using
     multiple processors. (bmy, 3/24/04)
(5 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
(6 ) Now references STT & TCVV from "tracer_mod.f" (bmy, 7/20/04)
(7 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
     "pbl_mix_mod.f".  Also reference GET_PBL_MAX_L from "pbl_mix_mod.f"
     Vertical DO-loops can run up to PBL_MAX and not LLTROP.   Also
     remove reference to header file CMN. (bmy, 2/22/05)
(8 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(9 ) Change loop back to over entire troposphere to correctly add production
```

```
      of MSA (PMSA_dms) to the MSA tracer array.
     Added reference USE_TROPOPAUSE_MOD, ONLY : ITS_IN_THE_STRAT
      as a precaution.  (pjh, 8/19/2009)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.12 chem_nh3

Subroutine CHEM_NH3 removes NH3 from the surface via dry deposition. (rjp, bdf, bmy, 1/2/02, 10/25/05)

INTERFACE:

```
SUBROUTINE CHEM_NH3
```

USES:

```
USE DAO_MOD,      ONLY : AD
USE DIAG_MOD,     ONLY : AD44
USE DRYDEP_MOD,   ONLY : DEPSAV
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,  ONLY : GET_FRAC_UNDER_PBLTOP, GET_PBL_MAX_L
USE TIME_MOD,     ONLY : GET_TS_CHEM
USE TRACER_MOD,   ONLY : STT, TCVV, XNUMOL
USE TRACERID_MOD, ONLY : IDTNH3

USE CMN_SIZE_MOD       ! Size parameters
USE CMN_DIAG_MOD       ! ND44
```

REMARKS:

```
Reaction List:
============================================================================
(1 ) NH3 = NH3_0 * EXP( -dt )  where d = dry deposition rate [s-1]
```

REVISION HISTORY:

```
(1 ) Now reference AD from "dao_mod.f".  Added parallel DO-loops.
     Updated comments, cosmetic changes. (rjp, bmy, bdf, 9/16/02)
(2 ) Now replace DXYP(J+J0)*1d4 with routine GET_AREA_CM2 from "grid_mod.f"
     Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(3 ) Now reference PBLFRAC from "drydep_mod.f".  Now apply dry deposition
     to the entire PBL.  Added L and FREQ variables.  Recode to avoid
     underflow from the EXP() function. (rjp, bmy, 8/1/03)
(4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
     sum into AD44 array.  This preents numerical differences when using
     multiple processors. (bmy, 3/24/04)
```

```
(5 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
(6 ) Now references STT & TCVV from "tracer_mod.f" Also remove reference to
     CMN, it's not needed(bmy, 7/20/04)
(7 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
     "pbl_mix_mod.f".  Also reference GET_PBL_MAX_L from "pbl_mix_mod.f"
     Vertical DO-loops can run up to PBL_MAX and not LLTROP. (bmy, 2/22/05)
(8 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.13 chem_nh4

Subroutine CHEM_NH4 removes NH4 from the surface via dry deposition. (rjp, bdf, bmy, 1/2/02, 10/25/05)

INTERFACE:

```
SUBROUTINE CHEM_NH4
```

USES:

```
USE DAO_MOD,      ONLY : AD
USE DIAG_MOD,     ONLY : AD44
USE DRYDEP_MOD,   ONLY : DEPSAV
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,  ONLY : GET_FRAC_UNDER_PBLTOP, GET_PBL_MAX_L
USE TIME_MOD,     ONLY : GET_TS_CHEM
USE TRACER_MOD,   ONLY : STT, TCVV, XNUMOL
USE TRACERID_MOD, ONLY : IDTNH4

USE CMN_SIZE_MOD       ! Size parameters
USE CMN_DIAG_MOD       ! ND44
```

REMARKS:

```
Reaction List:
============================================================================
(1 ) NH4 = NH4_0 * EXP( -dt )  where d = dry deposition rate [s-1]
```

REVISION HISTORY:

```
(1 ) Now reference AD from "dao_mod.f".  Added parallel DO-loops.
     Updated comments, cosmetic changes. (rjp, bmy, bdf, 9/16/02)
(2 ) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid_mod.f".
     Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(3 ) Now reference PBLFRAC from "drydep_mod.f".  Now apply dry deposition
     to the entire PBL.  Added L and FREQ variables.  Recode to avoid
```

```
      underflow from EXP(). (rjp, bmy, 8/1/03)
(4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
      sum into AD44 array.  This preents numerical differences when using
      multiple processors. (bmy, 3/24/04)
(5 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
(6 ) Now reference STT & TCVV from "tracer_mod.f".   Also remove reference
      to CMN, it's not needed (bmy, 7/20/04)
(7 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
      "pbl_mix_mod.f".  Also reference GET_PBL_MAX_L from "pbl_mix_mod.f"
      Vertical DO-loops can run up to PBL_MAX and not LLTROP. (bmy, 2/22/05)
(8 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.14 chem_nh4aq

Subroutine CHEM_NH4aq removes NH4aq from the surface via dry deposition. (cas, bmy, 1/6/05, 10/25/05)

INTERFACE:

```
SUBROUTINE CHEM_NH4aq
```

USES:

```
USE DAO_MOD,      ONLY : AD
USE DIAG_MOD,     ONLY : AD44
USE DRYDEP_MOD,   ONLY : DEPSAV
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,  ONLY : GET_FRAC_UNDER_PBLTOP, GET_PBL_MAX_L
USE TIME_MOD,     ONLY : GET_TS_CHEM
USE TRACER_MOD,   ONLY : STT, TCVV, XNUMOL
USE TRACERID_MOD, ONLY : IDTNH4aq

USE CMN_SIZE_MOD       ! Size parameters
USE CMN_DIAG_MOD       ! ND44
```

REMARKS:

```
Reaction List:
============================================================================
(1 ) NH4aq = NH4_0aq * EXP( -dt )  where d = dry deposition rate [s-1]
```

REVISION HISTORY:

```
(1 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
      "pbl_mix_mod.f".  Also reference GET_PBL_MAX_L from "pbl_mix_mod.f"
```

```
      Vertical DO-loops can run up to PBL_MAX and not LLTROP. (bmy, 2/22/05)
(2 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.15 chem_nit

Subroutine CHEM_NIT removes SULFUR NITRATES (NIT) from the surface via dry deposition. (rjp, bdf, bmy, 1/2/02, 5/23/06)

INTERFACE:

```
      SUBROUTINE CHEM_NIT
```

USES:

```
      USE DAO_MOD,      ONLY : AD
      USE DIAG_MOD,     ONLY : AD44
      USE DRYDEP_MOD,   ONLY : DEPSAV
      USE GRID_MOD,     ONLY : GET_AREA_CM2
      USE LOGICAL_MOD,  ONLY : LSSALT
      USE PBL_MIX_MOD,  ONLY : GET_FRAC_UNDER_PBLTOP, GET_PBL_MAX_L
      USE TIME_MOD,     ONLY : GET_TS_CHEM
      USE TRACER_MOD,   ONLY : STT, TCVV, XNUMOL
      USE TRACERID_MOD, ONLY : IDTNIT, IDTNITs

      USE CMN_SIZE_MOD       ! Size parameters
      USE CMN_DIAG_MOD       ! ND44
```

REMARKS:

```
Reaction List:
============================================================================
(1 ) NIT = NIT_0 * EXP( -dt )  where d = dry deposition rate [s-1]
```

REVISION HISTORY:

```
(1 ) Now reference AD from "dao_mod.f".  Added parallel DO-loops.
      Updated comments, cosmetic changes. (rjp, bmy, bdf, 9/20/02)
(2 ) Now replace DXYP(J+J0)*1d4 with routine GET_AREA_CM2 from "grid_mod.f".
      Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(3 ) Now reference PBLFRAC from "drydep_mod.f".  Now apply dry deposition
      to the entire PBL.  Added L and FREQ variables.  Recode to avoid
      underflow from EXP(). (rjp, bmy, 8/1/03)
(4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
      sum into AD44 array.  This preents numerical differences when using
      multiple processors. (bmy, 3/24/04)
```

```
(5 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
(6 ) Now reference STT & TCVV from "tracer_mod.f".  Also remove reference
     to CMN, it's not needed anymore. (bmy, 7/20/04)
(7 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
     "pbl_mix_mod.f".  Also reference GET_PBL_MAX_L from "pbl_mix_mod.f"
     Vertical DO-loops can run up to PBL_MAX and not LLTROP. (bmy, 2/22/05)
(8 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(9 ) Rearrange error check to avoid SEG FAULTS (bmy, 5/23/06)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.16 emisssulfate

Subroutine EMISSSULFATE is the interface between the GEOS-CHEM model and the sulfate emissions routines in "sulfate_mod.f" (bmy, 6/7/00, 10/15/09)

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISSSULFATE(EMISSIONS)
#else
      SUBROUTINE EMISSSULFATE
#endif
```

USES:

```
      USE ERROR_MOD,         ONLY : DEBUG_MSG
      USE LOGICAL_MOD,       ONLY : LSHIPSO2,   LPRT,   LBIOMASS !(win,5/1/09)
      USE TIME_MOD,          ONLY : GET_SEASON, GET_MONTH
      USE TIME_MOD,          ONLY : GET_YEAR,   ITS_A_NEW_MONTH
      USE TIME_MOD,          ONLY : GET_DAY,    ITS_A_NEW_DAY
      USE TRACER_MOD,        ONLY : STT,        ITS_AN_AEROSOL_SIM
      USE TRACERID_MOD,      ONLY : IDTNITs,    IDTSO4s
      USE TRACERID_MOD,      ONLY : IDTDMS,     IDTSO2
      USE TRACERID_MOD,      ONLY : IDTSO4,     IDTNH3
      USE GFED2_BIOMASS_MOD, ONLY : GFED2_IS_NEW
      USE GFED3_BIOMASS_MOD, ONLY : GFED3_IS_NEW
      USE LOGICAL_MOD,       ONLY : LANTHRO, LBIOFUEL

      USE CMN_SIZE_MOD            ! Size parameters

#if defined( DEVEL )
      USE TRACER_MOD, ONLY   : N_TRACERS
#endif
```

REVISION HISTORY:

```
(1 ) BXHEIGHT is now dimensioned IIPAR,JJPAR,LLPAR (bmy, 9/26/01)
(2 ) Removed obsolete commented out code from 9/01 (bmy, 10/24/01)
(3 ) Now reference all arguments except FIRSTEMISS, LENV, LEEV from
      header files or F90 modules.  Removed NSRCE,  MONTH, JDAY,
      LWI, BXHEIGHT, DXYP, AD, PTOP, SIGE, PS, PBL, XTRA2, STT, DATA_DIR,
      JYEAR from the arg list.  Now reference GET_PEDGE from F90 module
      "pressure_mod.f" to compute grid box edge pressures.  Now uses
      GET_SEASON from "time_mod.f" to get the season.  Now references
      IDTDMS, IDTSO2, etc from "tracerid_mod.f".  Now make FIRSTEMISS
      a local SAVEd variable.  Now call READ_BIOMASS_NH3 to read NH3
      biomass and biofuel emissions. (bmy, 12/13/02)
(4 ) Now call READ_NATURAL_NH3 to read the NH3 source from natural
      emissions. (rjp, bmy, 3/23/03)
(5 ) Now use functions GET_SEASON and GET_MONTH from the new "time_mod.f"
      (bmy, 3/27/03)
(6 ) Added first-time printout message (bmy, 4/6/04)
(7 ) Now references CMN_SETUP.  Now read ship SO2 if LSHIPSO2=T.  Also
      references ITS_A_NEW_MONTH from "time_mod.f". (bec, bmy, 5/20/04)
(8 ) Now references STT and ITS_AN_AEROSOL_SIM from "tracer_mod.f".
      Now references LSHIPSO2 from "logical_mod.f" (bmy, 7/20/04)
(9 ) Now references GET_YEAR from "time_mod.f". (bmy, 8/1/05)
(10) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(11) Now check if GFED2 has been updated (yc, phs, 12/23/08)
(12) Add LANTHRO switch to properly turn off the anthropogenic emissions,
      READ_AIRCRAFT_SO2, READ_ANTHRO_SOx, READ_ANTHRO_NH3 (ccc, 4/15/09)
(13) Now read new volcanic SO2 emissions daily (jaf, bmy, 10/15/09)
(14) Add LBIOFUEL switch to properly turn off the biofuel emissions,
     READ_BIOFUEL_SO2, READ_BIOFUEL_NH3. (ccc, 7/16/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.17 SULFATE_PBL_MIX

Subroutine SULFATE_PBL_MIX partitions the total anthro sulfate emissions thru the entire boundary layer. Emissions above the PBL are not used, and left in their level, regardless of the mixing scheme. For non-local mixing scheme, all emissions within the PBL are put in the first level.

INTERFACE:

```
      SUBROUTINE SULFATE_PBL_MIX ( EMISS, SULFATE, FRAC_OF_PBL,
     $                             PBL_TOP, IS_LOCAL )
```

USES:

```
      USE ERROR_MOD,    ONLY : ERROR_STOP
      IMPLICIT NONE
#     include "define.h"
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: PBL_TOP ! Top level of boundary layer
      LOGICAL, INTENT(IN)    :: IS_LOCAL ! mixing scheme
      REAL*8,  INTENT(IN)    :: FRAC_OF_PBL(:) !
      REAL*8,  INTENT(IN)    :: EMISS(:)
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: SULFATE(:) ! partitioned emissions
```

REVISION HISTORY:

```
    27 Oct 2009 - P. Le Sager - initial
```

1.88.18 srcdms

Subroutine SRCDMS, from Mian Chin's GOCART model, add DMS emissions to the tracer array. Modified for use with the GEOS-CHEM model. (bmy, 6/2/00, 8/16/05)

INTERFACE:

```
#if defined( DEVEL)
      SUBROUTINE SRCDMS( TC, SFLX )
#else
      SUBROUTINE SRCDMS( TC )
#endif
```

USES:

```
      USE DIAG_MOD,     ONLY : AD13_DMS
      USE DAO_MOD,      ONLY : IS_WATER, LWI, PBL
      USE GRID_MOD,     ONLY : GET_AREA_M2
      USE PBL_MIX_MOD,  ONLY : GET_FRAC_OF_PBL, GET_PBL_TOP_L
      USE TIME_MOD,     ONLY : GET_TS_EMIS
      USE TRACERID_MOD,   ONLY : IDTDMS ! (Lin, 03/31/09)

      USE CMN_SIZE_MOD     ! Size parameters
      USE CMN_DIAG_MOD     ! ND13 (for now)
      USE CMN_GCTM_MOD     ! SCALE_HEIGHT
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! Initial tracer mass
#if defined( DEVEL )
      REAL*8,  INTENT(INOUT) :: SFLX(IIPAR,JJPAR)
#endif
                                                     ! [kg], plus DMS emiss
```

REVISION HISTORY:

```
(1 ) Now reference NSRCE, LWI, DXYP, XTRA2 from either header files or
     F90 modules.  Now use routines from "pressure_mod.f" to compute
     grid box surface pressures. (bmy, 9/18/02)
(2 ) Now replace DXYP(J) with routine GET_AREA_M2 of "grid_mod.f"
     Now use routine GET_TS_EMIS from the new "time_mod.f". (bmy, 3/27/03)
(3 ) For GEOS-4, convert PBL from [m] to [hPa] w/ the hydrostatic law.
     Now references SCALE_HEIGHT from "CMN_GCTM".  Added BLTHIK variable
     for PBL thickness in [hPa]. (bmy, 1/15/04)
(4 ) Remove reference to "pressure_mod.f".  Now reference GET_FRAC_OF_PBL
     and GET_PBL_TOP_L from "pbl_mix_mod.f". (bmy, 2/22/05)
(5 ) Switch from Liss & Merlivat to Nightingale formulation for DMS
     emissions. (swu, bmy, 8/16/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.19 srcso2

Subroutine SRCSO2 (originally from Mian Chin) computes SO2 emissons from aircraft, biomass, and anthro sources. (rjp, bdf, bmy, 6/2/00, 12/3/09)

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE SRCSO2( TC, NSEASON, SFLX )
#else
      SUBROUTINE SRCSO2( TC, NSEASON )
#endif
```

USES:

```
      USE BRAVO_MOD,      ONLY     : GET_BRAVO_ANTHRO, GET_BRAVO_MASK
      USE CAC_ANTHRO_MOD, ONLY     : GET_CANADA_MASK,  GET_CAC_ANTHRO
      USE DIAG_MOD,       ONLY     : AD13_SO2_an,      AD13_SO2_ac
      USE DIAG_MOD,       ONLY     : AD13_SO2_bb,      AD13_SO2_nv
      USE DIAG_MOD,       ONLY     : AD13_SO2_ev,      AD13_SO2_bf
      USE DIAG_MOD,       ONLY     : AD13_SO2_sh
      USE DAO_MOD,        ONLY     : BXHEIGHT, PBL
      USE EPA_NEI_MOD,    ONLY     : GET_EPA_ANTHRO,   GET_EPA_BIOFUEL
      USE EPA_NEI_MOD,    ONLY     : GET_USA_MASK
      USE ERROR_MOD,      ONLY     : ERROR_STOP,       GEOS_CHEM_STOP
      USE ERROR_MOD,      ONLY     : IS_SAFE_DIV
      USE GRID_MOD,       ONLY     : GET_AREA_CM2
      USE GRID_MOD,       ONLY     : GET_XOFFSET, GET_YOFFSET
      USE LOGICAL_MOD,    ONLY     : LBRAVO, LNEI99,   LSHIPSO2
      USE LOGICAL_MOD,    ONLY     : LCAC, LNEI05
      USE NEI2005_ANTHRO_MOD, ONLY : GET_NEI2005_ANTHRO
      USE NEI2005_ANTHRO_MOD, ONLY : NEI05_MASK => USA_MASK
      USE PBL_MIX_MOD,    ONLY     : GET_FRAC_OF_PBL,  GET_PBL_TOP_L
      USE PRESSURE_MOD,   ONLY     : GET_PEDGE
```

```
      USE TIME_MOD,       ONLY     : GET_TS_EMIS,      GET_DAY_OF_YEAR
      USE TIME_MOD,       ONLY     : GET_DAY_OF_WEEK
      USE TRACER_MOD,     ONLY     : XNUMOL
      USE TRACERID_MOD,   ONLY     : IDTSO2
 [eml
      USE LOGICAL_MOD,    ONLY     : LHIST
 eml]

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! ND13, LD13 (for now)
      USE CMN_GCTM_MOD             ! SCALE_HEIGHT
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: NSEASON ! Season #: 1=DJF; 2=MAM; 3=JJA; 4=SON
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! SO2 tracer mass [kg]
#if defined( DEVEL )
      REAL*8                 :: SFLX(IIPAR,JJPAR,LLPAR)
#endif
```

REVISION HISTORY:

(1) Now reference NSRCE, JDAY, PBL, XTRA2, BXHEIGHT from either header files or F90 modules. Also use routines from "pressure_mod.f" to compute grid box pressures. (bmy, 9/18/02)

(2) Now use routines GET_TS_EMIS and GET_DAY_OF_YEAR from the new "time_mod.f" (bmy, 3/27/03)

(3) For GEOS-4, convert PBL from [m] to [hPa] w/ the hydrostatic law. Now references SCALE_HEIGHT from "CMN_GCTM". Added BLTHIK variable to hold PBL thickness in [hPa]. (bmy, 1/15/04)

(4) Now references AD13_SO2_sh array from "diag_mod.f". Also references LSHIPSO2 from "CMN_SETUP" (bec, bmy, 5/20/04)

(5) Now references LSHIPSO2 from "logical_mod.f" (bmy, 7/20/04)

(6) Now references routines GET_EPA_ANTHRO and GET_USA_MASK from "epa_nei_mod.f". Now references GET_AREA_CM2 from "grid_mod.f". Now references GET_DAY_OF_WEEK from "time_mod.f" Now references LNEI99 from "logical_mod.f". Now can overwrite the anthro SOx emissions over the continental US if LNEI99=T. Now references IDTSO2 from "tracerid_mod.f. (rch, rjp, bmy, 11/16/04)

(7) Remove reference to "pressure_mod.f". Now reference GET_FRAC_OF_PBL and GET_PBL_TOP_L from "pbl_mix_mod.f". Removed reference to header file CMN. (bmy, 2/22/05)

(8) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)

(9) Now references GET_BRAVO_ANTHRO and GET_BRAVO_MASK from "bravo_mod.f" for BRAVO Mexican emissions. (rjp, kfb, bmy, 6/26/06)

```
(10) Bug fix: EPA emissions were overwritten by regular ones when both BRAVO
       and EPA were used. (phs, 10/4/07)
(11) Now use CAC Canadian emissions, if necessary (amv, 1/10/08)
(12) Bug fix: Always fill the diagnostic array AD13_SO2_sh because it
      is allocated anyway (phs, 2/27/09)
(13) Changed processing of volcanic SO2 emissions (jaf, bmy, 10/15/09)
(14) Read NEI now (amv, 10/07/2009)
(15) Now calls SULFATE_PBL_MIX to do the PBL mixing of
      emissions (phs, 10/27/09)
(16) Rewrite Aerocom SO2 emissions section to avoid errors on SunStudio
      compiler. Also avoid division by zero. (bmy, 12/3/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.20 srcso4

Subroutine SRCSO4 (originally from Mian Chin) computes SO4 emissions from anthropogenic sources (rjp, bdf, bmy, 6/2/00, 5/27/09)

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE SRCSO4( TC, SFLX )
#else
      SUBROUTINE SRCSO4( TC )
#endif
```

USES:

```
      USE BRAVO_MOD,          ONLY : GET_BRAVO_ANTHRO, GET_BRAVO_MASK
      USE CAC_ANTHRO_MOD,     ONLY : GET_CANADA_MASK,  GET_CAC_ANTHRO
      USE NEI2005_ANTHRO_MOD, ONLY : GET_NEI2005_ANTHRO
      USE NEI2005_ANTHRO_MOD, ONLY : NEI05_MASK => USA_MASK
      USE DAO_MOD,            ONLY : PBL
      USE DIAG_MOD,           ONLY : AD13_SO4_an,     AD13_SO4_bf
      USE EPA_NEI_MOD,        ONLY : GET_EPA_ANTHRO,  GET_EPA_BIOFUEL
      USE EPA_NEI_MOD,        ONLY : GET_USA_MASK
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE LOGICAL_MOD,        ONLY : LNEI99, LCAC, LBRAVO, LNEI05
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_OF_PBL, GET_PBL_TOP_L
      USE TIME_MOD,           ONLY : GET_DAY_OF_WEEK, GET_TS_EMIS
      USE TRACER_MOD,         ONLY : XNUMOL
      USE TRACERID_MOD,       ONLY : IDTSO4, IDTSO2
 [eml
      USE LOGICAL_MOD,        ONLY : LHIST
 eml]
```

```
      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! ND13 (for now)
      USE CMN_GCTM_MOD             ! SCALE_HEIGHT
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! SO4 mass [kg]
#if defined( DEVEL )
      REAL*8,  INTENT(INOUT) :: SFLX(IIPAR,JJPAR,LLPAR)
#endif
```

REVISION HISTORY:

```
(1 ) Emission of SO4 is read in SULFATE_READYR, in [kg/box/s].
     It is converted to [kg/box/timestep] here.
(2 ) Now use routine GET_TS_EMIS from the new "time_mod.f" (bmy, 3/27/03)
(3 ) For GEOS-4, convert PBL from [m] to [hPa] w/ the barometric law.
     Now references SCALE_HEIGHT from "CMN_GCTM".  Added BLTHIK variable
     to hold PBL thickness in [hPa]. (bmy, 1/15/04)
(4 ) Now references GET_EPA_ANTHRO, GET_EPA_BIOFUEL, and GET_USA_MASK from
     "epa_nei_mod.f".  Now references AD13_SO4_bf from "diag_mod.f".  Now
     references GET_AREA_CM2 from "grid_mod.f".  Now references
     GET_DAY_OF_WEEK from "time_mod.f".  Now references LNEI99 from
     "logical_mod.f".  Now can overwrite the anthro SOx emissions over
     the continental US if LNEI99=T.  Now references IDTSO4 from
     "tracerid_mod.f". (rch, rjp, bmy, 11/16/04)
(5 ) Remove reference to "pressure_mod.f".  Now reference GET_FRAC_OF_PBL
     and GET_PBL_TOP_L from "pbl_mix_mod.f".  Removed reference to header
     file CMN. (bmy, 2/22/05)
(6 ) Now references XNUMOL & XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(7 ) Now overwrite CAC emissions over Canada, if necessary (amv,  1/10/08)
(8 ) Need to add CAC_AN to the PRIVATE statement (bmy, 5/27/09)
(9 ) Now account for BRAVO SO4. Fix typo for CAC (phs, 8/24/09)
(10) Now account for NEI 2005 inventory (amv, 10/07/2009)
(11) Now calls SULFATE_PBL_MIX to do the PBL mixing of
     emissions (phs, 10/27/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.21 srcnh3

Subroutine SRCNH3 handles NH3 emissions into the GEOS-CHEM tracer array. (rjp, bmy, 12/17/01, 5/27/09)

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE SRCNH3( TC, SFLX )
#else
      SUBROUTINE SRCNH3( TC )
#endif
```

USES:

```
      USE CAC_ANTHRO_MOD,     ONLY : GET_CANADA_MASK
      USE CAC_ANTHRO_MOD,     ONLY : GET_CAC_ANTHRO
      USE NEI2005_ANTHRO_MOD, ONLY : GET_NEI2005_ANTHRO
      USE NEI2005_ANTHRO_MOD, ONLY : NEI05_MASK => USA_MASK
      USE DIAG_MOD,           ONLY : AD13_NH3_an, AD13_NH3_bb
      USE DIAG_MOD,           ONLY : AD13_NH3_bf, AD13_NH3_na
      USE DAO_MOD,            ONLY : PBL
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE EPA_NEI_MOD,        ONLY : GET_EPA_ANTHRO, GET_EPA_BIOFUEL
      USE EPA_NEI_MOD,        ONLY : GET_USA_MASK
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE LOGICAL_MOD,        ONLY : LNEI99, LCAC, LNEI05
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_OF_PBL, GET_PBL_TOP_L
      USE TIME_MOD,           ONLY : GET_DAY_OF_WEEK, GET_TS_EMIS
      USE TRACER_MOD,         ONLY : XNUMOL
      USE TRACERID_MOD,       ONLY : IDTNH3

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! ND13
      USE CMN_GCTM_MOD             ! SCALE_HEIGHT
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! NH3 tracer mass [kg]
#if defined( DEVEL )
      REAL*8,  INTENT(INOUT) :: SFLX(IIPAR,JJPAR,LLPAR)
#endif
```

REVISION HISTORY:

```
(1 ) Now save NH3 emissions to ND13 diagnostic (bmy, 12/13/02)
(2 ) Now reference AD13_NH3_na from "diag_mod.f", and archive natural
     source NH3 diagnostics for ND13.  Also consider natural source NH3
     when partitioning by level into the STT array. (rjp, bmy, 3/23/03)
(3 ) Now use routine GET_TS_EMIS from the new "time_mod.f" (bmy, 3/27/03)
(4 ) For GEOS-4, convert PBL from [m] to [hPa] w/ the barometric law.
     Now references SCALE_HEIGHT from "CMN_GCTM".  Added BLTHIK variable
     to hold PBL thickness in [hPa]. (bmy, 1/15/04)
(5 ) Now references GET_EPA_ANTHRO, GET_EPA_BIOFUEL, and GET_USA_MASK from
     "epa_nei_mod.f".  Now references GET_DAY_OF_WEEK from "time_mod.f".
     Now references LNEI99 from "logical_mod.f".  Now references
     GET_AREA_CM2 from "grid_mod.f".  Now references IDTNH3 from
```

```
      "tracerid_mod.f".  Now references XNUMOL from CMN_O3.  Now can
      overwrite the anthro & biofuel NH3 emissions over the continental US
      if LNEI99=T.  Now references IDTNH3 from "tracerid_mod.f".
      (rjp, rch, bmy, 11/16/04)
(6 ) Remove reference to "pressure_mod.f".  Now reference GET_FRAC_OF_PBL
      and GET_PBL_TOP_L from "pbl_mix_mod.f".  Removed reference to header
      file CMN. (bmy, 2/22/05)
(7 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(8 ) Need to add CAC_AN to the PRIVATE loop (bmy, 5/27/09)
(9 ) Added NIE 2005 (amv, 10/07/2009)
(10) Made NH3an 3D; Calls SULFATE_PBL_MIX to do the PBL mixing of
      emissions, and allows for emissions above the PBL (phs, 10/27/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.22 get_oh

Function GET_OH returns OH from SMVGEAR's CSPEC array (for coupled runs) or monthly mean OH (for offline runs). Imposes a diurnal variation on OH for offline simulations. (bmy, 12/16/02, 7/20/04)

INTERFACE:

```
FUNCTION GET_OH( I, J, L ) RESULT( OH_MOLEC_CM3 )
```

USES:

```
USE COMODE_MOD,    ONLY : CSPEC, JLOP
USE DAO_MOD,       ONLY : SUNCOS
USE ERROR_MOD,     ONLY : ERROR_STOP
USE GLOBAL_OH_MOD, ONLY : OH
USE TIME_MOD,      ONLY : GET_TS_CHEM
USE TRACER_MOD,    ONLY : ITS_A_FULLCHEM_SIM, ITS_AN_AEROSOL_SIM
USE TRACERID_MOD,  ONLY : IDOH

USE CMN_SIZE_MOD        ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L ! Indices for lon, lat, vertical level
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDOH (bmy, 11/1/02)
(2 ) Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(3 ) Now reference ITS_A_FULLCHEM_SIM, ITS_AN_AEROSOL_SIM from
      "tracer_mod.f".  Also replace IJSURF w/ an analytic function.
      (bmy, 7/20/04)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.23 set_oh

Subroutine SET_OH saves the modified OH value back to SMVGEAR's CSPEC array for coupled sulfate/aerosol simulations. (bmy, 12/16/02)

INTERFACE:

```
SUBROUTINE SET_OH( I, J, L, OH )
```

USES:

```
USE COMODE_MOD,   ONLY : CSPEC, JLOP
USE TRACERID_MOD, ONLY : IDOH

USE CMN_SIZE_MOD       ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L ! Indices for lon, lat, vertical level
REAL*8,  INTENT(IN) :: OH      ! OH at (I,J,L) to be saved into CSPEC
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDOH (bmy, 12/16/02)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.24 get_no3

Function GET_NO3 returns NO3 from SMVGEAR's CSPEC array (for coupled runs) or monthly mean OH (for offline runs). For offline runs, the concentration of NO3 is set to zero during the day. (rjp, bmy, 12/16/02)

INTERFACE:

```
FUNCTION GET_NO3( I, J, L ) RESULT( NO3_MOLEC_CM3 )
```

USES:

```
USE COMODE_MOD,     ONLY : CSPEC, JLOP
USE DAO_MOD,        ONLY : AD,    SUNCOS
USE ERROR_MOD,      ONLY : ERROR_STOP
USE GLOBAL_NO3_MOD, ONLY : NO3
USE TRACER_MOD,     ONLY : ITS_A_FULLCHEM_SIM, ITS_AN_AEROSOL_SIM
USE TRACERID_MOD,   ONLY : IDNO3

USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L ! Indices for lon, lat, vertical level
```

REVISION HISTORY:

```
(1 ) Now references ERROR_STOP from "error_mod.f".  We also assume that
     SETTRACE has been called to define IDNO3.  Now also set NO3 to
     zero during the day. (rjp, bmy, 12/16/02)
(2 ) Now reference ITS_A_FULLCHEM_SIM and ITS_AN_AEROSOL_SIM from
     "tracer_mod.f".  Also remove reference to CMN.   Also replace
     IJSURF with an analytic function. (bmy, 7/20/04)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.25 set_no3

Subroutine SET_NO3 saves the modified NO3 value back to SMVGEAR's CSPEC array for coupled lfate/aerosol simulations. (rjp, bmy, 12/16/02, 7/20/04)

INTERFACE:

```
SUBROUTINE SET_NO3( I, J, L, NO3 )
```

USES:

```
USE COMODE_MOD,   ONLY : CSPEC, JLOP
USE TRACERID_MOD, ONLY : IDNO3

USE CMN_SIZE_MOD       ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L ! Indices for lon, lat, vertical level
REAL*8,  INTENT(IN) :: NO3     ! NO3 at (I,J,L) to be saved into CSPEC
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDNO3. (bmy, 12/16/02)
(2 ) Remove references to "error_mod.f" and CMN (bmy, 7/20/04)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.26 get_o3

Function GET_O3 returns monthly mean O3 for offline sulfate aerosol simulations. (bmy, 12/16/02, 10/25/05)

INTERFACE:

```
FUNCTION GET_O3( I, J, L ) RESULT( O3_VV )
```

USES:

```
      USE COMODE_MOD,   ONLY : CSPEC, JLOP, VOLUME
      USE DAO_MOD,      ONLY : AIRDEN
      USE ERROR_MOD,    ONLY : ERROR_STOP
      USE TRACER_MOD,   ONLY : ITS_A_FULLCHEM_SIM, ITS_AN_AEROSOL_SIM
      USE TRACER_MOD,   ONLY : XNUMOLAIR
      USE TRACERID_MOD, ONLY : IDO3

      USE CMN_SIZE_MOD       ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: I, J, L ! Indices for lon, lat, vertical level
```

REVISION HISTORY:

```
    (1 ) We assume SETTRACE has been called to define IDO3. (bmy, 12/16/02)
    (2 ) Now reference inquiry functions from "tracer_mod.f" (bmy, 7/20/04)
    (3 ) Now remove reference to CMN, it's obsolete.  (bmy, 8/22/05)
    (4 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
    22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.27 read_nonerup_volc

Subroutine READ_NONERUP_VOLC reads SO2 emissions from non-eruptive volcanoes. (rjp, bdf, bmy, jaf, 9/19/02, 10/3/05, 10/15/09)

INTERFACE:

```
      SUBROUTINE READ_NONERUP_VOLC( INDAY, INMONTH, INYEAR )
```

USES:

```
      USE BPCH2_MOD,      ONLY : GET_TAU0, READ_BPCH2
      USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
      USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
      USE TIME_MOD,       ONLY : EXPAND_DATE

      USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)     :: INDAY   ! Current 2-digit day
      INTEGER, INTENT(IN)     :: INMONTH ! Current month number (1-12)
      INTEGER, INTENT(IN)     :: INYEAR  ! Current 4-digit year
```

REVISION HISTORY:

```
  (1 ) Split off from old module routine "sulfate_readyr" (bmy, 9/19/02)
  (2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
  (3 ) Now read files from "sulfate_sim_200508/" (bmy, 7/28/05)
  (4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
  (5 ) Complete re-write as volcanic emissions are now monthly and
 stored as BPCH files (jaf, bmy, 10/15/09)
  (6 ) Now use MNYEAR_VOLC and MXYEAR_VOLC as 1st and last year of emissions.
       (ccc, 9/30/10)
  (7 ) Volcanic data have been updated. Use a new directory. (ccc, 9/30/10)
  22 Dec 2011 - M. Payer    - Added ProTeX headers
  13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
  24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.88.28 read_erup_volc

Subroutine READ_ERUP_VOLC reads SO2 emissions from eruptive volcanoes. (rjp, bdf, bmy, jaf, 9/19/02, 10/3/05, 10/15/09)

INTERFACE:

```
      SUBROUTINE READ_ERUP_VOLC( INDAY, INMONTH, INYEAR )
```

USES:

```
      USE BPCH2_MOD,      ONLY : GET_TAU0, READ_BPCH2
      USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
      USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
      USE TIME_MOD,       ONLY : EXPAND_DATE

      USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)     :: INDAY   ! Current 2-digit day
      INTEGER, INTENT(IN)     :: INMONTH ! Current month number (1-12)
      INTEGER, INTENT(IN)     :: INYEAR  ! Current 4-digit year
```

REVISION HISTORY:

```
  (1 ) Split off from old module routine "sulfate_readyr" (bmy, 9/19/02)
  (2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
  (3 ) Now read files from "sulfate_sim_200508/" (bmy, 7/28/05)
  (4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
  (5 ) Complete re-write as volcanic emissions are now monthly and
 stored as BPCH files (jaf, bmy, 10/15/09)
  (6 ) Now use MNYEAR_VOLC and MXYEAR_VOLC as 1st and last year of emissions.
       (ccc, 9/30/10)
  (7 ) Volcanic data have been updated. Use a new directory. (ccc, 9/30/10)
```

```
    22 Dec 2011 - M. Payer    - Added ProTeX headers
    13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
    24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.88.29 read_anthro_sox

Suborutine READ_ANTHRO_SOx reads the anthropogenic SOx from disk, and partitions it into anthropogenic SO2 and SO4. (rjp, bdf, bmy, 9/20/02, 10/31/08)

INTERFACE:

```
      SUBROUTINE READ_ANTHRO_SOx( THISMONTH, NSEASON )
```

USES:

```
      USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
      USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
      USE DIRECTORY_MOD,        ONLY : DATA_DIR
      USE EDGAR_MOD,            ONLY : GET_EDGAR_ANTH_SO2
      USE EMEP_MOD,             ONLY : GET_EMEP_ANTHRO
      USE EMEP_MOD,             ONLY : GET_EUROPE_MASK
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff
      USE GRID_MOD,             ONLY : GET_XMID,        GET_YMID
      USE GRID_MOD,             ONLY : GET_AREA_CM2
      USE LOGICAL_MOD,          ONLY : LFUTURE,         LEDGARSOx
      USE LOGICAL_MOD,          ONLY : LSTREETS,        LEMEP
      USE STREETS_ANTHRO_MOD,   ONLY : GET_SE_ASIA_MASK
      USE STREETS_ANTHRO_MOD,   ONLY : GET_STREETS_ANTHRO
      USE TIME_MOD,             ONLY : GET_YEAR
      USE TRACER_MOD,           ONLY : XNUMOL
      USE TRACERID_MOD,         ONLY : IDTSO2, IDTSO4
      USE TRANSFER_MOD,         ONLY : TRANSFER_2D
      USE SCALE_ANTHRO_MOD,     ONLY : GET_ANNUAL_SCALAR
 [eml
      USE LOGICAL_MOD,          ONLY : LHIST
 eml]

      USE CMN_SIZE_MOD               ! Size parameters
      USE CMN_O3_MOD                 ! FSCALYR
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)           :: THISMONTH ! Current month number (1-12)
      INTEGER, INTENT(IN)           :: NSEASON   ! Season #: 1=DJF; 2=MAM;
                                                 !           3=JJA; 4=SON
```

REVISION HISTORY:

```
(1 ) Now use functions GET_XMID and GET_YMID to compute lon and lat
     centers of grid box (I,J).  Now replace DXYP(JREF)*1d4 with routine
     GET_AREA_CM2 of "grid_mod.f".  Now use functions GET_MONTH and
     GET_YEAR of time_mod.f".  Now call READ_BPCH2 with QUIET=.TRUE.
     (bmy, 3/27/03)
(2 ) Now references DATA_DIR from "directory_mod.f".  Also removed
     reference to CMN, it's not needed. (bmy, 7/20/04)
(3 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids (bmy, 8/16/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(6 ) Now computes future SOx emissions (swu, bmy, 5/30/06)
(7 ) Now can read either EDGAR or GEIA emissions (avd, bmy, 7/14/06)
(8 ) Now overwrite David Streets' SO2, if necessary (yxw, bmy, 8/14/06)
(9 ) Now accounts for FSCLYR (phs, 3/17/08)
(9 ) Bug fix: Using tracer #30 in the call to GET_STREETS_ANTHRO can cause
     problems when adding or removing species.  Replace w/ IDTNH3.
     (dkh, 10/31/08)
(10) Account for multilevels emissions (amv, 10/07/2009)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_XMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
```

1.88.30 read_ocean_dms

Subroutine READ_OCEAN_DMS reads seawater concentrations of DMS (nmol/L). (rjp, bdf, bmy, 9/20/02, 10/3/05)

INTERFACE:

```
SUBROUTINE READ_OCEAN_DMS( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD        ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Extracted from old module routine SULFATE_READMON (bmy, 9/18/02)
(2 ) Now call READ_BPCH2 with QUIET=.TRUE. (bmy, 3/27/03)
(3 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(4 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids (bmy, 8/16/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.31 read_sst

Subroutine READ_SST reads monthly mean sea surface temperatures. (rjp, bdf, bmy, 9/18/02, 7/13/09)

INTERFACE:

```
SUBROUTINE READ_SST( THISMONTH, THISYEAR )
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR,        DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE TRANSFER_MOD,   ONLY : TRANSFER_2D

USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)     :: THISMONTH ! Current month number (1-12)
INTEGER, INTENT(IN)     :: THISYEAR  ! Current 4-digit year
```

REVISION HISTORY:

```
(1 ) Extracted from old module routine SULFATE_READMON (bmy, 9/18/02)
(2 ) Now call READ_BPCH2 with QUIET=.TRUE. (bmy, 3/27/03)
(3 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(4 ) Now use interannual SST data from NOAA if present; otherwise use
     climatological SST data.  Now read data for both GCAP and GEOS
     grids (bmy, 8/16/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Now read int'annual SST data on the GEOS 1x1 grid (bmy, 11/17/05)
(7 ) Last year of data is now 2008 (bmy, 7/13/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.88.32 read_biofuel_so2

