File Specification for GEOS-5 DAS Gridded Output

Global Modeling and Assimilation Office
Goddard Space Flight Center, Greenbelt, Maryland

http://gmao.gsfc.nasa.gov

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Version 6.1
To support NASA instrument teams with GEOS-5.x

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Approved by:

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Code 610.1, NASA GSFC

REVISION HISTORY

Version Number	Revision Date	Extent of Changes	Approval Authority
6.0	03/24/2006	Baseline	
6.1	10/24/2006	• DELP and PS added to tavg3d_dyn_v, tavg3d_cld_v, tavg3d_mst_v, tavg3d_tmp_v, and tavg3d_wnd_v products for convenience • EFLUX added to tavg2d_met_x • SWGDWNCLR added to tavg2d_met_x • U50M and V50M added to inst2d_met_x and tavg2d_met_x • EMIS added to tavg2d_met_x • Variable name change for consistency and correctness in tavg2d_met_x: LWGDWNCLR to LWGNETCLR • Section 6: Vertical no longer listed under "Dimensions" for 2D files. • Size computation no longer explicitly described under each product heading. • Discontinued GEOS-4 convection parameters were added to the table in Appendix D. • Variable name change for consistency and correctness in tavg2d_met_x: SWTNET changes to SWTDWN • RHOA added to tavg2d_met_x • SNODP added to tavg2d_met_x • SNOMAS definition corrected (units were incorrect) • Added glossary of variables as Appendix E. • Minor changes were made for clarity to section 4, Grid Structure. • Minor changes were made for clarity to section 5.2, ESDT names. • All filenames will now have the ".hdf" suffix. • QI (Ice mixing ratio) & QL (Liquid water mixing ratio) are combined into QC (Total condensate mixing ratio) in the inst3d_met_p product • TQI (Total cloud ice) & TQL (Total cloud water) are combined into TQC (Total cloud condensate) in the inst2d_met_x product	

Table of Contents

1. Introduction

This document describes the gridded output files from the version 5 of the Goddard Earth Observing System Data Assimilation System (GEOS-5 DAS), which will support level-4 product generation. The intended audience is EOS instrument teams and other users of GEOS-5 products who need to write software to read Global Modeling and Assimilation Office (GMAO) products. The gridded data described in this document will be produced by the GEOS-5 DAS beginning in 2006 and be delivered to the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC). The GMAO operational assimilation runs 4 times/day approximately 12 hours behind real-time. We will no longer produce First-look and Late-look versions of GMAO products. With the exception of reanalysis activities, there will be only one operational stream produced. Information on the status of GMAO product generation can be found at http://gmao.gsfc.nasa.gov/operations/.

2. Format and File Organization

GEOS-5 files are in HDF-EOS format, which is an extension of the Hierarchical Data Format (HDF), Version 4 developed at the National Center for Supercomputing Applications (NCSA). Each GEOS-5 file will contain a single HDF-EOS grid, which in turn contains a number of geophysical quantities that we will refer to as "fields" or "variables." Some files will contain 2-D variables on a lon/lat grid and some files will contain 3-D variables on the same lon/lat grid but with an additional vertical dimension. In order to keep individual file sizes manageable, all files will contain only one valid data time, in contrast to the daily files produced by earlier GEOS systems.

The variables are created using the **GDdeffield** function from the HDF-EOS GD (grid) API which implements them as HDF Scientific Data Set (SDS) arrays so they can be read with standard HDF routines. In addition to the geophysical variables, the files will have SDS arrays that define dimension scales (or coordinate variables). There will be two distinct scales for each dimension, which will insure that a wide variety of graphical display tools can interpret the dimension scales. In particular, there is a set of dimension scales that adhere to the CF conventions as well as the older COARDS conventions (see References).

Due to the large size of these data files we will use szip, which provides a lossless compression of scientific data. Using szip, we can reduce our file sizes by 25 to 50% or even more. Szip has been integrated into HDF-4, release 2.0. The HDF-4 library must be compiled with the szip binary library and configured to use szip. Once the szip-enabled library is linked to an HDF-4 application, there should be no interface changes required to support reading szip'ed HDF. Details on downloading and building the HDF with szip support can be found at the NCSA HDF web site (see References).

ECS metadata and other information will be stored as global attributes. Note that metadata will change over the lifespan of the GEOS-5 system, so file sizes may not remain exactly the same over time.

2.1 Dimensions

GMAO HDF-EOS files will contain two sets of dimension scale (coordinate) information. One set of dimensions is defined using the **SDsetdimscale** function of the standard HDF SD interface. This set of scales will have an attribute named "units", set to an appropriate string defined by the CF and COARDS conventions that can be used by applications to identify the dimension. The other set of dimension scales is created using the **GDdeffield/GDwritefield** functions as suggested in the ECS technical paper "Writing HDF-EOS Grid Products for Optimum Subsetting Services."

Table 2.1-1. Dimension Variables Contained in GMAO HDF-EOS Files

Name	Description	Type	***units* attribute**
XDim:EOSGRID	longitude values	float32	degrees_east
YDim:EOSGRID	latitude values	float32	degrees_north
Height:EOSGRID (3D only)	pressure levels or lagrangian control volume (lcv) indices	float32	hPa or layer
TIME:EOSGRID	minutes since first time in	float32	minutes since YYYY-MM-DD

	file		HH:MM:SS
XDim	longitude values	float64	N/A
YDim	latitude values	float64	N/A
Height (3D only)	pressure levels or lcv indices	float64	N/A
Time	seconds since 1/1/93	float64	N/A

The 32-bit dimension variables have a "units" attribute that makes them COARDS-compliant, while the 64-bit dimension variables satisfy ECS requirements.

2.2 Variables

Variables are stored as SDS arrays even though they are defined with the HDF-EOS **GDdeffield** function. As a result, one can use the SD interface of the HDF library to read any variable from the file. The only thing one must know is the short name of the variable and the dimensions. You can quickly list the variables in the file by using common utilities such as *ncdump* or *hdp*. Both utilities are distributed from NCSA with the HDF library. In Section 8 we will present sample code for reading one or more data fields from this file. The short names for all variables in all GMAO data products are listed in the File Collections section, Section 6.

Each variable will have metadata attributes defined that may be useful. Many of these attributes are required by the CF and COARDS conventions while others are for internal GMAO use. A listing of required attributes follows:

Table 2.2-1 Metadata attributes associated with each SDS.

Attribute Name	Attribute Type	Description
_FillValue	32-bit floating point	Floating-point value used to identify missing data. Will normally be set to 1e15. Required by CF.
missing_value	32-bit floating point	Same as _FillValue. Required for COARDS backwards compatibility.
valid_range	32-bit floating point array of size 2.	This attribute defines the valid range of the variable. The first element is the smallest valid value and the second element is the largest valid value. Required by CF.
long_name	string	Ad hoc description of the variable. Required by COARDS.
standard_name	string	Standard description of the variable as defined in CF conventions. (See References)
units	string	The units of the variable. Must be a string that can be recognized by UNIDATA's Udunits package.
scale_factor	32-bit floating point	If variable is packed as 16-bit integers, this is the scale_factor for expanding to floating-point. Currently we do not plan to pack data, thus value

		will be 1.0
add_offset	32-bit floating point	If variable is packed as 16-bit integers, this is the offset for expanding to floating-point. Currently, we do no plan to pack data, thus value will be 0.0.

Other attributes may be present for internal GMAO use and can be ignored.

2.3 Global Attributes

In addition to SDS arrays containing variables and dimension scales, there is additional metadata stored in GMAO HDF-EOS files. Some metadata are required by the CF/COARDS conventions, some due to ECS requirements and others may exist as a convenience to internal GMAO users. A summary of global attributes that will exist in all GMAO files is shown in Table 2.3-1.

Table 2.3-1 Metadata attributes associated with each SDS.

Attribute Name	Attribute Type	Description
Conventions	character	Identification of the file convention used, currently “CF-1.0”
title	character	Experiment identification, i.e. “Operational”
history	character	CVS tag used for this release. CVS tags are used internally by the GMAO to designate a particular version of the system.
institution	character	“NASA Global Modeling and Assimilation Office”
source	character	System Version
references	character	GMAO website address
comment	character	TBD
HDFEOSVersion	character	Version of the HDF-EOS library used to create this file.
StructMetadata.0	character	This is the GridStructure metadata that is created by the HDF-EOS library.
CoreMetadata.0	character	The ECS inventory metadata.
ArchivedMetadata.0	character	The ECS archive metadata.

3. Assimilated Instantaneous Products vs. Model-generated Time-averaged Products

GEOS-5 gridded output files are identified as either instantaneous or time-averaged products. For upper-air fields, all pressure products are instantaneous and all lagrangian control volume (lcv) products are time-averaged. Single-level or surface products may be either instantaneous or time-averaged. The GMAO is no longer producing time-averaged pressure products, as was done with GEOS-3 and GEOS-4.

The instantaneous products described in section 6.1 are generated by the analysis segment of the assimilation process. All instantaneous products contain fields that are snapshots of a specific time, with a single time per file. Upper-air products such as "inst3d_met_p" have a time frequency of 6 hours, with data valid at the four standard *synoptic times* (00 GMT, 06 GMT, 12 GMT, and 18 GMT). Instantaneous single-level products, such as "inst2d_met_x," have a time-frequency of 3 hours, valid at the times listed above, plus the interim times of 03 GMT, 09 GMT, 15 GMT, and 21 GMT**.**

The time-averaged products described in section 6.2 are generated by the Incremental Analysis Update (IAU) segment of the analysis process. The IAU gradually forces the model integration through the 6-hour period between analysis times. Time-averaged products are averaged over a 3-hour period for single-level files and over a 6-hour period for lcv files. Single-level products consist of 8 files per day, with time-stamps at the center of the 3-hour averaging interval (i.e., 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, and 22:30 GMT), and there is a single time period per file (e.g., the first file for a given day is time stamped with 01:30 GMT and represents the average between 00 GMT and 03 GMT). Time-averaged lcv-level products consist of 4 files/day, with time-stamps of 00, 06, 12, and 18 GMT, with each file time-stamped at the center of a 6-hour average (e.g., the first file of a given day is time-stamped with 00 GMT and represents an average between 21 GMT of the previous day and 03 GMT of the given day).

4. Grid Structure

GEOS-5 gridded output will be on a global 2/3 x 1/2 degree longitude-latitude horizontal grid, consisting of IM**=540** points in the longitudinal direction and **JM=361** points in the latitudinal direction. The horizontal grid origin is the lower-left corner of the first grid box (I=1, J=1) and represents the geographical location (180W, 90S). Latitude and longitude as a function of their indices (I,J) can be determined by:

$$LON_I = -180 + (I-1) * dLON, \qquad I=1, IM$$
$$LAT_J = -90 + (J-1) * dLAT, \qquad J=1, JM$$

where dLON = 2/3° and dLAT = 1/2°. For all parameters of each file, a grid point represents the center of a box, i.e., the value at (LON=0, LAT=0) represents a box bounded by the points (LON=-0.33, LAT=0.25), (LON=-0.33, LAT=-0.25), (LON=0.33, LAT=-0.25), and (LON=0.33, LAT=0.25). Scalar values usually represent the volume mean within the box.

The vertical structure of gridded products will have three different configurations: single-level (can be vertical averages or surface values), pressure-level, or lcv-level. Single-level data for a given variable appear as 3-dimensional fields (x, y, time) with multiple times spanning multiple files, while pressure-level data appear as 4-dimensional fields (x, y, z, time). Pressure-level data will be output on **LMP=36** pressure levels (hPa). The appropriate grid structure will be specified both in the filename and the metadata.

The GEOS-5 terrain-following lagrangian control volume (lcv) coordinates are similar to an eta coordinate system. There are **LM=72** layers in the 5 lcv products: tavg3d_dyn_v, tavg3d_cld_v, tavg3d_mst_v, tavg3d_tmp_v, and tavg3d_wnd_v, with the values representing a layer-mean unless otherwise noted. Additionally there is the tavg3d_prs_v product, which contains the **LM**-layer 3D variable $\mathbf{PL}_{ijl}$, which defines the layer-mean pressure at every horizontal grid-point. Note that the delta pressure for each layer ($\mathbf{DELP}_{ijl}$) and the surface pressure ($\mathbf{PS}_{ij}$) are also included in the tavg3d_prs_v product, allowing one to easily compute the pressure at the edges of each layer. In the GEOS-4 eta files, one could compute the pressure on the edges by using the "ak" and "bk" values and the surface pressure; once the edge pressures were known, they could be used to compute the average pressure in the layer. In GEOS-5, the full 3-dimensional pressure variables are explicitly provided at both layer centers ($\mathbf{PL}_{ijl}$) and layer edges ($\mathbf{PLE}_{ijl}$). As of this writing the pressures reported are on a hybrid-sigma coordinate, and could be obtained from the "ak-bk" relationship. But this may change in the future and so users should rely on the reported 3-dimensional pressures and not attempt to compute them from "ak" and "bk". Figure 1 is a schematic (not to scale) of the GEOS-5 LCV coordinate system. Note that the indexing in the vertical starts at the top, i.e., lcv layer 1 is the layer at the top of the atmosphere while lcv layer **LM** is adjacent to the earth's surface.

Variables that are only defined on layer edges (such as vertical fluxes between layers) are provided in the tavg3d_met_e product, which has **LM**+1 levels representing the top and bottom edges of the **LM** lcv layers of the model. This product also contains the 3-D variable edge pressures, **PLE**.

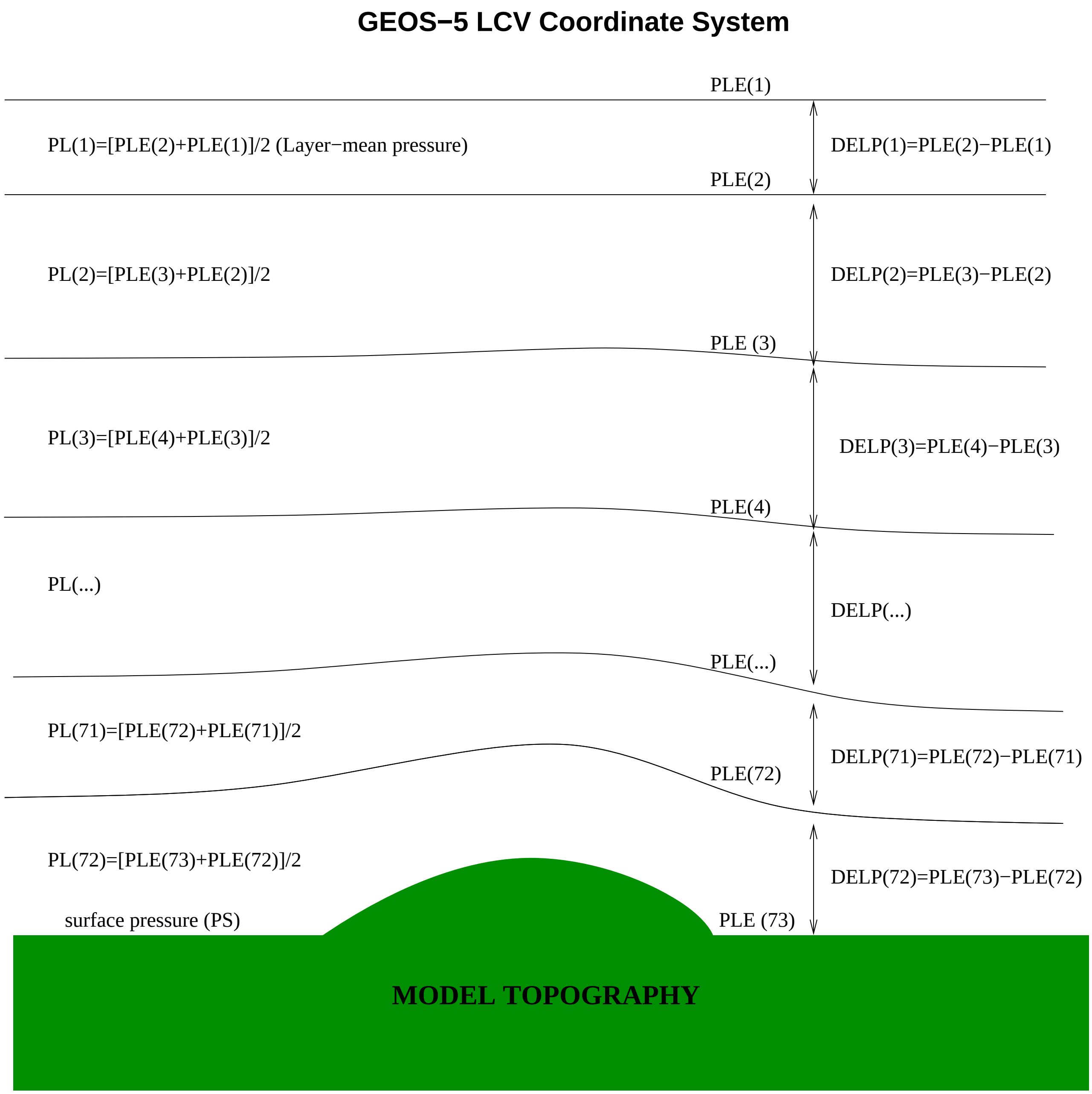

Figure 1: Schematic of GEOS-5 LCV coordinate system

5. File Naming Convention

Each GEOS-5 product will have a complete file name identified in the EOSDIS metadata as "LocalGranuleID". EOSDIS also requires abbreviated naming indices (8-character limit) for each Earth Science Data Type (ESDT). The ESDT indices convention is described in section 5.2.

5.1 File Name

The standard generic complete name for the assimilated GEOS-5 configuration products will appear as follows:

DAS.config.mode.filetype.expid.yyyymmdd_hhmm.version.format_suffix

A brief description of the node fields appear below:

DAS:
Identifies output as a Data Assimilation System product.

config:
GEOS-5 will run in only one operational configuration. Other configurations may be added later.

ops - Operational assimilation, approximately 12 hours behind real-time.

mode:
GEOS-5 can run in different modes of operation, but the only mode used to support EOS instrument teams is "asm".

asm - Assimilation. Uses a combination of atmospheric data analysis and model forecasting to generate a time-series of global atmospheric quantities.

filetype:
The major file types are subdivided into file collections. Collections contain several fields with common characteristics. These collections are necessary to keep file sizes reasonable. Each file type will contain the following information:

type/dimension_group_level

type/dimension:

There are four possible type/dimension conventions for the DAS data products:

inst2d - 2-dimensional instantaneous fields (no time averaging).
inst3d - 3-dimensional instantaneous fields (no time averaging).
tavg2d - 2-dimensional 3-hour time-averaged fields, time-stamped at the center of the averaging period. For example, 04:30 GMT30z output would be a 3 GMT – 6 GMT time average).
tavg3d - 3-dimensional 6-hour time-averaged fields, time-stamped at the center of the averaging period. For example, 6 GMT output would be a 3 GMT – 9 GMT time average.

group:

met: meteorological fields
prs: pressure fields
dyn: dynamical fields
mst: moisture fields
tmp: temperature fields
wnd: wind fields

level: There are four possible level types for the DAS data:

x: single-level data (surface, column-integrated, single-level)
p: pressure-level data (see Appendix C for pressure levels)
v: lagrangian control volume (lcv) layers
e: lagrangian control volume (lcv) layer edges

expid:
Experiment Identification. The GEOS-5 DAS data sets will be labeled:

GEOS5##

where ## is a two-digit number. The first operational release of GEOS-5 will have an experiment identification of GEOS501. When a modified version of GEOS-5 is used for either forward processing or reprocessing, we will increment the ## appropriately. As updated versions of the GEOS software are implemented in operations, the cvs tag in the metadata parameter "History" will be modified. Information on version upgrades will also be available on the GMAO operations status web page (http://gmao.gsfc.nasa.gov/operations/).

yyyymmdd_hhmm:
This node defines the date and time of the data in the file.

yyyy - year string (e.g. "2002")
mm - month string (e.g. "09" for September)
dd - day of the month string (e.g. "10" for the tenth day of the month)
hh – valid hour
mm – valid minutes (either “00” or “30”)

version:
This node defines the file version and takes the form V##. Under normal conditions ## will be 01. In the event of a processing error that requires a re-processing, this number will be incremented to identify the new version of this file. The file version will also be represented in the EOSDIS metadata as "LocalVersionID".

format_suffix:
Currently the format is HDF-EOS based on the HDF-4 release. The suffix will be “hdf”.

EXAMPLE:

DAS.ops.asm.tavg3d_dyn_v.GEOS501.20020915_0000.V01.hdf

This is an example of a DAS filename from the operational production. The data are 6-hour time averaged output on lcv levels (3 dimensions). The filetype consists of dynamical fields. The valid time for the data is Sep 15 at 00 GMT, which represents the 6-hour average from Sep 14 at 21 GMT through Sep 15 at 03 GMT. See the discussion on time-averaged data in section 3 for more information.

5.2 Earth Science Data Types (ESDT) Short Name

To accommodate EOSDIS toolkit requirements, GEOS-5 complete filenames are associated with shorter or abbreviated indices in the ESDTs. EOSDIS requires a short (8 character) name for each ESDT. Below is the abbreviated naming convention for the GEOS-5 gridded ESDTs. The standard ESDT naming convention for the GEOS-5 gridded output will have the form:

DSPTVCCC

D: DAS identifier.

D = DAS

S: Major system number.

5 = GEOS-5

P: Product

O = Operational

T: Type

I = Instantaneous
T = Time-averaged

V: Vertical Coordinate:

X = Single-Level
P = Pressure
V = lcv
E = lcv edge

CCC: Filetype

MET = meteorological
PRS = pressure
DYN = dynamics
MST = moisture
TMP = temperature
WND = wind

Example:

Short Name: **D5OIPMET**

Complete Name: **DAS.ops.asm.inst3d_met_p.GEOS501.20020915_0000.V01.hdf**

6. File Collections

Table 6-1. Summary of GEOS-5 data products.