Subroutine READ_BIOFUEL_SO2 reads monthly mean biomass burning emissions for SO2. SOx is read in, and converted to SO2. (rjp, bdf, bmy, phs, 1/16/03, 12/23/08)

INTERFACE:

```
      SUBROUTINE READ_BIOFUEL_SO2( THISMONTH )
```

USES:

```
      USE BIOMASS_MOD,          ONLY : BIOMASS
      USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
      USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
      USE DIRECTORY_MOD,        ONLY : DATA_DIR,        DATA_DIR_1x1
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2bf
      USE LOGICAL_MOD,          ONLY : LBIOMASS,        LFUTURE
      USE TIME_MOD,             ONLY : ITS_A_LEAPYEAR
      USE TRACER_MOD,           ONLY : XNUMOL
      USE TRACERID_MOD,         ONLY : IDTSO2
      USE TRANSFER_MOD,         ONLY : TRANSFER_2D
      USE REGRID_A2A_MOD,       ONLY : DO_REGRID_A2A
[eml
      USE LOGICAL_MOD,          ONLY : LHIST
      USE TIME_MOD,             ONLY : GET_HISTYR
eml]

      USE CMN_SIZE_MOD               ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)           :: THISMONTH ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Extracted from old module routine SULFATE_READMON (bmy, 9/18/02)
(2 ) Modified molar ratio of biomass burning SO2 per CO.  Added SO2
     emission from biofuel burning. (rjp, bmy, 1/16/03)
(3 ) Now replace DXYP(J+J0)*1d4 with routine GET_AREA_CM2 of "grid_mod.f"
     Now replace MONTH with the argument THISMONTH.  Now call READ_BPCH2
     with QUIET=.TRUE. (bmy, 3/27/03)
(4 ) Now references DATA_DIR from "directory_mod.f".  Also removed
     references to CMN and CMN_SETUP. (bmy, 7/20/04)
(5 ) Now can read either seasonal or interannual biomass burning emissions.
     Now references routines from both "logical_mod.f" and "time_mod.f".
     Now reads SO2 biomass emissions directly rather than computing
     it by mole fraction from CO. (rjp, bmy, 1/11/05)
(6 ) Now read data for both GCAP and GEOS grids (bmy, 8/16/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Now computes future biomass emissions, if necessary (swu, bmy, 5/30/06)
```

```
(9 ) Now only read the biofuel, we have moved the biomass-reading code
     to "gc_biomass_mod.f" for compatibility with GFED2 biomass emissions
     (bmy, 9/27/06)
(10) Now prevent seg fault if BIOMASS emissions are turned off.
     (bmy, 10/3/06)
(11) Renamed READ_BIOFUEL_SO2, and move all biomass code to GET_BIOMASS_SO2
     to account for several GFED2 products (yc, phs, 12/23/08)
(12) IDBSO2 is not used anymore (ccc, 01/29/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Removed reference to GET_AREA_CM2
08 Mar 2012 - M. Payer    - Added modifications for historical emissions of
                            SO2 (E. Leibensperger)
06 Apr 2012 - M. Payer    - Changed regrid algorithm to map_a2a (M. Cooper)
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
```

1.88.33 get_biomass_so2

Subroutine GET_BIOMASS_SO2 retrieve monthly/8-day/3hr biomass burning emissions for SO2. (yc, phs, 12/23/08)

INTERFACE:

```
SUBROUTINE GET_BIOMASS_SO2
```

USES:

```
!IDBSO2 now in tracerid_mod (fp, 6/2009)
!USE BIOMASS_MOD,          ONLY : BIOMASS,         IDBSO2
USE BIOMASS_MOD,          ONLY : BIOMASS
USE TRACERID_MOD,         ONLY : IDBSO2
USE GRID_MOD,             ONLY : GET_AREA_CM2
USE TRACER_MOD,           ONLY : XNUMOL
USE TRACERID_MOD,         ONLY : IDTSO2
USE TRANSFER_MOD,         ONLY : TRANSFER_2D

USE CMN_SIZE_MOD               ! Size parameters
```

REVISION HISTORY:

```
(1 ) Extracted from old module subroutine READ_BIOMASS_SO2
     (yc, phs, 12/23/08)
(2 ) IDBSO2 is now in tracerid_mod.f (fp, 6/2009)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.34 read_aircraft_so2

Subroutine READ_AIRCRAFT_SO2 reads monthly mean aircraft fuel emissions and converts them to SO2 emissions. (rjp, bdf, bmy, 9/18/02, 10/3/05)

INTERFACE:

```
SUBROUTINE READ_AIRCRAFT_SO2( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_RES_EXT, GET_TAU0, READ_BPCH2
USE DAO_MOD,       ONLY : BXHEIGHT
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IU_FILE, IOERROR

USE CMN_SIZE_MOD        ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: THISMONTH ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Extracted from old module routine SULFATE_READMON (bmy, 9/18/02)
(2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(3 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids (bmy, 8/16/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
02 Jul 2012 - R. Yantosca - Add simple kludge that prevents OOB error when
                            reading SO2 aircraft data for NA nested grid
```

1.88.35 read_ship_so2

Subroutine READ_SHIP_SO2 reads in ship SO2 emissions, from either Corbett et al or EDGAR inventories. (bec, qli, 10/01/03, 7/14/06)

INTERFACE:

```
SUBROUTINE READ_SHIP_SO2( THISMONTH )
```

USES:

```
USE ARCTAS_SHIP_EMISS_MOD,ONLY : GET_ARCTAS_SHIP
USE ICOADS_SHIP_MOD,      ONLY : GET_ICOADS_SHIP   !(cklee, 7/09/09)
USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD,        ONLY : DATA_DIR
USE EDGAR_MOD,            ONLY : GET_EDGAR_SHIP_SO2
```

```
      USE EMEP_MOD,             ONLY : GET_EMEP_ANTHRO, GET_EUROPE_MASK
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff
      USE GRID_MOD,             ONLY : GET_AREA_CM2
      USE LOGICAL_MOD,          ONLY : LEDGARSHIP,      LFUTURE,
     &                                 LARCSHIP,        LSHIPSO2,
     $                                 LEMEPSHIP
      USE LOGICAL_MOD,          ONLY : LICOADSSHIP  !(cklee, 6/30/09)
      USE TRACER_MOD,           ONLY : XNUMOL
      USE TRACERID_MOD,         ONLY : IDTSO2
      USE TRANSFER_MOD,         ONLY : TRANSFER_2D

      USE CMN_SIZE_MOD               ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)           :: THISMONTH ! Current month (1-12)
```

REVISION HISTORY:

```
(1 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(2 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids. (bmy, 8/16/05)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(5 ) Now get EDGAR ship SO2 emissions if necessary.  Also apply future
     emissions scale factors to the default Corbett et al ship emissions.
     (avd, bmy, 7/14/06)
(6 ) Now references GET_ARCTAS_HIP from 'arctas_ship_emiss_mod.f" and
     GET_EMEP_ANTHRO to get ARCTAS and EMEP SO2 ship emissions (phs,12/5/08)
(7 ) Now get ICOADS ship SO2 if necessary (phs, cklee, 6/30/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.36 read_anthro_nh3

Subroutine READ_ANTHRO_NH3 reads the monthly mean anthropogenic NH3 emissions from disk and converts to [kg NH3/box/s]. (rjp, bdf, bmy, 9/20/02, 3/5/10)

INTERFACE:

```
      SUBROUTINE READ_ANTHRO_NH3( THISMONTH )
```

USES:

```
      USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
      USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
      USE DIRECTORY_MOD,        ONLY : DATA_DIR
      USE EMEP_MOD,             ONLY : GET_EMEP_ANTHRO
```

```
      USE EMEP_MOD,             ONLY : GET_EUROPE_MASK
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NH3an
      USE LOGICAL_MOD,          ONLY : LFUTURE,         LSTREETS
      USE LOGICAL_MOD,          ONLY : LEMEP
      USE STREETS_ANTHRO_MOD,   ONLY : GET_SE_ASIA_MASK
      USE STREETS_ANTHRO_MOD,   ONLY : GET_STREETS_ANTHRO
      USE TRACERID_MOD,         ONLY : IDTNH3
      USE TRANSFER_MOD,         ONLY : TRANSFER_2D

      USE CMN_SIZE_MOD               ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)           :: THISMONTH ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Renamed from NH3_READ to READ_ANTHRO_NH3.  Also updated comments,
     made cosmetic changes. (bmy, 9/20/02)
(2 ) Changed filename to NH3_anthsrce.geos.*.  Also now reads data under
     category name "NH3-ANTH". (rjp, bmy, 3/23/03)
(3 ) Now reads from NH3emis.monthly.geos.* files.  Now call READ_BPCH2
     with QUIET=.TRUE. (bmy, 3/27/03)
(4 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(5 ) Now read files from "sulfate_sim_200508/". Now read data for both
     GCAP and GEOS grids. (bmy, 8/16/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Now compute future emissions, if necessary (swu, bmy, 5/30/06)
(7 ) Now overwrite w/ David Streets' NH3, if necessary (yxw, bmy, 8/17/06)
(8 ) Bug fix: Using tracer #30 in the call to GET_STREETS_ANTHRO can cause
     problems when adding or removing species.  Replace w/ IDTNH3.
     (dkh, 10/31/08)
(9 ) Now check if NH3 Streets is available (phs, 12/10/08)
(10) Bug fix -- STREETS needs to be PRIVATE (dkh, bmy, 3/5/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.37 read_natural_nh3

Subroutine READ_NATURAL_NH3 reads the monthly mean natural NH3 emissions from disk and converts to [kg NH3/box/s]. (rjp, bdf, bmy, 9/20/02, 10/3/05)

INTERFACE:

```
      SUBROUTINE READ_NATURAL_NH3( THISMONTH )
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
```

```
      USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE TRANSFER_MOD,  ONLY : TRANSFER_2D

      USE CMN_SIZE_MOD        ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: THISMONTH ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Updated FORMAT string.  Now also call READ_BPCH2 with QUIET=.TRUE.
     (bmy, 4/8/03)
(2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(3 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids. (bmy, 8/16/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.38 read_biofuel_nh3

Subroutine READ_BIOFUEL_NH3 reads the monthly mean biomass NH3 and biofuel emissions from disk and converts to [kg NH3/box/s]. (rjp, bdf, bmy, phs, 9/20/02, 12/23/08)

INTERFACE:

```
      SUBROUTINE READ_BIOFUEL_NH3( THISMONTH )
```

USES:

```
      !USE BIOMASS_MOD,          ONLY : BIOMASS,         IDBNH3
      USE BIOMASS_MOD,          ONLY : BIOMASS
      USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
      USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
      USE DIRECTORY_MOD,        ONLY : DATA_DIR
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NH3bf
      USE LOGICAL_MOD,          ONLY : LBIOMASS,        LFUTURE
      USE TIME_MOD,             ONLY : ITS_A_LEAPYEAR
      USE TRACER_MOD,           ONLY : XNUMOL
      USE TRACERID_MOD,         ONLY : IDTNH3
      USE TRANSFER_MOD,         ONLY : TRANSFER_2D

      USE CMN_SIZE_MOD               ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)           :: THISMONTH ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Renamed from NH3_READ to READ_BIOMASS_NH3.  Also updated comments,
     made cosmetic changes.  Now reads in both biomass and biofuel
     emissions. (rjp, bmy, 12/13/02)
(2 ) Now replace DXYP(J+J0) with routine GET_AREA_M2 of "grid_mod.f"
     Now use function GET_YEAR from "time_mod.f".  Replace MONTH with
     THISMONTH when referencing the NMDAY variable.  Now call READ_BPCH2
     with QUIET=.TRUE. (bmy, 3/27/03)
(3 ) If using interannual biomass emissions, substitute seasonal emissions
     for years where internannual emissions do not exist.  Now also
     reference GET_TAU from "time_mod.f" (bmy, 5/15/03)
(4 ) Now use ENCODE statement for PGI/F90 on Linux (bmy, 9/29/03)
(5 ) Changed cpp switch name from LINUX to LINUX_PGI (bmy, 12/2/03)
(6 ) Now references DATA_DIR from "directory_mod.f".  Now references LBBSEA
     from "logical_mod.f".  Removed references to CMN and CMN_SETUP.
     (bmy, 7/20/04)
(7 ) Now can read either seasonal or interannual biomass burning emissions.
     Now references routines from both and "time_mod.f".  Now reads SO2
     biomass emissions directly rather than computing it by mole fraction
     from CO. (rjp, bmy, 1/11/05)
(8 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids. (bmy, 8/16/05)
(9 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(10) Now only read the biofuel, we have moved the biomass-reading code to
     "gc_biomass_mod.f" for compatibility with GFED2 biomass emissions
     (bmy, 9/27/06)
(11) Prevent seg fault error when LBIOMASS=F (bmy, 11/3/06)
(12) Renamed READ_BIOFUEL_NH3, and move all biomass code to GET_BIOMASS_NH3
     to account for several GFED2 products (yc, phs, 12/23/08)
(13) IDBNH3 is not used anymore (ccc, 01/29/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Removed reference to GET_AREA_CM2
```

1.88.39 get_biomass_nh3

Subroutine GET_BIOMASS_NH3 retrieve the monthly/8days/3hr mean biomass NH3 (yc, phs, 12/23/08)

INTERFACE:

```
SUBROUTINE GET_BIOMASS_NH3
```

USES:

```
! IDBNH3 now in tracerid_mod (fp, 6/2009)
!USE BIOMASS_MOD,          ONLY : BIOMASS,         IDBNH3
USE BIOMASS_MOD,          ONLY : BIOMASS
```

```
      USE GRID_MOD,             ONLY : GET_AREA_CM2
      USE TRACER_MOD,           ONLY : XNUMOL
      USE TRACERID_MOD,         ONLY : IDTNH3, IDBNH3

      USE CMN_SIZE_MOD               ! Size parameters
```

REVISION HISTORY:

```
(1 ) Extracted from old module subroutine READ_BIOMASS_NH3
     (yc, phs, 12/23/08)
(2 ) IDBNH3 is in tracerid_mod.f now (fp, 6/2009)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.88.40 read_oxidant

Subroutine READ_OXIDANT reads in monthly mean H2O2 and O3 fields for the offline sulfate + aerosol simulation. (rjp, bdf, bmy, 11/1/02, 10/3/05)

INTERFACE:

```
      SUBROUTINE READ_OXIDANT( MONTH )
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
      USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE TRANSFER_MOD,  ONLY : TRANSFER_3D_TROP

      USE CMN_SIZE_MOD        ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: MONTH ! Emission timestep in minutes
```

REVISION HISTORY:

```
(1 ) Now call READ_BPCH2 with QUIET=.TRUE. (bmy, 3/27/03)
(2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(3 ) Now read files from "sulfate_sim_200508/offline/".  Now read data
     for both GEOS and GCAP grids (bmy, 8/16/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.41 ohno3time

Subroutine OHNO3TIME computes the sum of cosine of the solar zenith angle over a 24 hour day, as well as the total length of daylight. This is needed to scale the offline OH and NO3 concentrations. (rjp, bmy, 12/16/02, 3/30/04)

INTERFACE:

```
SUBROUTINE OHNO3TIME
```

USES:

```
USE GRID_MOD, ONLY : GET_XMID,    GET_YMID_R
USE TIME_MOD, ONLY : GET_NHMSb,   GET_ELAPSED_SEC
USE TIME_MOD, ONLY : GET_TS_CHEM, GET_DAY_OF_YEAR, GET_GMT

USE CMN_SIZE_MOD   ! Size parameters
USE CMN_GCTM_MOD
```

REVISION HISTORY:

```
(1 ) Copy code from COSSZA directly for now, so that we don't get NaN
     values.  Figure this out later (rjp, bmy, 1/10/03)
(2 ) Now replace XMID(I) with routine GET_XMID from "grid_mod.f".
     Now replace RLAT(J) with routine GET_YMID_R from "grid_mod.f".
     Removed NTIME, NHMSb from the arg list.  Now use GET_NHMSb,
     GET_ELAPSED_SEC, GET_TS_CHEM, GET_DAY_OF_YEAR, GET_GMT from
     "time_mod.f". (bmy, 3/27/03)
(3 ) Now store the peak SUNCOS value for each surface grid box (I,J) in
     the COSZM array. (rjp, bmy, 3/30/04)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.42 init_sulfate

Subroutine INIT_SULFATE initializes and zeros all allocatable arrays declared in "sulfate_mod.f" (bmy, 6/2/00, 10/15/09)

INTERFACE:

```
SUBROUTINE INIT_SULFATE
```

USES:

```
USE DRYDEP_MOD,    ONLY : DEPNAME, NUMDEP
USE ERROR_MOD,     ONLY : ALLOC_ERR
USE LOGICAL_MOD,   ONLY : LDRYD
USE TRACER_MOD,    ONLY : ITS_AN_AEROSOL_SIM

USE CMN_SIZE_MOD        ! Size parameters
```

REVISION HISTORY:

```
(1 ) Only allocate some arrays for the standalone simulation (NSRCX==10).
     Also reference NSRCX from "CMN".  Now eferences routine ALLOC_ERR
     from "error_mod.f" ((rjp, bdf, bmy, 10/15/02)
(2 ) Now also allocate the IJSURF array to keep the 1-D grid box indices
     for SUNCOS (for both coupled & offline runs).  Now allocate PH2O2m
     and O3m for offline runs.  Also allocate ESO2_bf (bmy, 1/16/03)
(3 ) Now allocate ENH3_na array (rjp, bmy, 3/23/03)
(4 ) Now allocate COSZM for offline runs (bmy, 3/30/04)
(5 ) Now allocate ESO2_sh array (bec, bmy, 5/20/04)
(6 ) Now allocates ITS_AN_AEROSOL_SIM from "tracer_mod.f".  Now remove
     IJSURF (bmy, 7/20/04)
(7 ) Now locate species in the DEPSAV array here instead of in CHEMSULFATE.
     Now reference LDRYD from "logical_mod.f".  Updated for AS, AHS, LET,
     SO4aq, NH4aq. (bmy, 1/6/06)
(8 ) Now allocates PSO4_ss, PNITs (bec, bmy, 4/13/05)
(9 ) Initialize drydep flags outside of IF block (bmy, 5/23/06)
(10) Now redimension EEV & NEV arrays for new SO2 volcanic emissions
     inventory.  Deleted obsolete arrays from older SO2 volcanic
     emissions inventory. (jaf, bmy, 10/15/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.88.43 cleanup_sulfate

Subroutine CLEANUP_SULFATE deallocates all previously allocated arrays for sulfate emissions – call at the end of the run (bmy, 6/1/00, 10/15/09)

INTERFACE:

```
SUBROUTINE CLEANUP_SULFATE
```

REVISION HISTORY:

```
(1 ) Now also deallocates IJSURF. (bmy, 11/12/02)
(2 ) Now also deallocates ENH3_na (rjp, bmy, 3/23/03)
(3 ) Now also deallocates COSZM (rjp, bmy, 3/30/04)
(4 ) Now also deallocates ESO4_sh (bec, bmy, 5/20/04)
(5 ) Now remove IJSURF (bmy, 7/20/04)
(6 ) Bug fix: now deallocate PSO4_ss, PNITs (bmy, 5/3/06)
(7 ) Deleted obsolete arrays from older SO2 volcanic emissions
     inventory (jaf, bmy, 10/15/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.89 Fortran: Module Interface tagged_ox_mod

Module TAGGED_OX_MOD contains variables and routines to perform a tagged Ox simulation. P(Ox) and L(Ox) rates need to be archived from a full chemistry simulation before

you can run w/ Tagged Ox.

INTERFACE:

```
      MODULE TAGGED_OX_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: ADD_STRAT_POX
      PUBLIC  :: CHEM_TAGGED_OX
      PUBLIC  :: CLEANUP_TAGGED_OX
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: GET_REGIONAL_POX
      PRIVATE :: INIT_TAGGED_OX
      PRIVATE :: READ_POX_LOX
```

REVISION HISTORY:

```
   20 Aug 2003 - A. Fiore    - Initial version
   (1 ) Now accounts for GEOS-4 PBL being in meters (bmy, 1/15/04)
   (2 ) Bug fix: don't put function call in WRITE statement (bmy, 2/20/04)
   (3 ) Now bracket AD44 with an !$OMP CRITICAL block (bmy, 3/24/04)
   (4 ) Now define regions w/ levels in GET_REGIONAL_POX (amf,rch,bmy,5/27/04)
   (5 ) Bug fix-avoid seg fault if PBLFRAC isn't allocated (bdf, bmy, 10/12/04)
   (6 ) Now reference "pbl_mix_mod.f" (bmy, 2/17/05)
   (7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (8 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
   (9 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
   (10) Modified for variable tropopause (phs, bmy, 1/19/07)
   (11) Now use LLTROP instead of LLTROP_FIX everywhere (bmy, 12/4/07)
   (12) Now use LD65 instead of LLTROP everywhere (phs, 11/17/08)
   (13) Updates for LINOZ (dbj, jliu, bmy, 10/26/09)
   19 Nov 2010 - R. Yantosca - Added ProTeX headers
   28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
   01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
```

1.89.1 add_strat_pox

Subroutine ADD_STRAT_POX adds the stratospheric influx of Ox to the stratospheric Ox tracer. This is called from routine Do_Synoz, which is applied when the tracer array has units of [v/v].

INTERFACE:

```
SUBROUTINE ADD_STRAT_POX( I, J, L, POx )
```

USES:

```
USE TRACER_MOD,   ONLY : STT
USE TRACERID_MOD, ONLY : IDTOxStrt

USE CMN_SIZE_MOD           ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I     ! GEOS-Chem grid box lon index
INTEGER, INTENT(IN) :: J     ! GEOS-Chem grid box lat index
INTEGER, INTENT(IN) :: L     ! GEOS-Chem grid box level index
REAL*8,  INTENT(IN) :: POx   ! P(Ox) in the stratosphere [v/v]
```

REVISION HISTORY:

```
19 Aug 2003 - R. Yantosca - Initial version
(1 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
10 Jun 2012 - L. Murray - Enable tagged Ox for Synoz.
```

1.89.2 read_pox_lox

Subroutine READ_POX_LOX reads previously-archived Ox production and loss rates from binary punch file format.

INTERFACE:

```
SUBROUTINE READ_POX_LOX
```

USES:

```
USE BPCH2_MOD,     ONLY : READ_BPCH2
USE DIRECTORY_MOD, ONLY : O3PL_DIR
USE TIME_MOD,      ONLY : EXPAND_DATE
USE TIME_MOD,      ONLY : GET_NYMD
USE TIME_MOD,      ONLY : GET_TAU
USE TRANSFER_MOD,  ONLY : TRANSFER_3D_TROP
! JLIU,2008/10/01
USE CHARPAK_MOD,   ONLY : STRREPL
USE TIME_MOD,      ONLY : YMD_EXTRACT
USE TIME_MOD,      ONLY : ITS_A_LEAPYEAR
USE TIME_MOD,      ONLY : GET_DAY_OF_YEAR
USE TIME_MOD,      ONLY : GET_YEAR
USE TIME_MOD,      ONLY : GET_HOUR
USE DIAG_PL_MOD                                    !dbj
USE JULDAY_MOD,    ONLY : JULDAY                   !dbj
```

```
      USE CMN_SIZE_MOD ! Size parameters
      USE CMN_DIAG_MOD ! LD65
```

REVISION HISTORY:

```
20 Aug 2003 - R. Yantosca - Initial version
(1 ) Updated from the old routine "chemo3_split.f" (rch, bmy, 8/20/03)
(2 ) Now references O3PL_DIR from "directory_mod.f" (bmy, 7/20/04)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Use LLTROP_FIX to limit array size to case of non-variable tropopause.
     Also zero ARRAY to avoid numerical problems (phs, 1/19/07)
(5 ) Now use LLTROP instead of LLTROP_FIX (phs, bmy, 12/4/07)
(6 ) Now use LD65, since this is the number of levels use to
     save diag20 (phs, 11/17/08)
(7 ) Updates for LINOZ (dbj, jliu, bmy, 10/16/09)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.89.3 get_regional_pox

Subroutine GET_REGIONAL_POX returns the P(Ox) for each of the tagged Ox tracers. Tagged Ox tracers are defined by both geographic location and altitude.

INTERFACE:

```
      SUBROUTINE GET_REGIONAL_POX( I, J, L, PP )
```

USES:

```
      USE DAO_MOD,         ONLY : PBL
      USE GRID_MOD,        ONLY : GET_XMID,  GET_YMID
      USE TIME_MOD,        ONLY : GET_TS_CHEM
      USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_TROP

      USE CMN_SIZE_MOD       ! Size parameters
      USE CMN_DIAG_MOD       ! ND44, ND65, LD65
      USE CMN_GCTM_MOD       ! SCALE_HEIGHT
```

INPUT PARAMETERS:

```
      ! GEOS-Chem grid box indices for lon, lat, alt
      INTEGER, INTENT(IN)  :: I, J, L
```

OUTPUT PARAMETERS:

```
      ! Array containing P(Ox) for each tagged tracer
      REAL*8,  INTENT(OUT) :: PP(IIPAR,JJPAR,LD65,N_TAGGED)
```

REVISION HISTORY:

```
19 Aug 2003 - A. Fiore - Initial version
(1 ) Updated from the old routine "chemo3_split.f" (rch, bmy, 8/20/03)
(2 ) For GEOS-4, convert PBL from [m] to [hPa] w/ the hydrostatic law.
     Now references SCALE_HEIGHT from "CMN_GCTM". (bmy, 1/15/04)
(3 ) Now uses model levels instead of pressure in order to delineate
     between PBL, MT, and UT regions (amf, rch, bmy, 5/27/04)
(4 ) Now references ITS_IN_THE_TROP from "tropopause_mod.f".  Now remove
     reference to "CMN", it's obsolete. (bmy, 8/22/05)
(5 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(6 ) Resize the PP array from LLTROP to LLTROP_FIX (phs, 1/19/07)
(7 ) Now use LLTROP instead of LLTROP_FIX (bmy, 12/4/07)
(8 ) Now use LD65 instead of LLTROP (phs, 11/17/08)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use GET_XMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
```

1.89.4 chem_tagged_ox

Subroutine CHEM_TAGGED_OX performs chemistry for several Ox tracers which are tagged by geographic and altitude regions.

INTERFACE:

```
SUBROUTINE CHEM_TAGGED_OX
```

USES:

```
USE DIAG_MOD,       ONLY : AD44
USE DIAG_PL_MOD,    ONLY : AD65
USE ERROR_MOD,      ONLY : GEOS_CHEM_STOP
USE DRYDEP_MOD,     ONLY : DEPSAV
USE GRID_MOD,       ONLY : GET_AREA_CM2
USE LOGICAL_MOD,    ONLY : LDRYD
USE PBL_MIX_MOD,    ONLY : GET_FRAC_UNDER_PBLTOP
USE PBL_MIX_MOD,    ONLY : GET_PBL_MAX_L
USE TIME_MOD,       ONLY : GET_TS_CHEM
USE TIME_MOD,       ONLY : ITS_A_NEW_DAY
USE TIME_MOD,       ONLY : TIMESTAMP_STRING
USE TRACER_MOD,     ONLY : STT
USE TRACER_MOD,     ONLY : N_TRACERS
USE TRACER_MOD,     ONLY : XNUMOL
USE TRACERID_MOD,   ONLY : IDTOX
USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_TROP
USE LOGICAL_MOD,    ONLY : LNLPBL

USE CMN_SIZE_MOD  ! Size parameters
USE CMN_DIAG_MOD  ! ND44, ND65, LD65
```

```
      IMPLICIT NONE
#     include "define.h"
```

REVISION HISTORY:

```
20 Aug 2003 - R. Hudman   - Initial version
(1 ) Updated from the old routine "chemo3_split.f" (rch, bmy, 8/20/03)
(2 ) Bug fix: don't put function call in WRITE statement (bmy, 2/20/04)
(3 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
     sum into AD44 array.  This prevents numerical differences when using
     multiple processors. (bmy, 3/24/04)
(4 ) Now references LDRYD from "logical_mod.f".  Now references STT
     and N_TRACERS from "tracer_mod.f".  Now references AD65 from
     "diag_pl_mod.f".  Now uses ITS_A_NEW_DAY from "time_mod.f".
     (bmy, 7/20/04)
(5 ) Bug fix: Now avoid a SEG FAULT error if PBLFRAC isn't allocated.
     (bdf, bmy, 10/12/04)
(6 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP
     from "pbl_mix_mod.f".  Now only sum ND44 diagnostic up to the
     maximum tropopsheric level. (bmy, 2/17/05)
(7 ) Resize PP, N D44_TMP arrays from LLTROP to LLTROP_FIX.  Now only loop
     up to LLTROP_FIX (phs, 1/19/07)
(8 ) Now use LLTROP instead of LLTROP_FIX (bmy, 12/4/07)
(9 ) Now use LD65 instead of LLTROP (phs, 11/17/08)
(10) Now only compute loss rate in troposphere (dbj, bmy, 10/26/09)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.89.5 init_tagged_ox

Subroutine INIT_TAGGED_OX allocates and zeroes all module arrays.

INTERFACE:

```
      SUBROUTINE INIT_TAGGED_OX
```

USES:

```
      USE ERROR_MOD,  ONLY : ALLOC_ERR
      USE ERROR_MOD,  ONLY : ERROR_STOP
      USE TRACER_MOD, ONLY : N_TRACERS

      USE CMN_SIZE_MOD   ! Size parameters
      USE CMN_DIAG_MOD   ! ND44, ND65, LD65
```

REVISION HISTORY:

```
20 Aug 2003 - R. Yantosca - Initial version
(1 ) Now reference N_TRACERS from "tracer_mod.f" (bmy, 7/20/04)
(2 ) Now use LD65 instead of LLTROP to dimension P24H, L24H (phs, 11/18/08)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.89.6 cleanup_tagged_ox

CLEANUP_TAGGED_OX deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_TAGGED_OX
```

REVISION HISTORY:

```
20 Aug 2003 - R. Yantosca - Initial version
08 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.90 Fortran: Module Interface toms_mod

Module TOMS_MOD contains variables and routines for reading the TOMS/SBUV O3 column data from disk (for use w/ the FAST-J photolysis routines).

INTERFACE:

```
MODULE TOMS_MOD
```

USES:

```
USE CMN_SIZE_MOD                    ! Size parameters

IMPLICIT NONE
#     include "define.h"
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: INIT_TOMS
PUBLIC :: READ_TOMS
PUBLIC :: COMPUTE_OVERHEAD_O3
PUBLIC :: GET_OVERHEAD_O3
PUBLIC :: CLEANUP_TOMS
```

PUBLIC DATA MEMBERS:

```
      ! First & last years for which TOMS/SBUV data is is available
      ! (update these as new data is added to the archive)
      INTEGER, PUBLIC, PARAMETER :: FIRST_TOMS_YEAR = 1979
#if   defined( GEOS_57 )
      !%%% KLUDGE for SEAC4RS: Use TOMS data up to 2010.  This has not
      !%%% yet gone into the std code since it needs to be benchmarked.
      !%%% (bmy, 7/3/12)
      INTEGER, PUBLIC, PARAMETER :: LAST_TOMS_YEAR  = 2010
#else
      !%%% Std GEOS-Chem: use TOMS data up to 2008 for the time being.
      !%%% (bmy, 7/3/12)
      INTEGER, PUBLIC, PARAMETER :: LAST_TOMS_YEAR  = 2008
#endif
```

REMARKS:

```
   References:
   ============================================================================
   Version 8 Merged Ozone Data Sets
   Total Ozone Revision 05
   DATA THROUGH: MAR 2009
   LAST MODIFIED: 01 MAY 2009
                                                                             .
   http://acdb-ext.gsfc.nasa.gov/Data_services/merged/index.html
                                                                             .
   TOMS/SBUV MERGED TOTAL OZONE DATA, Version 8, Revision 5.
   Resolution:  5 x 10 deg.
                                                                             .
   * Includes reprocessed N16 and N17 SBUV/2 data using latest calibration.
   * OMI data updated from Collection 2 to Collection 3.
   * New offsets derived based on revised data sets.
   * 1970-1972 N4 BUV data added with no adjustments. User may wish to apply
     offset based on Comparisons between BUV and Dobson Measurements.
                                                                             .
   Responsible NASA official:
   Dr. Richard Stolarski (Richard.S.Stolarski@nasa.gov)
   Stacey Frith          (Stacey.M.Frith@nasa.gov     )
```

REVISION HISTORY:

```
   14 Jul 2003 - R. Yantosca - Initial version
   (1 ) Now references "directory_mod.f" (bmy, 7/20/04)
   (2 ) Now can read files for GEOS or GCAP grids (bmy, 8/16/05)
   (3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (4 ) Now always use 2002 TOMS O3 data for GCAP (swu, bmy, 10/3/06)
   (5 ) Now reads from TOMS_200701 directory, w/ updated data (bmy, 2/1/07)
   (6 ) Now don't replace any tokens in the DATA_DIR variable (bmy, 12/5/07)
   (7 ) Latest year of TOMS data is now 2007 (bmy, 1/14/09)
   01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

```
06 Mar 2012 - R. Yantosca - Added function GET_TOTAL_O3
06 Mar 2012 - R. Yantosca - Added parameters FIRST_TOMS_YEAR, LAST_TOMS_YEAR
06 Mar 2012 - R. Yantosca - Updated comments
06 Mar 2012 - R. Yantosca - Now make TOMS, DTOMS1, DTOMS2 arrays PRIVATE
06 Mar 2012 - R. Yantosca - Add TO3_DAILY as a PRIVATE module array
25 Jun 2012 - S. Kim      - Now reads from TOMS_201203 directory, w/
                            updated data
03 Jul 2012 - R. Yantosca - Restrict reading from TOMS_201203 directory
                            to GEOS-5.7.2 met data for the time being.
```

1.90.1 read_toms

Subroutine READ_TOMS reads in TOMS O3 column data from a binary punch file for the given grid, month and year.

INTERFACE:

```
SUBROUTINE READ_TOMS( THISMONTH, THISYEAR )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D
USE BPCH2_MOD,     ONLY : GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0
USE BPCH2_MOD,     ONLY : READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TIME_MOD,      ONLY : EXPAND_DATE
USE TRANSFER_MOD,  ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: THISMONTH   ! Current month
INTEGER, INTENT(IN)    :: THISYEAR    ! Current year
```

REMARKS:

```
TOMS/SBUV MERGED TOTAL OZONE DATA, Version 8, Revision 5.
Resolution:  5 x 10 deg.

                                                                             .
Methodology
---------------------------------------------------------------------------
FAST-J comes with its own default O3 column climatology (from McPeters
1992 & Nagatani 1991), which is stored in the input file "jv_atms.dat".
These "FAST-J default" O3 columns are used in the computation of the
actinic flux and other optical quantities for the FAST-J photolysis.

                                                                             .
The TOMS/SBUV O3 columns and 1/2-monthly O3 trends (contained in the
TOMS_200906 directory) are read into GEOS-Chem by routine READ_TOMS in
"toms_mod.f".  Missing values (i.e. locations where there are no data)
```

```
in the TOMS/SBUV O3 columns are defined by the flag -999.

.

After being read from disk in routine READ_TOMS, the TOMS/SBUV O3 data
are then passed to the FAST-J routine "set_prof.F".  In "set_prof.F", a
test is done to make sure that the TOMS/SBUV O3 columns and 1/2-monthly
trends do not have any missing values for (lat,lon) location for the given
month.  If so, then the TOMS/SBUV O3 column data is interpolated to the
current day and is used to weight the "FAST-J default" O3 column.  This
essentially "forces" the "FAST-J default" O3 column values to better match
the observations, as defined by TOMS/SBUV.

.

If there are no TOMS/SBUV O3 columns (and 1/2-monthly trends) at a (lat,
lon) location for given month, then FAST-J will revert to its own "default"
climatology for that location and month.  Therefore, the TOMS O3 can be
thought of as an  "overlay" data -- it is only used if it exists.

.

Note that there are no TOMS/SBUV O3 columns at the higher latitudes.
At these latitudes, the code will revert to using the "FAST-J default"
O3 columns.

.

As of March 2012, we have TOMS/SBUV data for 1979 thru 2008.  We will
update to the latest TOMS/SBUV data set shortly.

.

This methodology was originally adopted by Mat Evans.
```

REVISION HISTORY:

```
10 Dec 2002 - M. Evans - Initial version
(1 ) Bundled into "toms_mod.f" (bmy, 7/14/03)
(2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(3 ) Now can read files for GEOS or GCAP grids (bmy, 8/16/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Now always use 2002 TOMS O3 data for GCAP (swu, bmy, 10/3/06)
(6 ) Now reads from TOMS_200701 directory, w/ updated data.  Also always
      use 1979 data prior to 1979 or 2005 data after 2005. (bmy, 2/12/07)
(7 ) Bug fix: don't include DATA_DIR in filename, just in case someone's
      file path has replaceable tokens (e.g. hh, mm, MM etc.) (bmy, 12/5/07)
(8 ) Latest year of TOMS data is now 2007 (bmy, 1/14/09)
(9 ) Updated TOMS data in TOMS_200906. Latest year is 2008. (ccc, 6/15/09)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
03 Jul 2012 - R. Yantosca - Restrict reading from TOMS_201203 directory
                            to GEOS-5.7.2 met data for the time being.
```

1.90.2 compute_overhead_o3

Subroutine COMPUTE_OVERHEAD_O3 returns the resultant total overhead O3 column for the FAST-J photolysis. This will be one of two options:

1. Default: TOMS/SBUV overhead O3 columns. These will be used be the FAST-J routine set_prof.F to overwrite the existing FAST-J climatology (cf McPeters & Nagatani 1992). Missing data (i.e. for months & locations where TOMS/SBUV data does not exist) is denoted by the value -999; FAST-J will skip over these points.

2. Overhead O3 columns taken directly from the met fields. These will be returned if the flag USE_O3_FROM_MET is set to TRUE.

INTERFACE:

```
SUBROUTINE COMPUTE_OVERHEAD_O3( DAY, USE_O3_FROM_MET, TO3 )
```

INPUT PARAMETERS:

```
! Day of month
INTEGER, INTENT(IN)  :: DAY

! Switch to denote if we should use the default TO3
! directly from the met fields
LOGICAL, INTENT(IN)  :: USE_O3_FROM_MET

! TO3 from the met fields
REAL*8,  INTENT(IN)  :: TO3(IIPAR,JJPAR)
```

REMARKS:

```
Reference for the TOMS/SBUV merged O3 columns:

1985 - 2005 are taken from:

  http://code916.gsfc.nasa.gov/Data_services/merged/index.html

  TOMS/SBUV MERGED TOTAL OZONE DATA, Version 8, Revision 3.
  Resolution:  5 x 10 deg.

  Contact person for the merged data product:
  Stacey Hollandsworth Frith (smh@hyperion.gsfc.nasa.gov)

2006 and 2007 are taken from:

   http://code916.gsfc.nasa.gov/Data_services/merged/index.html

   Version 8 Merged Ozone Data Sets
   Revision 04
   DATA THROUGH: SEP 2008
   LAST MODIFIED: 20 OCT 2008

 Methodology (bmy, 2/12/07)
 ------------------------------------------------------------------
 FAST-J comes with its own default O3 column climatology (from
```

```
McPeters 1992 & Nagatani 1991), which is stored in the input
file "jv_atms.dat".  These "FAST-J default" O3 columns are used
in the computation of the actinic flux and other optical
quantities for the FAST-J photolysis.

The TOMS/SBUV O3 columns and 1/2-monthly O3 trends (contained
in the TOMS_200701 directory) are read into GEOS-Chem by routine
READ_TOMS in "toms_mod.f".  Missing values (i.e. locations where
there are no data) in the TOMS/SBUV O3 columns are defined by
the flag -999.

After being read from disk in routine READ_TOMS, the TOMS/SBUV
O3 data are then passed to the FAST-J routine "set_prof.f".  In
"set_prof.f", a test is done to make sure that the TOMS/SBUV O3
columns and 1/2-monthly trends do not have any missing values
for (lat,lon) location for the given month.  If so, then the
TOMS/SBUV O3 column data is interpolated to the current day and
is used to weight the "FAST-J default" O3 column.  This
essentially "forces" the "FAST-J default" O3 column values to
better match the observations, as defined by TOMS/SBUV.

If there are no TOMS/SBUV O3 columns (and 1/2-monthly trends)
at a (lat,lon) location for given month, then FAST-J will revert
to its own "default" climatology for that location and month.
Therefore, the TOMS O3 can be thought of as an  "overlay" data
-- it is only used if it exists.

Note that there are no TOMS/SBUV O3 columns at the higher
latitudes.  At these latitudes, the code will revert to using
the "FAST-J default" O3 columns.

As of February 2007, we have TOMS/SBUV data for 1979 thru 2005.
2006 TOMS/SBUV data is incomplete as of this writing.  For years
2006 and onward, we use 2005 TOMS O3 columns.