Type	Description	ESDT	Frequency	Uncompressed size/day (Mb)	Compressed size/day (Mb)
inst2d_met_x	2D meteorological state, instantaneous at the surface, on a single-level, or vertically integrated	D5OIXMET	8/day	176	96
inst3d_met_p	3D meteorological state, instantaneous on pressure coordinates	D5OIPMET	4/day	898	472
tavg2d_met_x	2D meteorological state, time-averaged at the surface, on a single-level, or vertically integrated	D5OTXMET	8/day	480	272
tavg3d_prs_v	3D pressure information, time-averaged on lcv coordinates	D5OTVPRS	4/day	452	104
tavg3d_dyn_v	3D dynamics fields, time-averaged on lcv coordinates	D5OTVDYN	4/day	2920	1536
tavg3d_cld_v	3D cloud & precipitation fields, time-averaged on lcv coordinates	D5OTVCLD	4/day	2024	348
tavg3d_met_e	3D meteorological fields, time-averaged on lcv coordinate layer edges	D5OTEMET	4/day	1372	512
tavg3d_mst_v	3D moisture tendency fields, time-averaged on lcv coordinates	D5OTVMST	4/day	1248	573
tavg3d_tmp_v	3D temperature tendency fields, time-averaged on lcv coordinates	D5OTVTMP	4/day	2249	1296
tavg3d_wnd_v	3D wind tendency fields, time-averaged on lcv coordinates	D5OTVWND	4/day	2025	1152
TOTAL			**48/day**	**13844**	**6361**

File Collections summary table.

6.1 Assimilated Instantaneous Files

Below are the variables that are output into each **inst** file. These are instantaneous fields (no time averaging). The approximate size of each file below is determined by the following:

A x B x C x D x E = bytes/file

where:

A: X-Dimension
B: Y-Dimension
C: Vertical dimension
D: Number of fields in file
E: Number of bytes per floating point number

The method for calculating sizes is the same in 6.1 and 6.2.

NOTE: All HDF variable names are UPPERCASE. Italicized sizes in ( ) are estimates of the compressed file size, which will vary from day to day.

- **inst2d_met_x** (1 time per file, 8 times per day: 00, 03, 06, 09, 12, 15, 18, 21 GMT)
  ECS short name: D5OIXMET
  ECS long name: DAS Operational 2d meteorological state, instantaneous
  Dimensions:
  longitude: 540
  latitude: 361
  Number of 2D variables : 27
  Size: 22 *(13)* MB
  Size/day: 176 *(96)* MB

Variable Name	Description	Units
PHIS	Surface geopotential	$m^2 s^{-2}$
PS	Surface pressure	Pa
DISPH	Displacement height	m
EFLUX	Latent heat flux at surface	$W m^{-2}$
HFLUX	Sensible heat flux at surface	$W m^{-2}$
LWI	Surface types	0=water, 1=land, 2=ice
QV10M	Specific humidity at 10 m above displacement height	$kg kg^{-1}$
QV2M	Specific humidity at 2 m above displacement height	$kg kg^{-1}$
SLP	Sea level pressure	Pa
T10M	Temperature at 10 m above displacement height	K
T2M	Temperature at 2 m above displacement height	K
TAUX	Eastward (zonal) surface wind stress	$N m^{-2}$
TAUY	Northward (meridional) surface wind stress	$N m^{-2}$
TO3	Total column ozone	Dobson
TQC	Total cloud condensate (ice & water)	$kg m^{-2}$
TQV	Total water vapor (Total precipitable water)	$kg m^{-2}$
TROPP	Tropopause pressure	Pa
TROPQ	Tropopause specific humidity	$kg kg^{-1}$

Variable Name	Description	Units
TROPT	Tropopause temperature	K
TSKIN	Skin temperature	K
TTO3	Tropospheric total column ozone	Dobson
U10M	Eastward (zonal) wind at 10 m above displacement height	$m\ s^{-1}$
U2M	Eastward (zonal) wind at 2 m above displacement height	$m\ s^{-1}$
U50M	Eastward (zonal) wind at 50 m above displacement height	$m\ s^{-1}$
V10M	Northward (meridional) wind at 10 m above displacement height	$m\ s^{-1}$
V2M	Northward (meridional) wind at 2 m above displacement height	$m\ s^{-1}$
V50M	Northward (meridional) wind at 50 m above displacement height	$m\ s^{-1}$

- **inst3d_met_p** (1 time per file, 4 files per day: 00, 06, 12, 18 GMT)
  ECS short name: D5OIPMET
  ECS long name: DAS Operational 3d meteorological state, instantaneous on pressure coordinates
  Dimensions:
  longitude: 540
  latitude: 361
  vertical pressure levels: 36
  Number of 3D variables: 8
  Size: 225 *(118)* MB
  Size/day: 898 *(472)* MB

Variable Name	Description	Units
H	Geopotential height	m
O3	Ozone mixing ratio	$kg\ kg^{-1}$
QC	Total condensate mixing ratio	$kg\ kg^{-1}$
QV	Specific humidity	$kg\ kg^{-1}$
RH	Relative humidity	percent
T	Air temperature	K
U	Eastward wind component	$m\ s^{-1}$
V	Northward wind component	$m\ s^{-1}$

6.2 Model-generated Time Averaged Files

Below are the variables that are output in each "tavg" file. These are time-averaged fields. Single-level, or 2-dimensional data will be output every 3 hours while 3-dimensional data will be output every 6 hours.

- **tavg2d_met_x** (1 file per time, 8 files per day: 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT)
  ECS short name: D5OTXMET
  ECS long name: DAS Operational 2d meteorological fields, time-averaged
  Dimensions:
  longitude: 540
  latitude: 361
  Number of 2D variables: 79

Size: 62 *(34)* MB
Size/day: 500 *(276)* MB

Variable Name	Description	Units
ALBEDO	Surface albedo	fraction
ALBNIRDF	Diffuse beam NIR surface albedo	fraction
ALBNIRDR	Direct beam NIR surface albedo	fraction
ALBVISDF	Diffuse beam VIS surface albedo	fraction
ALBVISDR	Direct beam VIS surface albedo	fraction
BSTAR	Surface buoyancy scale	$m\ s^{-2}$
CLDHGH	High-level (above 400 hPa) cloud fraction	fraction
CLDLOW	Low-level (1000-700 hPa) cloud fraction	fraction
CLDMID	Mid-level (700-400 hPa) cloud fraction	fraction
CLDTOT	Total cloud fraction	fraction
DISPH	Displacement Height	m
DTG	Total rate of change in skin temperature	$K\ s^{-1}$
EFLUX	Latent heat flux (positive upward)	$W\ m^{-2}$
EMIS	Surface emissivity	dimensionless
EVAP	Surface evaporation	$kg\ m^{-2}\ s^{-1}$
FRLAKE	Fraction of lake type in grid box	fraction
FRLAND	Fraction of land type in grid box	fraction
FRLANDICE	Fraction of land ice type in grid box	fraction
FROCEAN	Fraction of ocean in grid box	fraction
GRN	Vegetation greenness fraction	fraction
GWETROOT	Root zone soil wetness	fraction
GWETTOP	Top soil layer wetness	fraction
HFLUX	Sensible heat flux (positive upward)	$W\ m^{-2}$
LAI	Leaf area index	$m^2\ m^{-2}$
LWGDWN	Surface downward longwave flux	$W\ m^{-2}$
LWGNETCLR	Net surface downward longwave flux assuming clear sky	$W\ m^{-2}$
LWGNET	Net surface downward longwave flux at the ground	$W\ m^{-2}$
LWGUP	Longwave flux emitted from surface (upward)	$W\ m^{-2}$
LWI	Surface types	0=water, 1=land, 2=ice
LWTUP	Upward longwave flux at top of atmosphere	$W\ m^{-2}$
LWTUPCLR	Upward longwave flux at top of atmosphere assuming clear sky	$W\ m^{-2}$
PARDF	Surface downward photosynthetically active radiation diffuse flux	$W\ m^{-2}$
PARDR	Surface downward photosynthetically active radiation beam flux	$W\ m^{-2}$
PBLH	Planetary boundary layer height	m
PRECANV	Surface precipitation flux from anvils	$kg\ m^{-2}\ s^{-1}$
PRECCON	Surface precipitation flux from convection	$kg\ m^{-2}\ s^{-1}$
PRECLSC	Surface precipitation flux from large-scale	$kg\ m^{-2}\ s^{-1}$
PRECSNO	Surface snowfall flux	$kg\ m^{-2}\ s^{-1}$
PRECTOT	Total surface precipitation flux	$kg\ m^{-2}\ s^{-1}$
PS	Time averaged surface pressure	Pa
QV10M	Specific humidity interpolated to 10 m above the displacement height	$kg\ kg^{-1}$

Variable Name	Description	Units
QV2M	Specific humidity interpolated to 2 m above the displacement height	kg kg^{-1}
RHOA	Surface air density	kg m^{-3}
SLP	Sea level pressure	Pa
SNOMAS	Snow mass as liquid water equivalent depth	m
SNODP	Snow depth	m
SWGDWN	Surface downward shortwave flux	W m^{-2}
SWGDWNCLR	Surface downward shortwave flux assuming clear sky	W m^{-2}
SWGNET	Net surface downward shortwave flux	W m^{-2}
SWGNETCLR	Net surface downward shortwave flux assuming clear sky	W m^{-2}
SWTDWN	Incident shortwave radiation at top of atmosphere	W m^{-2}
SWTUP	Top of atmosphere outgoing shortwave flux	W m^{-2}
SWTUPCLR	Top of atmosphere outgoing shortwave flux assuming clear sky	W m^{-2}
T10M	Temperature interpolated to 10 m above the displacement height	K
T2M	Temperature interpolated to 2 m above the displacement height	K
TAUGWX	Eastward (zonal) gravity wave surface stress	N m^{-2}
TAUGWY	Northward (meridional) gravity wave surface stress	N m^{-2}
TAUHGH	Optical thickness of high clouds	dimensionless
TAULOW	Optical thickness of low clouds	dimensionless
TAUMID	Optical thickness of mid-level clouds	dimensionless
TAUTOT	Optical thickness of all clouds	dimensionless
TAUX	Eastward (zonal) surface wind stress	N m^{-2}
TAUY	Northward (meridional) surface wind stress	N m^{-2}
TO3	Total Column Ozone	Dobson
TPW	Total precipitable water	kg m^{-2}
TROPP	Tropopause pressure	Pa
TROPQ	Tropopause specific humidity	kg kg^{-1}
TROPT	Tropopause temperature	K
TSKIN	Skin temperature	K
TTO3	Tropospheric Total Ozone Column	Dobson
U10M	Eastward (zonal) wind at 10 m above displacement height	m s^{-1}
U2M	Eastward (zonal) wind at 2 m above the displacement height	m s^{-1}
U50M	Eastward (zonal) wind at 50 m above displacement height	m s^{-1}
USTAR	Surface velocity scale	m s^{-1}
V10M	Northward (meridional) wind at 10 m above the displacement height	m s^{-1}
V2M	Northward (meridional) wind at 2 m above the displacement height	m s^{-1}
V50M	Northward (meridional) wind at 50 m above displacement height	m s^{-1}
Z0H	Roughness length, sensible heat	m

Variable Name	Description	Units
Z0M	Roughness length, momentum	m

- **tavg3d_prs_v** (1 time per file, 4 files/day: 00, 06, 12,18 GMT)
  ECS short name: D5OTVPRS
  ECS long name: DAS Operational 3d pressure information, time-averaged on lcv coordinates
  Dimensions:
    longitude: 540
    latitude: 361
    vertical layers (lcv): 72
  Number of 2D variables: 1
  Number of 3D variables: 2
  Size: 113 *(26)* MB
  Size/day: 452 *(104)* MB

Variable Name	Description	Units
PS	Surface pressure (two-dimensional field)	Pa
DELP	Pressure difference between layer edges	Pa
PL	Layer pressure	Pa

- **tavg3d_dyn_v** (1 time per file, 4 files/day: 00, 06, 12,18 GMT)
  ECS short name: D5OTVDYN
  ECS long name: DAS Operational 3d dynamics fields, time-averaged on lcv coordinates
  Dimensions:
    longitude: 540
    latitude: 361
    vertical layers (lcv): 72
  Number of 2D variables: 1
  Number of 3D variables: 13
  Size: 730 *(384)* MB
  Size/day: 2920 *(1536)* MB

Variable Name	Description	Units
PS	Surface pressure (two-dimensional field)	Pa
DELP	Pressure difference between layer edges	Pa
DTDTTOT	Temperature tendency from physics (total diabatic)	K s^{-1}
HGHT	Geopotential height at mid-layer	m
MFXC	Eastward layer mass flux on the C-Grid	Pa m^2 s^{-1}
MFYC	Northward layer mass flux on the C-Grid	Pa m^2 s^{-1}
O3	Ozone Mixing Ratio	kg kg^{-1}
OMEGA	Vertical pressure velocity	Pa s^{-1}
PV	Ertel's potential vorticity	m^2 kg^{-1} sec^{-1}
QV	Specific humidity	kg kg^{-1}
RH	Relative humidity	percent
T	Air emperature	K
U	Eastward wind	m s^{-1}
V	Northward wind	m s^{-1}

- **tavg3d_cld_v** (1 time per file, 4 files/day: 00, 06, 12, 18 GMT)
  ECS short name: D5OTVCLD

ECS long name: DAS Operational 3d cloud & precipitation fields, time-averaged lcv coordinates
Dimensions:
longitude: 540
latitude: 361
vertical layers (lcv): 72
Number of 2D variables: 1
Number of 3D variables: 9
Size: 506 *(87)* MB
Size/day: 2024 *(348)* MB

Variable Name	Description	Units
PS	Surface pressure (two-dimensional field)	Pa
DELP	Pressure difference between layer edges	Pa
CLOUD	3-D Cloud fraction	fraction
DQRCON	Rain production rate – convective	kg m^{-2} s^{-1}
DQRLSC	Rain production rate - large-scale	kg m^{-2} s^{-1}
DTRAIN	Detrainment cloud mass flux	kg m^{-2} s^{-1}
QI	Cloud ice water mixing ratio	kg kg^{-1}
QL	Cloud liquid water mixing ratio	kg kg^{-1}
TAUCLI	Layer total optical thickness of ice clouds	dimensionless
TAUCLW	Layer total optical thickness of liquid clouds	dimensionless

- **tavg3d_met_e** (1 time per file, 4 files/day: 00, 06, 12, 18 GMT)
  ECS short name: D5OTEMET
  ECS long name: DAS Operational 3d meteorological fields, time-averaged on lcv layer edges
  Dimensions:
  longitude: 540
  latitude: 361
  vertical layer edges (lcv): 73
  Number of 3D variables: 6
  Size: 343 *(128)* MB
  Size/day: 1372 *(512)* MB

Variable Name	Description	Units
PLE	Edge pressure	Pa
CMFMC	Upward moist convective mass flux	kg m^{-2} s^{-1}
HGHTE	Geopotential height at layer edges	m
KH	Total scalar diffusivity	m^2 s^{-1}
KM	Total momentum diffusivity	m^2 s^{-1}
MFZ	Upward resolved Mass flux	kg m^{-2} s^{-1}

- **tavg3d_mst_v** (1 time per file, 4 files/day: 00, 06, 12, 18 GMT)
  ECS short name: D5OTVMST
  ECS long name: DAS Operational 3d moist tendency fields, time-averaged lcv coordinates
  Dimensions:
  longitude: 540
  latitude: 361
  vertical layers (lcv): 72
  Number of 2D variables: 1
  Number of 3D variables: 6
  Size: 337 *(143)* MB
  Size/day: 1348 *(573)* MB

Variable Name	Description	Units
PS	Surface pressure (two-dimensional field)	Pa
DELP	Pressure difference between layer edges	Pa
DQIDTMST	Ice tendency from moist physics	kg kg^{-1} s^{-1}
DQLDTMST	Liquid water tendency from moist physics	kg kg^{-1} s^{-1}
DQVDTDYN	Water vapor tendency from dynamics	kg kg^{-1} s^{-1}
DQVDTMST	Water vapor tendency from moist physics	kg kg^{-1} s^{-1}
DQVDTTRB	Water vapor tendency from turbulence	kg kg^{-1} s^{-1}

- **tavg3d_tmp_v** (1 time per file, 4 files/day: 00, 06, 12, 18 GMT)
  ECS short name: D5OTVTMP
  ECS long name: DAS Operational 3d temperature tendency fields, time-averaged, lcv coordinates
  Dimensions:
    longitude: 540
    latitude: 361
    vertical layers (lcv): 72
  Number of 2D variables: 1
  Number of 3D variables: 10
  Size: 562 *(324)* MB
  Size/day: 2249 *(1296)* MB

Variable Name	Description	Units
PS	Surface pressure (two-dimensional field)	Pa
DELP	Pressure difference between layer edges	Pa
DTDTDYN	Temperature tendency from dynamics	K s^{-1}
DTDTFRI	Temperature tendency from frictional heating	K s^{-1}
DTDTGWD	Temperature tendency from gravity wave drag	K s^{-1}
DTDTLWR	Temperature tendency from long wave radiation	K s^{-1}
DTDTLWRCLR	Temperature tendency from long wave radiation (clear sky)	K s^{-1}
DTDTMST	Temperature tendency from moist physics	K s^{-1}
DTDTSWR	Temperature tendency from short wave radiation	K s^{-1}
DTDTSWRCLR	Temperature tendency from short wave radiation (clear sky)	K s^{-1}
DTDTTRB	Temperature tendency from turbulence	K s^{-1}

- **tavg3d_wnd_v** (1 time per file, 4 files/day: 00, 06, 12, 18 GMT)
  ECS short name: D5OTVWND
  ECS long name: DAS Operational 3d wind tendency fields, time-averaged on lcv coordinates
  Dimensions:
    longitude: 540
    latitude: 361
    vertical layers (lcv): 72
  Number of 2D variables: 1
  Number of 3D variables: 9
  Size: 506 *(288)* MB
  Size/day: 2025 *(1152)* MB

Variable Name	Description	Units
PS	Surface pressure (two-dimensional field)	Pa
DELP	Pressure difference between layer edges	Pa
DUDTDYN	U-wind tendency from dynamics	$m\ s^{-2}$
DUDTGWD	U-wind tendency from gravity wave drag	$m\ s^{-2}$
DUDTMST	U-wind tendency from moist physics	$m\ s^{-2}$
DUDTTRB	U-wind tendency from turbulence	$m\ s^{-2}$
DVDTDYN	V-wind tendency from dynamics	$m\ s^{-2}$
DVDTGWD	V-wind tendency from gravity wave drag	$m\ s^{-2}$
DVDTMST	V-wind tendency from moist physics	$m\ s^{-2}$
DVDTTRB	V-wind tendency from turbulence	$m\ s^{-2}$

7. Metadata

GEOS-5 gridded output files will include or be linked to two types of metadata. When using the HDF-EOS library and tools, the EOSDIS metadata will be used. Other utilities such as GrADS will use the CF metadata.

7.1 EOSDIS Metadata

The EOSDIS toolkit will only use the EOSDIS metadata. EOSDIS identifies two major types of metadata:, collection and granule.

Collection metadata are stored in a separate index file. This file describes an ESDT and is like a card in a library catalog. Each GMAO data product will have an ESDT description in the EOS Core System that contains its unique collection attributes. Appendix B describes the ESDT collection metadata.

Granule metadata is the "table of contents" information stored on the data file itself. The EOSDIS granule metadata include:

- File name (local granule ID)
- Grid structure
- Number of times stored in the file (1)
- Number of vertical levels for each variable in this file
- Names of variables in this file
- Variable format (32-bit floating point, 16-bit integer, etc.)
- Variable storage dimensions

    2-d fields will have 3 storage dimensions, time, latitude and longitude

    3-d fields will have 4 storage dimensions, time, latitude, longitude and vertical levels
- "Missing" value for each variable
- Unpacking scale factor for each packed variable (see section 8)
- Unpacking offset value for each packed variable (see section 8)

7.2 CF Metadata

When GrADS or FERRET are used to view GEOS-5 gridded data sets, the application will use the CF metadata imbedded in the data products. These metadata will comply with the CF conventions and include the following information:

- Space-time grid information (dimension variables)
- Variable long names (descriptions)
- Variable units
- "Missing" value for each variable

- Unpacking scale factor for each packed variable (see section 8)
- Unpacking offset value for each packed variable (see section 8)