This methodology was originally adopted by Mat Evans.  Symeon
Koumoutsaris was responsible for creating the downloading and
processing the TOMS O3 data files from 1979 thru 2005 in the
TOMS_200701 directory.
```

REVISION HISTORY:

```
06 Mar 2012 - R. Yantosca - Initial version, pulled code out from
                            the FAST-J routine SET_PROF; based on the
                            GEOS-Chem column code routine
```

1.90.3 get_overhead_O3

Function GET_OVERHEAD_O3 returns the total overhead O3 column [DU] (which is taken either from TOMS/SBUV or directly from the met fields) at a given surface grid box location (I,J).

INTERFACE:

```
FUNCTION GET_OVERHEAD_O3( I, J ) RESULT( OVERHEAD_O3 )
```

INPUT PARAMETERS:

```
INTEGER :: I             ! Grid box longitude index
INTEGER :: J             ! Grid box latitude index
```

RETURN VALUE:

```
REAL*8  :: OVERHEAD_O3   ! Total overhead O3 column [DU]
```

REVISION HISTORY:

```
06 Mar 2012 - R. Yantosca - Initial version
```

1.90.4 init_toms

Subroutine INIT_TOMS allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_TOMS
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
14 Jul 2003 - R. Yantosca - Initial version
01 Dec 2010 - R. Yantosca - Added ProTeX headers
06 Mar 2012 - R. Yantosca - Now allocate TO3_DAILY
```

1.90.5 cleanup_toms

Subroutine CLEANUP_TOMS deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_TOMS
```

REVISION HISTORY:

```
   14 Jul 2003 - R. Yantosca - Initial version
   01 Dec 2010 - R. Yantosca - Added ProTeX headers
   06 Mar 2012 - R. Yantosca - Now deallocate TO3_DAILY
```

1.91 Fortran: Module Interface tpcore_bc_mod

Module TPCORE_BC_MOD contains modules and variables which are needed to save and read TPCORE nested-grid boundary conditions to/from disk.

INTERFACE:

```
      MODULE TPCORE_BC_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      !-------------------------------------------------------------
      ! I0_W : Lon offset of TPCORE REGION [# boxes]
      ! J0_W : Lat offset of TPCORE REGION [# boxes]
      ! IM_W : Lon extent of TPCORE REGION [# boxes]
      ! JM_W : Lat extent of TPCORE REGION [# boxes]
      ! I1_W : Lower left-hand  (LL) lon index of NESTED WINDOW
      ! J1_W : Lower left-hand  (LL) lat index of NESTED WINDOW
      ! I2_W : Upper right-hand (UR) lon index of NESTED WINDOW
      ! J2_W : Upper right-hand (UR) lat index of NESTED WINDOW
      ! IGZD : ???
      ! Please also see the diagram in the REMARKS section.
      !-------------------------------------------------------------
      INTEGER, PUBLIC :: I0_W, J0_W
      INTEGER, PUBLIC :: I1_W, J1_W
      INTEGER, PUBLIC :: I2_W, J2_W
      INTEGER, PUBLIC :: IM_W, JM_W
      INTEGER, PUBLIC :: IGZD
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: INIT_TPCORE_BC
      PUBLIC :: DO_WINDOW_TPCORE_BC
      PUBLIC :: SET_CLEAN_BC
      PUBLIC :: SAVE_GLOBAL_TPCORE_BC
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: OPEN_BC_FILE
PRIVATE :: CLEAN_WINDOW_TPCORE_BC
PRIVATE :: READ_WINDOW_TPCORE_BC
PRIVATE :: GET_4x5_BC
PRIVATE :: GET_2x25_BC
PRIVATE :: ITS_TIME_FOR_BC
PRIVATE :: CLEANUP_TPCORE_BC
```

REMARKS:

Reference Diagram:

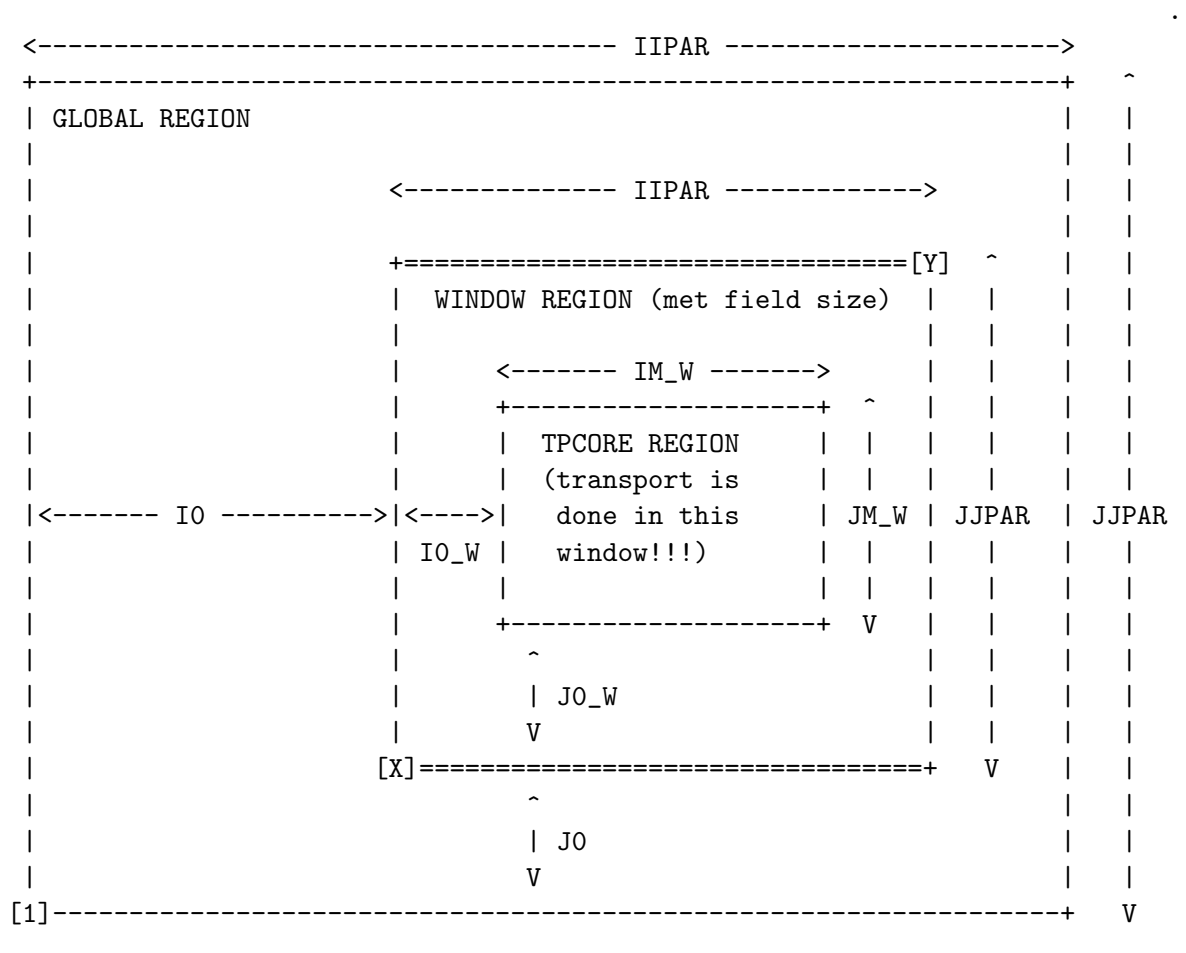


DIAGRAM NOTES:

(a) The outermost box ("Global Region") is the global grid size. This region has IIPAR boxes in longitude and JJPAR boxes in latitude. The origin of the "Global Region" is at the south pole, at the lower left-hand corner (point [1]).

(b) The next innermost box ("Window Region") is the nested-grid window. This region has IIPAR boxes in longitude and JJPAR boxes in latitude.

```
      This is the size of the trimmed met fields that will be used for
      a 1 x 1 "nested-grid" simulation.

  (c) The innermost region ("TPCORE Region") is the actual area in which
      TPCORE transport will be performed.  Note that this region is smaller
      than the "Window Region".  It is set up this way since a cushion of
      grid boxes is needed TPCORE Region for boundary conditions.

  (d) I0 is the longitude offset (# of boxes) and J0 is the latitude offset
      (# of boxes) which translate between the "Global Region" and the
      "Window Region".

  (e) I0_W is the longitude offset (# of boxes), and J0_W is the latitude
      offset (# of boxes) which translate between the "Window Region"
      and the "TPCORE Region".

  (f) The lower left-hand corner of the "Window Region" (point [X]) has
      longitude and latitude indices (I1_W, J1_W).  Similarly, the upper
      right-hand corner (point [Y]) has longitude and latitude indices
      (I2_W, J2_W).

  (g) Note that if I0=0, J0=0, I0_W=0, J0_W=0, IIPAR=IIPAR, JJPAR=JJPAR
      specifies a global simulation.  In this case the "Window Region"
      totally coincides with the "Global Region".

  (h) In order for the nested-grid to work we must save out concentrations
      over the WINDOW REGION from a coarse model (e.g. 4x5) corresponding to
      the same WINDOW REGION at 1x1.  These concentrations are copied along
      the edges of the 1x1 WINDOW REGION and are thus used as boundary
      conditions for TPCORE.
```

REVISION HISTORY:

```
  04 Mar 2003 - R. Yantosca - Initial version
  (1 ) Bug fix for LINUX w/ TIMESTAMP_STRING (bmy, 9/29/03)
  (2 ) Now references "tracer_mod.f", "directory_mod.f", and
       "logical_mod.f" (bmy, 7/20/04)
  (3 ) Now get HALFPOLAR for GEOS or GCAP grids (bmy, 6/28/05)
  (4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
  (5 ) Rename arguments in GET_4x5_BC to avoid name conflict (bmy, 10/24/05)
  (6 ) Now use EXPAND_DATE instead of obsolete DATE_STRING (bmy, 3/15/06)
  (7 ) Added 2x2.5 boundary condition output (created GET_2x25_BC).
       Added multi-boundary condition output (NA, EU, CH and Custom region).
       Unternally defined boundary condition regions for NA, EU and CH.
       (amv, bmy, 12/18/09)
  16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
  01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
  15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.91.1

Subroutine SET_CLEAN_BC initializes the CLEAN_BC logical flag. CLEAN_BC decides whether or not we will zero the nested-grid tpcore boundary conditions.

INTERFACE:

```
SUBROUTINE SET_CLEAN_BC( THIS_CLEAN_BC )
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN) :: THIS_CLEAN_BC
```

REVISION HISTORY:

```
04 Mar 2003 - R. Yantosca - Initial versioni
15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.91.2 open_bc_file

Subroutine OPEN_BC_FILE opens the file which contains boundary conditions saved from the coarse-grid WINDOW REGION for either reading or writing.

INTERFACE:

```
SUBROUTINE OPEN_BC_FILE( FOR_READ, FOR_WRITE, WINDOW )
```

USES:

```
USE BPCH2_MOD,     ONLY : OPEN_BPCH2_FOR_WRITE
USE BPCH2_MOD,     ONLY : OPEN_BPCH2_FOR_READ
USE DIRECTORY_MOD, ONLY : TPBC_DIR,     TPBC_DIR_NA
USE DIRECTORY_MOD, ONLY : TPBC_DIR_CH,  TPBC_DIR_EU
USE DIRECTORY_MOD, ONLY : TPBC_DIR_SE
USE FILE_MOD,      ONLY : IU_BC,        IU_BC_NA
USE FILE_MOD,      ONLY : IU_BC_EU,     IU_BC_CH
USE FILE_MOD,      ONLY : IU_BC_SE
USE TIME_MOD,      ONLY : EXPAND_DATE,  GET_NYMD
USE TIME_MOD,      ONLY : ITS_A_NEW_DAY

#     include "define.h"
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN), OPTIONAL :: FOR_READ   ! Open file for read?
LOGICAL, INTENT(IN), OPTIONAL :: FOR_WRITE  ! Open file for write?
INTEGER, INTENT(IN)           :: WINDOW     ! Specifies nested region
```

REVISION HISTORY:

```
    07 Mar 2003 - R. Yantosca - Initial version
    (1 ) Now use ITS_A_NEW_DAY from "time_mod.f".  Now references TPBC_DIR
         from "directory_mod.f" (bmy, 7/20/04)
    (2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (3 ) DATE_STRING is now obsolete; use EXPAND_DATE instead (bmy, 3/15/06)
    (4 ) Can now read files from different directories (amv, bmy, 12/18/09)
    15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.91.3 save_global_tpcore_bc

Subroutine SAVE_GLOBAL_TPCORE_BC saves concentrations from the WINDOW REGION of a coarse-resolution model run to a bpch file. A new boundary conditions file is created for each day.

INTERFACE:

```
      SUBROUTINE SAVE_GLOBAL_TPCORE_BC
```

USES:

```
      USE CMN_SIZE_MOD
      USE BPCH2_MOD
      USE FILE_MOD
      USE TIME_MOD,    ONLY : GET_NYMD,  GET_NHMS
      USE TIME_MOD,    ONLY : GET_TAU,   TIMESTAMP_STRING
      USE TRACER_MOD,  ONLY : N_TRACERS, STT
      USE LOGICAL_MOD, ONLY : LWINDO_CU, LWINDO_NA
      USE LOGICAL_MOD, ONLY : LWINDO_CH, LWINDO_EU
      USE LOGICAL_MOD, ONLY : LWINDO_SE
#if   defined( APM )
      USE TRACER_MOD,  ONLY : N_APMTRA
#endif
```

REVISION HISTORY:

```
    04 Mar 2003 - Y. Wang     - Initial version
    (1 ) Now references N_TRACERS and STT from "tracer_mod.f".  Also now
         references TIMESTAMP_STRING from "time_mod.f".  (bmy, 7/20/04)
    (2 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
         value for GEOS or GCAP grids (bmy, 6/28/05)
    (3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (4 ) Can now save files to different directories (amv, bmy, 12/18/09)
    16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
    15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.91.4 do_window_tpcore_bc

Subroutine DO_WINDOW_TPCORE_BC is a driver routine for assigning TPCORE boundary conditions to the tracer array STT.

INTERFACE:

```
      SUBROUTINE DO_WINDOW_TPCORE_BC
```

USES:

```
      USE CMN_SIZE_MOD
      USE LOGICAL_MOD, ONLY : LWINDO2x25
      USE TRACER_MOD,  ONLY : N_TRACERS, STT
#if   defined( APM )
      USE TRACER_MOD,  ONLY : N_APMTRA
#endif
```

REVISION HISTORY:

```
   07 Mar 2003 - R. Yantosca - Initial version
   (1 ) Now references N_TRACERS and STT from "tracer_mod.f" (bmy, 7/20/04)
   (2 ) Now can use 2 x 2.5 BC's (amv, bmy, 12/18/09)
   16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
   08 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.91.5 clean_window_tpcore_bc

Subroutine CLEAN_WINDOW_TPCORE_BC zeroes the boundary conditions array BC at each timestep. (bmy, 3/7/03, 12/18/09)

INTERFACE:

```
      SUBROUTINE CLEAN_WINDOW_TPCORE_BC
```

USES:

```
      USE CMN_SIZE_MOD
      USE TRACER_MOD,    ONLY : N_TRACERS
      USE LOGICAL_MOD,   ONLY : LWINDO_NA, LWINDO_EU
      USE LOGICAL_MOD,   ONLY : LWINDO_CH, LWINDO_CU
      USE LOGICAL_MOD,   ONLY : LWINDO_SE
#if   defined( APM )
      USE TRACER_MOD,    ONLY : N_APMTRA
#endif

#     include "define.h"
```

REVISION HISTORY:

```
07 Mar 2003 - M. Prather  - Initial version
(1 ) Now references N_TRACERS from "tracer_mod.f" (bmy, 7/20/04)
(2 ) Now zeroes the arrays for the different regions (amv, bmy, 12/18/09)
16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.91.6 read_window_tpcore_bc

Subroutine READ_WINDOW_TPCORE_BC reads tracer concentrations saved on the WINDOW REGION of a coarse-grid simulation (e.g. 4x5, 2x2.5). These concentrations will be used as boundary conditions for TPCORE transport.

INTERFACE:

```
SUBROUTINE READ_WINDOW_TPCORE_BC
```

USES:

```
USE CMN_SIZE_MOD
USE FILE_MOD,   ONLY : IOERROR, IU_BC
USE TIME_MOD,   ONLY : GET_TAU, TIMESTAMP_STRING
USE TRACER_MOD, ONLY : N_TRACERS
```

REVISION HISTORY:

```
07 Mar 2003 - R. Yantosca - Initial version
(1 ) LINUX has a problem putting a function call w/in a WRITE statement.
      Now save output from TIMESTAMP_STRING to STAMP and print that.
      (bmy, 9/29/03)
(2 ) Now references N_TRACERS from "tracer_mod.f" (bmy, 7/20/04)
(3 ) Rewritten to be more generic (amv, bmy, 12/18/09)
15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.91.7 get_4x5_bc

Function GET_4x5_BC returns a value from the 4x5 BC boundary conditions array at the location of a nested grid box.

INTERFACE:

```
FUNCTION GET_4x5_BC( I_1x1, J_1x1, L_1x1, N_1x1 ) RESULT( VALUE )
```

USES:

```
USE CMN_SIZE_MOD
USE GRID_MOD,      ONLY : GET_XMID, GET_YMID
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I_1x1   ! Nested-grid lon    index
INTEGER, INTENT(IN) :: J_1x1   ! Nested-grid lat    index
INTEGER, INTENT(IN) :: L_1x1   ! Nested-grid level  index
INTEGER, INTENT(IN) :: N_1x1   ! Nested-grid tracer index
```

RETURN VALUE:

```
REAL*8              :: VALUE   ! 4 x 5 BC @ location of nested grid box
```

REMARKS:

```
NOTE: This routine was originally written for the 1 x 1 nested grid,
but this now works for the GEOS-5 0.5 x 0.666 nested grid data.  Keep
variable names I_1x1, J_1x1, etc. unchanged for the present.

For now we will assume that we have saved tracer concentrations from
a  4x5 window which overlays the corresponding 1x1 WINDOW REGION.
These 4x5 tracer concentrations are used as boundary conditions for
TPCORE.
```

REVISION HISTORY:

```
07 Mar 2003 - Y. Wang, R. Yantosca - Initial version
(1 ) Rename arguments to avoid conflict w/ I1x1, J1x1 parameters in
     CMN_SIZE. (bmy, 10/24/05)
01 Mar 2012 - R. Yantosca - Now use GET_XMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.91.8 get_2x25_bc

Function GET_2x25_BC returns a value from the 2 x 2.5 BC boundary conditions array at the location of a nested grid box.

INTERFACE:

```
FUNCTION GET_2x25_BC( I_1x1, J_1x1, L_1x1, N_1x1 ) RESULT( VALUE )
```

USES:

```
USE CMN_SIZE_MOD
USE GRID_MOD,     ONLY : GET_XMID, GET_YMID
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I_1x1   ! Nested-grid lon    index
INTEGER, INTENT(IN) :: J_1x1   ! Nested-grid lat    index
INTEGER, INTENT(IN) :: L_1x1   ! Nested-grid level  index
INTEGER, INTENT(IN) :: N_1x1   ! Nested-grid tracer index
```

RETURN VALUE:

```
REAL*8              :: VALUE   ! 2 x 2.5 BC @ location of nested grid box
```

REMARKS:

```
NOTE: This routine was originally written for the 1 x 1 nested grid,
but this now works for the GEOS-5 0.5 x 0.666 nested grid data.  Keep
variable names I_1x1, J_1x1, etc. unchanged for the present.

For now we will assume that we have saved tracer concentrations from
a 2 x 2.5 window which overlays the corresponding NESTED WINDOW REGION.
These 2 x 2.5 tracer concentrations are used as boundary conditions
for TPCORE.
```

REVISION HISTORY:

```
18 Dec 2009 - A. van Donkeelar - Initial version
01 Mar 2012 - R. Yantosca - Now use GET_XMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.91.9 its_time_for_bc

Subroutine ITS_TIME_FOR_BC returns TRUE if it is time to read in the next set of boundary conditions for TPCORE, or FALSE otherwise.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_BC() RESULT( FLAG )
```

USES:

```
USE TIME_MOD, ONLY : GET_ELAPSED_MIN
```

RETURN VALUE:

```
LOGICAL :: FLAG   ! =T if it's time to read BC's from disk
```

REVISION HISTORY:

```
05 Mar 2003 - R. Yantosca - Initial version
15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.91.10 init_tpcore_bc

Subroutine INIT_TPCORE_BC initializes module variables and arrays.

INTERFACE:

```
      SUBROUTINE INIT_TPCORE_BC( TS, I0W, J0W, I1, J1, I2, J2 )
```

USES:

```
      USE CMN_SIZE_MOD
      USE DIRECTORY_MOD, ONLY : TPBC_DIR
      USE ERROR_MOD,     ONLY : ALLOC_ERR
      USE GRID_MOD,      ONLY : GET_XOFFSET, GET_YOFFSET
      USE GRID_MOD,      ONLY : ITS_A_NESTED_GRID
      USE LOGICAL_MOD,   ONLY : LWINDO,    LWINDO_NA,  LWINDO_CU
      USE LOGICAL_MOD,   ONLY : LWINDO_EU, LWINDO_CH,  LWINDO2x25
      USE LOGICAL_MOD,   ONLY : LWINDO_SE
      USE TRACER_MOD,    ONLY : N_TRACERS

#     include "define.h"
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: TS          ! Timestep for BC data
      INTEGER, INTENT(IN) :: I0W, J0W    ! Transport region offsets
      INTEGER, INTENT(IN) :: I1,  J1     ! Lon, lat indices @ LL corner
      INTEGER, INTENT(IN) :: I2,  J2     ! Lon, lat indices @ UR corner
```

REVISION HISTORY:

```
   10 Feb 2003 - R. Yantosca - Initial version
   (1 ) Now references N_TRACERS from "tracer_mod.f".  Now references LWINDO
        from "logical_mod.f".  Now references TPBC_DIR from "directory_mod.f".
        Now references ITS_A_NESTED_GRID from "grid_mod.f".  Also added
        arguments to take values from "input_mod.f". (bmy, 7/20/04)
   15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.91.11 cleanup_tpcore_bc

Subroutine CLEANUP_TPCORE_BC deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_TPCORE_BC
```

REVISION HISTORY:

```
   04 Mar 2003 - R. Yantosca - Initial version
   15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.92 Fortran: Module Interface tracer_mod

Module TRACER_MOD contains GEOS-CHEM tracer array STT plus various other related quantities. TRACER_MOD also contains inquiry functions that can be used to determine the type of GEOS-CHEM simulation.

INTERFACE:

```
MODULE TRACER_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: ITS_A_RnPbBe_SIM
PUBLIC :: ITS_A_CH3I_SIM
PUBLIC :: ITS_A_FULLCHEM_SIM
PUBLIC :: ITS_A_HCN_SIM
PUBLIC :: ITS_A_TAGOX_SIM
PUBLIC :: ITS_A_TAGCO_SIM
PUBLIC :: ITS_A_C2H6_SIM
PUBLIC :: ITS_A_CH4_SIM
PUBLIC :: ITS_AN_AEROSOL_SIM
PUBLIC :: ITS_A_MERCURY_SIM
PUBLIC :: ITS_A_CO2_SIM
PUBLIC :: ITS_A_H2HD_SIM
PUBLIC :: ITS_NOT_COPARAM_OR_CH4
PUBLIC :: GET_SIM_NAME
PUBLIC :: CHECK_STT
PUBLIC :: CHECK_STT_05x0666
PUBLIC :: INIT_TRACER
PUBLIC :: CLEANUP_TRACER
```

PUBLIC DATA MEMBERS:

```
!=========================================================================
! Module Variables:
! SIM_TYPE       : Number denoting simulation type
! N_TRACERS      : Number of GEOS-CHEM tracers
! N_MEMBERS      : Max # of constituents a tracer can have
! ID_TRACER      : Array of tracer numbers
! ID_EMITTED     : Index of which constituent has the emissions
! STT            : GEOS-CHEM Tracer array [kg]
! TCVV           : Molecular weight air / molecular weight tracer
! TRACER_COEFF   : Coefficient of each tracer constituent
! TRACER_MW_G    : Tracer molecular weight [g/mole]
! TRACER_MW_KG   : Tracer molecular weight [kg/mole]
! TRACER_N_CONST : Array of number of constituents per tracer
```

```
      ! TRACER_NAME    : Array of tracer names
      ! TRACER_CONST   : Array of names for tracer constituents
      ! SALA_REDGE_um  : Accum  mode seasalt radii bin edges [um]
      ! SALC_REDGE_um  : Coarse mode seasalt radii bin edges [um]
      ! XNUMOL         : Ratio of (molec/mole) / (kg/mole) = molec/kg
      ! XNUMOLAIR      : XNUMOL ratio for air
      !=================================================================

      ! Scalars
      INTEGER,           PUBLIC              :: SIM_TYPE
      INTEGER,           PUBLIC              :: N_TRACERS
#if   defined( APM )
      INTEGER,           PUBLIC              :: N_APMTRA
#endif
      ! N_MEMBERS increased from 10 to 15 (FP 8/2009)
      INTEGER,           PUBLIC, PARAMETER   :: N_MEMBERS = 15
      REAL*8,            PUBLIC, PARAMETER   :: XNUMOLAIR = 6.022d+23 /
     &                                                      28.9644d-3

      ! Arrays
      INTEGER,           PUBLIC, ALLOCATABLE :: ID_TRACER(:)
      INTEGER,           PUBLIC, ALLOCATABLE :: ID_EMITTED(:)
      INTEGER,           PUBLIC, ALLOCATABLE :: TRACER_N_CONST(:)
      REAL*8,    TARGET, PUBLIC, ALLOCATABLE :: STT(:,:,:,:)
      REAL*8,            PUBLIC, ALLOCATABLE :: TCVV(:)
      REAL*8,            PUBLIC, ALLOCATABLE :: TRACER_COEFF(:,:)
      REAL*8,            PUBLIC, ALLOCATABLE :: TRACER_MW_G(:)
      REAL*8,            PUBLIC, ALLOCATABLE :: TRACER_MW_KG(:)
      REAL*8,            PUBLIC, ALLOCATABLE :: XNUMOL(:)
      CHARACTER(LEN=14), PUBLIC, ALLOCATABLE :: TRACER_NAME(:)
      CHARACTER(LEN=14), PUBLIC, ALLOCATABLE :: TRACER_CONST(:,:)

      ! Define seasalt radii bin edges [um] here since these
      ! need to be used both in "seasalt_mod.f" and "drydep_mod.f"
      REAL*8,            PUBLIC              :: SALA_REDGE_um(2)
      REAL*8,            PUBLIC              :: SALC_REDGE_um(2)
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca -  Initial version
(1 ) Added function GET_SIM_NAME (bmy, 5/3/05)
(2 ) Removed ITS_A_COPARAM_SIM; the CO-OH param is obsolete (bmy, 6/24/05)
(3 ) Added ITS_A_CO2_SIM (pns, bmy, 7/25/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Now added XNUMOL, XNUMOLAIR as module variables (bmy, 10/25/05)
(6 ) Added public routine ITS_A_H2HD_SIM (phs, 9/18/07)
16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.1 its_a_rnpbbe_sim

Function ITS_A_RnPbBe_SIM returns TRUE if we are doing a GEOS-CHEM Rn-Pb-Be simulation.

INTERFACE:

```
FUNCTION ITS_A_RnPbBe_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.2 its_a_ch3i_sim

Function ITS_A_CH3I_SIM returns TRUE if we are doing a GEOS-CHEM CH3I (Methyl Iodide) simulation.

INTERFACE:

```
FUNCTION ITS_A_CH3I_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.3 its_a_fullchem_sim

Function ITS_A_FULLCHEM_SIM returns TRUE if we are doing a GEOS-CHEM full chemistry/aerosol simulation (i.e. via SMVGEAR).

INTERFACE:

```
FUNCTION ITS_A_FULLCHEM_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.4 its_a_hcn_sim

Function ITS_A_HCN_SIM returns TRUE if we are doing a GEOS-CHEM HCN (Hydrogen Cyanide) simulation.

INTERFACE:

```
FUNCTION ITS_A_HCN_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.5 its_a_tagox_sim

Function ITS_A_TAGOX_SIM returns TRUE if we are doing a GEOS-CHEM tagged Ox simulation.

INTERFACE:

```
FUNCTION ITS_A_TAGOX_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.6 its_a_tagco_sim

Function ITS_A_TAGCO_SIM returns TRUE if we are doing a GEOS-CHEM tagged CO simulation.

INTERFACE:

```
FUNCTION ITS_A_TAGCO_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.7 its_a_c2h6_sim

Function ITS_A_C2H6_SIM returns TRUE if we are doing a GEOS-CHEM C2H6 (Ethane) simulation.

INTERFACE:

```
FUNCTION ITS_A_C2H6_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.8 its_a_ch4_sim

Function ITS_A_CH4_SIM returns TRUE if we are doing a GEOS-CHEM CH4 (Methane) simulation.

INTERFACE:

```
FUNCTION ITS_A_CH4_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.9 its_an_aerosol_sim

Function ITS_AN_AEROSOL_SIM returns TRUE if we are doing a GEOS-CHEM offline Sulfate/Carbon/dust/seasalt aerosol simulation.

INTERFACE:

```
FUNCTION ITS_AN_AEROSOL_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.10 its_a_mercury_sim

Function ITS_A_MERCURY_SIM returns TRUE if we are doing a GEOS-CHEM Hg0/Hg2/HgP offline mercury simulation.

INTERFACE:

```
FUNCTION ITS_A_MERCURY_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.11 its_a_co2_sim

Function ITS_A_CO2_SIM returns TRUE if we are doing a GEOS-CHEM CO2 offline simulation.

INTERFACE:

```
FUNCTION ITS_A_CO2_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
25 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.12 its_a_h2hd_sim

Function ITS_A_H2HD_SIM returns TRUE if we are doing a GEOS-CHEM H2-HD simulation.

INTERFACE:

```
FUNCTION ITS_A_H2HD_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
18 Sep 2007 - P. Le Sager - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.13 its_not_coparam_or_ch4

Function ITS_NOT_COPARAM_OR_CH4 returns TRUE if we are doing a GEOS-CHEM simulation other than CO with parameterized OH or CH4.

INTERFACE:

```
FUNCTION ITS_NOT_COPARAM_OR_CH4() RESULT( VALUE )
```

REMARKS:

```
The CO-OH param (SIM_TYPE=5) is now obsolete (bmy, 6/24/05)
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.14 get_sim_name

Function GET_SIM_NAME returns the name (e.g. "NOx-Ox-Hydrocarbon-Aerosol", "Tagged CO", etc.) of the GEOS-CHEM simulation.

INTERFACE:

```
FUNCTION GET_SIM_NAME() RESULT( NAME )
```

RETURN VALUE:

```
CHARACTER(LEN=40) :: NAME
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
(1 ) The CO-OH simulation has been removed (bmy, 6/24/05)
(2 ) Added CASE blocks for CO2 and H2/HD simulations (bmy, 9/18/07)
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.15 check_stt

Subroutine CHECK_STT checks the STT tracer array for negative values, NaN values, or Infinity values. If any of these are found, the code will stop with an error message.

INTERFACE:

```
SUBROUTINE CHECK_STT( LOCATION )
```

USES:

```
      USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
      USE ERROR_MOD, ONLY : IT_IS_NAN
      USE ERROR_MOD, ONLY : IT_IS_FINITE

      USE CMN_SIZE_MOD    ! Size parameters
```

INPUT PARAMETERS:

```
      CHARACTER(LEN=*), INTENT(IN) :: LOCATION
```

REVISION HISTORY:

```
    (1 ) CHECK_STT uses the interfaces defined above -- these will do the
         proper error checking for either SGI or DEC/Compaq platforms.
         (bmy, 3/8/01)
    (2 ) Now call GEOS_CHEM_STOP to shutdown safely.  Now use logicals LNAN,
         LNEG, LINF to flag if we have error conditions, and then stop the
         run outside of the parallel DO-loop. (bmy, 11/27/02)
    (3 ) Bug fix in FORMAT statement: replace missing commas (bmy, 3/23/03)
    (4 ) Moved from "error_mod.f" to "tracer_mod.f" (bmy, 7/15/04)
    (5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.16 check_stt_05x0666

Subroutine CHECK_STT_05x0666 checks the STT tracer array for negative values, NaN values, or Infinity values. If any of these are found, the STT array will be set to a specified value.

INTERFACE:

```
      SUBROUTINE CHECK_STT_05x0666( LOCATION )
```

USES:

```
      USE ERROR_MOD, ONLY : IT_IS_NAN
      USE ERROR_MOD, ONLY : IT_IS_FINITE

      USE CMN_SIZE_MOD    ! Size parameters
```

INPUT PARAMETERS:

```
      CHARACTER(LEN=*), INTENT(IN) :: LOCATION
```

REVISION HISTORY:

```
    05 Mar 2012 - M. Payer    - Initial version based on CHECK_STT and updates
                                for nested grid by Yuxuan Wang.
    05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.17 init_tracer

Subroutine INIT_TRACER initializes all module arrays.

INTERFACE:

```
      SUBROUTINE INIT_TRACER
```

USES:

```
      USE ERROR_MOD,     ONLY : ALLOC_ERR
#if   defined( APM )
      USE APM_INIT_MOD,  ONLY : APM_NTRACERS
      USE APM_INIT_MOD,  ONLY : LAPM
#endif

      USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
   15 Jul 2004 - R. Yantosca - Initial version
   25 Oct 2005 - R. Yantosca - Now allocate XNUMOL
   16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
   05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.92.18 cleanup_tracer

Subroutine CLEANUP_TRACER deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_TRACER
```

REVISION HISTORY:

```
   15 Jul 2004 - R. Yantosca - Initial version
   25 Oct 2005 - R. Yantosca - Now deallocates XNUMOL
   05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.93 Fortran: Module Interface tropopause_mod

Module TROPOPAUSE_MOD contains routines and variables for reading and returning the value of the annual mean tropopause.

INTERFACE:

```
      MODULE TROPOPAUSE_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_TROPOPAUSE
      PUBLIC  :: CHECK_VAR_TROP
      PUBLIC  :: COPY_FULL_TROP
      PUBLIC  :: DIAG_TROPOPAUSE
      PUBLIC  :: GET_MIN_TPAUSE_LEVEL
      PUBLIC  :: GET_MAX_TPAUSE_LEVEL
      PUBLIC  :: GET_TPAUSE_LEVEL
      PUBLIC  :: ITS_IN_THE_TROP
      PUBLIC  :: ITS_IN_THE_STRAT
      PUBLIC  :: READ_TROPOPAUSE
      PUBLIC  :: SAVE_FULL_TROP
#if defined( DEVEL)
      PUBLIC  :: LMIN, LMAX
#endif
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: INIT_TROPOPAUSE
```

REVISION HISTORY:

```
   22 Aug 2005 - R. Yantosca - Initial version
   (1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (2 ) Simplify counting of tropospheric boxes (bmy, 11/1/05)
   (3 ) Added case of variable tropopause.
        The definition of the tropopause boxes is different in the two cases.
        They are part of the troposphere in the case of a variable
        troposphere. LMAX, LMIN are the min and max extent of the troposphere
        in that case.  (bdf, phs, 1/19/07)
   (4 ) Bug fix: set NCS=NCSURBAN for safety's sake (bmy, 4/25/07)
   (5 ) Updated comments (bmy, 9/18/07)
   (6 ) Bug fix: make ITS_IN_THE_STRAT more robust. (phs, 11/14/08)
   09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.93.1 copy_full_trop

Subroutine COPY_FULL_TROP takes the saved full troposphere and copies chemical species into the current troposphere that will be used in SMVGEAR for this timestep.

INTERFACE:

```
      SUBROUTINE COPY_FULL_TROP
```

USES:

```
      USE COMODE_MOD,     ONLY : CSPEC,  CSPEC_FULL
      USE COMODE_MOD,     ONLY : IXSAVE, IYSAVE, IZSAVE

      USE CMN_SIZE_MOD
      USE COMODE_LOOP_MOD
```

REMARKS:

```
    ROUTINE NEEDED BECAUSE WITH VARIABLE TROPOPAUSE
    JLOOP WILL NOT ALWAYS REFER TO THE SAME (I,J,L) BOX
```

REVISION HISTORY:

```
    14 Sep 2006 - P. Le Sager - Initial version
    (1 ) Very similar to a get_properties of an object. Should probably
         be in COMODE_MOD.F, and called GET_SPECIES_CONCENTRATION (phs)
    (2 ) Bug fix: set NCS=NCSURBAN for safety's sake (bmy, 4/25/07)
    09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.93.2 save_full_trop

Subroutine SAVE_FULL_TROP takes the current troposphere and copies chemical species into the full troposphere that will be used in SMVGEAR for this timestep.

INTERFACE:

```
      SUBROUTINE SAVE_FULL_TROP
```

USES:

```
      USE COMODE_MOD,     ONLY : CSPEC,  CSPEC_FULL
      USE COMODE_MOD,     ONLY : IXSAVE, IYSAVE, IZSAVE

      USE CMN_SIZE_MOD
      USE COMODE_LOOP_MOD
```

REMARKS:

```
    ROUTINE NEEDED BECAUSE WITH VARIABLE TROPOPAUSE
    JLOOP WILL NOT ALWAYS REFER TO THE SAME (I,J,L) BOX
```

REVISION HISTORY:

```
    14 Sep 2006 - P. Le Sager - Initial version
    (1 ) Very similar to a set_properties of an object. Should probably
         be in COMODE_MOD.F, and called SAVE_SPECIES_CONCENTRATION (phs)
    (2 ) Bug fix: set NCS=NCSURBAN for safety's sake! (bmy, 4/25/07)
    09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.93.3 check_var_trop

Subroutine CHECK_VAR_TROP checks that the entire variable troposphere is included in the 1..LLTROP range, and set the LMIN and LMAX to current min and max tropopause.

INTERFACE:

```
SUBROUTINE CHECK_VAR_TROP
```

USES:

```
USE DAO_MOD,       ONLY : TROPP
USE ERROR_MOD,     ONLY : GEOS_CHEM_STOP

USE CMN_SIZE_MOD      ! Size parameters
USE CMN_MOD           ! LPAUSE, for backwards compatibility
```

REVISION HISTORY:

```
24 Aug 2006 - P. Le Sager - Initial version
(1 ) LLTROP is set at the first level entirely above 20 km (phs, 9/29/06)
(2 ) Fix LPAUSE for CH4 chemistry (phs, 1/19/07)
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.93.4 read_tropopause

Subroutine READ_TROPOPAUSE reads in the annual mean tropopause.

INTERFACE:

```
SUBROUTINE READ_TROPOPAUSE
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE ERROR_MOD,     ONLY : GEOS_CHEM_STOP
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD      ! Size parameters
USE CMN_MOD           ! LPAUSE, for backwards compatibility
```

REVISION HISTORY:

```
13 Dec 1999 - Q. Li, R. Yantosca - Initial version
(1 ) Call READ_BPCH2 to read in the annual mean tropopause data
      which is stored in binary punch file format. (bmy, 12/13/99)
(2 ) Now also read integer flags for ND27 diagnostic -- these determine
```

```
      how to sum fluxes from boxes adjacent to the annual mean tropoause.
      (qli, bmy, 1/7/00)
(3 ) Cosmetic changes (bmy, 3/17/00)
(4 ) Reference F90 module "bpch2_mod" which contains routine "read_bpch2"
      for reading data from binary punch files (bmy, 6/28/00)
(5 ) Call TRANSFER_2D from "transfer_mod.f" to cast data from REAL*4 to
      INTEGER and also to resize to (IIPAR,JJPAR).  ARRAY needs to be of
      size (IIPAR,JJPAR).  Also updated comments and made cosmetic changes.
      Removed obsolete variables.(bmy, 9/26/01)
(6 ) Removed obsolete code from 9/01 (bmy, 10/26/01)
(7 ) Now read annual mean tropopause files from the ann_mean_trop_200202/
      subdirectory of DATA_DIR (bmy, 1/24/02)
(8 ) Eliminated obsolete code from 1/02 (bmy, 2/27/02)
(9 ) Now write file name to stdout (bmy, 4/3/02)
(10) Now reference GEOS_CHEM_STOP from "error_mod.f", which frees all
      allocated memory before stopping the run. (bmy, 10/15/02)
(11) Now call READ_BPCH2 with QUIET=.TRUE. to suppress printing of extra
      info to stdout.  Also updated FORMAT strings. (bmy, 3/14/03)
(12) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(13) Now bundled into "tropopause_mod.f' (bmy, 2/10/05)
(14) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(15) Simplify counting of # of tropospheric boxes (bmy, 11/1/05)
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.93.5 get_max_tpause_level

Function GET_MAX_TPAUSE_LEVEL returns GEOS-Chem level at the highest extent of the annual mean tropopause.

INTERFACE:

```
FUNCTION GET_MAX_TPAUSE_LEVEL() RESULT( L_MAX )
```

RETURN VALUE:

```
INTEGER :: L_MAX    ! Maximum tropopause level
```

REVISION HISTORY:

```
10 Feb 2005 - R. Yantosca - Initial version
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.93.6 get_min_tpause_level

Function GET_MIN_TPAUSE_LEVEL returns GEOS-Chem level at the lowest extent of the annual mean tropopause.

INTERFACE:

```
FUNCTION GET_MIN_TPAUSE_LEVEL() RESULT( L_MIN )
```

RETURN VALUE:

```
INTEGER :: L_MIN   ! Minimum tropopause level
```

REVISION HISTORY:

```
10 Feb 2005 - R. Yantosca - Initial version
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.93.7 get_tpause_level

Function GET_TPAUSE_LEVEL returns the tropopause level L_TP at surface location (I,J). Therefore, grid box (I,J,L_TP) is partially in the troposphere and partially in the stratosphere. The grid box below this, (I,J,L_TP-1), is the last totally tropospheric box in the column.