8. Sample Software

Presented here is software that illustrates using the standard HDF library or the ECS HDF-EOS library to read GEOS-5 products. The program shown below will accept as command line arguments a file name and a field name. It will open the file, read the requested field at the first time, compute an average for this field, and print the result to standard output. There are two versions of this program. The first version uses the HDF-EOS library to read the file. The second version uses the standard HDF library to read the file. Electronic copies of these programs can be obtained from the Operations section of the GMAO web page:

http://gmao.gsfc.nasa.gov/operations/

```
/****************************************************************************/
/* This program demonstrates how to read a field from a GMAO HDF-EOS */
/* product using the HDF-EOS library. It will take a file name and */
/* field name on the command line, read the first time of the given */
/* field, calculate an average of that time and print the average. */
/* */
/* usage: avg <file name> <field name> */
/* */
/* Rob Lucchesi */
/* rlucchesi@GMAO.gsfc.nasa.gov */
/* 2/12/1999 */
/****************************************************************************/

#include "hdf.h"
#include "mfhdf.h"
#include <stdio.h>

#define XDIM 540
#define YDIM 361
#define ZDIM 36

main(int argc,char *argv[]) {
int32 sd_id, sds_id, status;
int32 sds_index;
int32 start[4], edges[4], stride[4];
char *fname, *vname;
float32 data_array[ZDIM][YDIM][XDIM];
float32 avg, sum;
int32 i,j,k;
int32 file_id, gd_id;

if (argc != 3) {
printf("Usage: avg <filename> <field> \n");
exit (-1);
}
```

```
fname = argv[1];
vname = argv[2];

/* Open the file (read-only) */

file_id = GDopen (fname, DFACC_RDONLY);
if (file_id < 0) {
printf ("Could not open %s\n",fname);
exit(-1);
}

/* Attach to the EOS grid contained within the file. */
/* The GMAO uses the generic name "EOSGRID" for the grid in all products. */

gd_id = GDattach (file_id,"EOSGRID");
if (gd_id < 0) {
printf ("Could not open %s\n",fname);
exit(-1);
}

/* Set positioning arrays to read the entire field at the first time. */

start[0] = 0;
start[1] = 0;
start[2] = 0;
start[3] = 0;

stride[0] = 1;
stride[1] = 1;
stride[2] = 1;
stride[3] = 1;

edges[0] = 1;
edges[1] = ZDIM;
edges[2] = YDIM;
edges[3] = XDIM;

/*In this program, we read the entire field. By manipulating the start
and edges arrays, it is possible to read a subset of the entire array.
For example, to read a 3D section defined by x=100,224; y=50,149;
z=15,16 you would set the start and edges arrays to the following:

start[0] = 0; time start location
start[1] = 15; z-dim start location
start[2] = 50; y-dim start location
start[3] = 100; x-dim start location

edges[0] = 1; time length
edges[1] = 2; z-dim length
```

```
edges[2] = 100; y-dim length
edges[3] = 125; x-dim length

*/

/* Read the data into data_array */

status = GDreadfield (gd_id, vname, start, stride, edges, data_array);
printf ("Read status=%d\n",status);

/* Calculate and print the average */

sum=0.0;
for (i=0; i<XDIM; i++)
for (j=0; j<YDIM; j++)
for (k=0; k<ZDIM; k++)
sum += data_array[k][j][i];

avg = sum/(XDIM*YDIM*ZDIM);

printf ("Average of %s in 3 dimensions is=%f\n",vname,avg);

/* Close file. */

status = GDdetach (gd_id);
status = GDclose (file_id);

}/**************************************************************************/
/* This program demonstrates how to read a field from a GMAO HDF-EOS */
/* product using the HDF library (HDF-EOS not required). It will take */
/* a file name and field name on the command line, read the first time */
/* of the given field, calculate an average of that time and print the average. */
/* */
/* usage: avg <file name> <field name> */
/* */
/* Rob Lucchesi */
/* rlucchesi@GMAO.gsfc.nasa.gov */
/* 2/12/1999 */
/**************************************************************************/

#include "hdf.h"
#include "mfhdf.h"
#include <stdio.h>

#define XDIM 540
#define YDIM 361
#define ZDIM 36

main(int argc,char *argv[]) {
```

```
int32 sd_id, sds_id, status;
int32 sds_index;
int32 start[4], edges[4], stride[4];
char *fname, *vname;
float32 data_array[ZDIM][YDIM][XDIM];
float32 avg, sum;
int32 i,j,k;

if (argc != 3) {
printf("Usage: avg <filename> <field> \n");
exit (-1);
}

fname = argv[1];
vname = argv[2];

/* Open the file (read-only) */

sd_id = SDstart (fname, DFACC_RDONLY);
if (sd_id < 0) {
printf ("Could not open %s\n",fname);
exit(-1);
}

/* Find the index and ID of the SDS for the given variable name. */

sds_index = SDnametoindex (sd_id, vname);
if (sds_index < 0) {
printf ("Could not find %s\n",vname);
exit(-1);
}

sds_id = SDselect (sd_id,sds_index);

/* Set positioning arrays to read the entire field at the first time. */

start[0] = 0;
start[1] = 0;
start[2] = 0;
start[3] = 0;

stride[0] = 1;
stride[1] = 1;
stride[2] = 1;
stride[3] = 1;

edges[0] = 1;
edges[1] = ZDIM;
edges[2] = YDIM;
```

```
edges[3] = XDIM;

/*
In this program, we read the entire field. By manipulating the start
and edges arrays, it is possible to read a subset of the entire array.
For example, to read a 3D section defined by x=100,224; y=50,149;
z=15,16 you would set the start and edges arrays to the following:

start[0] = 0; time start location
start[1] = 15; z-dim start location
start[2] = 50; y-dim start location
start[3] = 100; x-dim start location

edges[0] = 1; time length
edges[1] = 2; z-dim length
edges[2] = 100; y-dim length
edges[3] = 125; x-dim length

*/

/* Read the data into data_array */

status = SDreaddata (sds_id, start, stride, edges, (VOIDP) data_array);
printf ("read status=%d\n",status);

/* Calculate and print the average */

sum=0.0;
for (i=0; i<XDIM; i++)
for (j=0; j<YDIM; j++)
for (k=0; k<ZDIM; k++)
sum += data_array[k][j][i];

avg = sum/(XDIM*YDIM*ZDIM);


printf ("Average of %s in 3 dimensions is=%f\n",vname,avg);

/* Close file. */

status = SDendaccess (sds_id);
status = SDend (sd_id);
```

Appendix A. Types of Assimilation Configurations

Operational Assimilation: Atmospheric observations from satellites, balloons, aircraft, ships, and other sources are grouped into six-hour data windows and processed by the atmospheric analysis four times each day. The operational analysis will run approximately 12 hours after the 4 analysis times (0Z, 6Z, 12Z, 18Z). It will run using whatever conventional and satellite observations are available at the data cut-off time. Products produced from this and any other *assimilation* are a combination of output from the statistical analysis system and a short GCM forecast.

Forecast/Simulation: This is a GCM forecast, with no insertion of atmospheric data via the analysis. The only outside data that enters the system are the boundary conditions, i.e., sea surface temperature and sea-ice concentration. Five-day forecasts are typically generated to support NASA field campaigns and to assess assimilation and forecast skill. Multi-year simulations are produced to investigate the climatology of the GCM. GMAO forecast products are not distributed to ECS and file formats are not discussed in this document.

Reprocessing: The GMAO may reprocess specified time periods since EOS-Terra launch using a recent version of the GEOS DAS software to support instrument team reprocessing requirements. It is expected that new ECS ESDTs will be generated for each reprocessing run.

Reanalysis:. The GMAO will occasionally run reanalysis experiments. Reanalysis is the same as reprocessing except the time period is often much longer and not necessarily part of the EOS period. Reanalysis experiments are often run using baseline versions of the GEOS DAS system to support a wide variety of research activities internal and external to the GMAO. Unique ESDTs will be generated for any reanalysis data distributed through GES DISC.

Appendix B. Collection Metadata

GEOS-5 collection metadata will contain the following. To view the ESDTs associated with GMAO products, which include collection metadata, see the GMAO Operations web page: http://gmao.gsfc.nasa.gov/operations.

ECS Collection

- Revision Date
- Suggested Usage

Single Type Collection

- Collection State
- Maintenance and Update Frequency

Spatial

- Spatial Coverage Type

Bounding Rectangle

- West Bounding Coordinate
- North Bounding Coordinate
- East Bounding Coordinate
- South Bounding Coordinate

Altitude System Definition (for 3d files only)

- Altitude Datum Name
- Altitude Distance Units
- Altitude Encoding Method
- Altitude Resolution Class
- Altitude Resolution

Depth System Definition (land surface files only)

- Depth Datum Name
- Depth Distance Units
- Depth Encoding Method
- Depth Resolution Class
- Depth Resolution

Geographic Coordinate System

- Latitude Resolution
- Longitude Resolution
- Geographic Coordinate Units

Temporal

- Time Type
- Date Type
- Temporal Range Type
- Precision of Seconds

Ends at Present Flag

Range Date Time

Range Beginning Date
Range Beginning Time
Range Ending Date
Range Ending Time

Contact Person

Role
Hours of Service
Contact Job Position
Contact First Name
Contact Middle Name
Contact Last Name

Contact Person Address

Street address
City
State/Province
Postal Code
Country

Telephone

Telephone Container
Telephone Number
Telephone Number Type

Email

Electronic Mail Address

Contact Organization

Role
Hours of Service
Contact Instruction
Contact Organization Name

Contact Organization Address

Street Address
City
State/Province
Postal Code
Country

Organization Telephone Number

Telephone Number
Telephone Number Type

Organizational Email
Electronic Mail Address

Discipline Topic Parameters
ECS Discipline Keyword
ECS Topic Keyword
ECS Term Keyword
ECS Variable Keyword
ECS Parameter Keyword

Temporal Keyword Class
Temporal Keyword

Spatial Keyword Class
Spatial Keyword

Processing Level
Processing Level Description
Processing Level ID

Analysis Source
Analysis Short Name
Analysis Long Name
Analysis Technique
Analysis Type

CSDT Description
Primary CSDT

Additional Attributes
Additional Attribute Data Type
Additional Attribute Description
Additional Attribute Name

Physical Parameter Details
Parameter Units of Measure
Parameter Range
Parameter Value Accuracy
Parameter Value Accuracy Explanation
Parameter Measurement Resolution

Storage Medium Class (filled in by GES DISC)

Storage Medium

Appendix C. Vertical Grid Structure

Pressure-level data will be output on the following 36 pressure levels:

Level	P(hPa)	Level	P (hPa)	Level	P (hPa)
1	1000	13	600	25	50
2	975	14	550	26	40
3	950	15	500	27	30
4	925	16	450	28	20
5	900	17	400	29	10
6	875	18	350	30	7
7	850	19	300	31	5
8	825	20	250	32	3
9	800	21	200	33	2
10	750	22	150	34	1
11	700	23	100	35	0.4
12	650	24	70	36	0.2

Appendix D: Table mapping variable names from GEOS-3, GEOS-4, and GEOS-5

Table of variable names (2D instantaneous)