INTERFACE:

```
FUNCTION GET_TPAUSE_LEVEL( I, J ) RESULT( L_TP )
```

USES:

```
USE DAO_MOD,      ONLY : TROPP, PSC2
USE LOGICAL_MOD,  ONLY : LVARTROP
USE ERROR_MOD,    ONLY : GEOS_CHEM_STOP
USE PRESSURE_MOD, ONLY : GET_PEDGE

USE CMN_SIZE_MOD            ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I      ! Longitude index
INTEGER, INTENT(IN) :: J      ! Latitude index
```

RETURN VALUE:

```
INTEGER             :: L_TP   ! Tropopause level at (I,J)
```

REVISION HISTORY:

```
22 Aug 2005 - R. Yantosca - Initial version
09 Sep 2010 - R. Yantosca - Added ProTeX headers
10 Sep 2010 - R. Yantosca - Update comments, remove obsolete documentation
```

1.93.8 its_in_the_trop

Function ITS_IN_THE_TROP returns TRUE if grid box (I,J,L) lies within the troposphere, or FALSE otherwise.

INTERFACE:

```
FUNCTION ITS_IN_THE_TROP( I, J, L ) RESULT ( IS_TROP )
```

USES:

```
USE DAO_MOD,      ONLY : TROPP, PSC2
USE LOGICAL_MOD,  ONLY : LVARTROP
USE PRESSURE_MOD, ONLY : GET_PEDGE
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I         ! Longitude index
INTEGER, INTENT(IN) :: J         ! Latitude index
INTEGER, INTENT(IN) :: L         ! Level index
```

RETURN VALUE:

```
LOGICAL             :: IS_TROP   ! =T if we are in the troposphere
```

REMARKS:

REVISION HISTORY:

```
10 Feb 2005 - P. Le Sager - Initial version
(1 ) Modified for variable tropopause (phs, 9/14/06)
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.93.9 its_in_the_strat

Function ITS_IN_THE_STRAT returns TRUE if grid box (I,J,L) lies within the stratosphere, or FALSE otherwise.

INTERFACE:

```
FUNCTION ITS_IN_THE_STRAT( I, J, L ) RESULT( IS_STRAT )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I          ! Longitude index
INTEGER, INTENT(IN) :: J          ! Latitude index
INTEGER, INTENT(IN) :: L          ! Level index
```

RETURN VALUE:

```
LOGICAL             :: IS_STRAT   ! =T if we are in the stratosphere
```

REVISION HISTORY:

```
10 Feb 2005 - P. Le Sager - Initial version
(1 ) Modified for variable tropopause (phs, 9/14/06)
(2 ) Now return the opposite value of ITS_IN_THE_TROP.  This should help
      to avoid numerical issues. (phs, 11/14/08)
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.93.10 diag_tropopause

Subroutine TROPOPAUSE archives the ND55 tropopause diagnostic.

INTERFACE:

```
SUBROUTINE DIAG_TROPOPAUSE
```

USES:

```
USE DAO_MOD,         ONLY : BXHEIGHT
USE DAO_MOD,         ONLY : TROPP
USE DIAG_MOD,        ONLY : AD55
USE LOGICAL_MOD,     ONLY : LVARTROP
USE PRESSURE_MOD,    ONLY : GET_PCENTER
USE PRESSURE_MOD,    ONLY : GET_PEDGE

USE CMN_SIZE_MOD  ! Size parameters
USE CMN_DIAG_MOD  ! Diagnostic switches
```

REMARKS:

```
For GEOS-4, GEOS-5, 'MERRA', we use the tropopause pressure from the met
field archive to determine if we are in the tropopause or not.  Therefore,
the 3rd slot of AD55 should be archived with the tropopause pressure from
the met fields.

For other met fields, we have to estimate the tropopause pressure from the
tropopause level.  Archive the pressure at the midpoint of the level in
which the tropopause occurs.  NOTE: this may result in lower minimum
tropopause pressure than reality.
```

REVISION HISTORY:

```
30 Nov 1999 - H. Liu, R. Yantosca - Initial version
(1 ) Make sure the DO-loops go in the order L-J-I, wherever possible.
(2 ) Now archive ND55 diagnostic here rather than in DIAG1.F.  Also,
      use an allocatable array (AD55) to archive tropopause heights.
(3 ) HTPAUSE is now a local variable, since it is only used here.
(4 ) Make LTPAUSE a local variable, since LPAUSE is used to store
      the annual mean tropopause. (bmy, 4/17/00)
(5 ) Replace PW(I,J) with P(I,J).  Also updated comments. (bmy, 10/3/01)
```

```
(6 ) Removed obsolete code from 9/01 and 10/01 (bmy, 10/24/01)
(7 ) Added polar tropopause for GEOS-3 in #if defined( GEOS_3 ) block
     (bmy, 5/20/02)
(8 ) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(9 ) Now use GET_PCENTER from "pressure_mod.f" to compute the pressure
     at the midpoint of box (I,J,L).  Also deleted obsolete, commented-out
     code. (dsa, bdf, bmy, 8/21/02)
(10) Now reference BXHEIGHT and T from "dao_mod.f".  Also reference routine
     ERROR_STOP from "error_mod.f" (bmy, 10/15/02)
(11) Now uses routine GET_YMID from "grid_mod.f" to compute grid box
     latitude. (bmy, 2/3/03)
(12) Add proper polar tropopause level for GEOS-4 (bmy, 6/18/03)
(13) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(14) Get tropopause level from TROPOPAUSE_MOD.F routines (phs, 10/17/06)
10 Sep 2010 - R. Yantosca - Added ProTeX headers
10 Sep 2010 - R. Yantosca - For GEOS-4, GEOS-5, MERRA met fields, take the
                            the tropopause pressure directly from the
                            met fields rather than computing it here.
10 Sep 2010 - R. Yantosca - Remove reference to LPAUSE, it's obsolete
10 Sep 2010 - R. Yantosca - Reorganize #if blocks for clarity
10 Sep 2010 - R. Yantosca - Renamed to DIAG_TROPOPAUSE and bundled into
                            tropopause_mod.f
```

1.93.11 init_tropopause

Subroutine INIT_TROPOPAUSE allocates and zeroes module arrays.

INTERFACE:

```
SUBROUTINE INIT_TROPOPAUSE
```

USES:

```
! References to F90 modules
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
10 Feb 2005 - R. Yantosca - Initial version
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.93.12 cleanup_tropopause

Subroutine CLEANUP_TROPOPAUSE deallocates module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_TROPOPAUSE
```

REVISION HISTORY:

```
10 Feb 2005 - R. Yantosca - Initial version
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.94 Fortran: Module Interface Tpcore_FvDas_Mod

Overview

Module Tpcore_Fvdas_Mod contains routines for the TPCORE transport scheme, as implemented in the GMI model (cf. John Tannahill), based on Lin Rood 1995. The Harvard Atmospheric Chemistry Modeling Group has added modifications to implement the Philip-Cameron Smith pressure fixer for mass conservation. Mass flux diagnostics have also been added.

References

1. Lin, S.-J., and R. B. Rood, 1996: *Multidimensional flux form semi-Lagrangian transport schemes*, Mon. Wea. Rev., **124**, 2046-2070.

2. Lin, S.-J., W. C. Chao, Y. C. Sud, and G. K. Walker, 1994: *A class of the van Leer-type transport schemes and its applications to the moisture transport in a General Circulation Model*, Mon. Wea. Rev., **122**, 1575-1593.

Selecting E/W, N/S and vertical advection options

The flags IORD, JORD, KORD select which transport schemes are used in the E/W, N/S, and vertical directions, respectively. Here is a list of the possible values that IORD, JORD, KORD may be set to (original notes from S-J Lin):

1. 1st order upstream scheme (too diffusive, not a real option; it can be used for debugging purposes; this is THE only known "linear" monotonic advection scheme.).
2. 2nd order van Leer (full monotonicity constraint; see Lin et al 1994, MWR)
3. monotonic PPM* (Collela & Woodward 1984)
4. semi-monotonic PPM (same as 3, but overshoots are allowed)
5. positive-definite PPM (constraint on the subgrid distribution is only strong enough to prevent generation of negative values; both overshoots & undershoots are possible).

6. un-constrained PPM (nearly diffusion free; faster but positivity of the subgrid distribution is not quaranteed. Use this option only when the fields and winds are very smooth.

7. Huynh/Van Leer/Lin full monotonicity constraint. Only KORD can be set to 7 to enable the use of Huynh's 2nd monotonicity constraint for piece-wise parabolic distribution.

Recommended values:

- IORD=JORD=3 for high horizontal resolution.
- KORD=3 or 7

The implicit numerical diffusion decreases as _ORD increases. DO NOT use option 4 or 5 for non-positive definite scalars (such as Ertel Potential Vorticity).

In GEOS-Chem we have been using IORD=3, JORD=3, KORD=7. We have tested the OpenMP parallelization with these options. GEOS-Chem users who wish to use different (I,J,K)ORD options should consider doing single-procsessor vs. multi-processor tests to test the implementation of the parallelization.

GEOS-4 and GEOS-5 Hybrid Grid Definition

For GEOS-4 and GEOS-5 met fields, the pressure at the bottom edge of grid box (I,J,L) is defined as follows:

$$P_{edge}(I,J,L) = A_k(L) + [B_k(L) * P_{surface}(I,J)]$$

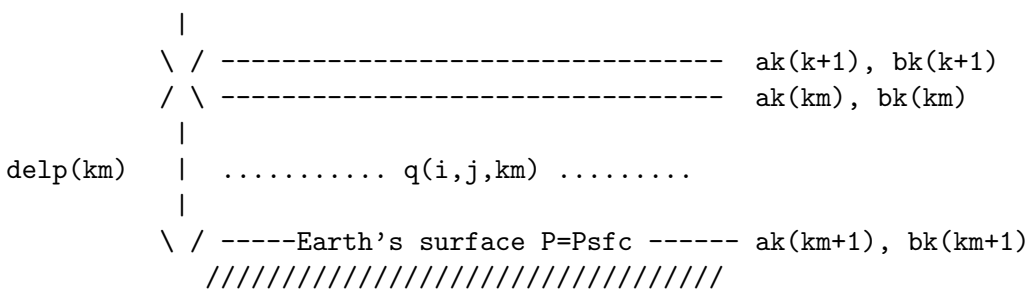
where

- $P_{surface}$(I,J) is the "true" surface pressure at lon,lat (I,J)
- A_k(L) has the same units as surface pressure [hPa]
- B_k(L) is a unitless constant given at level edges

$A_k(L)$ and $B_k(L)$ are supplied to us by GMAO.

REMARKS:

```
Ak(L) and Bk(L) are defined at layer edges.
                ////////////////////////////////
             / \ ------ Model top P=ak(1) --------- ak(1), bk(1)
              |
  delp(1)     |  ........... q(i,j,1) ............
              |
             \ / ---------------------------------  ak(2), bk(2)
             / \ ---------------------------------  ak(k), bk(k)
              |
  delp(k)     |  ........... q(i,j,k) ............
```



Note: surface pressure can be of any unit (e.g., pascal or mb) as long as it is consistent with the definition of (ak, bk) defined above. Winds (u,v), ps, and q are assumed to be defined at the same points.

The latitudes are given to the initialization routine: init_tpcore.

INTERFACE:

```
MODULE Tpcore_FvDas_Mod
```

USES:

```
  IMPLICIT NONE
#     include "define.h"
#     include "define.h"
  PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
  PUBLIC  ::  Init_Tpcore
  PUBLIC  ::  Exit_Tpcore
  PUBLIC  ::  Tpcore_FvDas
```

PRIVATE MEMBER FUNCTIONS:

```
  PRIVATE ::  Average_Const_Poles
  PRIVATE ::  Set_Cross_Terms
  PRIVATE ::  Calc_Vert_Mass_Flux
  PRIVATE ::  Set_Jn_Js
  PRIVATE ::  Calc_Advec_Cross_Terms
  PRIVATE ::  Qckxyz
  PRIVATE ::  Set_Lmts
  PRIVATE ::  Set_Press_Terms
  PRIVATE ::  Calc_Courant
  PRIVATE ::  Calc_Divergence
  PRIVATE ::  Do_Divergence_Pole_Sum
  PRIVATE ::  Do_Cross_Terms_Pole_I2d2
  PRIVATE ::  Xadv_Dao2
  PRIVATE ::  Yadv_Dao2
  PRIVATE ::  Do_Yadv_Pole_I2d2
  PRIVATE ::  Do_Yadv_Pole_Sum
  PRIVATE ::  Xtp
  PRIVATE ::  Xmist
```

```
PRIVATE ::  Fxppm
PRIVATE ::  Lmtppm
PRIVATE ::  Ytp
PRIVATE ::  Ymist
PRIVATE ::  Do_Ymist_Pole1_I2d2
PRIVATE ::  Do_Ymist_Pole2_I2d2
PRIVATE ::  Fyppm
PRIVATE ::  Do_Fyppm_Pole_I2d2
PRIVATE ::  Do_Ytp_Pole_Sum
PRIVATE ::  Fzppm
PRIVATE ::  Average_Press_Poles
!PRIVATE DATA MEMBERS:

REAL*8, ALLOCATABLE, SAVE :: dtdx5(:)
REAL*8, ALLOCATABLE, SAVE :: dtdy5(:)
REAL*8, ALLOCATABLE, SAVE :: cosp(:)
REAL*8, ALLOCATABLE, SAVE :: cose(:)
REAL*8, ALLOCATABLE, SAVE :: gw(:)
REAL*8, ALLOCATABLE, SAVE :: DLAT(:)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, GMAO
Modified for GMI model by John Tannahill, LLNL (jrt@llnl.gov)
Implemented into GEOS-Chem by Claire Carouge (ccarouge@seas.harvard.edu)
ProTeX documentation added by Bob Yantosca (yantosca@seas.harvard.edu)
OpenMP parallelization added by Bob Yantosca (yantosca@seas.harvard.edu)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from the GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Added
                            OpenMP parallel loops in various routines (and
                            made some modifications to facilitate OpenMP).
01 Apr 2009 - C. Carouge  - Modified OpenMp parallelization and move the
                            loops over vertical levels outside the
                            horizontal transport routines for reducing
                            processing time.
```

1.94.1 Init_Tpcore

Subroutine Init_Tpcore allocates and initializes all module variables,

INTERFACE:

```
SUBROUTINE Init_Tpcore( IM, JM, KM, JFIRST, JLAST, NG, MG, dt, ae, clat )
```

USES:

```
USE CMN_GCTM_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: IM        ! Global E-W dimension
INTEGER, INTENT(IN)  :: JM        ! Global N-S dimension
INTEGER, INTENT(IN)  :: KM        ! Vertical dimension
INTEGER, INTENT(IN)  :: NG        ! large ghost width
INTEGER, INTENT(IN)  :: MG        ! small ghost width
REAL*8,  INTENT(IN)  :: dt        ! Time step in seconds
REAL*8,  INTENT(IN)  :: ae        ! Earth's radius (m)
REAL*8,  INTENT(IN)  :: clat(JM)  ! latitude in radian
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: JFIRST    ! Local first index for N-S direction
INTEGER, INTENT(OUT) :: JLAST     ! Local last  index for N-S direction
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.94.2 Exit_Tpcore

Subroutine Exit_Tpcore deallocates all module variables.

INTERFACE:

```
SUBROUTINE Exit_Tpcore
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.94.3 Tpcore_FvDas

Subroutine Tpcore_FvDas takes horizontal winds on sigma (or hybrid sigma-p) surfaces and calculates mass fluxes, and then updates the 3D mixing ratio fields one time step (tdt). The basic scheme is a Multi-Dimensional Flux Form Semi-Lagrangian (FFSL) based on the van Leer or PPM (see Lin and Rood, 1995).

INTERFACE:

```
SUBROUTINE Tpcore_FvDas( dt,       ae,       IM,       JM,      KM,       &
                         JFIRST,   JLAST,    ng,       mg,      nq,       &
                         ak,       bk,       u,        v,       ps1,      &
                         ps2,      ps,       q,        iord,    jord,     &
                         kord,     n_adj,    XMASS,    YMASS,   FILL,     &
                         MASSFLEW, MASSFLNS, MASSFLUP, AREA_M2, TCVV,     &
                         ND24,     ND25,     ND26 )
```

USES:

```
! Include file w/ physical constants
USE CMN_GCTM_MOD
```

INPUT PARAMETERS:

```
! Transport time step [s]
REAL*8,  INTENT(IN)    :: dt

! Earth's radius [m]
REAL*8,  INTENT(IN)    :: ae

! Global E-W, N-S, and vertical dimensions
INTEGER, INTENT(IN)    :: IM
INTEGER, INTENT(IN)    :: JM
INTEGER, INTENT(IN)    :: KM

! Latitude indices for local first box and local last box
! (NOTE: for global grids these are 1 and JM, respectively)
INTEGER, INTENT(IN)    :: JFIRST
INTEGER, INTENT(IN)    :: JLAST

! Primary ghost region
! (NOTE: only required for MPI parallelization; use 0 otherwise)
INTEGER, INTENT(IN)    :: ng

! Secondary ghost region
! (NOTE: only required for MPI parallelization; use 0 otherwise)
INTEGER, INTENT(IN)    :: mg

! Ghosted latitudes (3 required by PPM)
! (NOTE: only required for MPI parallelization; use 0 otherwise)
```

```
      INTEGER, INTENT(IN)    :: nq

      ! Flags to denote E-W, N-S, and vertical transport schemes
      INTEGER, INTENT(IN)    :: iord
      INTEGER, INTENT(IN)    :: jord
      INTEGER, INTENT(IN)    :: kord

      ! Number of adjustments to air_mass_flux (0 = no adjustment)
      INTEGER, INTENT(IN)    :: n_adj

      ! Ak and Bk coordinates to specify the hybrid grid
      ! (see the REMARKS section below)
      REAL*8,  INTENT(IN)    :: ak(KM+1)
      REAL*8,  INTENT(IN)    :: bk(KM+1)

      ! u-wind (m/s) at mid-time-level (t=t+dt/2)
      REAL*8,  INTENT(IN)    :: u(IM,JFIRST:JLAST,KM)

      ! E/W and N/S mass fluxes [kg/s]
      ! (These are computed by the pressure fixer, and passed into TPCORE)
      REAL*8,  INTENT(IN)    :: XMASS(IM,JM,KM)
      REAL*8,  INTENT(IN)    :: YMASS(IM,JM,KM)

      ! Grid box surface area for mass flux diag [m2]
      REAL*8,  INTENT(IN)    :: AREA_M2(JM)

      ! Tracer masses for flux diag
      REAL*8,  INTENT(IN)    :: TCVV(NQ)

      ! Diagnostic flags
      INTEGER, INTENT(IN)    :: ND24    ! Turns on E/W     flux diagnostic
      INTEGER, INTENT(IN)    :: ND25    ! Turns on N/S     flux diagnostic
      INTEGER, INTENT(IN)    :: ND26    ! Turns on up/down flux diagnostic

      LOGICAL, INTENT(IN)    :: FILL    ! Fill negatives ?
```

INPUT/OUTPUT PARAMETERS:

```
      ! V-wind (m/s) at mid-time-level (t=t+dt/2)
      REAL*8,  INTENT(INOUT) :: v(IM, JFIRST-MG:JLAST+MG, KM)

      ! surface pressure at current time
      REAL*8,  INTENT(INOUT) :: ps1(IM, JFIRST:JLAST)

      ! surface pressure at future time=t+dt
      REAL*8,  INTENT(INOUT) :: ps2(IM, JFIRST:JLAST)

      ! Tracer "mixing ratios" [v/v]
      REAL*8,  INTENT(INOUT) :: q(IM, JFIRST-NG:JLAST+NG, KM, NQ)
```

```
    ! E/W, N/S, and up/down diagnostic mass fluxes
 --- Previous to (ccc, 12/3/09)
     REAL*8,  INTENT(INOUT) :: MASSFLEW(IM,JM,KM,NQ)  ! for ND24 diagnostic
     REAL*8,  INTENT(INOUT) :: MASSFLNS(IM,JM,KM,NQ)  ! for ND25 diagnostic
     REAL*8,  INTENT(INOUT) :: MASSFLUP(IM,JM,KM,NQ)  ! for ND26 diagnostic
    REAL*8,  INTENT(INOUT) :: MASSFLEW(:,:,:,:)  ! for ND24 diagnostic
    REAL*8,  INTENT(INOUT) :: MASSFLNS(:,:,:,:)  ! for ND25 diagnostic
    REAL*8,  INTENT(INOUT) :: MASSFLUP(:,:,:,:)  ! for ND26 diagnostic
```

OUTPUT PARAMETERS:

```
    ! "Predicted" surface pressure [hPa]
    REAL*8,  INTENT(OUT)   :: ps(IM,JFIRST:JLAST)
```

AUTHOR:

```
    Original code from Shian-Jiann Lin, DAO)
    John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
    05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                               Yeh with the TPCORE routines from GMI model.
                               This eliminates the polar overshoot in the
                               stratosphere.
    05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                               Declare all REAL variables as REAL*8.  Also
                               make sure all numerical constants are declared
                               with the "D" double-precision exponent.  Added
                               OpenMP parallel DO loops.
    01 Apr 2009 - C. Carouge  - Modified OpenMp parallelization and move the
                               loops over vertical levels outside the
                               horizontal transport routines for reducing
                               processing time.
    03 Dec 2009 - C. Carouge  - Modify declarations of MASSFLEW, MASSFLNS and
                               MASSFLUP to save memory space.
```

1.94.4 Average_Const_Poles

Subroutine Average_Const_Poles averages the species concentrations at the Poles when the Polar cap is enlarged. It makes the last two latitudes equal.

INTERFACE:

```
  SUBROUTINE Average_Const_Poles( dap ,   dbk,   rel_area, pctm1, const1, &
                                  JU1_GL, J2_GL, I2_GL,    I1,    I2,     &
                                  JU1,    J2,    ILO,    &
                                  IHI,    JULO,  JHI )
```

INPUT PARAMETERS:

```
! Global latitude indices of the South Pole and North Pole
INTEGER, INTENT(IN)   :: JU1_GL, J2_GL

! Global max longitude index
INTEGER, INTENT(IN)   :: I2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)   :: I1,  I2
INTEGER, INTENT(IN)   :: JU1, J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: ILO,  IHI
INTEGER, INTENT(IN)   :: JULO, JHI

! Pressure difference across layer from (ai * pt) term [hPa]
REAL*8,  INTENT(IN)   :: dap

! Difference in bi across layer - the dSigma term
REAL*8,  INTENT(IN)   :: dbk

! Relative surface area of grid box [fraction]
REAL*8,  INTENT(IN)   :: rel_area(JU1:J2)

! CTM surface pressure at t1 [hPa]
REAL*8,  INTENT(IN)   :: pctm1( ILO:IHI, JULO:JHI )
```

INPUT/OUTPUT PARAMETERS:

```
! Species concentration, known at zone center [mixing ratio]
REAL*8, INTENT(INOUT) :: const1( I1:I2, JU1:J2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.94.5 Set_Cross_Terms

Subroutine Set_Cross_Terms sets the cross terms for E-W horizontal advection.

INTERFACE:

```
SUBROUTINE Set_Cross_Terms( crx,   cry,   ua, va, J1P,   J2P,   &
                            I1_GL, I2_GL, JU1_GL, J2_GL, ILO,   &
                            IHI,   JULO,  JHI,    I1,    I2,    &
                            JU1,   J2,    CROSS )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)   :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: I1_GL,  I2_GL
INTEGER, INTENT(IN)   :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)   :: I1,     I2
INTEGER, INTENT(IN)   :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: ILO,    IHI
INTEGER, INTENT(IN)   :: JULO,   JHI

! Courant number in E-W direction
REAL*8,  INTENT(IN) :: crx(ILO:IHI, JULO:JHI)

! Courant number in N-S direction
REAL*8,  INTENT(IN) :: cry(ILO:IHI, JULO:JHI)

! Logical switch.  If CROSS=T then cross-terms will be computed.
LOGICAL, INTENT(IN) :: CROSS
```

OUTPUT PARAMETERS:

```
! Average of Courant numbers from il and il+1
REAL*8, INTENT(OUT) :: ua(ILO:IHI, JULO:JHI)

! Average of Courant numbers from ij and ij+1
REAL*8, INTENT(OUT) :: va(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
```

```
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.6 Calc_Vert_Mass_Flux

Subroutine Calc_Vert_Mass_Flux calculates the vertical mass flux.

INTERFACE:

```
SUBROUTINE Calc_Vert_Mass_Flux( dbk, dps_ctm, dpi, wz, I1,  &
                                I2,  JU1,     J2,  K1, K2 )
```

INPUT PARAMETERS:

```
! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)   :: I1,  I2
INTEGER, INTENT(IN)   :: JU1, J2
INTEGER, INTENT(IN)   :: K1,  K2

! Difference in bi across layer - the dSigma term
REAL*8,  INTENT(IN)  :: dbk(K1:K2)

! CTM surface pressure tendency; sum over vertical of dpi
! calculated from original mass fluxes [hPa]
REAL*8,  INTENT(IN)  :: dps_ctm(I1:I2, JU1:J2)

! Divergence at a grid point; used to calculate vertical motion [mb]
REAL*8,  INTENT(IN)  :: dpi(I1:I2, JU1:J2, K1:K2)
```

OUTPUT PARAMETERS:

```
! Large scale mass flux (per time step tdt) in the vertical
! direction as diagnosed from the hydrostatic relationship [hPa]
REAL*8, INTENT(OUT) :: wz(I1:I2, JU1:J2, K1:K2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops
```

1.94.7 Set_Jn_Js

Subroutine Set_Jn_Js determines Jn and Js, by looking where Courant number is ¿ 1.

INTERFACE:

```
SUBROUTINE Set_Jn_Js( jn,  js,     crx,   ILO, IHI, JULO, &
                      JHI, JU1_GL, J2_GL, J1P, J2P, I1,   &
                      I2,  JU1,    J2,    K1,  K2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)   :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)   :: I1,     I2
INTEGER, INTENT(IN)   :: JU1,    J2
INTEGER, INTENT(IN)   :: K1,     K2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: ILO,    IHI
INTEGER, INTENT(IN)   :: JULO,   JHI

! Courant number in E-W direction
REAL*8,  INTENT(IN)  :: crx(ILO:IHI, JULO:JHI, K1:K2)
```

OUTPUT PARAMETERS:

```
! Northward of latitude index = jn; Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(OUT) :: jn(K1:K2)

! Southward of latitude index = js; Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(OUT) :: js(K1:K2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REMARKS:

```
We cannot parallelize this subroutine because there is a CYCLE statement
within the outer loop.
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.94.8 Calc_Advec_Cross_Terms

Subroutine Calc_Advec_Cross_Terms calculates the advective cross terms.

INTERFACE:

```
SUBROUTINE Calc_Advec_Cross_Terms( jn,     js,    qq1,  qqu,  qqv,   &
                                   ua,     va,    J1P,  J2P,  I2_GL, &
                                   JU1_GL, J2_GL, ILO,  IHI,  JULO,  &
                                   JHI,    I1,    I2,   JU1,  J2,    &
                                   CROSS )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
```

```
INTEGER, INTENT(IN)  ::         I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Northward of latitude index = jn, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)  :: Jn

! Southward of latitude index = js, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)  :: Js

! Species concentration (mixing ratio)
REAL*8,  INTENT(IN)  :: qq1(ILO:IHI, JULO:JHI)

! Average of Courant numbers from il and il+1
REAL*8,  INTENT(IN)  :: ua (ILO:IHI, JULO:JHI)

! Average of Courant numbers from ij and ij+1
REAL*8,  INTENT(IN)  :: va (ILO:IHI, JULO:JHI)

! Logical switch: If CROSS=T then cross-terms are being computed
LOGICAL, INTENT(IN)  :: CROSS
```

OUTPUT PARAMETERS:

```
! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(OUT) :: qqu(ILO:IHI, JULO:JHI)

! concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(OUT) :: qqv(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
```

```
                              stratosphere.
     05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                              Declare all REAL variables as REAL*8.  Also
                              make sure all numerical constants are declared
                              with the "D" double-precision exponent.  Added
                              OpenMP parallel do loops.
     01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.9 Qckxyz

Subroutine Qckxyz routine checks for "filling".

INTERFACE:

```
SUBROUTINE Qckxyz( dq1, J1P, J2P,  JU1_GL, J2_GL, &
                   ILO, IHI, JULO, JHI,    I1,    &
                   I2,  JU1, J2,   K1,     K2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max latitude (J) indices
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2
INTEGER, INTENT(IN)  :: K1,     K2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI
```

INPUT/OUTPUT PARAMETERS:

```
! Species density [hPa]
REAL*8,  INTENT(INOUT) :: dq1(ILO:IHI, JULO:JHI, K1:K2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
```

1.94.10 Set_Lmts

Subroutine Set_Lmts sets ILMT, JLMT, KLMT.

INTERFACE:

```
SUBROUTINE Set_Lmts( ilmt, jlmt, klmt, I2_GL, J2_GL, iord, jord, kord )
```

INPUT PARAMETERS:

```
! Global maximum longitude (I) and longitude (J) indices
INTEGER, INTENT(IN)  :: I2_GL, J2_GL

! Flags to denote E-W, N-S, and vertical transport schemes
! (See REMARKS section of routine Tpcore_FvDas for more info)
INTEGER, INTENT(IN)  :: iord, jord, kord
```

OUTPUT PARAMETERS:

```
! Controls various options in E-W advection
INTEGER, INTENT(OUT) :: ilmt

! Controls various options in N-S advection
INTEGER, INTENT(OUT) :: jlmt

! Controls various options in vertical advection
INTEGER, INTENT(OUT) :: klmt
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
```

```
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.94.11 Set_Press_Terms

Subroutine Set_Press_Terms sets the pressure terms: DELP1, DELPM, PU.

INTERFACE:

```
SUBROUTINE Set_Press_Terms( dap,   dbk,  pres1,  pres2, delp1,   &
                           delpm, pu,   JU1_GL, J2_GL, ILO,     &
                           IHI,   JULO, JHI,    J1P,   J2P,     &
                           I1,    I2,   JU1,    J2)
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max latitude (J) indices
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Pressure difference across layer from (ai * pt) term [hPa]
REAL*8,  INTENT(IN)  :: dap

! Difference in bi across layer - the dSigma term
REAL*8,  INTENT(IN)  :: dbk

! Surface pressure at t1 [hPa]
REAL*8,  INTENT(IN)  :: pres1(ILO:IHI, JULO:JHI)

! Surface pressure at t1+tdt [hPa]
REAL*8,  INTENT(IN)  :: pres2(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Pressure thickness, the pseudo-density in a
! hydrostatic system at t1 [hPa]
REAL*8, INTENT(OUT) :: delp1(ILO:IHI, JULO:JHI)

! Pressure thickness, the pseudo-density in a
! hydrostatic system at t1+tdt/2 (approximate) [hPa]
REAL*8, INTENT(OUT) :: delpm(ILO:IHI, JULO:JHI)

! Pressure at edges in "u" [hPa]
REAL*8, INTENT(OUT) :: pu(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.12 Calc_Courant

Subroutine Calc_Courant calculates courant numbers from the horizontal mass fluxes.

INTERFACE:

```
SUBROUTINE Calc_Courant( cose, delpm, pu,     xmass, ymass, crx, cry,  &
                         J1P,  J2P,   JU1_GL, J2_GL, ILO,   IHI, JULO, &
                         JHI,  I1,    I2,     JU1,   J2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max latitude (J) indices
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL
```

```
! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Cosine of grid box edges
REAL*8,  INTENT(IN)  :: cose (JU1_GL:J2_GL)

! Pressure thickness, the pseudo-density in a hydrostatic system
! at t1+tdt/2 (approximate) (mb)
REAL*8,  INTENT(IN)  :: delpm(ILO:IHI, JULO:JHI)

! pressure at edges in "u"  (mb)
REAL*8,  INTENT(IN)  :: pu   (iLO:IHI, JULO:JHI)

! horizontal mass flux in E-W and N-S directions [hPa]
REAL*8,  INTENT(IN)  :: xmass(ILO:IHI, JULO:JHI)
REAL*8,  INTENT(IN)  :: ymass(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Courant numbers in E-W and N-S directions
REAL*8,  INTENT(OUT) :: crx(ILO:IHI, JULO:JHI)
REAL*8,  INTENT(OUT) :: cry(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.13 Calc_Divergence

Subroutine Calc_Divergence calculates the divergence.

INTERFACE:

```
SUBROUTINE Calc_Divergence( do_reduction, geofac_pc, geofac, dpi,   &
                            xmass,        ymass,     J1P,    J2P,   &
                            I1_GL,        I2_GL,     JU1_GL, J2_GL, &
                            ILO,          IHI,       JULO,   JHI,   &
                            I1,           I2,        JU1,    J2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Set to F if called on Master or T if called by Slaves
! (NOTE: This is only for MPI parallelization, for OPENMP it should be F)
LOGICAL, INTENT(IN)  :: do_reduction

! Special geometrical factor (geofac) for Polar cap
REAL*8 , INTENT(IN)  :: geofac_pc

! Geometrical factor for meridional advection; geofac uses correct
! spherical geometry, and replaces acosp as the meridional geometrical
! factor in TPCORE
REAL*8 , INTENT(IN)  :: geofac(JU1_GL:J2_GL)

! Horizontal mass flux in E/W and N/S directions [hPa]
REAL*8 , INTENT(IN)  :: xmass(ILO:IHI, JULO:JHI)
REAL*8 , INTENT(IN)  :: ymass(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Divergence at a grid point; used to calculate vertical motion [hPa]
```

```
REAL*8,  INTENT(OUT) :: dpi(I1:I2, JU1:J2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.14 Do_Divergence_Pole_Sum

Subroutine Do_Divergence_Pole_Sum sets the divergence at the Poles.

INTERFACE:

```
SUBROUTINE Do_Divergence_Pole_Sum( do_reduction, geofac_pc, dpi, ymass, &
                                   I1_GL,        I2_GL,     J1P, J2P,   &
                                   JU1_GL,       J2_GL,     ILO, IHI,   &
                                   JULO,         JHI,       I1,  I2,    &
                                   JU1,          J2)
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2
```

```
! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Set to T if called on Master or F if called by slaves
! NOTE: This seems not to be used here....)
LOGICAL, INTENT(IN)   :: do_reduction

! Special geometrical factor (geofac) for Polar cap
REAL*8,  INTENT(in)   :: geofac_pc

! Horizontal mass flux in N-S direction [hPa]
REAL*8,  INTENT(IN)   :: ymass(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Divergence at a grid point; used to calculate vertical motion [hPa]
REAL*8,  INTENT(OUT)  :: dpi(I1:I2, JU1:J2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent. Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.15 Do_Cross_Terms_Pole_I2d2

Subroutine Do_Cross_Terms_Pole_I2d2 sets "va" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Cross_Terms_Pole_I2d2( cry,   va,  I1_GL, I2_GL, JU1_GL, &
                                     J2_GL, J1P, ILO,   IHI,   JULO,   &
                                     JHI,   I1,  I2,    JU1,   J2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edge of the South polar cap
! J1P=JU1_GL+1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Courant number in N-S direction
REAL*8,  INTENT(IN)  :: cry(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Average of Courant numbers from ij and ij+1
REAL*8,  INTENT(OUT) :: va(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.16 Xadv_Dao2

Subroutine Xadv_Dao2 is the advective form E-W operator for computing the adx (E-W) cross term.

INTERFACE:

```
SUBROUTINE Xadv_Dao2( iad,    jn,    js,  adx,  qqv, &
                      ua,     ILO,   IHI, JULO, JHI, &
                      JU1_GL, J2_GL, J1P, J2P,  I1,  &
                      I2,     JU1,   J2)
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max latitude (J) indices
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! if iad = 1, use 1st order accurate scheme;
! if iad = 2, use 2nd order accurate scheme
INTEGER, INTENT(IN)  :: iad

! Northward of latitude index = jn, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)  :: jn

! southward of latitude index = js, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)  :: js

! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqv(ILO:IHI, JULO:JHI)

! Average of Courant numbers from il and il+1
REAL*8,  INTENT(IN)  :: ua(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Cross term due to E-W advection [mixing ratio]
REAL*8,  INTENT(OUT) :: adx(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.17 Yadv_Dao2

Subroutine Yadv_Dao2 is the advective form N-S operator for computing the ady (N-S) cross term.

INTERFACE:

```
SUBROUTINE Yadv_Dao2( iad,   ady,    qqu,   va,  I1_GL, &
                      I2_GL, JU1_GL, J2_GL, J1P, J2P,   &
                      ILO,   IHI,    JULO,  JHI, I1,    &
                      I2,    JU1,    J2)
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! If iad = 1, use 1st order accurate scheme;
! If iad = 2, use 2nd order accurate scheme
INTEGER, INTENT(IN)  :: iad
```

```
! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO:JHI)

! Average of Courant numbers from ij and ij+1
REAL*8,  INTENT(IN)  :: va(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Cross term due to N-S advection (mixing ratio)
REAL*8,  INTENT(OUT) :: ady(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.18 Do_Yadv_Pole_I2d2

Subroutine Do_Yadv_Pole_I2d2 sets "qquwk" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Yadv_Pole_I2d2 ( qqu, qquwk, I1_GL, I2_GL, JU1_GL, J2_GL, &
                               J1P, ILO,   IHI,   JULO,  JHI,    I1,    &
                               I2,  JU1,   J2  )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the South polar cap
! J1P=JU1_GL+1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL
```

```
! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! qqu working array [mixing ratio]
REAL*8,  INTENT(OUT) :: qquwk(ILO:IHI, JULO-2:JHI+2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.19 Do_Yadv_Pole_Sum

Subroutine Do_Yadv_Pole_Sum sets the cross term due to N-S advection at the Poles.

INTERFACE:

```
SUBROUTINE Do_Yadv_Pole_Sum( ady, I1_GL, I2_GL, JU1_GL, J2_GL, J1P, &
                             ILO, IHI,   JULO,  JHI,    I1,    I2,  &
                             JU1, J2)
```

INPUT PARAMETERS:

```
! Global latitude index at the edge of the South polar cap
! J1P=JU1_GL+1; for a polar cap of 1 latitude band
```

```
! J1P=JU1_GL+2; for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)    :: J1P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: I1_GL,  I2_GL
INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2
INTEGER, INTENT(IN)    :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI
```

OUTPUT PARAMETERS:

```
! Cross term due to N-S advection (mixing ratio)
REAL*8,  INTENT(INOUT) :: ady(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.  Also make a logical
                            to test if we are using an extended polar cap.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.20 Xtp

Subroutine Xtp does horizontal advection in the E-W direction.

INTERFACE:

```
SUBROUTINE Xtp( ilmt, jn,  js,    pu,     crx,   dq1, qqv, xmass, fx,  &
                J1P,  J2P, I2_GL, JU1_GL, J2_GL, ILO, IHI, JULO,  JHI, &
                I1,   I2,  JU1,   J2,  iord )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)    :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    ::         I2_GL
INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2
INTEGER, INTENT(IN)    :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI

! Controls various options in E-W advection
INTEGER, INTENT(IN)    :: ilmt

! Northward of latitude index = jn, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)    :: jn

! Southward of latitude index = js, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)    :: js

! Option for E-W transport scheme.  See module header for more info.
INTEGER, INTENT(IN)    :: iord

! pressure at edges in "u" [hPa]
REAL*8,  INTENT(IN)    :: pu(ILO:IHI, JULO:JHI)

! Courant number in E-W direction
REAL*8,  INTENT(IN)    :: crx(ILO:IHI, JULO:JHI)

! Horizontal mass flux in E-W direction [hPa]
REAL*8,  INTENT(IN)    :: xmass(ILO:IHI, JULO:JHI)
```

INPUT/OUTPUT PARAMETERS:

```
! Species density [hPa]
REAL*8,  INTENT(INOUT) :: dq1(ILO:IHI, JULO:JHI)

! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(INOUT) :: qqv(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! E-W flux [mixing ratio]
REAL*8,  INTENT(OUT)   :: fx(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.21 Xmist

Subroutine Xmist computes the linear tracer slope in the E-W direction. It uses the Lin et. al. 1994 algorithm.

INTERFACE:

```
SUBROUTINE Xmist( dcx,  qqv, J1P, J2P, I2_GL, JU1_GL, J2_GL, ILO, IHI, &
                  JULO, JHI, I1,  I2,  JU1,   J2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  ::         I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
```

```
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqv(-I2/3:I2+I2/3, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Slope of concentration distribution in E-W direction [mixing ratio]
REAL*8,  INTENT(OUT) :: dcx(-I2/3:I2+I2/3, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.22 Fxppm

Subroutine Fxppm is the 1D "outer" flux form operator based on the Piecewise Parabolic Method (PPM; see also Lin and Rood 1996) for computing the fluxes in the E-W direction.