GEOS-3 name product: tsyn2d_mis_x	GEOS-4 name product: tsyn2d_mis_x	GEOS-5 name product:inst2d_met_x
PHIS (m^2 s^{-2})	PHIS (m^2 s^{-2})	PHIS (m^2 s^{-2})
ALBEDO (fraction)		
PS (hPa)	PS (hPa)	PS (Pa)
SLP (hPa)	SLP (hPa)	SLP (Pa)
		DISPH (m)
SURFTYPE (index)	SURFTYPE (0=water,1=land,2=ice)	LWI (0=water,1=land,2=ice)
VAVEU (m s^{-1})		
VAVEV (m s^{-1})		
VAVET(K)		
TPW (g cm^{-2})		
GWET (fraction)		
SNOW (mm)		
TGROUND (K)	TSKIN (K)	TSKIN (K)
T2M (K)	T2M (K)	T2M (K)
T10M (K)	T10M (K)	T10M (K)
Q2M (g kg^{-1})	Q2M (g kg^{-1})	QV2M (kg kg^{-1})
Q10M (g kg^{-1})	Q10M (g kg^{-1})	QV10M (kg kg^{-1})
U2M (m s^{-1})	U2M (m s^{-1})	U2M (m s^{-1})
U10M (m s^{-1})	U10M (m s^{-1})	U10M (m s^{-1})
V2M (m s^{-1})	V2M (m s^{-1})	V2M (m s^{-1})
V10M (m s^{-1})	V10M (m s^{-1})	V10M (m s^{-1})
TROPP (hPa)	TROPP (hPa)	TROPP (Pa)
TROPT (K)	TROPT (K)	TROPT (K)
	TROPQ (g kg^{-1})	TROPQ (kg kg^{-1})
	UFLUX (N m^{-2})	UFLUX (N m^{-2})
	VFLUX (N m^{-2})	VFLUX (N m^{-2})
	HFLUX (W m^{-2})	HFLUX (W m^{-2})
		EFLUX (W m^{-2})
		TQV (kg m^{-2})
		TQL (kg m^{-2})
		TQI (kg m^{-2})
		TO3 (Dobson)
		TTO3 (dobson)
		U50M (m s^{-1})
		V50M (m s^{-1})

Table of variable names (3D instantaneous)

GEOS-3 name product: tsyn3d_mis_p	GEOS-4 name product: tsyn3d_mis_p	GEOS-5 name product:inst3d_met_p
UWND (m s^{-1})	UWND (m s^{-1})	U (m s^{-1})
VWND (m s^{-1})	VWND (m s^{-1})	V (m s^{-1})
HGHT (m)	HGHT (m)	H (m)
TMPU (K)	TMPU (K)	T (K)
SPHU (g kg^{-1})	SPHU (g kg^{-1})	QV (kg kg^{-1})
		QL (kg kg^{-1})
		QI (kg kg^{-1})
		O3 (kg kg^{-1})

GEOS-3 name product: tsyn3d_mis_p	GEOS-4 name product: tsyn3d_mis_p	GEOS-5 name product:inst3d_met_p
RH (percent)	RH (percent)	RH (percent)
OMEGA (hPa day^{-1})		

Table of variable names (2D time-averaged)

GEOS-3 name product: various	GEOS-4 name product: various	GEOS-5 name product: tavg2d_met_x
		FRLAKE (fraction)
		FRLAND (fraction)
		FRLANDICE (fraction)
		FROCEAN (fraction)
PREACC (mm day^{-1})	PREACC (mm day^{-1})	PRECTOT (kg m^{-2} s^{-1})
PRECON (mm day^{-1})	PRECON (mm day^{-1})	PRECCON (kg m^{-2} s^{-1})
	PRECL (mm day^{-1})	PRECLSC (kg m^{-2} s^{-1})
		PRECANV (kg m^{-2} s^{-1})
		PRECSNO (kg m^{-2} s^{-1})
TPW (g cm^{-2})	TPW (g cm^{-2})	TPW (kg m^{-2})
EVAP (mm day^{-1})	EVAP (mm day^{-1})	EVAP (kg m^{-2} s^{-1})
HFLUX (W m^{-2})	HFLUX (W m^{-2})	HFLUX (W m^{-2})
	GWETROOT (fraction)	GWETROOT (fraction)
	GWETTOP (fraction)	GWETTOP (fraction)
QICE (W m^{-2})		
CT (m s^{-1})		
TGROUND (K)	TSKIN (K)	TSKIN (K)
T2M (K)	T2M (K)	T2M (K)
T10M (K)	T10M (K)	T10M (K)
Q2M (g kg^{-1})	Q2M (g kg^{-1})	QV2M (kg kg^{-1})
Q10M (g kg^{-1})	Q10M (g kg^{-1})	QV10M (kg kg^{-1})
RADLWG (W m^{-2})	RADLWG (W m^{-2})	LWGNET (W m^{-2})
RADSWG (W m^{-2})	RADSWG (W m^{-2})	SWGNET (W m^{-2})
		SWGDWN (W m^{-2})
ALBEDO (fraction)	ALBEDO (fraction)	ALBEDO (fraction)
ALBVISDR (fraction)	ALBVISDR (fraction)	ALBVISDR (fraction)
ALBVISDF (fraction)	ALBVISDF (fraction)	ALBVISDF (fraction)
ALBNIRDR (fraction)	ALBNIRDR (fraction)	ALBNIRDR (fraction)
ALBNIRDF (fraction)	ALBNIRDF (fraction)	ALBNIRDF (fraction)
LWGCLR (W m^{-2})	LWGCLR (W m^{-2})	LWGDWNCLR (W m^{-2})
SWGCLR (W m^{-2})	SWGCLR (W m^{-2})	SWGNETCLR (W m^{-2})
VAVEUQ (m g s^{-1} kg^{-1})	VAVEUQ (m g s^{-1} kg^{-1})	
VAVEVQ (m g s^{-1} kg^{-1})	VAVEVQ (m g s^{-1} kg^{-1})	
VAVEUT (m K s^{-1})	VAVEUT (m K s^{-1})	
VAVEVT (m K s^{-1})	VAVEVT (m K s^{-1})	
	VAVEU (m s^{-1})	
	VAVEV (m s^{-1})	
	VAVET (K)	
VAVEQIAU (mm day^{-1})		
VAVEQFIL (mm day^{-1})		
VAVETIAU (K day^{-1})		
RAINCON (mm day^{-1})	RAINCON (mm day^{-1})	PRECCON (kg m^{-2} s^{-1})
SNOWFALL (mm day^{-1})		PRECSNO (kg m^{-2} s^{-1})
RAINLSP (mm day^{-1})	RAINLSP (mm day^{-1})	PRECLSC (kg m^{-2} s^{-1})
LWGDOWN (W m^{-2})	LWGDOWN (W m^{-2})	LWGDWN (W m^{-2})

GEOS-3 name product: various	GEOS-4 name product: various	GEOS-5 name product: tavg2d_met_x
LWGUP (W m^{-2})	LWGUP (W m^{-2})	LWGUP (W m^{-2})
PARDF (W m^{-2})	PARDF (W m^{-2})	PARDF (W m^{-2})
PARDR (W m^{-2})	PARDR (W m^{-2})	PARDR (W m^{-2})
LAI (index)	LAI (index)	LAI (m m^{-2})
GREEN (percent)		GRN (fraction)
DLWDTC (W m^{-2} K^{-1})		
DTG (K s^{-1})	DTG (K s^{-1})	DTG (K s^{-1})
SNOW (mm)	SNOW (mm)	SNOMAS (m)
PS (hPa)	PS (hPa)	PS (Pa)
UFLUX (N m^{-2})	UFLUX (N m^{-2})	TAUX (N m^{-2})
VFLUX (N m^{-2})	VFLUX (N m^{-2})	TAUY (N m^{-2})
GWDUS (N m^{-2})	GWDUS (N m^{-2})	TAUGWX (N m^{-2})
GWDVS (N m^{-2})	GWDVS (N m^{-2})	TAUGWY (N m^{-2})
GWDUT (N m^{-2})		
GWDVT (N m^{-2})		
CU		
USTAR (m s^{-1})	USTAR (m s^{-1})	USTAR (m s^{-1})
		BSTAR (m s^{-1})
Z0 (m)		
	Z0H (m)	Z0H (m)
	Z0M (m)	Z0M (m)
		DISPH (m)
PBL (hPa)	PBLH (m)	PBLH (m)
U2M (m s^{-1})	U2M (m s^{-1})	U2M (m s^{-1})
V2M (m s^{-1})	V2M (m s^{-1})	V2M (m s^{-1})
U10M (m s^{-1})	U10M (m s^{-1})	U10M (m s^{-1})
V10M (m s^{-1})	V10M (m s^{-1})	V10M (m s^{-1})
PIAU (hPa day^{-1})		
OLR (W m^{-2})	OLR (W m^{-2})	LWTUP (W m^{-2})
OLRCLR (W m^{-2})	OLRCLR (W m^{-2})	LWTUPCLR (W m^{-2})
RADSWT (W m^{-2})	RADSWT (W m^{-2})	SWTNET (W m^{-2})
OSR (W m^{-2})	OSR (W m^{-2})	SWTUP (W m^{-2})
OSRCLR (W m^{-2})	OSRCLR (W m^{-2})	SWTUPCLR (W m^{-2})
CLDFRC (fraction)	CLDFRC (fraction)	CLDTOT (fraction)
TAULOW (dimensionless)		TAULOW (dimensionless)
TAUMID (dimensionless)		TAUMID (dimensionless)
TAUHI (dimensionless)		TAUHGH (dimensionless)
		TAUTOT (dimensionless)
CLDLOW (fraction)	CLDLOW (fraction)	CLDLOW (fraction)
CLDMID (fraction)	CLDMID (fraction)	CLDMID (fraction)
CLDHI (fraction)	CLDHI (fraction)	CLDHGH (fraction)
CLDTMP (K)		
CLDPRS (hPa)		
		LWI (0=water,1=land,2=ice)
		EMIS (dimensionless)
		U50M (m s^{-1})
		V50M (m s^{-1})
		SNODP (m)
		RHOA (kg m^{-3})

Table of variable names (3D time-averaged)