INTERFACE:

```
SUBROUTINE Fxppm( ij,  ilmt, crx, dcx, fx, qqv,     &
                  ILO, IHI, JULO, JHI, I1,  I2 )
```

INPUT PARAMETERS:

```
! Local min & max longitude (I) and altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI

! Latitude (IJ) and altitude (IK) indices
```

```
INTEGER, INTENT(IN)    :: ij

! Controls various options in E-W advection
INTEGER, INTENT(IN)    :: ilmt

! Courant number in E-W direction
REAL*8,  INTENT(IN)    :: crx(I1:I2, JULO:JHI)
```

INPUT/OUTPUT PARAMETERS:

```
  ! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(INOUT) :: qqv(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Slope of concentration distribution in E-W direction (mixing ratio)
REAL*8,  INTENT(OUT)   :: dcx(ILO:IHI, JULO:JHI)

! E-W flux [mixing ratio]
REAL*8,  INTENT(OUT)   :: fx(I1:I2, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REMARKS:

```
This routine is called from w/in a OpenMP parallel loop fro
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
                            Also remove the allocatable arrays, which
                            interfere w/ OpenMP parallelization.
01 Apr 2009 - C. Carouge  - The input arrays are now 2D only.
```

1.94.23 Lmtppm

Subroutine Lmtppm enforces the full monotonic, semi-monotonic, or the positive-definite constraint to the sub-grid parabolic distribution of the Piecewise Parabolic Method (PPM).

INTERFACE:

```
SUBROUTINE Lmtppm( lenx, lmt, a6, al, ar, dc, qa )
```

INPUT PARAMETERS:

```
! If 0 => full monotonicity;
! If 1 => semi-monotonic constraint (no undershoots);
! If 2 => positive-definite constraint
INTEGER, INTENT(IN)    :: lmt

! Vector length
INTEGER, INTENT(IN)    :: lenx
```

INPUT/OUTPUT PARAMETERS:

```
! Curvature of the test parabola
REAL*8,  INTENT(INOUT) :: a6(lenx)

! Left edge value of the test parabola
REAL*8,  INTENT(INOUT) :: al(lenx)

! Right edge value of the test parabola
REAL*8,  INTENT(INOUT) :: ar(lenx)

! 0.5 * mismatch
REAL*8,  INTENT(INOUT) :: dc(lenx)

! Cell-averaged value
REAL*8,  INTENT(INOUT) :: qa(lenx)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.94.24 Ytp

Subroutine Ytp does horizontal advection in the N-S direction.

INTERFACE:

```
SUBROUTINE Ytp( jlmt,  geofac_pc, geofac, cry,  dq1,   qqu,    qqv,    &
                ymass, fy,        J1P,    J2P,  I1_GL, I2_GL,  JU1_GL, &
                J2_GL, ilong,     ILO,    IHI,  JULO,  JHI,    I1,     &
                I2,    JU1,       J2,    jord )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)    :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: I1_GL,  I2_GL
INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2
INTEGER, INTENT(IN)    :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI

! ???
INTEGER, INTENT(IN)    :: ilong

! Controls various options in N-S advection
INTEGER, INTENT(IN)    :: jlmt

! N-S transport scheme (see module header for more info)
INTEGER, INTENT(IN)    :: jord

! special geometrical factor (geofac) for Polar cap
REAL*8,  INTENT(IN)    :: geofac_pc

! geometrical factor for meridional advection; geofac uses correct
! spherical geometry, and replaces acosp as the  meridional geometrical
! factor in tpcore
REAL*8,  INTENT(IN)    :: geofac(JU1_GL:J2_GL)

! Courant number in N-S direction
REAL*8,  INTENT(IN)    :: cry(ILO:IHI, JULO:JHI)

! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)    :: qqu(ILO:IHI, JULO:JHI)

! Horizontal mass flux in N-S direction [hPa]
REAL*8,  INTENT(IN)    :: ymass(ILO:IHI, JULO:JHI)
```

INPUT/OUTPUT PARAMETERS:

```
! Species density [hPa]
REAL*8,  INTENT(INOUT) :: dq1(ILO:IHI, JULO:JHI)

! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(INOUT) :: qqv(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! N-S flux [mixing ratio]
REAL*8,  INTENT(OUT)   :: fy(ILO:IHI, JULO:JHI+1)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.25 Ymist

Subroutine Ymist computes the linear tracer slope in the N-S direction. It uses the Lin et. al. 1994 algorithm.

INTERFACE:

```
SUBROUTINE Ymist( id,    dcy, qqu, I1_GL, I2_GL, JU1_GL, &
                  J2_GL, J1P, ILO, IHI,   JULO,  JHI,    &
                  I1,    I2,  JU1, J2 )
```

INPUT PARAMETERS:

```
! Global latitude index at the edge of the South polar cap
! J1P=JU1_GL+1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P
```

```
! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! The "order" of the accuracy in the computed linear "slope"
! (or mismatch, Lin et al. 1994); it is either 2 or 4.
INTEGER, INTENT(IN)  :: id

! Concentration contribution from E-W advection (mixing ratio)
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Slope of concentration distribution in N-S direction [mixing ratio]
REAL*8,  INTENT(OUT) :: dcy(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.26 Do_Ymist_Pole1_I2d2

Subroutine Do_Ymist_Pole1_I2d2 sets "dcy" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Ymist_Pole1_I2d2( dcy,   qqu, I1_GL, I2_GL, JU1_GL,   &
                                J2_GL, ILO, IHI,   JULO,  JHI,      &
                                I1,    I2,  JU1,   J2 )
```

INPUT PARAMETERS:

```
! Global min & max longitude (I) and latitude (J) indices
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO-2:JHI+2)
```

OUTPUT PARAMETERS:

```
! Slope of concentration distribution in N-S direction [mixing ratio]
REAL*8, INTENT(OUT)  :: dcy(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.27 Do_Ymist_Pole2_I2d2

Subroutine Do_Ymist_Pole2_I2d2 sets "dcy" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Ymist_Pole2_I2d2( dcy,   qqu, I1_GL, I2_GL, JU1_GL, &
                                J2_GL, J1P, ILO,   IHI,   JULO,   &
                                JHI,   I1,  I2,    JU1,   J2 )
```

INPUT PARAMETERS:

```
! Global latitude index at the edge of the South polar cap
! J1P=JU1_GL+1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO-2:JHI+2)
```

OUTPUT PARAMETERS:

```
! Slope of concentration distribution in N-S direction [mixing ratio]
REAL*8,  INTENT(OUT) :: dcy(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.28 Fyppm

Subroutine Fyppm is the 1D "outer" flux form operator based on the Piecewise Parabolic Method (PPM; see also Lin and Rood 1996) for computing the fluxes in the N-S direction.

INTERFACE:

```
SUBROUTINE Fyppm( jlmt,  cry,   dcy,    qqu,   qqv,   j1p, j2p,    &
                  i1_gl, i2_gl, ju1_gl, j2_gl, ilong, ilo, ihi,    &
                  julo,  jhi,   i1,     i2,    ju1,   j2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! ILONG ??
INTEGER, INTENT(IN)  :: ilong

! Controls various options in N-S advection
INTEGER, INTENT(IN)  :: jlmt

! Courant number in N-S direction
REAL*8,  INTENT(IN)  :: cry(ILO:IHI, JULO:JHI)

! Slope of concentration distribution in N-S direction [mixing ratio]
REAL*8,  INTENT(IN)  :: dcy(ILO:IHI, JULO:JHI)

! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(OUT) :: qqv(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.29 Do_Fyppm_Pole_I2d2

Subroutine Do_Fyppm_Pole_I2d2 sets "al" & "ar" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Fyppm_Pole_I2d2( al,  ar,  I1_GL, I2_GL, JU1_GL, J2_GL, &
                               ILO, IHI, JULO,  JHI,   I1,     I2,    &
                               JU1, J2 )
```

INPUT PARAMETERS:

```
! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: I1_GL,  I2_GL
INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2
INTEGER, INTENT(IN)    :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI
```

OUTPUT PARAMETERS:

```
! Left (al) and right (ar) edge values of the test parabola
REAL*8,  INTENT(INOUT) :: al(ILO:IHI, JULO:JHI)
REAL*8,  INTENT(INOUT) :: ar(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.30 Do_Ytp_Pole_Sum

Subroutine Do_Ytp_Pole_Sum sets "dq1" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Ytp_Pole_Sum( geofac_pc, dq1,    qqv,   fy,  I1_GL,  &
                            I2_GL,     JU1_GL, J2_GL, J1P, J2P,    &
                            ILO,       IHI,    JULO,  JHI, I1,     &
                            I2,        JU1,    J2 )
!input PARAMETERS:
  ! Global latitude indices at the edges of the S/N polar caps
  ! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
  ! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
  INTEGER, INTENT(IN)    :: J1P,    J2P

  ! Global min & max longitude (I) and latitude (J) indices
  INTEGER, INTENT(IN)    :: I1_GL,  I2_GL
  INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

  ! Local min & max longitude (I), latitude (J), altitude (K) indices
  INTEGER, INTENT(IN)    :: I1,     I2
  INTEGER, INTENT(IN)    :: JU1,    J2

  ! Local min & max longitude (I) and latitude (J) indices
  INTEGER, INTENT(IN)    :: ILO,    IHI
  INTEGER, INTENT(IN)    :: JULO,   JHI

  ! Special geometrical factor (geofac) for Polar cap
  REAL*8,  INTENT(IN)    :: geofac_pc
```

```
! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(IN)    :: qqv(ILO:IHI, JULO:JHI)
```

INPUT/OUTPUT PARAMETERS:

```
! Species density [hPa]
REAL*8,  INTENT(INOUT) :: dq1(ILO:IHI, JULO:JHI)

! N-S mass flux [mixing ratio]
REAL*8,  INTENT(INOUT) :: fy (ILO:IHI, JULO:JHI+1)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.94.31 Fzppm

Subroutine Fzppm is the 1D "outer" flux form operator based on the Piecewise Parabolic Method (PPM; see also Lin and Rood 1996) for computing the fluxes in the vertical direction.

Fzppm was modified by S.-J. Lin, 12/14/98, to allow the use of the KORD=7 (klmt=4) option. KORD=7 enforces the 2nd monotonicity constraint of Huynh (1996). Note that in Huynh's original scheme, two constraints are necessary for the preservation of monotonicity. To use Huynh's algorithm, it was modified as follows. The original PPM is still used to obtain the first guesses for the cell edges, and as such Huynh's 1st constraint is no longer needed. Huynh's median function is also replaced by a simpler yet functionally equivalent in-line algorithm.

INTERFACE:

```
SUBROUTINE Fzppm( klmt,  delp1,  wz,  dq1, qq1,  fz,      &
                  J1P,   JU1_GL, J2_GL, ILO, IHI, JULO, JHI,     &
                  ILONG, IVERT,  I1,    I2,  JU1, J2,   K1,  K2 )
```

INPUT PARAMETERS:

```
! Global latitude index at the edges of the South polar cap
! J1P=JU1_GL+1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)    :: J1P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2
INTEGER, INTENT(IN)    :: JU1,    J2
INTEGER, INTENT(IN)    :: K1,     K2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI

! Dimensions in longitude & altitude ???
INTEGER, INTENT(IN)    :: ilong,  ivert

! Controls various options in vertical advection
INTEGER, INTENT(IN)    :: klmt

! Pressure thickness, the pseudo-density in a
! hydrostatic system at t1 [hPa]
REAL*8,  INTENT(IN)    :: delp1(ILO:IHI, JULO:JHI, K1:K2)

! Large scale mass flux (per time step tdt) in the vertical
! direction as diagnosed from the hydrostatic relationship [hPa]
REAL*8,  INTENT(IN)    :: wz(I1:I2, JU1:J2, K1:K2)

! Species concentration [mixing ratio]
REAL*8,  INTENT(IN)    :: qq1(ILO:IHI, JULO:JHI, K1:K2)
```

INPUT/OUTPUT PARAMETERS:

```
! Species density [hPa]
REAL*8,  INTENT(INOUT) :: dq1(ILO:IHI, JULO:JHI, K1:K2)
```

OUTPUT PARAMETERS:

```
! Vertical flux [mixing ratio]
REAL*8,  INTENT(OUT)   :: fz(ILO:IHI, JULO:JHI,  K1:K2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.94.32 Average_Press_Poles

Subroutine Average_Press_Poles averages pressure at the Poles when the Polar cap is enlarged. It makes the last two latitudes equal.

INTERFACE:

```
SUBROUTINE Average_Press_Poles( area_1D, press, I1,  I2,   JU1,  &
                                J2,      ILO,   IHI, JULO, JHI )
```

INPUT PARAMETERS:

```
! Local min & max longitude (I), latitude (J)
INTEGER, INTENT(IN)   :: I1,     I2
INTEGER, INTENT(IN)   :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: ILO,    IHI
INTEGER, INTENT(IN)   :: JULO,   JHI

! Surface area of grid box
REAL*8,  INTENT(IN)   :: AREA_1D(JU1:J2)
```

INPUT/OUTPUT PARAMETERS:

```
! Surface pressure [hPa]
REAL*8, INTENT(INOUT) :: press(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
Implemented into GEOS-Chem by Claire Carouge (ccarouge@seas.harvard.edu)
```

REMARKS:

```
Subroutine from pjc_pfix.  Call this one once everything is working fine.
```

REVISION HISTORY:

```
     05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                                 Yeh with the TPCORE routines from GMI model.
                                 This eliminates the polar overshoot in the
                                 stratosphere.
     05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                                 Declare all REAL variables as REAL*8.  Also
                                 make sure all numerical constants are declared
                                 with the "D" double-precision exponent.
```

1.95 Fortran: Module Interface transport_mod

Module TRANSPORT_MOD is used to call the proper version of the TPCORE advection scheme for GCAP, GEOS-4, GEOS-5, or GEOS-5.7 nested-grid or global simulations.

INTERFACE:

```
      MODULE TRANSPORT_MOD
```

USES:

```
      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_TRANSPORT
      PUBLIC  :: DO_TRANSPORT
      PUBLIC  :: INIT_TRANSPORT
      PUBLIC  :: INIT_GEOS5_WINDOW_TRANSPORT
      PUBLIC  :: INIT_GEOS57_WINDOW_TRANSPORT
      PUBLIC  :: SET_TRANSPORT
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: GEOS4_GEOS5_GLOBAL_ADV
      PRIVATE :: GCAP_GLOBAL_ADV
      PRIVATE :: DO_GEOS5_WINDOW_TRANSPORT
      PRIVATE :: DO_GEOS57_WINDOW_TRANSPORT
      !PRIVATE :: DO_WINDOW_TRANSPORT
      PRIVATE :: GET_AIR_MASS
```

REVISION HISTORY:

```
   10 Mar 2003 - Y. Wang, R. Yantosca - Initial version
   (1 ) Now can select transport scheme for GEOS-3 winds.  Added code for PJC
        pressure fixer. (bdf, bmy, 5/8/03)
   (2 ) Now delete DSIG array, it's obsolete.  Also added new PRIVATE function
        GET_AIR_MASS to compute air masses from the input/output pressures
```

```
      from the new GEOS-4/fvDAS TPCORE. (bmy, 6/24/03)
(3 ) Now references DEBUG_MSG from "error_mod.f". (bmy, 8/7/03)
(4 ) Bug fix in DO_GLOBAL_TRANSPORT (bmy, 10/21/03)
(5 ) IORD, JORD, KORD are now module variables.  Now references
      "logical_mod.f" and "tracer_mod.f" (bmy, 7/20/04)
(6 ) Add mass-flux diagnostics to TPCORE_FVDAS (bdf, bmy, 9/28/04)
(7 ) Now references "diag_mod.f" (bmy, 9/28/04)
(8 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(9 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(10) Now flip arrays in call to TPCORE_FVDAS (bmy, 6/16/06)
(11) Added modifications for SUN compiler (bmy, 7/12/06)
(12) Bug fixes in DO_GLOBAL_TRANSPORT (bmy, 11/29/06)
(13) Split off GCAP, GEOS-3, GEOS-4/GEOS-5 specific calling sequences
      into separate subroutines.  Also removed some obsolete module
      variables. (bmy, 10/30/07)
(14) Modifications for GEOS-5 nested grid (yxw, dan, bmy, 11/6/08)
(15) Bug fix in mass balance in GCAP_GLOBAL_ADV and GEOS4_GEOS5_GLOBAL_ADV.
      (ccc, 2/17/09)
26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
26 Feb 2010 - R. Yantosca - Added ProTex Headers
08 Mar 2010 - C. Carouge  - Modify call to tpcore_fvdas. We do not re-order
                            mass fluxes diagnostics anymore.
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
21 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in vertical
21 Jun 2012 - R. Yantosca - Comment out GEOS-3 window subroutine
```

1.95.1 do_transport

Subroutine DO_TRANSPORT is the driver routine for the proper TPCORE program for GEOS-3, GEOS-4/GEOS-5, or window simulations.

INTERFACE:

```
SUBROUTINE DO_TRANSPORT
```

USES:

```
USE GRID_MOD,      ONLY : ITS_A_NESTED_GRID
USE TPCORE_BC_MOD, ONLY : INIT_TPCORE_BC

USE CMN_SIZE_MOD      ! Size parameters
```

REVISION HISTORY:

```
10 Mar 2003 - R. Yantosca - Initial version
(1 ) Removed IORD, JORD, KORD from the arg list.  Also now removed
```

```
      reference to CMN, it's not needed. (bmy, 7/20/04)
(2 ) Now call separate routines for different met fields. (bmy, 10/30/07)
(3 ) Now references subroutine INIT_TPCORE_BC from tpcore_bc_mod.f and
      DO_GEOS5_FVDAS_WINDOW_TRANSPORT from
      "tpcore_geos5_fvdas_window_mod.f90". (yxw, dan, bmy, 11/6/08)
26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
26 Feb 2010 - R. Yantosca - Added ProTeX headers
06 Oct 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5.
28 Feb 2012 - R. Yantosca - Treat GEOS-5.7 in the same way as MERRA
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.95.2 geos4_geos5_global_adv

Subroutine GEOS4_GEOS5_GLOBAL_ADV is the driver routine for TPCORE with the GMAO GEOS-4 or GEOS-5 met fields.

INTERFACE:

```
      SUBROUTINE GEOS4_GEOS5_GLOBAL_ADV
```

USES:

```
      USE DAO_MOD,          ONLY : PSC2, UWND, VWND
      USE DIAG_MOD,         ONLY : MASSFLEW, MASSFLNS, MASSFLUP
      USE ERROR_MOD,        ONLY : IT_IS_NAN, DEBUG_MSG, SAFE_DIV
      USE LOGICAL_MOD,      ONLY : LFILL, LMFCT, LPRT, LWINDO
      USE PJC_PFIX_MOD,     ONLY : DO_PJC_PFIX
      USE PRESSURE_MOD,     ONLY : GET_PEDGE, SET_FLOATING_PRESSURE
      USE TIME_MOD,         ONLY : GET_TS_DYN
      USE TPCORE_BC_MOD,    ONLY : SAVE_GLOBAL_TPCORE_BC
      USE TPCORE_FVDAS_MOD, ONLY : TPCORE_FVDAS
      USE TRACER_MOD,       ONLY : N_TRACERS, STT, TCVV
#if   defined( APM )
      USE TRACER_MOD,       ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD         ! Size parameters
      USE CMN_DIAG_MOD         ! NDxx flags
      USE CMN_GCTM_MOD         ! Physical constants
```

REVISION HISTORY:

```
30 Oct 2007 - R. Yantosca - Initial version
(1 ) Split off the GEOS-4 & GEOS-5 relevant parts from the previous
      routine DO_GLOBAL_TRANSPORT (bmy, 10/30/07)
(2 ) Activate the call to SAVE_GLOBAL_TPCORE_BC (yxw, dan, bmy, 11/6/08)
(3 ) Bug fix in mass balance: only account for cells of STT with non-zero
```

```
      concentrations when doing the computation (ccc, bmy, 2/17/09)
  26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
  26 Feb 2010 - R. Yantosca - Added ProTeX headers
  16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
  21 Jun 2012 - R. Yantosca - Now use pointers to flip indices in vertical
```

1.95.3 gcap_global_adv

Subroutine GCAP_GLOBAL_ADV is the driver routine for TPCORE with the GCAP/GISS met fields.

INTERFACE:

```
      SUBROUTINE GCAP_GLOBAL_ADV
```

USES:

```
      USE DAO_MOD,          ONLY : PSC2, UWND, VWND
      USE DIAG_MOD,         ONLY : MASSFLEW, MASSFLNS, MASSFLUP
      USE ERROR_MOD,        ONLY : IT_IS_NAN, DEBUG_MSG
      USE LOGICAL_MOD,      ONLY : LFILL, LMFCT, LPRT, LWINDO
      USE PJC_PFIX_MOD,     ONLY : DO_PJC_PFIX
      USE PRESSURE_MOD,     ONLY : GET_PEDGE, SET_FLOATING_PRESSURE
      USE TIME_MOD,         ONLY : GET_TS_DYN
      USE TPCORE_FVDAS_MOD, ONLY : TPCORE_FVDAS
      USE TRACER_MOD,       ONLY : N_TRACERS, STT, TCVV
#if   defined( APM )
      USE TRACER_MOD,       ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD         ! Size parameters
      USE CMN_DIAG_MOD         ! NDxx flags
      USE CMN_GCTM_MOD         ! Physical constants
```

REVISION HISTORY:

```
  30 Oct 2007 - R. Yantosca - Initial version
  (1 ) Split off the GCAP relevant parts from the previous routine
       DO_GLOBAL_TRANSPORT (bmy, 10/30/07)
  (2 ) Bug fix in mass balance: only account for cells of STT with non-zero
       concentrations when doing the computation (ccc, bmy, 2/17/09)
  26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
  26 Feb 2010 - R. Yantosca - Added ProTeX headers
  16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
  21 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in the vertical
```

1.95.4 do_geos5_window_transport

Subroutine DO_GEOS5_WINDOW_TRANSPORT is the driver program for the proper TP-CORE program for the GEOS-5 nested-grid simulations.

INTERFACE:

```
      SUBROUTINE DO_GEOS5_WINDOW_TRANSPORT
```

USES:

```
      ! References to F90 modules
      USE DAO_MOD,                   ONLY : PSC2,     UWND,     VWND
      USE DIAG_MOD,                  ONLY : MASSFLEW, MASSFLNS, MASSFLUP
      USE ERROR_MOD,                 ONLY : IT_IS_NAN,     DEBUG_MSG
      USE GRID_MOD,                  ONLY : GET_XOFFSET,   GET_YOFFSET
      USE LOGICAL_MOD,               ONLY : LFILL,  LMFCT
      USE LOGICAL_MOD,               ONLY : LPRT,   LWINDO
      USE PJC_PFIX_GEOS5_WINDOW_MOD, ONLY : DO_PJC_PFIX_GEOS5_WINDOW
      USE PRESSURE_MOD,              ONLY : GET_PEDGE
      USE PRESSURE_MOD,              ONLY : SET_FLOATING_PRESSURE
      USE TIME_MOD,                  ONLY : GET_TS_DYN
      USE TPCORE_BC_MOD,             ONLY : I0_W, J0_W, I1_W, J1_W
      USE TPCORE_BC_MOD,             ONLY : I2_W, J2_W, IM_W, JM_W, IGZD
      USE TPCORE_BC_MOD,             ONLY : DO_WINDOW_TPCORE_BC
      USE TPCORE_WINDOW_MOD,         ONLY : TPCORE_WINDOW
      USE TPCORE_GEOS5_WINDOW_MOD,   ONLY : TPCORE_GEOS5_WINDOW
      USE TRACER_MOD,                ONLY : N_TRACERS, STT, TCVV
#if   defined( APM )
      USE TRACER_MOD,                ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD                  ! Size parameters
      USE CMN_DIAG_MOD                  ! NDxx flags
      USE CMN_GCTM_MOD                  ! Physical constants
```

REVISION HISTORY:

```
   10 Mar 2003 - R. Yantosca - Initial version

   26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
   26 Feb 2010 - R. Yantosca - Added ProTeX headers
   16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
   21 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in the vertical
```

1.95.5 do_geos5_window_transport

Subroutine DO_GEOS5_WINDOW_TRANSPORT is the driver program for the proper TP-CORE program for the GEOS-5 nested-grid simulations.

INTERFACE:

```
      SUBROUTINE DO_GEOS57_WINDOW_TRANSPORT
```

USES:

```
      ! References to F90 modules
      USE DAO_MOD,                   ONLY : PSC2,     UWND,     VWND
      USE DIAG_MOD,                  ONLY : MASSFLEW, MASSFLNS, MASSFLUP
      USE ERROR_MOD,                 ONLY : IT_IS_NAN,     DEBUG_MSG
      USE GRID_MOD,                  ONLY : GET_XOFFSET,   GET_YOFFSET
      USE LOGICAL_MOD,               ONLY : LFILL,  LMFCT
      USE LOGICAL_MOD,               ONLY : LPRT,   LWINDO
      USE PJC_PFIX_GEOS57_WINDOW_MOD,ONLY : DO_PJC_PFIX_GEOS57_WINDOW
      USE PRESSURE_MOD,              ONLY : GET_PEDGE
      USE PRESSURE_MOD,              ONLY : SET_FLOATING_PRESSURE
      USE TIME_MOD,                  ONLY : GET_TS_DYN
      USE TPCORE_BC_MOD,             ONLY : I0_W, J0_W, I1_W, J1_W
      USE TPCORE_BC_MOD,             ONLY : I2_W, J2_W, IM_W, JM_W, IGZD
      USE TPCORE_BC_MOD,             ONLY : DO_WINDOW_TPCORE_BC
      USE TPCORE_WINDOW_MOD,         ONLY : TPCORE_WINDOW
      USE TPCORE_GEOS57_WINDOW_MOD,  ONLY : TPCORE_GEOS57_WINDOW
      USE TRACER_MOD,                ONLY : N_TRACERS, STT, TCVV
#if   defined( APM )
      USE TRACER_MOD,                ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD                  ! Size parameters
      USE CMN_DIAG_MOD                  ! NDxx flags
      USE CMN_GCTM_MOD                  ! Physical constants
```

REVISION HISTORY:

```
   10 Mar 2003 - R. Yantosca - Initial version

   26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
   26 Feb 2010 - R. Yantosca - Added ProTeX headers
   16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
   21 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in the vertical
```

1.95.6 get_air_mass

Function GET_AIR_MASS returns the air mass based on the pressures returned before and after the call to the GEOS-4/fvDAS TPCORE code. (bmy, 6/24/03)

INTERFACE:

```
FUNCTION GET_AIR_MASS( I, J, L, P_SURF ) RESULT( AIR_MASS )
```

USES:

```
USE CMN_SIZE_MOD              ! Size parameters
USE CMN_GCTM_MOD              ! g0_100
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L   ! GEOS-Chem lon, lat, level indices
REAL*8,  INTENT(IN) :: P_SURF    ! Surface pressure [hPa] at (I,J,L=1)
```

REVISION HISTORY:

```
24 Jun 2003 - R. Yantosca - Initial version
26 Feb 2010 - R. Yantosca - Added ProTeX headers
```

1.95.7 set_transport

Subroutine SET_TRANSPORT passes IORD, JORD, KORD values from "input_mod.f".

INTERFACE:

```
SUBROUTINE SET_TRANSPORT( I_ORD, J_ORD, K_ORD )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I_ORD  ! IORD option for E/W advection
INTEGER, INTENT(IN) :: J_ORD  ! JORD option for N/S advection
INTEGER, INTENT(IN) :: K_ORD  ! KORD option for vertical diffusion
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
26 Feb 2010 - R. Yantosca - Added ProTeX headers
```

1.95.8 init_transport

Subroutine INIT_TRANSPORT initializes all module variables and arrays.

INTERFACE:

```
SUBROUTINE INIT_TRANSPORT
```

USES:

```
USE ERROR_MOD,         ONLY : ALLOC_ERR
USE GRID_MOD,          ONLY : GET_AREA_M2, GET_YMID_R
USE LOGICAL_MOD,       ONLY : LTPFV,       LTRAN
USE PRESSURE_MOD,      ONLY : GET_AP,      GET_BP
USE TIME_MOD,          ONLY : GET_TS_DYN
USE TPCORE_FVDAS_MOD, ONLY : INIT_TPCORE
USE TRACER_MOD,        ONLY : N_TRACERS

USE CMN_SIZE_MOD          ! Size parameters
USE CMN_GCTM_MOD          ! Re
```

REVISION HISTORY:

```
10 Mar 2003 - R. Yantosca - Initial version
(1 ) Now references GET_TS_DYN from "time_mod.f", INIT_TPCORE_FVDAS from
     "tpcore_fvdas_mod.f90", and GET_YMID_R from "grid_mod.f".  Now also
     include "CMN_SETUP".  (bdf, bmy, 4/28/03)
(2 ) Remove reference to DSIG, it's obsolete. (bmy, 6/24/03)
(3 ) Now references LEMBED & LTPFV from "logical_mod.f".  Now references
     N_TRACERS from "tracer_mod.f". (bmy, 7/20/04)
(4 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(5 ) Removed reference to USE_GEOS_4_TRANSPORT, STT_I1, STT_I2, STT_J1,
     STT_J2, variables (bmy, 10/30/07)
(6 ) Deleted reference to CMN, it's not needed anymore (bmy, 11/6/08)
26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
26 Feb 2010 - R. Yantosca - Added ProTeX headers
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R_W(I,J,L) from grid_mod.F90
```

1.95.9 init_geos5_window_transport

Subroutine INIT_GEOS5_WINDOW_TRANSPORT initializes all module variables and arrays for the GEOS-5 nested grid simulation. This routine is only called if we are using the GEOS-5 nested grid simulation.

INTERFACE:

```
SUBROUTINE INIT_GEOS5_WINDOW_TRANSPORT
```

USES:

```
USE ERROR_MOD,               ONLY : ALLOC_ERR
USE GRID_MOD,                ONLY : GET_AREA_M2
USE GRID_MOD,                ONLY : GET_YMID_R_W
USE LOGICAL_MOD,             ONLY : LTPFV,  LTRAN
USE PRESSURE_MOD,            ONLY : GET_AP, GET_BP
```

```
USE TIME_MOD,                ONLY : GET_TS_DYN
USE TPCORE_FVDAS_MOD,        ONLY : INIT_TPCORE
USE TPCORE_BC_MOD,           ONLY : I0_W, J0_W, I1_W, J1_W
USE TPCORE_BC_MOD,           ONLY : I2_W, J2_W, IM_W, JM_W
USE TPCORE_BC_MOD,           ONLY : IGZD, INIT_TPCORE_BC
USE TPCORE_GEOS5_WINDOW_MOD, ONLY : INIT_GEOS5_WINDOW
USE TRACER_MOD,              ONLY : N_TRACERS

USE CMN_SIZE_MOD                  ! Size parameters
USE CMN_GCTM_MOD                  ! Re
```

REVISION HISTORY:

```
06 Jun 2008 - D. Chen & R. Yantosca - Initial version
26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
26 Feb 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R_W(I,J,L) from grid_mod.F90
```

1.95.10 init_geos57_window_transport

Subroutine INIT_GEOS57_WINDOW_TRANSPORT initializes all module variables and arrays for the GEOS-57 nested grid simulation. This routine is only called if we are using the GEOS-57 nested grid simulation.

INTERFACE:

```
SUBROUTINE INIT_GEOS57_WINDOW_TRANSPORT
```

USES:

```
USE ERROR_MOD,                ONLY : ALLOC_ERR
USE GRID_MOD,                 ONLY : GET_AREA_M2
USE GRID_MOD,                 ONLY : GET_YMID_R_W
USE LOGICAL_MOD,              ONLY : LTPFV,  LTRAN
USE PRESSURE_MOD,             ONLY : GET_AP, GET_BP
USE TIME_MOD,                 ONLY : GET_TS_DYN
USE TPCORE_FVDAS_MOD,         ONLY : INIT_TPCORE
USE TPCORE_BC_MOD,            ONLY : I0_W, J0_W, I1_W, J1_W
USE TPCORE_BC_MOD,            ONLY : I2_W, J2_W, IM_W, JM_W
USE TPCORE_BC_MOD,            ONLY : IGZD, INIT_TPCORE_BC
USE TPCORE_GEOS57_WINDOW_MOD,ONLY : INIT_GEOS57_WINDOW
USE TRACER_MOD,               ONLY : N_TRACERS

USE CMN_SIZE_MOD                  ! Size parameters
USE CMN_GCTM_MOD                  ! Re
```

REVISION HISTORY:

```
06 Jun 2008 - D. Chen & R. Yantosca - Initial version
26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
26 Feb 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R_W(I,J,L) from grid_mod.F90
```

1.95.11 cleanup_transport

Subroutine CLEANUP_TRANSPORT deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_TRANSPORT
```

REVISION HISTORY:

```
10 Mar 2003 - R. Yantosca - Initial version
(1 ) Remove reference to DSIG, it's obsolete. (bmy, 6/24/03)
(2 ) Remove obsolete embedded chemistry arrays (bmy, 10/30/07)
26 Feb 2010 - R. Yantosca - Added ProTeX headers
```

1.96 Fortran: Module Interface vdiff_mod

Module VDIFF_MOD includes all routines for the non-local PBL mixing scheme.

INTERFACE:

```
MODULE VDIFF_MOD
```

USES:

```
  USE TRACER_MOD,    ONLY : pcnst => N_TRACERS
  USE LOGICAL_MOD,   ONLY : LPRT
  USE ERROR_MOD,     ONLY : DEBUG_MSG
#if defined( DEVEL )
  USE VDIFF_PRE_MOD, ONLY : plev  => LLPAR
  USE CMN_SIZE_MOD,  ONLY : IIPAR, JJPAR, LLPAR
#else
  USE VDIFF_PRE_MOD, ONLY : LLPAR
#endif

  IMPLICIT NONE
#     include "define.h"

  PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
  public :: DO_PBL_MIX_2
  !PRIVATE DATA MEMBERS:

  save


#if defined( DEVEL )
  integer :: plevp
#else
  integer, parameter :: plev = LLPAR, plevp = plev + 1
#endif

  real*8, parameter ::          &
       rearth = 6.37122d6,      & ! radius earth (m)
       cpwv   = 1.81d3,         &
       cpair  = 1004.64d0,      &
       rair   = 287.04d0,       &
       rh2o   = 461.d0,         &
       zvir   = rh2o/rair - 1., &
       gravit = 9.80616d0,      &
       ra     = 1.d0/rearth,    &
       epsilo = 0.622d0,        &
       latvap = 2.5104d06,      &
       latice = 3.336d5,        &
       cappa  = rair/cpair,     &
       rhoh2o = 1.d3,           &
       r_g    = rair / gravit,  &
       tfh2o  = 273.16d0

 -----------------------------------------------------------------------
   ... pbl constants
 -----------------------------------------------------------------------

  ! These are constants, so use PARAMETER tag
  real*8, parameter ::   &
       betam  = 15.d0,   & ! constant in wind gradient expression
       betas  =  5.d0,   & ! constant in surface layer gradient expression
       betah  = 15.d0,   & ! constant in temperature gradient expression
       fak    =  8.5d0,  & ! constant in surface temperature excess
       fakn   =  7.2d0,  & ! constant in turbulent prandtl number
       ricr   =   .3d0,  & ! critical richardson number
       sffrac =   .1d0,  & ! surface layer fraction of boundary layer
       vk     =   .4d0     ! von karmans constant

  ! These are assigned later, so we can't use the PARAMETER tag
  real*8 ::              &
```

```
       g,                & ! gravitational acceleration
       onet,             & ! 1/3 power in wind gradient expression
       ccon,             & ! fak * sffrac * vk
       binm,             & ! betam * sffrac
       binh                ! betah * sffrac

 !-----------------------------------------------------------------------
   ... constants used in vertical diffusion and pbl
 !-----------------------------------------------------------------------
  real*8 :: &
       zkmin            ! minimum kneutral*f(ri)
#if defined( DEVEL )
  real*8, allocatable :: ml2(:)   ! mixing lengths squaredB
#else
  real*8 :: ml2(plevp)   ! mixing lengths squared
#endif
  real*8, allocatable :: qmincg(:)   ! min. constituent concentration
                                     !  counter-gradient term

  integer :: &
       ntopfl, &        ! top level to which vertical diffusion is applied.
       npbl             ! maximum number of levels in pbl from surface

  logical, parameter :: divdiff = .true. , arvdiff = .false.

  logical, parameter :: pblh_ar = .true.

  logical, parameter :: pbl_mean_drydep = .false.  ! use mean concentration
                                                   !  within the  PBL for
                                                   ! calculating drydep fluxes
  logical, parameter :: drydep_back_cons = .false. ! backward consistency
                                                   !  with previous GEOS-Chem
                                                   !  drydep budgets
                                                   !-- useless when
                                                   !   pbl_mean_drydep=.false.
```

REVISION HISTORY:

```
   (1 ) This code is modified from mo_vdiff.F90 in MOZART-2.4. (lin, 5/14/09)
   07 Oct 2009 - R. Yantosca - Added CVS Id Tag
   24 Sep 2010 - J. Lin      - Modified ND15 to account for all mixing
                               processes but not dry deposition and emissions.
   17 Dec 2010 - R. Yantosca - Declare constants w/ the PARAMETER attribute
   20 Dec 2010 - R. Yantosca - Bug fixes for the parallelization
   02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                               involve explicitly using "D" exponents
   25 Mar 2011 - R. Yantosca - Corrected bug fixes noted by Jintai Lin
   08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.2 met
   22 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in vertical
```

1.96.1 pbinti

Subroutine PBINTI initializes time independent variables of pbl package

INTERFACE:

```
subroutine pbinti( gravx )
```

USES:

```
implicit none
```

INPUT PARAMETERS:

```
real*8, intent(in) :: gravx     !  acceleration of gravity
```

REVISION HISTORY:

```
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
```

1.96.2 pbldif

Subroutine PBLDIF computes the atmospheric boundary layer. The nonlocal scheme determines eddy diffusivities based on a diagnosed boundary layer height and a turbulent velocity scale. Also, countergradient effects for heat and moisture, and constituents are included, along with temperature and humidity perturbations which measure the strength of convective thermals in the lower part of the atmospheric boundary layer.

References:

1. Holtslag, A. A. M., and B. A. Boville, 1993: *Local versus nonlocal boundary-layer diffusion in a global climate model*, J. Clim., **6**, 1825-1842.

INTERFACE:

```
subroutine pbldif( th      ,q       ,z       ,u       ,v, &
                   t       ,pmid    ,kvf     ,cflx    ,shflx, &
                   kvm     ,kvh, &
                   cgh     ,cgq     ,cgs     ,pblh    ,tpert, &
                   qpert   ,wvflx   ,cgsh    ,plonl, &
                   taux    ,tauy    ,ustar)
```

USES:

```
implicit none
```

INPUT PARAMETERS:

```
    integer, intent(in) :: &
  plonl
    real*8, intent(in) :: &
         th(plonl,plev), &          ! potential temperature [k]
         q(plonl,plev), &           ! specific humidity [kg/kg]
         z(plonl,plev), &           ! height above surface [m]
         u(plonl,plev), &           ! windspeed x-direction [m/s]
         v(plonl,plev), &           ! windspeed y-direction [m/s]
         t(plonl,plev), &           ! temperature (used for density)
         pmid(plonl,plev), &        ! midpoint pressures
         kvf(plonl,plevp), &        ! free atmospheric eddy diffsvty [m2/s]
         cflx(plonl,pcnst), &       ! surface constituent flux (kg/m2/s)
         wvflx(plonl), &            ! water vapor flux (kg/m2/s)
         shflx(plonl)               ! surface heat flux (w/m2)
```

INPUT/OUTPUT PARAMETERS:

```
    real*8, optional, intent(inout) :: &
         taux(plonl), &            ! x surface stress (n)
         tauy(plonl), &            ! y surface stress (n)
         ustar(plonl)              ! surface friction velocity

    real*8, intent(inout) :: pblh(plonl)       ! boundary-layer height [m]
```

OUTPUT PARAMETERS:

```
    real*8, intent(out) :: &
         kvm(plonl,plevp), &        ! eddy diffusivity for momentum [m2/s]
         kvh(plonl,plevp), &        ! eddy diffusivity for heat [m2/s]
         cgh(plonl,plevp), &        ! counter-gradient term for heat [k/m]
         cgq(plonl,plevp,pcnst), &  ! counter-gradient term for constituents
         cgsh(plonl,plevp), &       ! counter-gradient term for sh
         cgs(plonl,plevp), &        ! counter-gradient star (cg/flux)
         tpert(plonl), &            ! convective temperature excess
         qpert(plonl)               ! convective humidity excess
```

REVISION HISTORY:

```
   02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                               involve explicitly using "D" exponents
```

1.96.3 qvdiff

Subroutine QVDIFF solve vertical diffusion eqtn for constituent with explicit srfc flux.