GEOS-3 name product: various on pressure	GEOS-4 name product: various on pressure & eta	GEOS-5 name product: various on lcv coordinates
TAUCLD (dimensionless)		
	TAUCLI (dimensionless)	TAUCLI (dimensionless)
	TAUCLW (dimensionless)	TAUCLW (dimensionless)
CLDTOT (fraction)	CLDTOT (fraction)	CLOUD (fraction)
CLDRAS (fraction)		
TURBU ($m\ s^{-1}\ day^{-1}$)	TURBU ($m\ s^{-1}\ day^{-1}$)	DUDTTRB ($m\ s^{-2}$)
TURBV ($m\ s^{-1}\ day^{-1}$)	TURBV ($m\ s^{-1}\ day^{-1}$)	DVDTTRB ($m\ s^{-2}$)
GWDU ($m\ s^{-1}\ day^{-1}$)	GWDU ($m\ s^{-1}\ day^{-1}$)	DUDTGWD ($m\ s^{-2}$)
GWDV ($m\ s^{-1}\ day^{-1}$)	GWDV ($m\ s^{-1}\ day^{-1}$)	DVDTGWD ($m\ s^{-2}$)
		DUDTMST ($m\ s^{-2}$)
		DVDTMST ($m\ s^{-2}$)
		DUDTDYN ($m\ s^{-2}$)
		DVDTDYN ($m\ s^{-2}$)
RFU ($m\ s^{-1}\ day^{-1}$)		
RFV ($m\ s^{-1}\ day^{-1}$)		
UIAU ($m\ s^{-1}\ day^{-1}$)		
VIAU ($m\ s^{-1}\ day^{-1}$)		
DUDT ($m\ s^{-1}\ day^{-1}$)		
DVDT ($m\ s^{-1}\ day^{-1}$)		
TURBQ ($g\ kg^{-1}\ day^{-1}$)	TURBQ ($g\ kg^{-1}\ day^{-1}$)	DQVDTTRB ($kg\ kg^{-1}\ s^{-1}$)
MOISTQ ($g\ kg^{-1}\ day^{-1}$)	MOISTQ ($g\ kg^{-1}\ day^{-1}$)	DQVDTMST ($kg\ kg^{-1}\ s^{-1}$)
		DQLDTMST ($kg\ kg^{-1}\ s^{-1}$)
		DQIDTMST ($kg\ kg^{-1}\ s^{-1}$)
		DQVDTDYN ($kg\ kg^{-1}\ s^{-1}$)
DQLS ($g\ kg^{-1}\ day^{-1}$)		
QIAU ($g\ kg^{-1}\ day^{-1}$)		
QFILL ($g\ kg^{-1}\ day^{-1}$)		
DQDT ($g\ kg^{-1}\ day^{-1}$)		
TURBT ($K\ day^{-1}$)	TURBT ($K\ day^{-1}$)	DTDTTRB ($K\ s^{-1}$)
MOISTT ($K\ day^{-1}$)	MOISTT ($K\ day^{-1}$)	DTDTMST ($K\ s^{-1}$)
DTLS ($K\ day^{-1}$)		
RADLW ($K\ day^{-1}$)	RADLW ($K\ day^{-1}$)	DTDTLWR ($K\ s^{-1}$)
RADSW ($K\ day^{-1}$)	RADSW ($K\ day^{-1}$)	DTDTSWR ($K\ s^{-1}$)
LWCLR ($K\ day^{-1}$)		DTDTLWRCLR ($K\ s^{-1}$)
SWCLR ($K\ day^{-1}$)		DTDTSWRCLR ($K\ s^{-1}$)
RFT ($K\ day^{-1}$)		DTDTFRI ($K\ s^{-1}$)
GWDT ($K\ day^{-1}$)	GWDT ($K\ day^{-1}$)	DTDTGWD ($K\ s^{-1}$)
TIAU ($K\ day^{-1}$)		
DTDT ($K\ day^{-1}$)	DIABDT ($K\ day^{-1}$)	DTDTTOT ($K\ s^{-1}$)
		DTDTDYN ($K\ s^{-1}$)
KH ($m^2\ s^{-1}$)	KH ($m^2\ s^{-1}$)	KH ($m^2\ s^{-1}$)
KM ($m^2\ s^{-1}$)	KM ($m^2\ s^{-1}$)	KM ($m^2\ s^{-1}$)
CLDMAS ($kg\ m^{-2}\ s^{-1}$)	CLDMAS ($kg\ m^{-2}\ s^{-1}$)	CMFMC ($kg\ m^{-2}\ s^{-1}$)
DTRAIN ($kg\ m^{-2}\ s^{-1}$)	DTRAIN ($kg\ m^{-2}\ s^{-1}$)	DTRAIN ($kg\ m^{-2}\ s^{-1}$)
		DQRCON ($kg\ m^{-2}\ s^{-1}$)
		DQRLSC ($kg\ m^{-2}\ s^{-1}$)
		PL (Pa)
	HGHT (m)	HGHT (m)
	HGHTE (m)	HGHTE (m)
	UWND ($m\ s^{-1}$)	U ($m\ s^{-1}$)
	VWND ($m\ s^{-1}$)	V ($m\ s^{-1}$)
	TMPU (K)	T (K)
	OMEGA ($Pa\ s^{-1}$)	OMEGA ($Pa\ s^{-1}$)

GEOS-3 name product: various on pressure	**GEOS-4 name product: various on pressure & eta**	**GEOS-5 name product: various on lcv coordinates**
	PV (m^2 kg^{-1} s^{-1})	PV (K m^2 kg^{-1} s^{-1})
	RH (percent)	RH (percent)
		QL (kg kg^{-1})
		QI (kg kg^{-1})
	SPHU (kg kg^{-1})	QV (kg kg^{-1})
	HKBETA (fraction)	
	HKETA (kg m^{-2} s^{-1})	
	ZMDQR (kg kg^{-1} s^{-1})	
	ZMDU (Pa s^{-1})	
	ZMED (Pa s^{-1})	
	ZMEU (Pa s^{-1})	
	ZMMD (Pa s^{-1})	
	ZMMU (Pa s^{-1})	
		MFXC (Pa m+2 s-1)
		MFYC (Pa m+2 s-1)
		MFZ (kg m-2 s-1)
	CMFDTR (Pa/s)	
	CMFDQR2 (kg/kg/s)	
	CMFETR (Pa/s)	
	CMFMC (Pa/s)	
	CMFMC2 (Pa/s)	

Appendix E: Detailed Description of Output Variables

E.1: 3D Variables

CLOUD: The horizontal fractional cloud cover for each layer. In the vertical, clouds are assumed to fill the layer. This fraction is the combination of the model's predicted large-scale and convective fractions that is used for radiative purposes. See **CLDTOT** for a description of how these fractions are overlapped in the radiation calculations.

CMFMC: The total vertical convective mass flux through levels between model layers (edges), in kg m^{-2} s^{-1}. This is produced by the convection parameterization (RAS) and it includes the mass flux due to all cloud types crossing the level.

DELP: Pressure thickness of model layers, in Pa. See **PLE**. The layer mass is **DELP / 9.81** kg m^{-2}.

DQRCON, DQRLSC: The layer production rate of precipitating condensate from convective and large-scale processes per unit horizontal area, in kg m^{-2} s^{-1} Includes both liquid and frozen precipitating condensate, but not the production cloud condensates.

DQVDTMST, DQLDTMST, DQIDTMST: Tendency of vapor, liquid and ice water due to moist processes, in kg kg^{-1} s^{-1}. This includes the effects of the convection parameterization (RAS) and all other effects from the cloud microphysics and large scale and anvil precipitation schemes.

DQVDTDYN: Tendency of water vapor due to resolved dynamics, in kg kg^{-1} s^{-1}.

DQVDTTRB: Tendency of water vapor due to turbulence, including surface evaporation, in kg kg^{-1} s^{-1}.

DTDTDYN: Temperature tendency due to dynamics, including the spurious frictional dissipation of kinetic energy by numerical processes.

DTDTFRI: Temperature tendency due to the frictional dissipation of kinetic energy by turbulence, including surface friction, in K s^{-1}. It does not include dissipation from gravity wave drag or the implicit dissipation in the model's dynamics.

DTDTGWD: Temperature tendency due to the frictional dissipation of kinetic energy by gravity wave drag, in K s^{-1}.

DTDTLWR, DTDTLWRCLR: Temperature tendency due to terrestrial (longwave) radiation for all-sky and clear-sky conditions, in K s^{-1}.

DTDTMST: Temperature tendency due to terrestrial (longwave) radiation, in K s^{-1}.

DTDTSWR, DTDTSWRCLR: Temperature tendency due to solar (shortwave) radiation for all-sky and clear-sky conditions, in K s^{-1}.

DTDTTOT: The total diabatic temperature tendency for the model layers, in K s^{-1} . It is the same as the sum **DTDTFRI+DTDTGWD+DTDTLWR+DTDTSWR+DTDTMST+DTDTTRB,** and in the lon-term mean should balance **DTDTDYN**.

DTDTTRB: Temperature tendency due to turbulence, including surface sensible heat flux, but not including the heating due to frictional dissipation (see **DTDTFRI**), in K s^{-1}. Above the surface it includes the diffusive effects due to the Louis and Lock turbulence schemes (see **KH**).

DTRAIN: Mass flux detrained at cloud top from each convective cloud type in RAS, the model's convection parameterization, in kg m^{-2} s^{-1}.

DUDTDYN, DVDTDYN: Eastward (zonal) and northward (meridional) wind tendency due to dynamics, in m s^{-2}.

DUDTGWD, DVDTGWD: Eastward (zonal) and northward (meridional) wind tendencies due to gravity wave drag, in m s^{-2}.

DUDTMST, DVDTMST: Eastward (zonal) and northward (meridional) wind tendencies due to moist processes, in m s^{-2}. Currently this represents the "cumulus friction" effect of mixing momentum in a conservative way, using the convective mass fluxes from RAS.

DUDTTRB, DVDTTRB: Eastward (zonal) and northward (meridional) wind tendencies due to turbulent processes, in m s^{-2}. This includes surface friction. Above the surface, it includes the diffusive effects due to the Louis and Lock turbulence schemes (see **KM**).

HGHT: Geopotential height at the layer centers, in m. It is simply the average of **HGHTE** at the layer's bounding edges.

HGHTE: Geopotential height at the layer edges, in m. At the surface (LM+1) it is set to **PHIS**/g**.** Above the surface $\frac{1}{g}\left(\textbf{PHIS} + c_P \sum_{l=L}^{LM} \theta_v \Delta P\right)$**,** where ΔP is the difference in $\left(\frac{p}{p_o}\right)^{\kappa}$ at the lower and upper edges of layer l, and θ_v is the virtual potential temperature,

KH, KM : Turbulent diffusivity for heat and other scalars and for momentum (**U** and **V**), in m^2 s^{-1}. This is defined at the layer edges, beginning at the top, where it is zero. At the surface (LM+1) it is set ….. It includes the diffusive effects due to the Louis and Lock turbulence schemes.

MFXC, MFYC: The eastward and northward layer mass fluxes on the C-Grid, in Pa m^2 s^{-1}. **MF[X,Y]C =** $[\mathbf{U},\mathbf{V}]\mathrm{DELP}[a\Delta\varphi, a\cos(\varphi)\Delta\lambda]$**,** where **U** and **V** are the C-grid velocity components, a is the earth's radius, and $[a\Delta\varphi, a\cos(\varphi)\Delta\lambda] \equiv [\Delta y, \Delta x]$ are the meridional and zonal grid spacings at the appropriate C-grid locations, in meters.

MFZ: The vertical component of the large-scale mass flux at the lcv edges, in kg m^{-2} s^{-1}. Together with **MFXC, MFYC,** and **PS,** these satisfy the continuity equation

$$\frac{\partial}{\partial t}\mathrm{PS} = -\frac{1}{\Delta y \Delta x}(\delta_x\,\mathrm{MFXC} + \delta_y\,\mathrm{MFYC}) - \mathrm{g}\,\delta_z\,\mathrm{MFZ}$$

OMEGA: The kinematic vertical pressure velocity estimated by the Finite-Volume dynamics. It is defined for the layers, not the edges. For layer l, it is discretized vertically as $\omega_l = \left(\overline{\frac{\partial p}{\partial t}} + \overline{\dot{\eta}\frac{\partial p}{\partial \eta}}\right)_l + (V \bullet \nabla \overline{p})_l$, where the pressure is defined at the layer edges and the overbar indicates the average of the layer's upper and lower edges.

PL: The layer pressure defined as the average of the upper and lower edge pressures, **PLE,** in Pa (see **DELP**).