INTERFACE:

```
  subroutine qvdiff( ncnst, qm1, qflx, cc, ze, &
              term, qp1, plonl )
```

USES:

```
implicit none
```

INPUT PARAMETERS:

```
integer, intent(in) :: &
     plonl
integer, intent(in) :: &
     ncnst                    ! num of constituents being diffused
real*8, intent(in) :: &
     qm1(plonl,plev,ncnst), & ! initial constituent
     qflx(plonl,ncnst), &     ! sfc q flux into lowest model level
     cc(plonl,plev), &        ! -lower diag coeff.of tri-diag matrix
     term(plonl,plev)         ! 1./(1. + ca(k) + cc(k) - cc(k)*ze(k-1))
```

INPUT/OUTPUT PARAMETERS:

```
real*8, intent(inout) :: &
     ze(plonl,plev)           ! term in tri-diag. matrix system
```

OUTPUT PARAMETERS:

```
real*8, intent(out) :: &
     qp1(plonl,plev,ncnst)    ! final constituent
```

REMARKS:

```
Procedure for solution of the implicit equation follows :
Richtmyer and Morton (1967,pp 198-199)
```

REVISION HISTORY:

```
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
```

1.96.4 vdiffar

Subroutine VDIFFAR is the driver routine to compute vertical diffusion of trace constituents using archived coefficients for cgs and kvh. This is a gutted version of vdiff.

INTERFACE:

```
SUBROUTINE VDIFFAR( lat   ,tadv , &
                    pmid  ,pint ,rpdel_arg ,rpdeli_arg  ,ztodt, &
                    sflx  ,as2  ,kvh_arg   ,cgs_arg     ,plonl )
```

USES:

```
implicit none
```

INPUT PARAMETERS:

```
integer, intent(in) :: lat     ! latitude index
integer, intent(in) :: plonl   ! lon tile dim
real*8, intent(in) :: &
     ztodt , &                 ! 2 delta-t
     tadv(:,:,:), &        ! temperature input
     pmid(:,:,:), &     ! midpoint pressures
     pint(:,:,:), &    ! interface pressures
     rpdel_arg(:,:,:), &      ! 1./pdel  (thickness bet interfaces)
     rpdeli_arg(:,:,:), &     ! 1./pdeli (thickness bet midpoints)
     sflx(:,:,:), &      ! surface constituent flux (kg/m2/s)
     kvh_arg(:,:,:), &       ! coefficient for heat and tracers
     cgs_arg(:,:,:)          ! counter-grad star (cg/flux)
```

INPUT/OUTPUT PARAMETERS:

```
real*8, intent(inout) :: &
     as2(:,:,:,:)     ! moist, tracers after vert. diff
```

REVISION HISTORY:

```
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
```

1.96.5 pbldifar

Subroutine PBLDIFAR is a modified version of pbldif which only calculates cgq given cgs.

INTERFACE:

```
SUBROUTINE PBLDIFAR( t, pmid, cflx, cgs, cgq, plonl )
```

USES:

```
implicit none
```

INPUT PARAMETERS:

```
integer, intent(in) :: &
     plonl
real*8, intent(in) :: &
     t(plonl,plev), &        ! temperature (used for density)
     pmid(plonl,plev), &     ! midpoint pressures
     cflx(plonl,pcnst), &     ! surface constituent flux (kg/m2/s)
     cgs(plonl,plevp)        ! counter-gradient star (cg/flux)
```

OUTPUT PARAMETERS:

```
real*8, intent(out) :: &
     cgq(plonl,plevp,pcnst)  ! counter-gradient term for constituents
```

REVISION HISTORY:

```
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
```

1.96.6 vdinti

Subroutine VDINTI initializes time independent fields for vertical diffusion. Calls initialization routine for boundary layer scheme.

INTERFACE:

```
SUBROUTINE VDINTI
```

USES:

```
USE PRESSURE_MOD, ONLY : GET_AP, GET_BP
USE ERROR_MOD,    ONLY : ALLOC_ERR

implicit none
```

REVISION HISTORY:

```
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
```

1.96.7 vdiffdr

Subroutine VDIFFDR calculates the vertical diffusion on a latitude slice of data.

1. The dummy argument as2 is in vv. (lin, 06/04/08)
2. TCVV and TRACER_MW_KG assume 12 g/mol for all HCs. Thus, when using them to convert units of HCs to be the inputs for vdiffdr, the converted units are NOT kg/kg for concentrations and kg/m2/s for surface flux. However, since the units for both inputs are consistent, there should not be any problem. (lin, 06/04/08)

INTERFACE:

```
SUBROUTINE VDIFFDR(as2)
```

USES:

```
USE TRACER_MOD,   ONLY : N_TRACERS,  TRACER_MW_KG, TCVV, &
                         ID_EMITTED, TRACER_COEFF, TRACER_COEFF, &
                         TRACER_NAME
USE TRACER_MOD,   ONLY : ITS_A_TAGOX_SIM, ITS_A_TAGCO_SIM
USE TRACER_MOD,   ONLY : ITS_A_CH4_SIM
USE DAO_MOD,      ONLY : um1 => UWND, vm1 => VWND, tadv => T, &
                         hflx => HFLUX, eflux => EFLUX, &
                         USTAR, BXHEIGHT, shp => SPHU, PS => PSC2, &
                         AD,PBL
USE PRESSURE_MOD, ONLY : GET_PEDGE, GET_PCENTER
USE TIME_MOD,     ONLY : GET_TS_CONV, GET_TS_EMIS
USE COMODE_MOD,   ONLY : JLOP,      REMIS,   VOLUME
USE DRYDEP_MOD,   ONLY : DEPNAME, NUMDEP, NTRAIND, DEPSAV
```

```
      USE PBL_MIX_MOD,  ONLY : GET_PBL_TOP_m, COMPUTE_PBL_HEIGHT, &
                               GET_PBL_MAX_L, GET_FRAC_UNDER_PBLTOP

       USE VDIFF_PRE_MOD, ONLY : IIPAR, JJPAR, IDEMS, NEMIS, NCS, ND15, ND44, &
                                 NDRYDEP, emis_save
       USE DIAG_MOD,     ONLY : TURBFLUP, AD44
      USE VDIFF_PRE_MOD, ONLY : IIPAR, JJPAR, IDEMS, NEMIS, NCS, ND44, &
                                NDRYDEP, emis_save

      USE DIAG_MOD,     ONLY : AD44
      USE GRID_MOD,     ONLY : GET_AREA_M2

      USE TRACER_MOD,   ONLY : ITS_A_MERCURY_SIM ! (cdh 8/28/09)
      USE DEPO_MERCURY_MOD, ONLY : ADD_Hg2_DD, ADD_HgP_DD
      USE DEPO_MERCURY_MOD, ONLY : ADD_Hg2_SNOWPACK
      USE TRACERID_MOD, ONLY : IS_Hg0, IS_Hg2, IS_HgP
      USE LOGICAL_MOD,  ONLY : LDYNOCEAN, LGTMM !cdh
      USE DAO_MOD,      ONLY : LWI, IS_ICE, IS_LAND, SNOMAS, SNOW !cdh
      USE DAO_MOD,      ONLY : FRSNO, FRLANDIC, FROCEAN ! jaf
      USE OCEAN_MERCURY_MOD,  ONLY : LHg2HalfAerosol !cdh
      USE DRYDEP_MOD,   ONLY : DRYHg0, DRYHg2, DRYHgP !cdh
      USE TRACER_MOD,   ONLY: ITS_A_FULLCHEM_SIM  !bmy
      USE OCEAN_MERCURY_MOD, ONLY : Fp, Fg !hma

#     include "define.h"

      implicit none
```

INPUT/OUTPUT PARAMETERS:

```
      real*8, intent(inout), TARGET :: as2(IIPAR,JJPAR,LLPAR,N_TRACERS) ! advected species

       REAL*8                :: SNOW_HT !cdh - obsolete
      REAL*8                :: FRAC_NO_HG0_DEP !jaf
      LOGICAL               :: ZERO_HG0_DEP !jaf
```

REVISION HISTORY:

```
   (1 ) Calls to vdiff and vdiffar are now done with full arrays as arguments.
        (ccc, 11/19/09)
    04 Jun 2010 - C. Carouge  - Updates for mercury simulations with GTMM
    25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
    24 Sep 2010 - J. Lin      - Move ND15 to vdiff.
    21 Dec 2010 - R. Yantosca - Add logical flags for different sim types
    21 Dec 2010 - R. Yantosca - Now call ITS_A_FULLCHEM_SIM instead of
                                relying on NCS == 0
    22 Dec 2010 - C. Carouge  - Combine array flipping w/ unit conversion
                                to save on operations
    02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
```

```
                              involve explicitly using "D" exponents
    26 Apr 2011 - J. Fisher   - Use MERRA land fraction information
    25 Oct 2011 - H. Amos     - bring Hg2 gas-particle partitioning code into
                              v9-01-02
    08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.2 in the same way as MERRA
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    22 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in vertical
```

1.96.8 do_pbl_mix_2

Subroutine DO_PBL_MIX_2 is the driver routine for planetary boundary layer mixing. The PBL layer height and related quantities are always computed. Mixing of tracers underneath the PBL top is toggled by the DO_TURBDAY switch.

INTERFACE:

```
   SUBROUTINE DO_PBL_MIX_2( DO_TURBDAY )
```

USES:

```
     USE LOGICAL_MOD,   ONLY : LTURB, LPRT
     USE TRACER_MOD,    ONLY : N_TRACERS, STT, TCVV, ITS_A_FULLCHEM_SIM
     USE PBL_MIX_MOD,   ONLY : INIT_PBL_MIX, COMPUTE_PBL_HEIGHT

     USE VDIFF_PRE_MOD, ONLY : EMISRR, EMISRRN
     USE ERROR_MOD,     ONLY : DEBUG_MSG
     USE TIME_MOD,      ONLY : ITS_TIME_FOR_EMIS

     IMPLICIT NONE
 #     include "define.h"
```

INPUT PARAMETERS:

```
     LOGICAL, INTENT(IN) :: DO_TURBDAY  ! Switch which turns on PBL mixing of
                                        ! tracers
```

REVISION HISTORY:

```
    11 Feb 2005 - R. Yantosca - Initial version
    21 Dec 2010 - R. Yantosca - Now only call SETEMIS for fullchem simulations
    22 Dec 2010 - R. Yantosca - Bug fix: print debug output only if LPRT=T
```

1.97 Fortran: Module Interface vdiff_pre_mod

Module VDIFF_PRE_MOD contains variables used in VDIFF_MOD.

INTERFACE:

```
      MODULE VDIFF_PRE_MOD
```

USES:

```
      USE TRACER_MOD, ONLY : N_TRACERS

#     include "define.h"
      USE CMN_SIZE_MOD
      USE COMODE_LOOP_MOD                    ! IDEMS, NEMIS, NCS
      USE CMN_O3_MOD                        ! EMISRR, EMISRRN
      USE CMN_DIAG_MOD                      ! ND15

      IMPLICIT NONE

      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      PUBLIC :: IIPAR, JJPAR, LLPAR         ! from "CMN_SIZE_mod"
      PUBLIC :: IDEMS, NEMIS, NCS, NDRYDEP  ! from "comode_loop_mod"
      PUBLIC :: EMISRR, EMISRRN             ! from "CMN_O3_mod"
      PUBLIC :: ND15, ND44                  ! from "CMN_DIAG_mod"
      PUBLIC :: emis_save
#if defined( DEVEL )
      PUBLIC :: SET_VDIFF_PRE_MOD
#endif

      ! Make sure MAXTRACERS >= N_TRACERS
      INTEGER, PARAMETER :: MAXTRACERS = 100

#if defined( DEVEL )
      REAL*8, ALLOCATABLE :: emis_save(:,:,:)!(IIPAR, JJPAR, MAXTRACERS)
#else
      REAL*8 :: emis_save(IIPAR, JJPAR, MAXTRACERS) = 0.d0
#endif
```

REVISION HISTORY:

```
   01 Jun 2009 - C. Carouge & J. Lin - Initial version
   07 Oct 2009 - R. Yantosca         - Added CVS Id tag
```

1.98 Fortran: Module Interface vistas_anthro_mod

Module VISTAS_ANTHRO_MOD contains variables and routines to read the VISTAS anthropogenic emissions.

INTERFACE:

```
      MODULE VISTAS_ANTHRO_MOD
```

USES:

```
      USE EPA_NEI_MOD, ONLY : GET_USA_MASK

      IMPLICIT NONE
#     include "define.h"
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_VISTAS_ANTHRO
      PUBLIC :: EMISS_VISTAS_ANTHRO
      PUBLIC :: GET_VISTAS_ANTHRO
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: INIT_VISTAS_ANTHRO
      PRIVATE :: VISTAS_SCALE_FUTURE
      PRIVATE :: TOTAL_ANTHRO_Tg
```

REVISION HISTORY:

```
   24 Nov 2008 - A. v. Donkelaar - Initial version
   28 Jan 2009 - P. Le Sager     - Initial Version in GEOS-Chem
   01 Mar 2012 - R. Yantosca     - Now reference new grid_mod.F90
```

1.98.1 get_vistas_anthro

Function GET_VISTAS_ANTHRO returns the VISTAS emission for GEOS-Chem grid box (I,J) and tracer N. Emissions can be returned in units of [kg/s] or [molec/cm2/s].

INTERFACE:

```
      FUNCTION GET_VISTAS_ANTHRO( I,        J,           N,
     &                            WEEKDAY,  MOLEC_CM2_S, KG_S )
     &  RESULT( VALUE )
```

USES:

```
      USE GRID_MOD,     ONLY : GET_AREA_CM2
      USE TRACER_MOD,   ONLY : XNUMOL
      USE TRACERID_MOD, ONLY : IDTNOx
```

INPUT PARAMETERS:

```
      ! Longitude, latitude, and tracer indices
      INTEGER, INTENT(IN)           :: I, J, N

      ! Return weekday or weekend emissions
```

```
      LOGICAL, INTENT(IN)           :: WEEKDAY

      ! OPTIONAL -- return emissions in [molec/cm2/s]
      LOGICAL, INTENT(IN), OPTIONAL :: MOLEC_CM2_S

      ! OPTIONAL -- return emissions in [kg/s]
      LOGICAL, INTENT(IN), OPTIONAL :: KG_S
```

RETURN VALUE:

```
      ! Emissions output
      REAL*8                        :: VALUE
```

REVISION HISTORY:

```
   28 Jan 2009 - A. v. Donkelaar, P. Le Sager - Initial Version
   01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.98.2 emiss_vistas_anthro

Subroutine EMISS_VISTAS_ANTHRO reads the VISTAS emission fields at 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
#if defined( DEVEL )
      SUBROUTINE EMISS_VISTAS_ANTHRO(EMISS)
#else
      SUBROUTINE EMISS_VISTAS_ANTHRO
#endif
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
      USE LOGICAL_MOD,        ONLY : LFUTURE
      USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A
      USE TIME_MOD,           ONLY : GET_YEAR, GET_MONTH
      USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR_1x1

      USE CMN_SIZE_MOD              ! Size parameters
      USE CMN_O3_MOD                ! FSCALYR

#if defined( DEVEL )
      USE TIME_MOD,      ONLY : GET_DAY_OF_WEEK
      USE TRACER_MOD,    ONLY : N_TRACERS
      USE TRACER_MOD,    ONLY : XNUMOL
      USE TRACERID_MOD,  ONLY : IDTNOx
      USE GRID_MOD,      ONLY : GET_AREA_CM2
      USE ERROR_MOD,     ONLY : ALLOC_ERR
#endif
```

REVISION HISTORY:

```
28 Jan 2009 - A. v. Donkelaar, P. Le Sager - Initial Version
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fix minor bugs in map_a2a algorithm
```

1.98.3 vistas_scale_future

Subroutine VISTAS_SCALE_FUTURE applies the IPCC future scale factors to the VISTAS anthropogenic emissions.

INTERFACE:

```
SUBROUTINE VISTAS_SCALE_FUTURE
```

USES:

```
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff

USE CMN_SIZE_MOD             ! Size parameters
```

REVISION HISTORY:

```
28 Jan 2009 - A. v. Donkelaar, P. Le Sager - Initial Version
```

1.98.4 total_anthro_Tg

Subroutine TOTAL_ANTHRO_TG prints the totals for the anthropogenic emissions of NOx.

INTERFACE:

```
SUBROUTINE TOTAL_ANTHRO_TG( YEAR, THISMONTH )
```

USES:

```
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TRACER_MOD,   ONLY : TRACER_MW_KG
USE TRACERID_MOD, ONLY : IDTNOX

USE CMN_SIZE_MOD   ! Size parameters
```

INPUT PARAMETERS:

```
! Year and month of data for which to compute totals
INTEGER, INTENT(IN) :: YEAR, THISMONTH
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.98.5 init_vistas_anthro

Subroutine INIT_VISTAS_ANTHRO allocates and zeroes all module arrays. (phs, 1/28/09)

INTERFACE:

```
SUBROUTINE INIT_VISTAS_ANTHRO
```

USES:

```
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE LOGICAL_MOD, ONLY : LVISTAS

USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
01 Mar 2012 - R. Yantosca - Remove A_CM2 array, use GET_AREA_CM2 instead
```

1.98.6 cleanup_vistas_anthro

Subroutine CLEANUP_VISTAS_ANTHRO deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_VISTAS_ANTHRO
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
02 Mar 2012 - R. Yantosca - Remove A_CM2 array
```

1.99 Fortran: Module Interface Individual GEOS-Chem subroutines

Here follows a list of GEOS-Chem subroutines which do not belong to any F90 module.

1.99.1 anthroems

Subroutine ANTHROEMS reads anthropogenic tracers for each season. NOx emissions at levels other than the surface are now accounted for.

INTERFACE:

```
SUBROUTINE ANTHROEMS( NSEASON )
```

USES:

```
      USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_ALK4ff
      USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_C2H6ff
      USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_C3H8ff
      USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_COff
      USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_NOxff
      USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_PRPEff
      USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_TONEff
      USE GEIA_MOD,            ONLY : READ_GEIA,    READ_C3H8_C2H6_NGAS
      USE GEIA_MOD,            ONLY : READ_LIQCO2,  READ_TODX
      USE GEIA_MOD,            ONLY : READ_TOTCO2,  TOTAL_FOSSIL_TG
      USE GRID_MOD,            ONLY : GET_AREA_CM2, GET_XOFFSET
      USE GRID_MOD,            ONLY : GET_YOFFSET
      USE LOGICAL_MOD,         ONLY : LFUTURE
      USE TIME_MOD,            ONLY : GET_TS_EMIS,  GET_YEAR
      USE TIME_MOD,            ONLY : GET_SEASON
      USE TRACER_MOD,          ONLY : TRACER_MW_KG
      USE TRACERID_MOD,        ONLY : IDEACET,      IDEALK4
      USE TRACERID_MOD,        ONLY : IDEC2H6,      IDEC3H8
      USE TRACERID_MOD,        ONLY : IDECO,        IDEMEK
      USE TRACERID_MOD,        ONLY : IDENOX,       IDEPRPE
      USE TRACERID_MOD,        ONLY : NEMANTHRO
      USE TRACERID_MOD,        ONLY : IDEBENZ,     IDETOLU,    IDEXYLE
      USE TRACERID_MOD,        ONLY : IDEC2H4,      IDEC2H2
      USE TRACERID_MOD,        ONLY : IDTBENZ,     IDTTOLU,    IDTXYLE
      USE TRACERID_MOD,        ONLY : IDTC2H4,      IDTC2H2
      USE SCALE_ANTHRO_MOD,    ONLY : GET_ANNUAL_SCALAR
      USE SCALE_ANTHRO_MOD,    ONLY : GET_ANNUAL_SCALAR_05x0666_NESTED
      USE EDGAR_MOD,           ONLY : READ_AROMATICS, READ_C2H4
      USE EDGAR_MOD,           ONLY : READ_C2H2
      USE EDGAR_MOD,           ONLY : READ_AROMATICS_05x0666
      USE EDGAR_MOD,           ONLY : READ_C2H4_05x0666
      USE EDGAR_MOD,           ONLY : READ_C2H2_05x0666

      USE CMN_SIZE_MOD              ! Size parameters
      USE COMODE_LOOP_MOD              ! IDEMS
      USE CMN_O3_MOD                ! EMIST, EMISR, EMISRR, etc.

      IMPLICIT NONE
#     include "define.h"
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: NSEASON   ! Current season (1-4)
```

REMARKS:

```
    NSEASON:  is the seasonal index for NOx emissions:
```

```
  NSEASON=1 --> winter (Dec, Jan, Feb)
  NSEASON=2 --> spring (Mar, Apr, May)
  NSEASON=3 --> summer (Jun, Jul, Aug)
  NSEASON=4 --> autumn (Sep, Oct, Nov)

Passed Via CMN_O3_mod:
=============================================================================
Fossil Fuel arrays: EMISTNOX,  EMISTCO,   EMISTETHE, EMISTPRPE,
                    EMISTC2H6, EMISTC3H8, EMISTALK4, EMISTACET,
                    EMISTMEK,  EMISTSOX

Emissions arrays:   EMIST, EMISTN, EMISR, EMISRN, EMISRR, EMISRRN
```

REVISION HISTORY:

```
04 Jun 1998 - R. Yantosca - Initial version
(1 ) We now read the new merge file, created for SASS. (bey, 2/99)
(2 ) ANTHROEMS should be called each time the season changes, since
      the GEIA NOx emissions are seasonal.
(3 ) NOx emissions are stored separately in EMISTN, EMISRN, EMISRRN.
      This is because the NOx emissions can be located across several
      sigma levels, whereas the other tracers are only emitted into
      the surface level.
(4 ) NO2 is no longer emitted as the emission species for Ox.
      (bey, bmy, 4/14/99)
(5 ) There are 3 different types of scale factors for anthro emissions:
      (a) Yearly since 1985: done in anthroems.f
      (b) Weekday/weekend:   done in emf_scale.f
      (c) Time of day:       done in emfossil.f
(6 ) At present NEMANTHRO = Total number of emitted tracers
      (set in tracerid.f).  We no longer use moments in emissions.
      ORDER = NOx, CO, PRPE, C3H8, ALK4, C2H6, ALD2.
(7 ) NOx is assumed to be the first tracer (N=1).  The first usable
      row for tracers other than NOx in EMIST(I,J,N), etc. is N=2.
(8 ) Need to offset EMISR, which has global dimensions.
      EMIST has window dimensions.
(9 ) Now trap I/O errors and stop gracefully if file open or read
      errors are encountered.  Print an error message to alert user
      which file triggered the I/O error. (bmy, 4/14/99)
(10) Eliminate GISS-specific code and PLUMES code (bmy, 4/14/99)
(11) Now use F90 syntax where expedient. (bmy, 4/14/99)
(12) Cosmetic changes, added comments (bmy, 3/17/00)
(13) Do not let SCALYEAR go higher than 1996, since right now we don't
      have FF scaling data beyond 1996.  Also cosmetic changes and
      updated comments. (bmy, 4/6/01)
(14) Now reference routines from GEIA_MOD for reading scale factor and
      other emissions data from disk. (bmy, 4/23/01)
(15) Now read fossil-fuel emissions from a binary punch file (bmy, 4/23/01)
```

```
(16) CO and hydrocarbons are read from disk once per year.  Fossil fuel
     scale factors are also applied once per
(17) Now comment out LNAPAPNOX.  Also total fossil fuel emissions
     and echo to std output. (bmy, 4/27/01)
(18) Bug fix: Now convert units for CO, Hydrocarbon tracers only once
     per year.  Convert units for NOx once per season. (bmy, 6/7/01)
(19) Bug fix: Now index CH26 correctly when totaling it (bmy, 8/30/01)
(20) Now take C3H8 and C2H6 emissions as scaled from natural gas.  Read
     these in subroutine READ_C3H8_C2H6_NGAS.  Also scale anthropogenic
     ACET by 0.82 in order to match the acetone paper (bdf, bmy, 9/10/01)
(21) Removed obsolete, commented-out code from 6/01 (bmy, 11/26/01)
(22) Eliminated obsolete code from 11/01 (bmy, 2/27/02)
(23) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(24) Now reference IDTNOX, IDENOX, etc. from "tracerid_mod.f".  Also
     do not let SCALEYEAR exceed 1998. (bmy, 1/13/03)
(25) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 from "grid_mod.f"
     Now use functions GET_XOFFSET and GET_YOFFSET from "grid_mod.f".
     Now I0 and J0 are local variables.  Now use functions GET_TS_EMIS,
     GET_YEAR, GET_SEASON from "time_mod.f". (bmy, 2/11/03)
(26) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(27) Now replace FMOL with TRACER_MW_KG (bmy, 10/25/05)
(28) Modified for IPCC future emissions scale factors (swu, bmy, 5/30/06)
(29) Extend max value for FSCALYR to 2002 (bmy, 7/18/06)
(30) Use updated int'annual scale factors for 1985-2003 (amv, 08/24/07)
(31) As default, use EDGARv2.0 emission (fossil fuel + industry)
     for year 1985, scale to target year with CO2 from liquid fuel,
     for aromatics, C2H4, and C2H2. (tmf, 6/13/07)
(32) GET_ANNUAL_SCALAR_05x0666_NESTED_CH renamed to
     GET_ANNUAL_SCALAR_05x0666_NESTED (amv, bmy, 12/18/09)
19 Nov 2010 - R. Yantosca - Added ProTeX headers
```

1.99.2 boxvl

The new function BOXVL converts the DAO grid box volume values stored in AIRVOL from m3 to cm3. The conversion factor is (100)**3 = 1e6 cm3 per m3.

INTERFACE:

```
      REAL*8 FUNCTION BOXVL( I, J, L )
```

USES:

```
      USE DAO_MOD, ONLY : AIRVOL

      IMPLICIT NONE
#     include "define.h"
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I   ! Longitude index
      INTEGER, INTENT(IN) :: J   ! Latitude index
      INTEGER, INTENT(IN) :: L   ! Level index
```

REVISION HISTORY:

```
   30 Jan 1998 - R. Yantosca - Initial version
   (1 ) CMN_VOL is used to pass AIRVOL.
   (2 ) Use C-preprocessor #include statement to include CMN_SIZE, which
        has IIPAR, JJPAR, LLPAR, IIPAR, JJPAR, LGLOB.
   (3 ) Now use F90 syntax for declarations (bmy, 10/5/99)
   (4 ) Now reference AIRVOL from "dao_mod.f" instead of from common
        block header file "CMN_VOL". (bmy, 6/26/00)
   (5 ) Removed obsolete code from 6/26/00 (bmy, 8/31/00)
   (6 ) Updated comments (bmy, 8/5/02)
   02 Dec 2010 - R. Yantosca - Initial version
```

1.99.3 cldice_hbrhobr_rxn

Subroutine CLDICE_HBrHOBr_RXN calculates the rate constants for HBr and HOBr pseudo-reactions with ice.

INTERFACE:

```
      SUBROUTINE CLDICE_HBrHOBr_RXN( DENAIR, airvol, TEMP, QI,
     &                               CLDF,   AD,     hbr,  hobr,
     &                               k_hbr,  k_hobr, AREA  )
```

USES:

```
      USE ERROR_MOD,   ONLY : IS_SAFE_DIV, IT_IS_NAN
      USE ERROR_MOD,   ONLY : GEOS_CHEM_STOP

      IMPLICIT NONE
#include "define.h"
```

INPUT PARAMETERS:

```
      REAL*8,  INTENT(IN)  :: DENAIR   ! Density of air             [#/cm3]
      REAL*8,  INTENT(IN)  :: AIRVOL   ! Volume of air in a box     [m3]
      REAL*8,  INTENT(IN)  :: TEMP     ! Temperature in a given box [K]
      REAL*8,  INTENT(IN)  :: QI       ! Cloud ice mixing ratio     [kg/kg]
      REAL*8,  INTENT(IN)  :: CLDF     ! 3D cloud fraction          [unitless]
      REAL*8,  INTENT(IN)  :: AD       ! Dry air mass               [kg]
      REAL*8,  INTENT(IN)  :: hbr      ! Concentration of HBr       [#/cm3]
      REAL*8,  INTENT(IN)  :: hobr     ! Concentration of HOBr      [#/cm3]
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: k_hbr    ! Rate constant for HBr  + ice
                                       !   pseudo-rxn [cm3/s]
      REAL*8,  INTENT(OUT) :: k_hobr   ! Rate constant for HOBr + ice
                                       !   pseudo-rxn [cm3/s]
      REAL*8,  INTENT(OUT) :: AREA     ! Surface area [cm2/cm3]
```

REMARKS:

```
    The rate constant is calculated assuming:
                                                                             .
      1. A sticking coefficient of 0.1 [JPL 2006], Abbatt [1994],
         Chai et al. [2000]
      2. An effective radius is assumed as a function of (i) temperature and
         ice water content (IWC). This relationship is taken from Wyser [1998].
                                                                             .
    ** Calculations of a 1st order rate constent are borrowed from the
       subroutine arsl1k.F. Below are comments from that code:
                                                                             .
         The 1st-order loss rate on wet aerosol (Dentener's Thesis, p. 14)
         is computed as:
                                                                             .
           ARSL1K [1/s] = area / [ radius/dfkg + 4./(stkcf * nu) ]
                                                                             .
         where nu   = Mean molecular speed [cm/s] = sqrt(8R*TK/pi/M) for Maxwell
               DFKG = Gas phase diffusion coeff [cm2/s] (order of 0.1)
```

REVISION HISTORY:

```
    16 Jun 2011 - J. Parrella - Initial version
    22 May 2012 - M. Payer    - Added ProTeX headers
```

1.99.4 diag1

Subroutine DIAG1 accumulates diagnostic quantities on every dynamic timestep.

INTERFACE:

```
      SUBROUTINE DIAG1
```

USES:

```
      ! References to F90 modules
      USE DAO_MOD,         ONLY : AD,  AIRDEN, AVGW,     BXHEIGHT
      USE DAO_MOD,         ONLY : PBL, IS_ICE, IS_WATER, IS_LAND, IS_NEAR
      USE DIAG_MOD,        ONLY : AD30, AD31, AD33, AD35, AD45, AD54
      USE DIAG_MOD,        ONLY : AD47, AD67, AD68, AD69, LTOTH, LTO3
      USE DIAG_MOD,        ONLY : AD57
      USE DAO_MOD,         ONLY : T
      USE PRESSURE_MOD,    ONLY : GET_PCENTER
```

```
      USE GRID_MOD,       ONLY : GET_AREA_M2
      USE PRESSURE_MOD,   ONLY : GET_PEDGE
      USE TIME_MOD,       ONLY : ITS_TIME_FOR_CHEM
      USE TRACER_MOD,     ONLY : N_TRACERS, STT, TCVV
      USE TRACER_MOD,     ONLY : ITS_A_FULLCHEM_SIM
      USE TRACER_MOD,     ONLY : XNUMOLAIR
      USE TRACERID_MOD,   ONLY : IDTOX
      USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_TROP
      USE DIAG03_MOD       , ONLY : AD03_RGM, AD03_PBM, ND03
      USE OCEAN_MERCURY_MOD, ONLY : Fg, Fp, PARTITION_Hg2

#if   defined( APM )
      USE TRACER_MOD,     ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD  ! Size parameters
      USE CMN_O3_MOD    ! FRACO3
      USE CMN_DIAG_MOD  ! Diagnostic arrays & parameters
      USE CMN_GCTM_MOD  ! Physical constants

      IMPLICIT NONE
#     include "define.h"
```

REVISION HISTORY:

```
(1 ) This subroutine was reconstructed from gmg's version of (10/10/97)
(2 ) GISS-specific code has been eliminated (bmy, 3/15/99)
(3 ) UWND, VWND, WW no longer needs to be passed (bmy, 4/7/99)
(4 ) Use F90 syntax for declarations, etc (bmy, 4/7/99)
(5 ) Remove counter KWACC...this is now redundant (bmy, 11/5/99)
(6 ) ND31, ND33, ND35, ND67, and ND69 now use dynamically
      allocatable arrays declared in "diag_mod.f". (bmy, 3/9/00)
(7 ) LTOTH is now an allocatable array in "diag_mod.f". (bmy, 3/17/00)
(8 ) Add parallel loops over tracer where expedient (bmy, 5/4/00)
(9 ) Updated comments and diagnostics list.  Also add more parallel
      loops for ND31 and ND68.  (bmy, 6/21/00)
(10) Use NTRACE to dimension STT_VV instead of NNPAR (bmy, 10/17/00)
(11) Removed obsolete code from 10/17/00 (bmy, 12/21/00)
(12) Updated diagnostic list & comments, cosmetic changes (bmy, 6/19/01)
(13) Updated diagnostic list & comments (bmy, 9/4/01)
(14) Now reference AVGW from "dao_mod.f", and make sure it is allocated
      before we reference it in the ND68 diagnostic.  Also reference PBL,
      PS, AIRDEN from "dao_mod.f". (bmy, 9/25/01)
(15) Removed obsolete code from 9/01 (bmy, 10/23/01)
(16) Renamed ND33 to "ATMOSPHERIC COLUMN SUM OF TRACER", since this is
      a sum over all levels and not just in the troposphere.  Also
      removed more obsolete code from 9/01.  Now use P(I,J)+PTOP instead
      of PS, since that is the way to ensure that we use will be used
```

```
      consistently.  Remove reference to PS from "dao_mod.f"(bmy, 4/11/02)
(17) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
      to prevent namespace confusion for the new TPCORE.  Also removed
      obsolete, commented-out code.  Also now replaced reference to
      P(IREF,JREF) with P(I,J). (bmy, 6/25/02)
(18) Replaced references to P(I,J) with call to GET_PEDGE(I,J,1) from
      "pressure_mod.f"  Eliminated obsolete commented-out code from
      6/02. (dsa, bdf, bmy, 8/20/02)
(19) Now reference AD, and BXHEIGHT from "dao_mod.f".  Removed obsolete
      code.  Now refEerence IDTOX from "tracerid_mod.f". (bmy, 11/6/02)
(20) Now replace DXYP(J) with routine GET_AREA_M2 from "grid_mod.f"
      (bmy, 2/4/03)
(21) Now compute PBL top for ND67 for GEOS-4/fvDAS.  Also now include
      SCALE_HEIGHT from header file "CMN_GCTM". (bmy, 6/23/03)
(22) Now references N_TRACERS, STT, and ITS_A_FULLCHEM_SIM from
      "tracer_mod.f" (bmy, 7/20/04)
(23) Fixed ND67 PS-PBL for GCAP and GEOS-5 met fields (swu, bmy, 6/9/05)
(24) Now archive ND30 diagnostic for land/water/ice flags (bmy, 8/18/05)
(25) Now reference XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(26) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(27) Added count for time in the troposphere - array AD54 (phs, 9/22/06)
(28) Now only archive O3 in ND45 and ND47 at chem timsteps (phs, 1/24/07)
(29) Bug fix: Update ND30 for both GEOS-3 and otherwise.  Also now save
      3-D pressure edges in ND31 instead of PS-PTOP.  Revert to the !
      pre-near-land ND30 diagnostic algorithm. (bmy, 1/28/04)
(30) Use LTO3 for O3 in ND45. (ccc, 7/20/09)
(31) Add potential temperature diagnostic in ND57 (fp, 2/3/10)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
15 Feb 2011 - R. Yantosca - Added modifications for APM from G. Luo
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

REMARKS:

```
For a complete list of GEOS-Chem diagnostics, please see this web page:
   http://acmg.seas.harvard.edu/geos/doc/man/appendix_5.html
```

1.99.5 diag3

Subroutine DIAG3 prints out diagnostics to the BINARY PUNCH format file.

INTERFACE:

```
SUBROUTINE DIAG3
```

USES:

```
! Modules from Headers directory
```

```
      USE CMN_SIZE_MOD                      ! Size parameters
      USE CMN_MOD                           ! IFLX, LPAUSE
      USE CMN_O3_MOD                        ! FMOL, XNUMOL
      USE CMN_DIAG_MOD                      ! Diagnostic switches & arrays
      USE COMODE_LOOP_MOD                   ! IDEMS
      USE FILE_MOD
      USE GRID_MOD
      USE TIME_MOD

      ! Modules from GeosCore directory
      USE BPCH2_MOD                         ! For binary punch I/O routines
      USE BIOMASS_MOD                       ! For biomass emissions
      USE BIOFUEL_MOD                       ! For biofuel emissions
      USE DIAG_MOD                          ! For diagnostic arrays
      USE DIAG03_MOD                        ! For Hg diagnostic
      USE DIAG04_MOD                        ! For CO2 diagnostics
      USE DIAG41_MOD                        ! For afternoon PBL diag
      USE DIAG42_MOD                        ! For SOA diag
      USE DIAG56_MOD                        ! For time in tropopause diag
      USE DIAG_PL_MOD                       ! For prod/loss diagnostic
      USE DEPO_MERCURY_MOD                  ! For offline Hg simulation
      USE DRYDEP_MOD                        ! For dry deposition
      USE LOGICAL_MOD                       ! For logical switches
      USE TRACER_MOD                        ! For tracer array
      USE TRACERID_MOD                      ! For tracer flags
      USE WETSCAV_MOD                       ! For wet deposition

#if   defined( APM )
      ! Modules from GeosApm directory
      USE APM_DRIV_MOD, ONLY : IFTEMPOUT
      USE APM_DRIV_MOD, ONLY : TEMPOUT
      USE APM_DRIV_MOD, ONLY : NTEMPOUT
      USE APM_DRIV_MOD, ONLY : NPOUTSTEPS
#endif


      IMPLICIT NONE
#     include "define.h"
```

REVISION HISTORY:

```
   (40) Bug fix: Save levels 1:LD13 for ND13 diagnostic for diagnostic
        categories "SO2-AC-$" and "SO2-EV-$".  Now reference F90 module
        "tracerid_mod.f".  Now reference NUMDEP from "drydep_mod.f".
        Now save anthro, biofuel, biomass NH3 in ND13; also fixed ND13
        tracer numbers.  For ND13, change scale factor from SCALESRCE to 1.
        Now references "wetscav_mod.f".  Now also save true tracer numbers
```

```
      for ND38 and ND39 diagnostic.  Now also write out biomass SO2.
      Now convert ND01, ND02, ND44 diagnostics for Rn/Pb/Be from kg to
      kg/s here. (bmy, 1/24/03)
(41) Now save out natural NH3 in ND13 as "NH3-NATU" (rjp, bmy, 3/23/03)
(42) Now replace DXYP(JREF) by routine GET_AREA_M2, GET_XOFFSET, and
      GET_YOFFSET of "grid_mod.f".  Now references "time_mod.f".
      DIAGb, DIAGe are now local variables.  Now remove obsolete statements
      IF ( LBPNCH > 0 ).  Removed SCALE1, replaced with SCALEDYN.
      (bmy, 2/24/03)
(43) Added TSKIN, PARDF, PARDR, GWET to ND67 diagnostic.  For GEOS-4/fvDAS,
      UWND, VWND, TMPU, SPHU are A-6 fields.  Adjust the ND66 scale factors
      accordingly.  Delete KZZ from ND66.  Updated comments. (bmy, 6/23/03)
(44) Bug fix: use LD68 instead of ND68 in DO-loop to avoid out-of-bounds
      error. (bec, bmy, 7/15/03)
(45) Now print out NTRACE drydep fluxes for tagged Ox.  Also tagged Ox
      now saves drydep in molec/cm2/s.  Now print out Kr85 prod/loss in
      ND03. (bmy, 8/20/03)
(46) Now use actual tracer number for ND37 diagnostic. (bmy, 1/21/04)
(47) Now loop over the actual # of soluble tracers for ND17, ND18.
      (bmy, 3/19/04)
(48) Now use the actual tracer # for ND17 and ND18 diagnostics.
      Rearrange ND44 code for clarity. (bmy, 3/23/04)
(49) Added ND06 (dust aerosol) and ND07 (carbon aerosol) diagnostics.
      Now scale online dust optical depths by SCALECHEM in ND21 diagnostic.
      (rjp, tdf, bmy, 4/5/04)
(50) Added ND08 (seasalt aerosol) diagnostic (rjp, bec, bmy, 4/20/04)
(51) Now save out SO2 from ships (if LSHIPSO2=T) (bec, bmy, 5/20/04)
(52) Added NVOC source diagnostics for ND07 (rjp, bmy, 7/13/04)
(53) Now reference "logical_mod.f", "tracer_mod.f", and "diag_pl_mod.f".
      Bug fix in write to DMS_BIOG. (bmy, 7/20/04)
(54) Comment out ND27 for GEOS-4.  It isn't working 100% right.  If you
      examine the flux at 200 hPa, you get the same info. (bmy, 10/15/04)
(55) Added biofuel SO4 to the bpch file under ND13.  Bug fix: replace ND68
      with LD68 in call to BPCH2 (auvray, bmy, 11/17/04)
(56) Now save ND03 mercury diagnostic arrays to bpch file.  Also updated
      ND44 for tagged Hg tracers (eck, bmy, 12/14/04)
(57) Now print out extra ND21 diagnostics for crystalline sulfur tracers.
      Also now save total oceanic mass of Hg0 and Hg2.  Now call
      WRITE_DIAG03 from "diag03_mod.f" (bmy, 1/21/05)
(58) Now call WRITE_DIAG41 from "diag41_mod.f" (bmy, 2/17/05)
(59) Add P(SO4s) to row 8 of ND05 diagnostic.  Also remove special tracer
      numbers for the ND67 diagnostic.  Now do not save CLDMAS for ND67
      for GEOS-4, since GEOS-4 convection uses different met fields.
      (bec, bmy, 5/3/05)
(60) Bug fix in ND68 diagnostic: use LD68 instead of ND68 in call to BPCH2.
      Now modified for GEOS-5 and GCAP met fields.  Remove references to
      CO-OH param simulation.  Also remove references to TRCOFFSET since
      that is always zero now.  Now call GET_HALFPOLAR from "bpch2_mod.f"
```

```
      to get the HALFPOLAR value for GEOS or GCAP grids. (swu, bmy, 6/24/05)
(61) References ND04, WRITE_DIAG04 from "diag04_mod.f".  Also now updated
      ND30 diagnostic for land/water/ice flags.  Also remove reference
      to LWI array. (bmy, 8/18/05)
(62) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(63) Added MBO as tracer #5 in ND46 diagnostic (tmf, bmy, 10/20/05)
(64) Removed duplicate variable declarations.  Now remove restriction on
      printing out cloud mass flux in GEOS-4 for the ND66 diagnostic.
      (bmy, 3/14/06)
(65) References ND56, WRITE_DIAG56 from "diag56_mod.f" (ltm, bmy, 5/5/06)
(66) Now remove TRCOFFSET; it's obsolete.  References ND42, WRITE_DIAG42
      from "diag42_mod.f" (dkh, bmy, 5/22/06)
(67) Updated ND36 diagnostic for CH3I (bmy, 7/25/06)
(68) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(69) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
      (bmy, 9/5/06)
(70) Now write diag 54 (time in the troposphere) if asked for (phs, 9/22/06)
(71) Now use new time counters for ND43 & ND45,  Also now average between
      0 and 24 UT for ND47.  Bug fix in ND36. (phs, bmy, 3/5/07)
(72) Bug fix in ND65: use 3-D counter array (phs, bmy, 3/6/07)
(73) Bug fix in ND07: now save out IDTSOA4 tracer.  Modifications for H2/HD
      diagnostics (ND10, ND27, ND44) (tmf, phs, bmy, 9/18/07)
(74) Now save out true pressure at 3-D level edges for ND31.  Change ND31
      diagnostic category name to "PEDGE-$". Bug fix in ND28 diagnostic to
      allow you to print out individual biomass tracers w/o having to print
      all of them. (bmy, dkh, 1/24/08)
(75) Bug fix: Now divide ALBEDO in ND67 by SCALE_I6 for GEOS-3 met, but
      by SCALE_A3 for all other met types (phs, bmy, 10/7/08)
(76) Fix ND65, ND47, and ozone case in ND45. Now only ND45 depends
      on LD45 (phs, 11/17/08)
(77) Bug fix: Select the right index of AD34 to write.  Pick the right
       tracer field from AD22 if only a subset of tracers are requested
       to be printed out. (ccc, 12/15/08)
(78) Added ND52 for gamma(HO2) (jaegle, 02/26/09)
(79) Updated test on ship emissions flag for AD13 (phs, 3/3/09)
(80) Add AD07_SOAGM for dicarbonyl SOA formation (tmf, 3/6/09)
(81) Add output in AD22 for dicarbonyl photolysis J values (tmf, 3/6/09)
(82) Add output in AD46 for biogenic C2H4 emissions (tmf, 3/6/09)
(83) Modify ND17, ND18, ND37, ND38, ND44 to output the tracers selected
      by the user. (ccc, 5/29/09)
(84) Add EFLUX output information for ND67. (lin, ccc, 5/29/09)
(85) Add test on ICOADS (cklee, 06/30/09)
(86) Add SCALE_DIAG to scale diagnostics with the number of accumulation
      steps. (ccc, 7/20/09)
(87) Add diagnostics 19, 58 and 60 for methane. (kjw, 8/18/09)
(88) Account for 3D AD13_NH3_an now (phs, 10/22/09)
(89) NBIOMAX is now in CMN_SIZE (hotp 7/31/09)
(90) Add SOA5 to ND07_HC, add AD57 for potential temperature. (fp, 2/3/10)
```

```
(91) Modify ND44 for tracers with several deposition tracers. (ccc, 2/3/10)
(92) Add aromatics to ND43. (dkh, 06/21/07)
(93) Add ND57 for potential temperature. (fp, 2/3/10)
(94) Re-order levels in mass fluxes diagnostics before writing them to file.
     (ND24, 25, 26). (ccc, 3/8/10)
(95) Add call to update_dep for mercury simulation at the end.(ccc, 7/19/10)
20 Aug 2010 - R. Yantosca - Added ProTeX headers
20 Aug 2010 - R. Yantosca - Now pick proper scale for ND66 for MERRA
20 Aug 2010 - R. Yantosca - Now pick proper scale for ND67 for MERRA
20 Aug 2010 - R. Yantosca - Now added SCALE_A1 for hourly data
20 Aug 2010 - R. Yantosca - Now reference GET_A1_TIME from "time_mod.f"
26 May 2011 - R. Yantosca - For ND44, omit the special treatment of
                            isoprene tracers if we are not doing fullchem
27 May 2011 - R. Yantosca - Now use SCALEDIAG for ND54 (time-in-trop) diag
08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met
08 Feb 2012 - R. Yantosca - Restructure USE statements for clarity
08 Feb 2012 - R. Yantosca - Add counter for I3 (inst 3hr) met fields
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
05 Apr 2012 - R. Yantosca - Bug fix: use hourly scale for SLP in the
                            ND67 diagnostic for GEOS-5.7.x met fields
```

1.99.6 diag_2pm

Subroutine DIAG_2PM constructs the diagnostic flag arrays:

- LTJV: J-values (ND22)
- LTOH: OH concentrations (ND43)
- LTNO: NO concentrations (ND43)
- LTNO2: NO2 concentrations (ND43)
- LTHO2: HO2 concentrations (ND43)
- LTOTH: used for tracers (ND45)
- LTO3: for O3 (ND45)

These arrays are either 1 (if it is within a certain time interval) or 0 (if it is not within a certain time interval). The limits of the time intervals for CTOTH and CTJV are now defined in input.geos The arrays CTOTH, CTOH, CTNO, CTJV count the number of times the diagnostics are accumulated for each grid box (i.e LTOTH is 1)

INTERFACE:

```
SUBROUTINE DIAG_2PM
```

USES:

```
      USE DIAG_MOD,       ONLY : LTJV,  CTJV,  LTNO,  CTNO,  CTO3
      USE DIAG_MOD,       ONLY : LTOH,  CTOH,  LTOTH, CTOTH, LTNO2
      USE DIAG_MOD,       ONLY : CTNO2, LTHO2, CTHO2, LTNO3, CTNO3
      USE DIAG_MOD,       ONLY : CTO3_24h, LTO3
      USE DIAG_MOD,       ONLY : LTLBRO2H, LTLBRO2N
      USE DIAG_MOD,       ONLY : LTLTRO2H, LTLTRO2N
      USE DIAG_MOD,       ONLY : LTLXRO2H, LTLXRO2N
      USE DIAG_MOD,       ONLY : CTLBRO2H, CTLBRO2N
      USE DIAG_MOD,       ONLY : CTLTRO2H, CTLTRO2N
      USE DIAG_MOD,       ONLY : CTLXRO2H, CTLXRO2N
      USE TIME_MOD,       ONLY : GET_LOCALTIME
      USE TIME_MOD,       ONLY : ITS_TIME_FOR_DIAG, ITS_TIME_FOR_CHEM
      USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_TROP
      USE TIME_MOD,       ONLY : GET_ELAPSED_MIN
      USE TIME_MOD,       ONLY : GET_TS_DIAG

      USE CMN_SIZE_MOD   ! Size parameters
      USE CMN_DIAG_MOD   ! HR_OH1, HR_OH2, etc.

      IMPLICIT NONE
#     include "define.h"
```

REMARKS:

For now use GET_LOCALTIME(I, 1, 1) which will be independent of J and L for a pure cartesian grid. This may need to be revisited once G-C is interfaced into a GCM.

REVISION HISTORY:

26 Mar 1999 - R. Yantosca - Initial version
(1) Now use F90 syntax (bmy, 3/26/99)
(2) Now reference LTNO2, CTNO2, LTHO2, CTHO2 arrays from "diag_mod.f". Updated comments, cosmetic changes. (rvm, bmy, 2/27/02)
(3) Now removed NMIN from the arg list. Now use functions GET_LOCALTIME, ITS_TIME_FOR_CHEM, ITS_TIME_FOR_DYN from "time_mod.f" (bmy, 2/11/03)
(4) Now rewritten using a parallel DO-loop (bmy, 7/20/04)
(5) Now account for the time spent in the troposphere for ND43 and ND45 pure O3. Now only accumulate counter for 3D pure O3 in ND45 if it's a chemistry timestep. (phs, 1/24/07)
(6) Added 3D counter for ND65 and O3 in ND47 (phs, 11/17/08)
(7) Change re-initialization of ND45: only at the timestep after the diagnostics are accumulated. Add ITS_AFTER_DIAG and PREV_TS variables. (ccc, 6/12/09)
(8) Add LTO3 to accumulate O3 in ND45 at the same place as the chemistry (ccc, 7/17/09)
01 Mar 2012 - R. Yantosca - Now use GET_LOCALTIME(I,J,L) from time_mod.F90

1.99.7 diagoh

Subroutine DIAGOH saves chemical diagnostic quantities for the ND43 chemical diagnostics.

INTERFACE:

```
      SUBROUTINE DIAGOH
```

USES:

```
      USE DIAG_MOD, ONLY: AD43, LTNO, LTOH, LTNO2, LTHO2, LTNO3

      USE CMN_SIZE_MOD  ! Size parameters
      USE CMN_O3_MOD    ! SAVEOH, SAVENO
      USE CMN_DIAG_MOD  ! Diagnostic switches & arrays

      IMPLICIT NONE
#     include "define.h"
```

REVISION HISTORY:

```
   01 May 1998 - R. Yantosca - Initial version
   (1 ) Now use F90 syntax for declarations (bmy, 3/29/99)
   (2 ) Cosmetic changes (bmy, 3/29/99)
   (3 ) AD43 and DIAGCHLORO are now declared allocatable in "diag_mod.f".
        Also eliminate obsolete code. (bmy, 11/29/99)
   (4 ) LTNO, LTOH are now allocatable arrays in "diag_mod.f" (bmy, 3/17/00)
   (5 ) Don't save OH into STT(:,:,:NTRACER+2) anymore.  The SAVEOH
        array is now used to save OH concentrations for diagnostics.
        Also revised out-of-date comments. (bmy, 4/24/00)
   (6 ) Also save out NO2 and HO2 for use w/ the ND43 diagnostic.
        Now also reference LTNO2, LTHO2 arrays from "diag_mod.f".
        Updated comments, cosmetic changes. (rvm, bmy, 2/27/02)
   (7 ) Removed obsolete reference to DIAGCHLORO (bmy, 8/2/02)
   (8 ) Now save NO3 [molec/cm3] as AD43(:,:,:,5) (bmy, 1/13/03)
   (9 ) Corrected typo in comments (bmy, 8/10/09)
   15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.99.8 emfossil

Subroutine EMFOSSIL emits fossil fuels into the EMISRR and EMISRRN arrays, which are then passed to SMVGEAR.

INTERFACE:

```
      SUBROUTINE EMFOSSIL( I, J, N, NN, IREF, JREF, JSCEN )
```

USES:

```
      USE BRAVO_MOD,          ONLY : GET_BRAVO_ANTHRO, GET_BRAVO_MASK
      USE CAC_ANTHRO_MOD,     ONLY : GET_CANADA_MASK,  GET_CAC_ANTHRO
      USE DAO_MOD,            ONLY : IS_WATER
      USE DIAG_MOD,           ONLY : AD29,   AD32_an,  AD36
      USE EDGAR_MOD,          ONLY : GET_EDGAR_CO,     GET_EDGAR_NOx
      USE EDGAR_MOD,          ONLY : GET_EDGAR_TODN
      USE EMEP_MOD,           ONLY : GET_EMEP_ANTHRO,  GET_EUROPE_MASK
      USE EPA_NEI_MOD,        ONLY : GET_EPA_ANTHRO,   GET_USA_MASK
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE LOGICAL_MOD,        ONLY : LBRAVO, LEMEP,    LNEI99
      USE LOGICAL_MOD,        ONLY : LEDGARNOx,        LEDGARCO
      USE LOGICAL_MOD,        ONLY : LSTREETS,         LCAC
      USE LOGICAL_MOD,        ONLY : LEDGARSHIP,       LARCSHIP
      USE LOGICAL_MOD,        ONLY : LEMEPSHIP,        LVISTAS
      USE LOGICAL_MOD,        ONLY : LICARTT,          LNEI05
      USE LOGICAL_MOD,        ONLY : LRETRO
      USE RETRO_MOD,          ONLY : GET_RETRO_ANTHRO
      USE C2H6_MOD,           ONLY : GET_C2H6_ANTHRO
      USE NEI2005_ANTHRO_MOD, ONLY : GET_NEI2005_ANTHRO
      USE NEI2005_ANTHRO_MOD, ONLY : NEI05_MASK => USA_MASK
      USE LOGICAL_MOD,        ONLY : LICOADSSHIP !(cklee, 6/30/09)

      USE STREETS_ANTHRO_MOD, ONLY : GET_SE_ASIA_MASK
      USE STREETS_ANTHRO_MOD, ONLY : GET_STREETS_ANTHRO
      USE TIME_MOD,           ONLY : GET_TS_EMIS,      GET_DAY_OF_WEEK
      USE TIME_MOD,           ONLY : GET_HOUR
      USE TRACER_MOD,         ONLY : ITS_A_TAGCO_SIM
      USE TRACER_MOD,         ONLY : XNUMOL
      USE TRACERID_MOD,       ONLY : IDENOX, IDEOX,    IDEHNO3
      USE TRACERID_MOD,       ONLY : IDTOX,  IDTCO,    IDTHNO3
      USE TRACERID_MOD,       ONLY : IDTC2H6
      USE VISTAS_ANTHRO_MOD,  ONLY : GET_VISTAS_ANTHRO
      USE ICOADS_SHIP_MOD,    ONLY : GET_ICOADS_SHIP !(cklee, 7/09/09)
  [eml
      USE LOGICAL_MOD,        ONLY : LHIST
  eml]

      USE CMN_SIZE_MOD             ! Size parameters
      USE COMODE_LOOP_MOD          ! IHOUR
      USE CMN_O3_MOD               ! EMISR, EMISRR, etc...
      USE CMN_DIAG_MOD             ! Diagnostic switches & arrays

      IMPLICIT NONE
#     include "define.h"
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: I       ! GEOS-Chem longitude index
```

```
      INTEGER, INTENT(IN)   :: J       ! GEOS-Chem latitude index
      INTEGER, INTENT(IN)   :: N       ! GEOS-Chem emission species index
      INTEGER, INTENT(IN)   :: NN      ! GEOS-Chem advected tracer index
      INTEGER, INTENT(IN)   :: IREF    ! Offset index I+I0
      INTEGER, INTENT(IN)   :: JREF    ! Offset index J+J0
      INTEGER, INTENT(IN)   :: JSCEN   ! Day index (Sat=1, Sun=2, Weekday=3)
```

REMARKS:

In most cases, I0=J0=0, so IREF=I and JREF=J. The offsets I0 and J0 are mostly historical baggage.

NOTE: The source code for ship emissions has been commented out, but left in place. Although PARANOX computes ship emissions in CALCRATE, we may have to disable this for the Grid-Independent model (because we have to have a clean separation between emissions & chemistry).

REVISION HISTORY:

19 Apr 1999 - R. Yantosca - Initial version
(1) Uses the correct seasonal NOx and multi-level NOx (anthroems.f)
(2) Uses anthro scale factors for years since 1985 (from anthroems.f)
(3) Scales emissions based on weekday/weekend (emf_scale.f)
(4) Preserves old sensitivity study cases (emf_scale.f, emissdr.f)
(5) Scales emissions based on time of day (emfossil.f)
(6) Get rid of all GISS and PLUMES code (bmy, 4/19/99)
(7) Now use F90 syntax for declarations, etc. (bmy, 4/19/99)
(8) Now use allocatable arrays for ND29 and ND36 diagnostics.
Also made minor cosmetic changes & updated comments. (bmy, 3/16/00)
(9) Eliminate obsolete code and ND63 diagnostic (bmy, 4/12/00)
(10) Enhance anthropogenic CO emission by 8%, to account for CO production
from oxidation of anthropogenic VOC's (bnd, bmy, 1/2/01)
(11) Comment out scaling by 1.08 for anthro CO (bmy, 2/12/01)
(12) Eliminate obsolete commented-out code (bmy, 4/20/01)
(13) Now use 2% as the enhancment factor for CO instead of 1.08,
according to new jal numbers (bmy, 4/26/01)
(14) Now references "tracerid_mod.f" (bmy, 11/6/02)
(15) Now replaced DXYP(JREF)*1d4 with GET_AREA_CM2(J). Now use function
GET_TS_EMIS() from "time_mod.f" (bmy, 2/11/03)
(16) Now can overwrite existing emissions with EPA/NEI data over the
continental USA if LNEI99=T. Now reference LNEI99 from F90
module "logical_mod.f". Now reference GET_EPA_ANTHRO and
GET_USA_MASK from "epa_nei_mod.f". (rch, rjp, bmy, 11/5/04)
(17) Now references GET_DAY_OF_WEEK from "time_mod.f" to correctly figure
out if this is a weekday or weekend. (bmy, 7/6/05)
(18) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(19) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(20) Now apply EMEP European emissions if necessary. Remove reference

```
      to CMN, it's now obsolete. (bdf, bmy, 11/1/05)
(21) Rewrite IF statements to avoid seg fault errors when LEMEP and LNEI99
      are turned off. (bmy, 2/1/06)
(22) Now apply BRAVO Mexican emissions if necessary (rjp, kfb, bmy, 6/26/06)
(23) Now apply EDGAR emissions if necessary.  Also now only do the the
      EDGAR, EPA, EMEP, and BRAVO function calls in the LL=1 block.
      (avd, bmy, 7/10/06)
(24) Now do BRAVO emissions before EPA/NEI99 emissions in order to avoid
      zero emissions in some boxes.  Now add David Streets emissions for
      NOx over SE Asia and CO over just China (yxw, bmy, 8/17/06)
(25) Bug fix: Now only execute EDGAR CO block if the tracer is CO.
      Also, David Streets' CO is now applied over SE ASIA. (bmy, 9/8/06)
(26) Now references ITS_A_TAGCO_SIM from "tracer_mod.f".  Enhance CO prod
      by 18.5% for tagged CO sim here instead of in "tagged_co_mod.f".
      (bmy, 2/14/08)
(27) Use more robust test to only screen out "missing" values in EMEP,
      BRAVO, and David Streets emissions. (avd, phs, bmy, 11/19/08)
(28) Ship NOx is emitted as HNO3+10*O3  (phs, 3/4/08)
(29) Apply spatially-varying diurnal scalars for NOx (amv, 08/24/07)
(30) Now apply CAC Canadian emissions if necessary (amv, 01/09/08)
(31) Moved down BRAVO parts and add BRAVO and EPA emissions where they
      overlap (phs, 5/7/08)
(32) Now overwrite USA NOx with VISTAS if necessary (amv, 12/02/08)
(33) Modified CO scaling (jaf, 2/25/09)
(34) Add a test on existing emissions for EPA/NEI. (hotp, ccc, 5/29/09)
(35) Updated ship treatment (phs, 7/0/09)
(36) Add NEI2005 (amv, phs, 10/20/09)
(37) Bug fix for tagged CO and 0.5 x 0.666 Nested Grid (yxw, bmy, 11/23/09)
(38) Bug fix for array EMISRR, if emissions are already present in this
      array (e.g. ship O3 or HNO3) they no longer get overwritten.
      (gvinken, 11/16/10)
19 Nov 2010 - R. Yantosca - Added ProTeX headers
24 Feb 2012 - M. Payer    - Commented out ship emissions, which has been
                            moved to calcrate.F for PARANOX.  Left original
                            code in place, but commented out.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
22 Mar 2012 - M. Payer    - Update for C2H6. RETRO ethane emissions are too
                            low so we will use Yaping Xiao's offline emiss.
```

1.99.9 emf_scale

Subroutine EMF_SCALE does the following:

- Saves original values of EMISR, EMISRN, EMISPN so that they can be restored later (after scaling)
- Scales emissions to weekend or weekday usage (using scale factors stored in the SCNR89 array)

INTERFACE:

```
      SUBROUTINE EMF_SCALE( I,    J,    N,     NN,
     &                      IREF, JREF, JSCEN, XEMISR, XEMISRN )
```

USES:

```
      USE TRACERID_MOD, ONLY : IDTALK4, IDTC3H8, IDTISOP, IDTCO
      USE TRACERID_MOD, ONLY : IDTNOX,  IDTOX,   IDTPRPE
      USE TRACERID_MOD, ONLY : IDTMEK,  IDTC2H2, IDTC2H4, IDTACET
      USE TRACERID_MOD, ONLY : IDTBENZ, IDTTOLU, IDTXYLE, IDTC2H6

      USE CMN_SIZE_MOD
      USE COMODE_LOOP_MOD
      USE CMN_O3_MOD

      IMPLICIT NONE
#     include "define.h"
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: I       ! GEOS-Chem longitude index
      INTEGER, INTENT(IN)    :: J       ! GEOS-Chem latitude index
      INTEGER, INTENT(IN)    :: N       ! GEOS-Chem emission species index
      INTEGER, INTENT(IN)    :: NN      ! GEOS-Chem advected tracer index
      INTEGER, INTENT(IN)    :: IREF    ! Offset index I+I0
      INTEGER, INTENT(IN)    :: JREF    ! Offset index J+J0
      INTEGER, INTENT(IN)    :: JSCEN   ! Day index (Sat=1, Sun=2, Weekday=3)
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: XEMISR               ! HC emissions, scaled
      REAL*8,  INTENT(INOUT) :: XEMISRN(NOXLEVELS)   ! NOx emissions, scaled
```

REMARKS:

```
   This is historical baggage...we need to clean this up one of these days.
```

REVISION HISTORY:

```
   02 Apr 1998 - R. Yantosca - Initial version
   (1 ) Use F90 syntax for declarations, etc. (bmy, 4/14/99)
   (2 ) Now test with N instead of NN.  N is the emission species, and can
        be equal to zero, which denotes that the species is not emitted.
        This is necessary now, since IDEOX always = 0, but IDTOX is always
        nonzero. (bmy, 4/19/99)
   (3 ) Commented out special cases via ICASE.  Also made a few cosmetic
        changes and updated comments. (bmy, 1/2/01)
   (4 ) Remove old obsolete commented-out code (bmy, 4/20/01)
```

```
   (5 ) Now references "tracerid_mod.f" (bmy, 11/6/02)
   (6 ) Now references LFFNOX from "logical_mod.f" (bmy, 7/20/04)
   (7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (8 ) Modified to add weekday/weekend scaling to aromatics,
        C2H4, C2H2 (tmf, 1/7/09)
   19 Nov 2010 - R. Yantosca - Added ProTeX headers
```

1.99.10 fast_j.f

Subroutine FAST_J loops over longitude and latitude, and calls PHOTOJ to compute J-Values for each column at every chemistry time-step.

References:

1. H. Liu, J.H. Crawford, R.B. Pierce, P. Norris, S.E. Platnick, G. Chen, J.A. Logan, R.M. Yantosca, M.J. Evans, C. Kittaka, Y. Feng, and X. Tie, *Radiative effect of clouds on tropospheric chemistry in a global three-dimensional chemical transport model*, J. Geophys. Res., **111**, D20303, doi:10.1029/2005JD006403, 2006. http://research.nianet.org/ hyl/publicatio

INTERFACE:

```
      SUBROUTINE FAST_J( SUNCOS, OD, ALBD )
```

USES:

```
      USE DAO_MOD,      ONLY : T, CLDF
      USE ERROR_MOD,    ONLY : ERROR_STOP, ALLOC_ERR
      USE GRID_MOD,     ONLY : GET_YMID
      USE PRESSURE_MOD, ONLY : GET_PEDGE
      USE TIME_MOD,     ONLY : GET_MONTH, GET_DAY, GET_DAY_OF_YEAR
      USE TIME_MOD,     ONLY : GET_TAU,   GET_YEAR
      USE TOMS_MOD,     ONLY : GET_OVERHEAD_O3

#     include "define.h"

      USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR, LLPAR
      USE CMN_SIZE_MOD, ONLY : NDUST, MAXIJ, NAER, NRH
#if !defined( DEVEL )
      USE CMN_FJ_MOD, ONLY : IPAR, JPAR, LPAR
#endif
      USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD, ONLY : ODMDUST, PJ, NB, ODAER

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      ! Cosine of solar zenith angle [unitless]
      REAL*8, INTENT(IN)    :: SUNCOS(MAXIJ)

      ! Cloud optical depth [unitless]
      REAL*8, INTENT(IN)    :: OD(LLPAR,IIPAR,JJPAR)

      ! UV albedo [unitless]
      REAL*8, INTENT(IN)    :: ALBD(IIPAR,JJPAR)
```

REMARKS:

```
Parameter to choose cloud overlap algorithm:
=============================================================================
(1 ) OVERLAP (INTEGER) : 1 - Linear Approximation (used up to v7-04-12)
                         2 - Approximate Random Overlap (default)
                         3 - Maximum Random Overlap (computation intensive)
```

REVISION HISTORY:

```
01 Apr 1998 - P. Murti, R. Martin, R. Yantosca - Initial version
(1 ) Call this routine EACH chemistry time-step, before solver.
(2 ) This routine must know IMAX, JMAX, LMAX.
(3 ) Now use new !$OMP compiler directives for parallelization (bmy, 5/2/00)
(4 ) Now reference "cmn_fj.h" and "jv_cmn.h" for the aerosol
     optical depths (bmy, 10/2/00)
(5 ) Add OPTDUST as a local variable -- make OPTDUST private for
     the parallel DO-loop, since it stores 1 column of aerosol optical
     depth for each dust type (bmy, rvm, 10/2/00)
(6 ) For now, LPAR in "cmn_fj.h" = LGLOB in "CMN_SIZE".  Therefore we
     assume that we are always doing global runs. (bmy, 10/2/00)
(7 ) Removed obsolete code from 10/2/00 (bmy, 12/21/00)
(8 ) Replace {IJL}GLOB w/ IIPAR,JJPAR,LLPAR everywhere.  Also YLMID(NLAT)
     needs to be referenced by YLMID(NLAT+J0). (bmy, 9/26/01)
(9 ) Remove obsolete code from 9/01.  Updated comments. (bmy, 10/24/01)
(10) Add OPTAER as a local variable, make it private for the parallel
     DO loop, since it stores 1 column of aerosol optical depths for each
     aerosol type.  Pass OPTAER to PHOTOJ via the argument list.  Declare
     OPTAER as PRIVATE for the parallel DO-loop. (rvm, bmy, 2/27/02)
(11) Now reference GET_PEDGE from "pressure_mod.f", which returns the
     correct "floating" pressure. (dsa, bdf, bmy, 8/20/02)
(12) Now reference T from "dao_mod.f" (bmy, 9/23/02)
(13) Now uses routine GET_YMID from "grid_mod.f" to compute grid box
     latitude.  Now make IDAY, MONTH local variables.  Now use function
     GET_DAY_OF_YEAR from "time_mod.f".  Bug fix: now IDAY (as passed to
     photoj.f) is day of year rather than cumulative days since Jan 1,
     1985. (bmy, 2/11/03)
(14) Now reference routine GET_YEAR from "time_mod.f".  Added LASTMONTH
     as a SAVEd variable.  Now call READ_TOMSO3 from "toms_mod.f" at the
     beginning of a new month (or the first timestep) to read TOMS O3
```

```
      columns which will be used by "set_prof.f".  Now also reference
      routine GET_DAY from "time_mod.f".  Rename IDAY to DAY_OF_YR. Pass
      day of month to PHOTOJ.  Updated comments, cosmetic changes.
      (bmy, 7/17/03)
(15) Bug fix: PRES needs to be the true surface pressure for GEOS-4, but
      PS-PTOP for all prior GEOS models.  (bmy, 2/6/04)
(16) Now account for cloud overlap (Maximum-Random Overlap and Random
      Overlap) in each column (hyl, phs, bmy, 9/18/07)
(17) Now initialize the PJ array here, instead of two layers below in
      "set_prof.f".  Now no longer pass PRES to "photoj.f". (bmy, 11/29/07)
(18) Now switch to approx. random overlap option (hyl, phs, bmy, 10/7/08)
(19) Now can handle GEOS-5 reprocessed met data with OPTDEPTH being
      in-cloud optical depths. (bmy, hyl, 10/24/08)
(10) Remove references to IN_CLOUD_OD (bmy, 10/15/09)
13 Aug 2010 - R. Yantosca - Added ProTeX headers
13 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
06 Mar 2012 - R. Yantosca - Now call GET_OVERHEAD_O3 to get the total
                            overhead O3 column for FAST-J
```

1.99.11 photoj

Subroutine PHOTOJ is the driver routine for the FAST-J photolysis package.

INTERFACE:

```
      SUBROUTINE PHOTOJ( NLON,   NLAT, YLAT,    DAY_OF_YR,
     &                   MONTH,  DAY,  CSZA,    T,
     &                   SA,     OD,   OPTDUST, OPTAER,
     &                   O3COL                             )
```

USES:

```
#     include "define.h"

      USE CMN_SIZE_MOD, ONLY : NDUST, NAER, NRH,  LLPAR
      USE CMN_FJ_MOD,   ONLY : JPMAX, JPPJ, JPNL, ZPJ
      USE JV_CMN_MOD,   ONLY : ZJ,    U0,   SZA,  SZAMAX

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: NLON                ! Grid box lon index
      INTEGER, INTENT(IN)    :: NLAT                ! Grid box lat index
      REAL*8,  INTENT(IN)    :: YLAT                ! Latitude [degrees]
      INTEGER, INTENT(IN)    :: DAY_OF_YR           ! Day of year
```

```
      INTEGER, INTENT(IN)    :: MONTH                ! Current month
      INTEGER, INTENT(IN)    :: DAY                  ! Day of month
      REAL*8,  INTENT(IN)    :: CSZA                 ! Cosine(SZA) [unitless]
      REAL*8,  INTENT(IN)    :: T(LLPAR)             ! Temperature [K]
      REAL*8,  INTENT(IN)    :: SA                   ! UV albedo [unitless]
      REAL*8,  INTENT(IN)    :: OD(LLPAR)            ! Visible OD [unitless]
      REAL*8,  INTENT(IN)    :: O3COL                ! Overhead O3 column [DU]
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: OPTDUST(LLPAR,NDUST)   ! Dust OD [unitless]
      REAL*8,  INTENT(INOUT) :: OPTAER(LLPAR,NAER*NRH) ! Aerosol OD [unitless]
```

AUTHOR:

```
Oliver Wild & Michael Prather
```

REMARKS:

```
New FAST J-Value code, troposphere only (mjprather 6/96); uses special
wavelength quadrature spectral data (jv_spec.dat) that includes only
289 nm - 800 nm  (later a single 205 nm add-on); uses special compact Mie
code based on Feautrier/Auer/Prather vers.

.

Important variables from other modules:
(1) ZJ   : Column array for J-values
(2) ZPJ  : Global array for J-values (passed to SMVGEAR)
(3) JPNL : # of GEOS-CHEM layers in which to compute J-values
(4) JPPJ : # of photolysis rxns for FAST-J

.

NOTE: The value of PI listed here is slightly different than the value
in CMN_GCTM_mod.F.  The last digit is 4, whereas in CMN_GCTM_mod.F, the
last digit is 3.  Keep for now during testing of grid-independent code, but
this may be something to revisit at a later data. (bmy, 3/6/12)
```

REVISION HISTORY:

```
01 Jun 1996 - M. Prather & O. Wild - Initial version
(1 ) Renamed NSLON to NLON and NSLAT to NLAT.  Now add DAY_OF_YR
      (formerly IDAY) and DAY to the arg list.  Swap places in arg list
      of SA and OD.  Now pass NLON, NLAT, DAY_OF_YR and DAY to "set_prof.f".
      Added standard documentation header; cosmetic changes. (bmy, 7/15/03)
(2 ) We don't need to pass "P" via the arg list (bmy, 2/13/07)
06 Mar 2012 - R. Yantosca - Now pass O3COL via the arg list
06 Mar 2012 - R. Yantosca - Added ProTeX headers
```

1.99.12 set_prof

Subroutine SET_PROF sets up atmospheric profiles required by Fast-J using a doubled version of the level scheme used in the CTM. First pressure and z* altitude are defined,

then O3 and T are taken from the supplied climatology and integrated to the CTM levels (may be overwritten with values directly from the CTM, if desired) and then black carbon and aerosol profiles are constructed.

INTERFACE:

```
      SUBROUTINE SET_PROF( NLON,    NLAT,   YLAT, MONTH,
     &                     DAY,     T,      SA,   ODCOL,
     &                     OPTDUST, OPTAER, O3COL )
```

USES:

```
#     include "define.h"

      USE CMN_SIZE_MOD,  ONLY : LLPAR
      USE CMN_FJ_MOD,    ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: NLON                   ! Grid box lon index
      INTEGER, INTENT(IN)    :: NLAT                   ! Grid box lat index
      REAL*8,  INTENT(IN)    :: YLAT                   ! Latitude [degrees]
      INTEGER, INTENT(IN)    :: MONTH                  ! Current month
      INTEGER, INTENT(IN)    :: DAY                    ! Day of month
      REAL*8,  INTENT(IN)    :: T(LLPAR)               ! Temperature [K]
      REAL*8,  INTENT(IN)    :: SA                     ! UV albedo [unitless]
      REAL*8,  INTENT(IN)    :: OPTDUST(LLPAR,NDUST)   ! Dust OD [unitless]
      REAL*8,  INTENT(IN)    :: OPTAER(LLPAR,NAER*NRH) ! Aerosol OD [unitless]
      REAL*8,  INTENT(IN)    :: O3COL                  ! Overhd O3 column [DU]
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: ODCOL(LLPAR)           ! Visible OD [unitless]
```

AUTHOR:

```
    Oliver Wild & Michael Prather
```

REMARKS:

```
    References:
    ============================================================================
    TOMS/SBUV MERGED TOTAL OZONE DATA, Version 8, Revision 3.
    Resolution:  5 x 10 deg.
                                                                               .
    Source: http://code916.gsfc.nasa.gov/Data_services/merged/index.html
                                                                               .
    Contact person for the merged data product:
```

```
Stacey Hollandsworth Frith (smh@hyperion.gsfc.nasa.gov)
                                                                              .
Important module variables:
=============================================================================
(1 ) PJ     :  Pressure at boundaries of model levels [hPa]
(2 ) Z      :  Altitude of boundaries of model levels [cm]
(4 ) MASFAC :  Conversion factor for pressure to column density
(5 ) TJ     :  Temperature profile on model grid
(6 ) DM     :  Air column for each model level [molecules/cm2])
(7 ) DO3    :  Ozone column for each model level [molecules/cm2]
(8 ) DBC    :  Mass of Black Carbon at each model level [g/cm3]
(9 ) PSTD   :  Approximate pressures of levels for supplied climatology
```

REVISION HISTORY:

```
01 Jun 1996 - M. Prather & O. Wild - Initial version
(1 ) Since we parallelize over columns, T, ODCOL, OPTDUST, and OPTAER
     are 1-D vectors. In the original code from Oliver Wild, these were
     3-D arrays.  Also P and SA are just scalars since we just pass one
     surface location at a time w/in the parallel loop. (bmy, 9/13/99)
(2 ) Mineral dust profiles are also constructed (rvm, 06/04/00)
(3 ) Other aerosol profiles are also constructed (rvm, bmy, 2/27/02)
(4 ) Added NLON, NLAT, DAY to the arg list.  Now weight the O3 column by
     the observed monthly mean EP-TOMS data.  Also updated comments and
     added standard GEOS-CHEM documentation header. (mje, bmy, 7/13/03)
(5 ) We don't need to initialize the PJ array with ETAA and ETAB anymore.
     PJ is now defined in "fast_j.f".  Updated comments. (bmy, 10/30/07)
(6 ) Modified to use GEOS-5 O3 columns when TOMS/SBUV data don't exist,
     i.e. after 2008. (ccc, 7/13/09)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.99.13 initialize

Subroutine INITIALIZE does the following:

1. Zeroes globally defined GEOS-CHEM variables.
2. Zeroes accumulating diagnostic arrays.
3. Resets certain year/month/day and counter variables used in GEOS-Chem diagnostic subroutines.

INTERFACE:

```
SUBROUTINE INITIALIZE( IFLAG )
```

USES:

```
      ! Modules from Headers subdirectory
      USE CMN_SIZE_MOD
      USE CMN_DIAG_MOD
      USE ERROR_MOD
      USE TIME_MOD

      ! Modules from GeosCore subdirectory
      USE DIAG_MOD
      USE DIAG03_MOD
      USE DIAG04_MOD
      USE DIAG41_MOD
      USE DIAG42_MOD
      USE DIAG56_MOD
      USE DIAG_PL_MOD
      USE LOGICAL_MOD

      IMPLICIT NONE

#     include "define.h"
```

INPUT PARAMETERS:

```
      ! If IFLAG=1, zero global CTM arrays
      ! If IFLAG=2, zero accumulating diagnostic arrays
      ! If IFLAG=3, zero accumulating diagnostic counters
      INTEGER, INTENT(IN)  :: IFLAG
```

REMARKS:

```
   Eventually we will fold this into "diag_mod.f" in a cleaner,
    more consistent fashion.  Think about this later (bmy, 11/14/02)
```

REVISION HISTORY:

```
   15 Jun 1998 - M. Prather  - Initial version
   (1 ) INITIALIZE is written in Fixed-Form Fortran 90.
   (2 ) To ensure double precision accuracy, use 0d0 instead of 0.0.
   (3 ) Also zero the mass flux arrays from TPCORE (bmy, 4/26/99)
   (4 ) Only zero allocatable arrays that are turned on. (bmy, 11/29/99)
   (5 ) Added arrays for ND13 diagnostic -- sulfur emissions.
        Also updated comments (bmy, 6/21/00)
   (6 ) Remove SAVEJ and SAVEL -- we don't call DIAG0 anymore (bmy, 9/8/00)
   (7 ) Add array AD32_bf for ND32 NOx biofuel diagnostic (bmy, 9/12/00)
   (8 ) Also zero the FAMPL array for ND65 (bmy, 12/5/00)
   (9 ) Now initialize AD34 array for biofuel emissions (bmy, 3/15/01)
   (10) Now initialize AD12 array for boundary layer emissions in "setemis.f".
        Also made cosmetic changes & updated comments. (bdf, bmy, 6/15/01)
   (11) Now initialize AD11 array for acetone diagnostic (bmy, 8/1/01)
   (12) Remove reference to AVGF -- it is obsolete.  Also, AVGW is now
```

```
      included in "dao_mod.f", and is initialized there. (bmy, 9/25/01)
(13) Removed obsolete code from 9/01 (bmy, 10/24/01)
(14) Make sure FAMPL is allocated before we reference it (bmy, 1/15/02)
(15) Eliminated obsolete code from 1/02.  Now also zero CTNO2, CTHO2
      counter arrays. (bmy, 2/27/02)
(16) Bug fix: CTHO2 and CTNO2 should be zeroed if ND43 > 0, not if
      ND45 > 0.  Fix this typo. (bmy, 4/19/02)
(17) Now also zero AD01, AD02 arrays (bmy, 8/7/02)
(18) Remove reference to arrays P, SIG, SIGE from "CMN", since we now
      use floating pressure + the hybrid grid. (dsa, bdf, bmy, 8/21/02)
(19) Now zero the AD05 array for sulfate P-L (rjp, bdf, bmy, 9/20/02)
(20) Now we no longer have to zero the T array.  Also reference ERROR_STOP
      from "error_mod.f". Now also initialize AD13_NH3_an, AD13_NH3_bb,
      AD13_NH3_bf. (bmy, 12/13/02)
(21) Now also zero AD13_NH3_na array for ND13 (rjp, bmy, 3/23/03)
(22) Now references "time_mod.f" (bmy, 3/27/03)
(23) Now zeroes AD03 array for Kr85 prod/loss diag. (jsw, bmy, 8/20/03)
(24) Now also zeroes AD06 and AD07* arrays (rjp, tdf, bmy, 4/5/04)
(25) Now also zeroes AD08 array (rjp, bec, bmy, 4/20/04)
(26) Now also initialize AD13_SO2_sh array (bec, bmy, 5/20/04)
(27) Now also initialize AD07_HC array (rjp, bmy, 7/13/04)
(28) Now references AD65 & FAM_PL from "diag_pl_mod.f".  Now remove
      reference to DIAGCHLORO, it's obsolete. (bmy, 7/20/04)
(29) Now initialize extra arrays for ND03 mercury diag.  Also remove
      reference to obsolete TOFDY0 variable. (eck, bmy, 12/7/04)
(30) Now initialize AD21_cr array for ND21 diag.  Also references
      LCRYST from "logical_mod.f"  Now call ZERO_DIAG03 from "diag03_mod.f"
      to zero ND03 arrays (bmy, 1/21/05)
(31) Now call ZERO_DIAG41 from "diag41_mod.f".  Also removed references
      to AD41 and AFTTOT. (bmy, 2/17/05)
(32) Now zero AD09 and AD09_em for HCN simulation (xyp, bmy, 6/27/05)
(33) Now references ND04, ZERO_DIAG04 from "diag04_mod.f".  Also remove
      reference to "CMN" and XTRA2.  Now zeroes AD30 array (bmy, 8/18/05)
(34) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(35) Now resets SET_CT_XTRA at the beginning of the run. (tmf, 10/20/05)
(36) Now references ND56, ZERO_DIAG56 from "diag56_mod.f" (ltm, bmy, 5/5/06)
(37) Now references ND42, ZERO_DIAG42 from "diag42_mod.f" (dkh, bmy,5/22/06)
(38) take care of AD54 (time in the troposphere diagnostic) (phs, 10/17/06)
(39) Now also zero CTO3 array.  Bug fix: ZERO_DIAG42 is now called when
      ND42 is turned on. (phs, bmy, 1/30/07)
(40) Now zero AD10 and AD10em for H2HD simulation (phs, 9/18/07)
(41) Now zero CTO3_24h (phs, 11/17/08)
(42) Now zero AD52 for Gamma HO2 diag. (ccc, jaegle, 2/26/09)
(43) Updated to diagnose GLYX production of SOAG in ND07. (tmf, 1/7/09)
(44) Add initialization of counter for diag time steps. (ccc, 7/20/09)
(45) Define new diagnostics, ND19, ND58, ND60 for methane
     (kjw, 8/18/09)
(46) Add potential temperature diagnostic. (fp, 06/09)
```