PLE: The time-averaged pressure at the upper edge of a layer**. PLE** = **PS** + $\sum_{l=L}^{LM}$ **DELP** $_l$. This is the preferred way of obtaining edge pressures in lcv-coordinates, rather than relying on the model's hybrid-sigma coordinate system (i.e., the **AK**s and **BK**s), which may change in future releases.

PV: The Ertel's potential vorticity, approximated as $g(\zeta + f)\frac{\partial \ln(\theta_v)}{\partial p}$, in m^2 kg^{-1} sec^{-1}. Here ζ is the vertical component of relative vorticity, f is the Coriolis parameter, and θ_v is the virtual potential temperature, Note the definition in terms of entropy instead of potential temperature and the neglect of the part associated with the horizontal components of vorticity.

TAUCLI, TAUCLW: Each layer's total cloud optical thickness in the visible (0.40 to 0.69 micron band), for ice clouds and liquid water clouds, respectively.

E.2: 2D Variables

ALBEDO: The time-averaged surface albedo defined as the ratio of the time-averaged incident and reflected fluxes and should satisfy **ALBEDO = SWGDWN/(SWGDWN-SWGNET).** At night points, this is set to **_FillValue**.

ALBVISDF, ALBVISDR, ALBNIRDF, ALBNIRDR: The direct (beam) and diffuse albedos for the "visible" (the GCM uses the same albedos for the UV and the PAR spectral regions—0.175 to 0.69 microns) and the "near-infrared" (0.69 to 3.85 microns). These are simply time-averaged surface properties, but are defined only where there was daylight at the point during the averaging interval. They do not correspond to the ratios of time-averaged incident and reflected fluxes.

BSTAR: The buoyancy scale of the surface layer in m s^{-2}. It is defined as $\frac{g}{\rho_a u^*}\frac{F_{s_v}}{c_P T_a}$, where ρ_a is the near-surface air density (**RHOA**) and T_a the near-surface air temperature, u^* is the friction velocity (**USTAR**), and F_{s_v} is the surface flux of virtual dry static energy in W m^{-2}, F_{s_v} = (**HFLUX** + $(1-\varepsilon)$ **EFLUX**).

CLDHGH, CLDMID, CLDLOW, CLDTOT: High, middle, low, and total cloudiness. The high, middle, low-level values correspond to the three superlayers used in the GEOS-5 solar and terrestrial radiation parameterizations. Clouds within these superlayers are assumed to be maximally overlapped. High clouds are those occurring above roughly 400 hPa and low clouds are those occurring below 700 hPa, although the groupings are done ion the model's terrain following coordinate and so the bounding pressures will differ significantly from these values over high topography. The model assumes that the overlapped between the superlayers is random, and the total cloudiness uses this assumption. The total cloudiness is computed each time the radiation is called, and so its time mean cannot be exactly constructed from the time-mean cloudiness in the three super layers.

DISPH: Surface displacement height in meters. See the description of the neutral drag coefficient.

DTG: Change in surface temperature during the averaging interval in deg K. This refers to the area-mean surface temperature under each atmospheric column, and so, it may contain contributions from land-, water-, and ice-covered parts of the grid box.

EFLUX: The upward turbulent flux of latent heat flux at the surface, in W m^{-2}. This includes the latent heat relative to liquid of all turbulent moisture fluxes through the surface (see **EVAP**).

EMIS: The surface emissivity. This is a really averaged over all surface tiles and is constant in time.

EVAP: Evaporation in kg m^{-2} s^{-1}. Actually the total turbulent flux of water vapor at the surface, including fluxes from transpiration, sublimation, and surface condensation. The turbulent flux of could condensate (fog) is assumed to be zero. .

FRLAKE, FRLAND, FRLANDICE, FROCEAN: GEOS-5 uses these four primary surface types and these are their fractions under each atmospheric column.

GRN: The "greenness" or fraction transpiring leaves averaged over the land areas of a grid box. If there are several vegetation tiles within the land part of a grid box, the average is **LAI** weighted. **GRN** is set to **_FillValue** where **FRLAND** = 0.

GWETROOT, GWETTOP: The degree of saturation or "wetness" in the root-zone (top meter of soil) and top soil layer (top 2 cm). These are defined as the ratio of the volumetric soil moisture to the porosity. These quantities are set to **_FillValue** where **FRLAND** = 0. Elsewhere they are time-mean and area-mean values of the ratio over the land part of the grid box.

HFLUX: The upward turbulent sensible heat flux at the surface, in W m^{-2}.

LAI: The a real average of the leaf-area index over all land parts of a grid box. **LAI** is set to **_FillValue** where **FRLAND** = 0.

LWGDWN, LWGDWNCLR: The all-sky and cloud-free fluxes of downwelling terrestrial (longwave) radiation at the surface in W m^{-2}.

LWGNET: The net downward flux of terrestrial (longwave) radiation at the surface in W m^{-2}. This is identical to **LWGDWN- LWGUP.**

LWGUP: The all-sky upwelling terrestrial (longwave) radiation at the surface, in W m^{-2}. This includes both the surface emission and the reflection..

LWI: A Land-Water-Ice mask provided for backward compatibility with the GEOS-4 product. It is 1 over continental areas, 0 over open ocean, and 2 over sea-ice covered ocean. Since in GEOS-5 a grid box can be a combination of these, continental areas are arbitrarily defined as those where **FRLAND+FRLANDICE>=0.5.** The remaining grid boxes are designated as sea-ice if the ice cover exceeds 50%; otherwise they are open (ice-free) ocean.

LWTUP, LWTUPCLR: Outgoing longwave (terrestrial) radiation at the top of the model's atmosphere (currently 0.01 hPa) for all-sky and clear-sky conditions, in W m^{-2}.

PARDF, PARDR: Incident flux of of diffuse and direct PAR at the surface, in W m^{-2}. PAR is defied as the solar radiation between 0.4 and 0.69 microns.

PBLH: Height above the surface of the planetary boundary layer in meters. This is obtained diagnostically at every time step from the heat diffusivity in the model layers. It is defined as the height of the lowest layer in which the diffusivity fals below 2 $m^2 s^{-1}$. Where no layer is above this value, the boundary layer height is set to the height of the surface layer.

PHIS: The surface geopotential, gh_s, in m^{-2} s^{-2}. Here h_s is the height of the surface above sea level, and $g = 9.81\ \mathrm{m\,s^{-2}}$.

PRECANV, PRECLSC, PRECCON: the large-scale precipitation from anvils, the non-anvil large-scale precipitation, and the convective precipitation, in kg m^{-2} s^{-1}. These include both rainfall and snowfall.

PRECTOT: The total precipitation (**PRECANV+PRECLSC+PRECCON**) in kg m^{-2} s^{-1}.

PRECSNO: The "snowfall" includes all frozen precipitation, in kg m^{-2} s^{-1}.

PS: The surface pressure in Pa. The height at this pressure can be obtained from the surface geopotential **PHIS.** The total atmospheric mass is $\frac{1}{g}\mathbf{PS}$ kg m^{-2}.

QV10M, QV2M: The specific humidity at 10 m and 2m above the displacement height (**DISPH**) in the surface layer, in kg kg^{-1}.

RHOA: Surface air density in the lowest model layer, in kg m^{-3}. This is the density used in bulk formulas.

SLP: The surface pressure reduced to sea level, in Pa. Over topography the reduction is done by assuming a lapse rate of 6.5 K km^{-1} from a free atmospheric temperature, which is currently taken as the lowest model layer above 150 hPa above the surface.

SNOMAS: The mass of snow in per unit of land area in meters of liquid-water-equivalent depth (i.e., 10^{3} kg m^{-2}). In grid boxes with no land (**FRLAND+FRLANDICE=0**) it is set to **_FillValue.** Where **FRLANDICE>0.9** it is arbitrarily set to 4 meters. Over other land areas it represents an average over the non-glaciated part.

SNODP: The geometric snow depth in meters. This accounts for packing and aging of the snow.

SWGDWN, SWGDWNCLR: Incident solar radiation (0.175 to 3.85 microns) at the surface for all-sky and clear-sky conditions, in W m^{-2}. Since we do a single atmospheric transfer calculation in a grid box, we assume the incident diffuse radiation is the same for all land tiles within the box.

SWGNET, SWGNETCLR: Net downward flux of solar radiation at the surface averaged over all land tiles for all-sky and clear-sky conditions, in W m^{-2}.

SWTUP, SWTUPCLR: The outgoing (reflected) flux of solar radiation at the top of the model's atmosphere (currently 0.01 hPa) for all-sky and clear-sky conditions, in W m^{-2}.

SWTDWN: Incident flux of solar radiation at the top of the atmosphere, in W m^{-2}.

T10M, T2M: The air temperature at 10 m and 2m above the displacement height (**DISPH**) in the surface layer, in K.

TAUGWX, TAUGWY: The eastward (zonal) and northward (meridional) components of the atmospheric stress on the surface due to atmospheric gravity wave drag, in N m^{-2}.

TAUHGH, TAUMID, TAULOW, TAUTOT: Total cloud optical thickness in the 0.40 to 0.69 micron band for the high, middle, and low cloud regions (see **CLDHGH)** and for the entire column.

TAUX, TAUY: The eastward (zonal) and northward (meridional) components of the atmospheric frictional stress on the surface, in N m^{-2}.

TO3 : The vertically integrated ozone, in Dobson units.

TPW, TQV: The vertically integrated water vapor in the column, in kg m^{-2}.. These are synonyms.

TQL, TQI: The vertically integrated liquid and ice water in the column, in kg m^{-2}.

TQC: The vertically integrated combined liquid and ice water in the column, in kg m^{-2}.

TROPP: The tropopause pressure in Pa. The tropopause pressure is defined as the pressure where the function $\alpha T(p) - \log_{10} p$ reaches its first minimum above the surface. Here $\alpha = 0.03$ and p is in hPa. If no minimum is found between 550 hPa and 40 hPa, **TROPP** is set to **_FillValue.**

TROPQ: The tropopause specific humidity in kg kg^{-1}. The tropopause is defined as in **TROPP.**

TROPT: The tropopause temperature in K. The tropopause is defined as in **TROPP.**

TSKIN: The area weighted skin temperature of all surface tiles in a grid box, in K.

TTO3: The vertically integrated ozone in the troposphere, in Dobson units. The troposphere is defined as all levels below **TROPP. TTO3** and **TROPP** are computed at every time step and averaged separately.

U50M, U10M, U2M: The eastward wind component at 50m, 10 m, and 2m above the displacement height (**DISPH**) in the surface layer, in m s^{-1}.

USTAR: The surface friction velocity, $u^* = \sqrt{\frac{|\tau|}{\rho_a}}$, in m s^{-1}. This mean quantity is formed by doing the the areal average over the surface tiles in a grid box instantaneously to $|\tau|$, and the time averaging on u^* itself. It is thus not exactly what would be obtained from **TAUX, TAUY,** and **RHOA.**

V50M, V10M, V2M: The northward wind component at 50m, 10 m, and 2m above the displacement height (**DISPH**) in the surface layer, in m s^{-1}.

Z0H: The surface roughness for heat, in m.

Z0M: The dynamic surface roughness, in m.

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