```
25 Aug 2010 - R. Yantosca - Added ProTeX headers
25 Aug 2010 - R. Yantosca - Now also reset the counter for A1 timesteps
08 Feb 2012 - R. Yantosca - Rewrote USE statements, for clarity
08 Feb 2012 - R. Yantosca - Now also reset the counter for I3 timesteps
```

1.99.14 ndxx_setup

Subroutine NDXX_SETUP dynamically allocates memory for certain diagnostic arrays that are declared allocatable in "diag_mod.f".

This allows us to reduce the amount of memory that needs to be declared globally. We only allocate memory for arrays if the corresponding diagnostic is turned on.

INTERFACE:

```
SUBROUTINE NDXX_SETUP
```

USES:

```
!NBIOMAX moved to CMN_SIZE_mod (fp, 6/2009)
!USE BIOMASS_MOD,     ONLY : NBIOMAX
USE BIOFUEL_MOD,     ONLY : NBFTRACE
USE DIAG_MOD,        ONLY : AD01,        AD02,        AD05
USE DIAG_MOD,        ONLY : AD06,        AD07,        AD07_BC
USE DIAG_MOD,        ONLY : AD07_OC,     AD07_HC,     AD08
USE DIAG_MOD,        ONLY : AD07_SOAGM
USE DIAG_MOD,        ONLY : AD09,        AD09_em,     AD11
USE DIAG_MOD,        ONLY : AD12,        AD13_DMS,    AD13_SO2_ac
USE DIAG_MOD,        ONLY : AD13_SO2_an, AD13_SO2_bb, AD13_SO2_bf
USE DIAG_MOD,        ONLY : AD13_SO2_ev, AD13_SO2_nv, AD13_SO4_an
USE DIAG_MOD,        ONLY : AD13_SO4_bf, AD13_SO2_sh, AD13_NH3_an
USE DIAG_MOD,        ONLY : AD13_NH3_na, AD13_NH3_bb, AD13_NH3_bf
USE DIAG_MOD,        ONLY : CONVFLUP,    TURBFLUP,    AD16
USE DIAG_MOD,        ONLY : CT16,        AD17,        CT17
USE DIAG_MOD,        ONLY : AD18,        CT18,        AD21
USE DIAG_MOD,        ONLY : AD21_cr,     AD22,        LTJV
USE DIAG_MOD,        ONLY : CTJV,        MASSFLEW,    MASSFLNS
USE DIAG_MOD,        ONLY : MASSFLUP,    AD28,        AD29
USE DIAG_MOD,        ONLY : AD30,        AD31
!FP_ISOP potential temperature diag (6/2009)
USE DIAG_MOD,        ONLY : AD57
USE DIAG_MOD,        ONLY : AD32_ac,     AD32_an,     AD32_bb
USE DIAG_MOD,        ONLY : AD32_bf,     AD32_fe,     AD32_li
USE DIAG_MOD,        ONLY : AD32_so,     AD32_ub,     AD33
USE DIAG_MOD,        ONLY : AD34,        AD35,        AD36
USE DIAG_MOD,        ONLY : AD37,        AD38,        AD39
USE DIAG_MOD,        ONLY : AD43,        LTNO
USE DIAG_MOD,        ONLY : CTNO,        LTOH,        CTOH
```

```
      USE DIAG_MOD,        ONLY : LTHO2,       CTHO2,       LTNO2
      USE DIAG_MOD,        ONLY : CTNO2,       LTNO3,       CTNO3
      ! update for arom (dkh, 06/21/07)
      USE DIAG_MOD,        ONLY : CTLBRO2H,    CTLBRO2N
      USE DIAG_MOD,        ONLY : CTLTRO2H,    CTLTRO2N
      USE DIAG_MOD,        ONLY : CTLXRO2H,    CTLXRO2N
      USE DIAG_MOD,        ONLY : LTLBRO2H,    LTLBRO2N
      USE DIAG_MOD,        ONLY : LTLTRO2H,    LTLTRO2N
      USE DIAG_MOD,        ONLY : LTLXRO2H,    LTLXRO2N
      USE DIAG_MOD,        ONLY : AD44,        AD45,        LTOTH
      USE DIAG_MOD,        ONLY : CTOTH,       AD46,        AD47
      USE DIAG_MOD,        ONLY : AD52,        AD54,        AD63
      USE DIAG_MOD,        ONLY : AD19,        AD58,        AD60
      USE DIAG_MOD,        ONLY : AD55,        AD66,        AD67
      USE DIAG_MOD,        ONLY : AD68,        AD69,        CTO3
      USE DIAG_MOD,        ONLY : AD10,        AD10em,      CTO3_24h
      USE DIAG63_MOD,      ONLY : DO_SAVE_DIAG63
      ! Add O3 for ND45 diag. (ccc, 8/12/09)
      USE DIAG_MOD,        ONLY : LTO3
      USE DIAG_OH_MOD,     ONLY : INIT_DIAG_OH
      USE DRYDEP_MOD,      ONLY : NUMDEP
      USE ERROR_MOD,       ONLY : ALLOC_ERR,   ERROR_STOP
      USE LOGICAL_MOD,     ONLY : LDUST, LCARB, LSSALT, LCRYST, LDRYD
      ! Added for mercury simulation. (ccc, 6/4/10)
      USE LOGICAL_MOD,     ONLY : LGTMM
      USE PLANEFLIGHT_MOD, ONLY : SETUP_PLANEFLIGHT
      USE TRACER_MOD,      ONLY : ITS_A_CH3I_SIM
      USE TRACER_MOD,      ONLY : ITS_A_FULLCHEM_SIM
      USE TRACER_MOD,      ONLY : ITS_A_MERCURY_SIM
      USE TRACER_MOD,      ONLY : ITS_A_TAGOX_SIM
      USE TRACER_MOD,      ONLY : ITS_A_H2HD_SIM
      USE TRACER_MOD,      ONLY : N_TRACERS
      USE TRACERID_MOD,    ONLY : NEMANTHRO
      USE WETSCAV_MOD,     ONLY : GET_WETDEP_NMAX
#if   defined( APM )
      USE DIAG_MOD,        ONLY : AD07_OM
      USE TRACER_MOD,      ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD          ! Size parameters
      USE CMN_DIAG_MOD          ! Diagnostic switches & arrays

      IMPLICIT NONE
#     include "define.h"
```

REVISION HISTORY:

```
   16 Jun 1998 - I. Bey, R. Yantosca - Initial version
```

```
(1 ) This subroutine was split off from subroutine INPUT, for clarity
(2 ) Added call to READ49 (bey, 2/99)
(3 ) Eliminate GISS-Specific code, and AIJ, AIL diagnostics (bmy, 3/15/99)
(4 ) Define tracer offset TRCOFFSET for "alternate chemistry" runs.
(5 ) Multi-level diagnostics ND21, ND22, ND43, ND45, ND66, and ND68 have
      now been split off from the AIJ arrays (bmy, 3/29/99)
(6 ) Added code for ND14 and ND15.  Also eliminated obsolete code
      and updated comments (bmy, 11/10/99)
(7 ) Added new ND41 and ND51 diagnostics (from amf).  Freed up obsolete
      diagnostics ND34. ND37, and ND42 and updated comments. (bmy, 11/15/99)
      Also note: ND41 uses allocatable array AD41. (bmy, 12/6/99)
(8 ) The following diagnostic arrays are now declared allocatable
      in "diag_mod.f": AD21, AD22, AD38, AD39, AD43, AD45, AD47,
      AD66, AD68, CONVFLUP, TURBFLUP, MASSFLEW, MASSFLNS, MASSFLUP, TCOBOX
      Allocate memory for these arrays only if their respective
      diagnostic is turned on.  This will save memory. (bmy, 11/29/99)
(9 ) Added ND55 diagnostic for tropopause heights (hyl, bmy, 12/1/99)
(10) ND50 and ND20 now have dynamically allocatable arrays. (bmy, 1/5/00)
(11) ND27 diagnostic now also turns on ND24, ND25, ND26 (bmy, 1/7/00)
(12) ND31, ND33, ND35, ND37, ND67, and ND69 now use dynamically
      allocatable arrays declared in "diag_mod.f". (bmy, 2/17/00)
(13) ND16, ND17, ND18 now use allocatable arrays.  Also now use internal
      subroutine "alloc_err" to print error messages. (bmy, 3/14/00)
(14) AIJ is now obsolete.  All diagnostic variables now use allocatable
      arrays (cf. "diag_mod.f").  This is necessary in order to keep the
      size of the 2 x 2.5 executable within machine limits. (bmy, 3/28/00)
(15) Removed obsolete code.  Added TRCOFFSET of 3 for CO run
      with parameterized OH.  Removed reference to KAIJPAR. (bmy, 4/19/00)
(16) Add TRCOFFSET of 50 for DMS/SO2/SO4/MSA.  Also added arrays for
      ND13 diagnostic for sulfur emissions (bmy, 6/6/00)
(17) Add reference to F90 module "biomass_mod.f".  Also added array
      AD32_bf for biofuel NOx. (bmy, 9/11/00)
(18) Use NTRACE + 2 prodloss families for Tagged CO for the
      ND65 diagnostic (bmy, 10/6/00)
(19) Adjust TRCOFFSET for 10-tracer Tagged CO run.  Redimensioned
      AD45 and AD47 to save memory.  Renamed STATUS to AS. (bmy, 10/18/00)
(20) Removed obsolete code from 10/00.  Save out ND65 only to LLTROP
      levels for full chemistry.  Save out ND43 only to LLTROP levels
      for full chemistry.  Dimension DIAGCHLORO up to LLTROP for
      full chemistry (or LLPAR for CO/OH chemistry).  ND24, ND25, ND26
      can now save out less than LLPAR levels.  Eliminate dependence
      on PD35, PD37, PD39 parameters (bmy, 12/5/00)
(21) Only save out a maximum of LCONVM layers for ND14 (bmy, 12/7/00)
(22) Removed obsolete code from 7/00, 9/00, and 12/00 (bmy, 12/21/00)
(23) Increase to NTRACE + 4 prodloss families for Tagged CO (bmy, 1/2/01)
(24) Add TRCOFFSET of 54 for CH4 chemistry (NSRCX == 9) (bmy, 1/16/01)
(25) Now allocate DIAGCHLORO (ND23 diagnostic) for CH4 runs (bmy, 1/18/01)
(26) For ND43, save up to LLTROP for full chemistry, but save up to
```

```
      LLPAR for Tagged CO or CO-OH chemistry (bmy, 2/12/01)
(27) Now allocate AD34 for biofuel burning emissions (bmy, 3/15/01)
(28) Add L(CH3I) to ND65 diagnostic (nad, bmy, 3/20/01)
(29) For full chemistry, we only need to save up to LLTROP levels
      for the ND22 J-value diagnostic (bmy, 4/2/01)
(30) Remove reference to NBIOMAX from "biomass_mod.f" (bmy, 4/17/01)
(31) Eliminate obsolete commented-out code (bmy, 4/20/01)
(32) Now also allocate the AD12 diagnostic array (bdf, bmy, 6/15/01)
(33) Now assign TRCOFFSET = 40 for multi-tracer Ox run (when NSRCX = 6
      and LSPLIT = T).  Reference CMN_SETUP for LSPLIT.  Allocate AD44
      with NTRACE instead of NUMDEP for single or multi-tracer Ox runs
      (NSRCX = 6).  Now define NFAM as NTRACE*2 for single or multi-tracer
      Ox runs.  Updated comments & made cosmetic changes. (bmy, 7/3/01)
(34) Added AD11 diagnostic for acetone source.  Also removed obsolete
      code from 7/01. (bmy, 9/4/01)
(35) Turn off ND23 unless NSRCX = 3, 5, or 9.  This prevents us from
      referencing an unallocated DIAGCHLORO array.  Add error check for
      ND65, make sure that NFAM > 0.  Also clean up the code that
      allocates AD65 and FAMPL arrays. (bmy, 1/14/02)
(36) Now set TRCOFFSET = 64 for tagged C2H6 chemistry (bmy, 1/25/02)
(37) Eliminate obsolete code from 1/02 and 2/02.  Also allocate LTNO2,
      CTNO2, LTHO2, CTHO2 for the ND43 diagnostic. (bmy, 2/27/02)
(38) Call SETUP_PLANEFLIGHT to initialize the ND40 plane flight diagnostic
      for non-SMVGEAR chemistry runs. (mje, bmy, 7/2/02)
(39) Now set up variables & arrays for ND01 and ND02 diagnostics (i.e.
      Rn-Pb-Be emissions and decay).  (bmy, 9/20/02)
(40) Now allocate AD05 array.   Now allocate routines ALLOC_ERR and
      ERROR_STOP from "error_mod.f".  Now reference NEMANTHRO from F90
      module "tracerid_mod.f" instead of "comtrid.h".  Also added array
      AD13_SO2_bf for biofuel SO2. (bmy, 1/16/03)
(41) Now also allocate AD13_NH3_na array for ND13 (rjp, bmy, 3/23/03)
(42) Added ND03 diagnostic for Kr85 prod/loss.  Also removed special case
      TRCOFFSET for single-tracer Ox. (jsw, bmy, 8/20/03)
(43) Now use GET_WETDEP_NMAX to get max # of soluble tracers for ND37,
      ND18, and ND19.  Also set NFAM=NTRACE+5 for Tagged CO simulation.
      (3/18/04)
(44) Now initialize AD06 and AD07* arrays (rjp, tdf, bmy, 4/5/04)
(45) Now initialize AD08 array.  Reset TRCOFFSET for tagged CO from
      84 to 80.  Also activate ND52 diagnostic for ICARTT.
      (rjp, bec, stu, cas, bmy, 4/20/04)
(46) Now allocate AD13_SO2_sh array for ND13 (bec, bmy, 5/20/04)
(47) Now allocate AD07_HC array for ND07 (rjp, bmy, 7/13/04)
(48) Now references "tracer_mod.f" and "logical_mod.f" instead of "CMN"
      and "CMN_SETUP".  Now references INIT_DIAG_OH from "diag_oh_mod.f"
      Adjust TRCOFFSET for various aerosol simulations. (bmy, 7/20/04)
(49) Make sure ND21 only goes from 1-LLTROP (bmy, 9/28/04)
(50) Now allocate AD13_SO4_bf array (bmy, 11/17/04)
(51) Now allocate extra arrays for ND03 mercury diag.  Also set up for
```

```
      mercury tracers in ND44 diagnostic. (bmy, 12/14/04)
(52) Added separate ND21 array for cryst sulfur tracers.  Now reinstated
      AD03 array for mercury simulation.  Now move ND03 diagnostics into
      a separate module.  Remove TCOBOX reference, it's obsolete.
      (cas, sas, bmy, 1/21/05)
(53) Now remove references to AD41 & AFTTOT.  Now call SETUP_PLANEFLIGHT
      for non-full-chemistry runs in main.f -- this will allow it to look
      for flight files for each day (bmy, 3/24/05)
(54) Now use PD05=10 to dimension AD05 array (bmy, 4/13/05)
(55) Now also allocates AD09 and AD09_em (bmy, 6/27/05)
(56) Now allocates AD30 (bmy, 8/18/05)
(57) Removed duplicate variable declarations (bmy, 2/6/06)
(58) Now remove NBIOTRCE; it's obsolete.  Replace w/ NBIOMAX (bmy, 4/5/06)
(59) Now remove TRCOFFSET; it's obsolete (bmy, 5/16/06)
(60) Added the ND54 for time spend in the troposphere (phs, 10/17/06)
(61) Now allocate ND43 and ND45 counter arrays as 3-D (phs, 1/19/07)
(62) For ND20 diagnostic, reset ND65 diagnostic with LLTROP_FIX instead of
      LLTROP.  Added ND10 diagnostic setup.  Added modifications for H2-HD
      simulation. (phs, bmy, 9/18/07)
(63) Now save true pressure edges for ND31 diagnostic (bmy, 11/16/07)
(64) Now stop the run if ND20 is defined but ND65 isn't (bmy, 12/4/07)
(65) Allocate CTO3_24h (phs, 11/18/08)
(66) We don't need to set LD65=1 here anymore, we now call NDXX_SETUP!
      after DIAG_PL_MOD. (phs, bmy, 12/18/08)
(67) Added ND52 for GAMMA HO2 diagnostic. (ccc, jaegle, 2/26/09)
(68) Add AD07_SOAGM (tmf, 1/7/09)
(67) Added ND52 for GAMMA HO2 diagnostic. (ccc, jaegle, 2/26/09)
(68) Add AD07_SOAGM (tmf, 1/7/09)
(69) Now always allocate Mass Flux arrays (phs, 4/15/09)
(70) Allocate LTO3. (ccc, 7/20/09)
(71) Add AD19, AD58, AD60 (kjw, 8/18/09)
(72) Now AD13_SO2_an and AD13_SO4_an have NOXLEVELS levels to accomodate
   NEI 2005 (amv, 10/9/09)
(73) AD13_NH3_an is 3D now (phs, 10/22/09)
(74) Add new diagnostic ND59, ND60, ND61 (win, 7/9/09)
(75) Increase size for AD44 for TOMAS aerosol mass (win, 7/14/09)
(76) Initialize values for LD59, LD60, and LD61 (win, 8/10/09)
(77) NBIOMAX is now in CMN_SIZE. (fp, 2/26/10)
26 Aug 2010 - R. Yantosca - Added ProTeX headers
16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
```

1.99.15 ohsave

Subroutine OHSAVE stores the concentrations of OH, HO2, NO, NO2, and NO3 for the ND43 diagnostic. Also the O3/Ox, NO/NOx and NO2/NOx fractions are computed and returned to the calling program.

INTERFACE:

```
      SUBROUTINE OHSAVE( N_TRACERS, XNUMOL,  STT,    FRACO3,
     &                   FRACNO,    FRACNO2, SAVEOH, SAVEHO2,
     &                   SAVENO,    SAVENO2, SAVENO3 )
```

USES:

```
      USE COMODE_MOD,   ONLY : AIRDENS, CSPEC, JLOP, T3, VOLUME
      USE DIAG_MOD,     ONLY : DIAGCHLORO
      USE TRACERID_MOD, ONLY : IDTOX, IDTNOX, IDO3,  IDNO
      USE TRACERID_MOD, ONLY : IDNO2, IDOH,   IDHO2, IDNO3

      USE CMN_SIZE_MOD     ! Size parameters
      USE COMODE_LOOP_MOD     ! VOLUME, CSPEC, NPVERT, NLAT, NLONG

      IMPLICIT NONE
#     include "define.h"
```

INPUT PARAMETERS:

```
      ! Number of tracers in XNUMOL and STT
      INTEGER, INTENT(IN) :: N_TRACERS

      ! Array of molec/kg for each tracer
      REAL*8, INTENT(IN)  :: XNUMOL(N_TRACERS)

      ! Array containing CTM tracers
      REAL*8, INTENT(IN)  :: STT(IIPAR,JJPAR,LLPAR,N_TRACERS)
```

OUTPUT PARAMETERS:

```
      ! Array of O3/Ox fractions
      REAL*8, INTENT(OUT) :: FRACO3(IIPAR,JJPAR,LLPAR)

      ! Array of NO/NOx fractions
      REAL*8, INTENT(OUT) :: FRACNO(IIPAR,JJPAR,LLPAR)

      ! Array of NO2/NOx fractions
      REAL*8, INTENT(OUT) :: FRACNO2(IIPAR,JJPAR,LLPAR)

      ! Array of OH  concentrations [molec/cm3]
      REAL*8, INTENT(OUT) :: SAVEOH(IIPAR,JJPAR,LLPAR)

      ! Array of HO2 concentrations [v/v]
      REAL*8, INTENT(OUT) :: SAVEHO2(IIPAR,JJPAR,LLPAR)

      ! Array of NO  concentrations [v/v]
      REAL*8, INTENT(OUT) :: SAVENO(IIPAR,JJPAR,LLPAR)
```

```
! Array of NO2 concentrations [v/v]
REAL*8, INTENT(OUT) :: SAVENO2(IIPAR,JJPAR,LLPAR)

! Array of NO3 concentrations [v/v]
REAL*8, INTENT(OUT) :: SAVENO3(IIPAR,JJPAR,LLPAR)
```

REVISION HISTORY:

```
27 Feb 2002 - R. Yantosca - Initial version
(1 ) Original code from lwh, gmg, djj, jyl, etc, 1990's.  Modified for
     GEOS-CHEM by Bob Yantosca et al.
(2 ) Added comment header and F90 declaration syntax.  Also now specify
     the units of each variable for clarity.
(3 ) Deleted NTRACER, it is not used.  Also added FRACNO2 and SAVEHO2
     variables.  Updated comments, cosmetic changes (rvm, bmy, 2/27/02)
(4 ) Bug fix: swap the order of the lines where TMPNOX is computed.
     Also deleted obsolete code from 2/02. (bmy, 7/31/02)
(5 ) Now reference IDTOX, IDTNOX, etc from "tracerid_mod.f". (1/13/03)
(6 ) Added OpenMP parallelization commands (bmy, 8/1/03)
(7 ) Now compute quantities for mean OH in "diag_oh_mod.f".  Now also
     references STT from "tracer_mod.f".  Added N_TRACERS to the arg list.
     Now dimension args XNUMOL, STT w/ N_TRACERS and not NNPAR.
     (bmy, 7/20/04)
(8 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(9 ) Reset FRAC* and SAVE* arrays, so that we don't carry dubious data
     over from boxes that used to be in the tropopause but aren't anymore.
     (phs, 1/19/07)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.99.16 rdsoil

Subroutine RDSOIL reads in soiltype data, fertilizer data, and monthly soil precipitation data.

INTERFACE:

```
SUBROUTINE RDSOIL
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_RES_EXT
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IU_FILE, IOERROR
USE ERROR_MOD,     ONLY : GEOS_CHEM_STOP
USE TIME_MOD,      ONLY : GET_MONTH

USE CMN_SIZE_MOD   ! Size parameters
```

```
      USE COMMSOIL_MOD ! Soil variables

      IMPLICIT NONE
#     include "define.h"
```

REMARKS:

```
RDSOIL is one of the original GEOS-CHEM subroutines, and has its origins
from the GISS-II model that was used at Harvard in the early 90's.  This
was cleaned up and improved error checking was added. (bmy, 4/2/02)
                                                                             .
Variables from "commsoil.h" header file:
============================================================================
(1 ) NCONSOIL  (INTEGER) : Olson -> soil type mapping index
(2 ) INDEXSOIL (INTEGER) : Array containing grid box indices (I,J)
(3 ) SOILFERT  (REAL*8 ) : Array containing fertilizer NOx [ng N/m2/s]
(4 ) SOILPREP  (REAL*8 ) : Array containing 2 months of observed
                           soil precipitation [mm/day]
                                                                             .
Files read in by "rdsoil.f":
============================================================================
(1 ) DATA_DIR/soil_NOx_200203/soiltype.dat       : Olson and soil land types
(2 ) DATA_DIR/soil_NOx_200203/fert_scale.dat     : NOx from fertilizers
(3 ) DATA_DIR/soil_NOx_200203/climatprep4x5.dat  : 1x1   monthly soil precip
                              climatprep2x25.dat : 2x2.5 monthly soil precip
                              climatprep1x1.dat  : 4x5   monthly soil precip
```

REVISION HISTORY:

```
05 Jan 1994 - Y. H. Wang, G. M. Gardner, - Initial version
(1 ) Be sure to force double precision with the DBLE function and the "D"
     exponent, wherever necessary (bmy, 10/6/99)            *
(2 ) Now read soil data files directly from the from
     DATA_DIR/soil_NOx_200203/ subdirectory.  Now use IOERROR to trap
     I/O errors across all platforms.  Added comment header.  Updated
     comments, cosmetic changes. (bmy, 4/2/02)
(3 ) Removed obsolete code from April 2002.  Now reference IU_FILE and
     IOERROR from "file_mod.f".  Now use IU_FILE as the file unit number,
     assign it to IUNIT. (bmy, 6/27/02)
(4 ) Now reference GEOS_CHEM_STOP from "error_mod.f".  Bug fix: remove
     duplicate declaration of IOS.  This causes compile errors for the
     ALPHA platform. (gcc, bmy, 11/6/02)
(5 ) Now use function GET_MONTH from "time_mod.f".  Now make MONTH a local
     variable. (bmy, 2/11/03)
(6 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.99.17 read_jv_atms_dat

Reads the default T and O3 profiles for FAST-J photolysis. This replaces the obsolete rd_prof.F routine, which read from the ASCII file "jv_atms.dat".

INTERFACE:

```
SUBROUTINE READ_JV_ATMS_DAT()
```

USES:

```
  ! Modules for netCDF read
  USE m_netcdf_io_open
  USE m_netcdf_io_read
  USE m_netcdf_io_readattr
  USE m_netcdf_io_close

  ! GEOS-Chem modules
  USE DIRECTORY_MOD, ONLY : DATA_DIR_1x1    ! Data directory
  USE JV_CMN_MOD,    ONLY : TREF            ! Default T profile [K]
  USE JV_CMN_MOD,    ONLY : OREF            ! Default O3 profile [ppm]

  IMPLICIT NONE

# include "netcdf.inc"
```

REMARKS:

```
This file was automatically generated by the Perl scripts in the
NcdfUtilities package (which ships w/ GEOS-Chem) and was subsequently
hand-edited.
```

REVISION HISTORY:

```
19 Apr 2012 - R. Yantosca - Initial version
```

1.99.18 ruralbox

Subroutine RURALBOX computes which boxes are tropospheric and which are stratospheric. SMVGEAR arrays are initialized with quantities from tropospheric boxes.

INTERFACE:

```
      SUBROUTINE RURALBOX( AD, T, AVGW, ALBD )
```

USES:

```
      USE COMODE_MOD,     ONLY : ABSHUM, AIRDENS,  IXSAVE, IYSAVE
      USE COMODE_MOD,     ONLY : IZSAVE, JLOP,     PRESS3, T3,  VOLUME
      USE PRESSURE_MOD,   ONLY : GET_PCENTER,      GET_PEDGE
      USE TROPOPAUSE_MOD, ONLY : ITS_IN_THE_STRAT, ITS_IN_THE_TROP
```

```
#     include "define.h"

      USE CMN_SIZE_MOD       ! Size parameters
      USE COMODE_LOOP_MOD       ! NPVERT

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      REAL*8,  INTENT(IN) :: AD(IIPAR,JJPAR,LLPAR)     ! Air mass [kg]
      REAL*8,  INTENT(IN) :: T(IIPAR,JJPAR,LLPAR)      ! Temperature [K]
      REAL*8,  INTENT(IN) :: AVGW(IIPAR,JJPAR,LLPAR)   ! Mix rat. of H2O [v/v]
      REAL*8,  INTENT(IN) :: ALBD(IIPAR,JJPAR)         ! Sfc albedo [unitless]
```

REMARKS:

```
   Developers: amf, bey, ljm, lwh, gmg, bdf, bmy, 7/16/01, 2/25/10)
```

REVISION HISTORY:

```
   01 Oct 1995 - M. Prather  - Initial version
   (1 ) Remove PTOP from the arg list.  PTOP is now a parameter
        in "CMN_SIZE". (bmy, 2/10/00)
   (2 ) Add C-preprocessor switch LSLOWJ to bracket code for
        SLOW-J photolysis (bmy, 2/25/00)
   (3 ) Now reference ABHSUM, AIRDENS, IXSAVE, IYSAVE, IZSAVE, JLOP, PRESS3,
        T3, and VOLUME from F90 module "comode_mod.f" (bmy, 10/19/00)
   (4 ) PTOP is already a parameter in "CMN_SIZE", don't declare it here
        (bmy, 7/16/01)
   (5 ) Replace IGCMPAR,JGCMPAR,LGCMPAR with IIPAR,JJPAR,LLPAR.  Also moved
        CLOUDREF to SLOW-J block.  Also remove IREF, JREF, IOFF, JOFF, these
        are now obsolete.  Updated comments. (bmy, 9/25/01)
   (6 ) Eliminate I00 and J00 as arguments, these are obsolete (bmy, 9/28/01)
   (7 ) Removed obsolete, commented out code from 9/01 (bmy, 10/24/01)
   (8 ) Updated comment header.  Also updated comments, and made cosmetic
        changes. (bmy, 4/15/02)
   (9 ) Bug fix: declare variables for SLOW-J photolysis.  Also eliminated
        obsolete code from 4/15/02. (bmy, 8/5/02)
   (10) Now reference GET_PCENTER and GET_PEDGE from "pressure_mod.f",
        which return the correct "floating" pressure.  Also deleted obsolete,
        commented-out code.  Also eliminate P, SIG, and NSKIPL from the arg
        list, since we don't need them anymore. (dsa, bdf, bmy, 8/20/02)
   (11) Added modifications for SMVGEAR II (gcc, bdf, bmy, 4/1/03)
   (12) SLOW-J is now obsolete; remove LSLOWJ #ifdef blocks (bmy, 6/23/05)
   (13) Now reference ITS_IN_THE_TROP and ITS_IN_THE_STRAT from
        "tropopause_mod.f" to diagnose trop & strat boxes.  Also remove
        LPAUSE from the arg list (bmy, 8/22/05)
```

```
(14) Remove ALT and CLOUDS from arg list -- they are obsolete (bmy, 4/10/06)
(15) Remove obsolete embedded chemistry stuff (bmy, 2/25/10)
10 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.99.19 setemis.f

Subroutine SETEMIS places emissions computed from GEOS-Chem subroutines into arrays for SMVGEAR II chemistry.

SETEMIS converts from units of [molec tracer/box/s] to units of [molec chemical species/cm3/s], and stores in the REMIS array. For hydrocarbons that are carried through the GEOS-CHEM model as [molec C], these are converted back to [molec hydrocarbon], and then stored in REMIS.

INTERFACE:

```
      SUBROUTINE SETEMIS( EMISRR, EMISRRN )
```

USES:

```
      USE AIRCRAFT_NOX_MOD,  ONLY : EMIS_AC_NOx
      USE BIOFUEL_MOD,       ONLY : BIOFUEL,   BFTRACE, NBFTRACE
      USE BIOMASS_MOD,       ONLY : BIOMASS,   BIOTRCE
      ! Use this array to determine if emissions are handled here (hotp 8/3/09)
      USE BIOMASS_MOD,       ONLY : BIOBGAS
      USE COMODE_MOD,        ONLY : JLOP,      REMIS,   VOLUME
      USE COMODE_MOD,        ONLY : IXSAVE,    IYSAVE,  IZSAVE
      USE DIAG_MOD,          ONLY : AD12
      USE GRID_MOD,          ONLY : GET_AREA_CM2
      USE LIGHTNING_NOX_MOD, ONLY : EMIS_LI_NOx
      USE PBL_MIX_MOD,       ONLY : GET_PBL_TOP_L
      USE PRESSURE_MOD,      ONLY : GET_PEDGE
      USE TRACERID_MOD,      ONLY : CTRMB,     IDEMIS,  IDENOX
      USE TROPOPAUSE_MOD,    ONLY : ITS_IN_THE_STRAT
      USE LOGICAL_MOD,       ONLY : LNLPBL ! (Lin, 03/31/09)
      USE LOGICAL_MOD, ONLY : LPRT

      ! NOx emissions scaling FP 15/12/09
      USE EMISSIONS_MOD,     ONLY : NOx_SCALING

#     include "define.h"
      USE CMN_SIZE_MOD  ! Size parameters
      USE COMODE_LOOP_MOD  ! IDEMS, NEMIS
      USE CMN_DIAG_MOD  ! Diagnostic flags
      USE CMN_NOX_MOD   ! GEMISNOX2

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
! CO, hydrocarbon emission   [molec tracer/box/s]
REAL*8,  INTENT(IN) :: EMISRR(IIPAR,JJPAR,NEMPARA+NEMPARB)

! Multi-level NOx emissions  [molec NOx/box/s]
REAL*8,  INTENT(IN) :: EMISRRN(IIPAR,JJPAR,NOXEXTENT)
```

REMARKS:

```
Developers: lwh, jyl, gmg, djj, bdf, bmy, 6/8/98, 6/11/08
(lwh, jyl, gmg, djj, bdf, bmy, 6/8/98, 6/11/08)

REMIS(JLOOP,N) = emis. rate of species corr. to tracer N in box JLOOP
                 (reaction number NTEMIS(N))
```

REVISION HISTORY:

```
(1 ) Original code from Harvard Tropospheric Chemistry Module for 3-D
      applications by Larry Horowitz, Jinyou Liang, Gerry Gardner,
      Prof. Daniel Jacob of Harvard University (Release V2.0)
(2 ) New version 3.0 by Bob Yantosca to place NOx emissions into boxes
      above the surface. (bmy, 6/8/98)
(3 ) Also now do chemistry up to the location of the annual mean
       tropopause (bmy, 12/9/99)
(4 ) BURNEMIS is now dynamically allocatable and is contained in F90
      module "biomass_mod.f".  BIOTRCE and NBIOTRCE are also contained
      in "biomass_mod.f".  (bmy, 9/12/00)
(5 ) BIOFUEL is now dynamically allocatable and is contained in F90
      module "biofuel_mod.f".  BFTRACE and NBFTRACE are also contained
      in "biofuel_mod.f" (bmy, 9/12/00, 4/17/01)
(6 ) BURNEMIS and BIOFUEL are now treated as true global arrays,
      and need to be referenced by the global offset variables
      IREF = I + I0 and JREF = J + J0 (bmy, 9/12/00)
(7 ) Now reference JLOP, REMIS, VOLUME from F90 module "comode_mod.f",
      in order to save memory (bmy, 10/19/00)
(8 ) Now add in up to NBFTRACE biofuel species (bmy, 4/17/01)
(9 ) Add new subroutine header, updated comments, cosmetic changes.
      (bmy, 4/17/01)
(10) Updated comments -- GEMISNOX is [molec/cm3/s]. (bdf, bmy, 6/7/01)
(11) For GEOS-3, we now distributes surface emissions throughout the
      boundary layer.  This is necessary since the first couple of GEOS-3
      surface layers are very thin.  Piling up of emissions into a small
      layer will cause SMVGEAR to choke.  (bdf, bmy, 6/15/01)
(12) Also now reference BFTRACE and NBFTRACE from "biofuel_mod.f",
      and reference AD12 from "diag_mod.f". (bdf, bmy, 6/15/01)
(13) For GEOS-1, GEOS-STRAT, emit into the surface layer, as we did
      in prior versions. (bmy, 6/26/01)
(14) Bug fix: corrected a typo for the biofuel emissions (bmy, 7/10/01)
(15) Bug fix: make sure BIOMASS and BIOFUEL, and SOIL NOx emissions have
```

```
      units of [molec/box/s] before distributing thru the boundary layer.
      This involves multiplication by VOLUME(JLOOP1) and division by
      VOLUME(JLOOP). (bmy, 7/16/01)
(16) XTRA2(IREF,JREF,5) is now XTRA2(I,J).  BIOFUEL(:,IREF,JREF) is now
      BIOFUEL(:,I,J). BURNEMIS(:,IREF,JREF) is now BURNEMIS(:,I,J).
      Replace PW(I,J) with P(I,J). (bmy, 9/28/01)
(17) Removed obsolete code from 9/01 (bmy, 10/24/01)
(18) Now references GET_PEDGE from "pressure_mod.f", to compute P at
      the bottom edge of grid box (I,J,L).  (dsa, bdf, bmy, 8/21/02)
(19) Now reference IDTNOX, IDENOX, etc from "tracerid_mod.f" (bmy, 11/6/02)
(20) Remove references to IREF, JREF (bmy, 2/11/03)
(21) NEMIS is now NEMIS(NCS) for SMVGEAR II (gcc, bdf, bmy, 4/1/03)
(22) Added parallel loop over N.  Also directly substituted JLOP(I,J,1)
      for all instances of JLOOP1.  Updated comments. (hamid, bmy, 3/19/04)
(23) Bug fix for COMPAQ compiler...do not use EXIT from w/in parallel loop.
      (auvray, bmy, 11/29/04)
(24) Now replace XTRA2 with GET_PBL_TOP_L in "pbl_mix_mod.f".  Now remove
      reference to CMN, it's obsolete.  Now references GET_TPAUSE_LEVEL
      from "tropopause_mod.f" (bmy, 8/22/05)
(25) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(26) Now updated for new "biomass_mod.f" (bmy, 4/5/06)
(27) Now account for the different definition of tropopause in case
      of variable tropopause.   The BIOMASS array from "biomass_mod.f" is
      now in units of [molec CO/cm2/s].  Adjust unit conversion accordingly.
      Also replace NBIOMAX with NBIOMAX_GAS, since aerosol biomass is
      handled elsewhere.  (bdf, phs, bmy, 9/27/06)
(28) Now replace GEMISNOX array (from CMN_NOX) with module arrays
      EMIS_LI_NOx and EMIS_AC_NOx (ltm, bmy, 10/3/07)
(29) Bug fix: resize EMISRR to be consistent w/ CMN_O3 (bmy, jaf, 6/11/08)
(30) Limit emissions into the surface level only (lin, 5/29/09)
(31) Bug fix: cycle if IDEMIS(NN) <= 0 to avoid array-out-of-bounds
      errors (bmy, 8/6/09)
(32) Check for emissions above PBL -anthro NOx only for now- (phs, 10/27/09)
(33) Modify selection of biomass burning emissions (hotp, 8/3/09)
(34) Moved NOx scaling to improve parallelization. (ccc, 11/10/10)
16 Dec 2010 - R. Yantosca - Removed obsolete, commented-out code
16 Dec 2010 - R. Yantosca - Added ProTeX headers
21 Dec 2010 - R. Yantosca - Now set REMIS=0d0.  Also updated comments.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now reference IXSAVE, IZSAVE from comode_mod.F
```

1.99.20 sfcwindsqr

Function SFCWINDSQR computes the surface wind squared from the U and V winds at 10 m above the surface.

INTERFACE:

```
      REAL*8 FUNCTION SFCWINDSQR( I, J )
```

USES:

```
      USE DAO_MOD, ONLY : U10M, V10M

      IMPLICIT NONE
#     include "define.h"
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I   ! Longitude index
      INTEGER, INTENT(IN) :: J   ! Latitude index
```

REVISION HISTORY:

```
   21 Dec 1998 - R. Yantosca - Initial version
   (1 ) The old SFCWINDSQR computed the surface wind squared (m/s)^2 from the
        the Harvard CTM winds (kg/s).  But since the DAO winds are already
        in units of (m/s) then the previous unit conversion is unnecessary
        and costly in terms of computer resources.
   (2 ) Since GEOS-1 has U and V at 10 m, these are more representative
        of the surface than UWND(I,J,1) and VWND(I,J,1).
   (3 ) Pass GEOS-1 U10M and V10M fields via CMN_UV10M so that the argument
        list does not have to be modified in several existing Harvard CTM
        subroutines.
   (4 ) GEOS-STRAT does not store U10M and V10M, so compute 10 m wind speed
        from UWND(I,J,1) and VWND(I,J,1) in MAKE_WIND10M.
   (5 ) Now check for NaN's (bmy, 4/27/00)
   (6 ) Now reference U10M and V10M from "dao_mod.f" instead of from
        common block header files "CMN_UV10M".  Also extend code
        to GEOS-2 and GEOS-3 met fields. (bmy, 7/11/00)
   (7 ) Now use interface IT_IS_NAN (from "error_mod.f") to trap NaN's.
        This will work on DEC/Compaq and SGI platforms. (bmy, 3/8/01)
   (8 ) Now call CHECK_VALUE from "error_mod.f".  This will test SFCWINDSQR
        for NaN or Infinity conditions.  Also updated comments and made
        cosmetic changes. (bmy, 7/16/01)
   (9 ) Removed obsolete, commented-out code from 7/01 (bmy, 11/26/01)
   (10) Remove support for GEOS-1 and GEOS-STRAT met fields.  Also remove
        call to CHECK_VALUE. (bmy, 8/4/06)
   08 Dec 2009 - R. Yantosca - Added ProTeX headers
```