File Specification for GEOS-DAS Gridded Output

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Version 4.3
To support EOS-Terra (formerly EOS-AM1)

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REVISION HISTORY

Revision	Revision Date	Pages Affected/Extent of Changes	Approval Authority
Version 1.0 (original - no electronic copy)	April 8, 1997	All	Not Approved
Version 3.0 (DAO-1001.30)	November 4, 1997	• Added 5 authors • Reorganized the document • Replaced Sections 3, 5, 6, and Appendix B	Not Approved
Version 3.1 (DAO-1001.31)	January 5, 1998	• Added Figure 1 • Revised size estimate for single level mis and lsm in Sections 6.1 and 6.2 • Made various changes to the list of variables in the assimilated time averaged files in Section 6.3	Rob Lucchesi 1/26/99 (Closed CR 131)
Version 3.2 (DAO-1001.32)	March 4, 1999	• Changed "GEOS-3" to "GEOS-AM1" throughout the document • Updated scope and launch date in Section 1 • Provided more detailed description of file format including Dimensions, Variables, and Attributes in Section 2 • Modified the horizontal resolution and clarified the description of the grids in Section 4 • Included version ID in the filename convention described in Section 5.1 • The file sizes were updated in Section 6 to reflect the new horizontal resolution • Improved the description of packing and included directions for unpacking in Section 8 • Two sample programs were added in Section 9 to demonstrate using the HDF library and the HDF-EOS library for reading the data files • Updated the description of First Look Analysis and added a description of Late Look Analysis in Appendix A • Added references for the data format	CCB 3/16/99

Version 4.0 (DAO-1001.4)	May 19, 1999	• Title changed to "File Specification for GEOS-DAS Gridded Output" • Changed details of internal products in Section 1 • Added a figure and description of the horizontal grid structure, removed references to sigma levels in the vertical grid description, and indicated differences in the grids of the CHM products in Section 4 • Indicated that forecast and analysis products will not be archived for distribution by ECS and removed filenaming information for sigma and forecast products in Section 5 • Various changes made to Section 6: - split product table into one table for first look and one for late look - removed sigma products and sigma sizes and definitions - added ESDTs - adjusted the horizontal resolution of CHM products - removed forecast products - added a discussion of the different horizontal and vertical grid structures of the CHM products • Updated the description of First Look Analysis in Appendix A • Added a new table of pressure levels for CHM products and removed the table of sigma levels in Appendix C • Added references for the data format • Levels 36 and 42 in Appendix C tables were changed from 0.1 to 0.2 because in 3D pressure products, 0.2 hPa is now the highest level, changed from 0.1 hPa in earlier documentation	CCB 5/19/99
Version 4.1 (DAO-1001v4.1)	August 18, 1999	• Slight adjustment of variable content for tavg_cld_p, tavg3d_tmp_p, and tavg3d_tmp_p products.	CCB 8/18/99
Version 4.2	January 21, 2000	• Re-write Section 3 to clarify description of time-averaged products. • Changed AM-1 to Terra throughout document. • Added approval dates to revision history for Version 4.0 and Version 4.1.	CCB 1/21/00
Version 4.3	May 3, 2000	• In Table 6.1, adjusted the sizes of three products to match the detailed descriptions in Section 6.2: - DFLAXENG changes from 66.7 to 58.4 - DLLAPCLD changes from 150.1 to 112.6 - DLLAPTMP changes from 337.8 to 412.9	CCB 5/17/00

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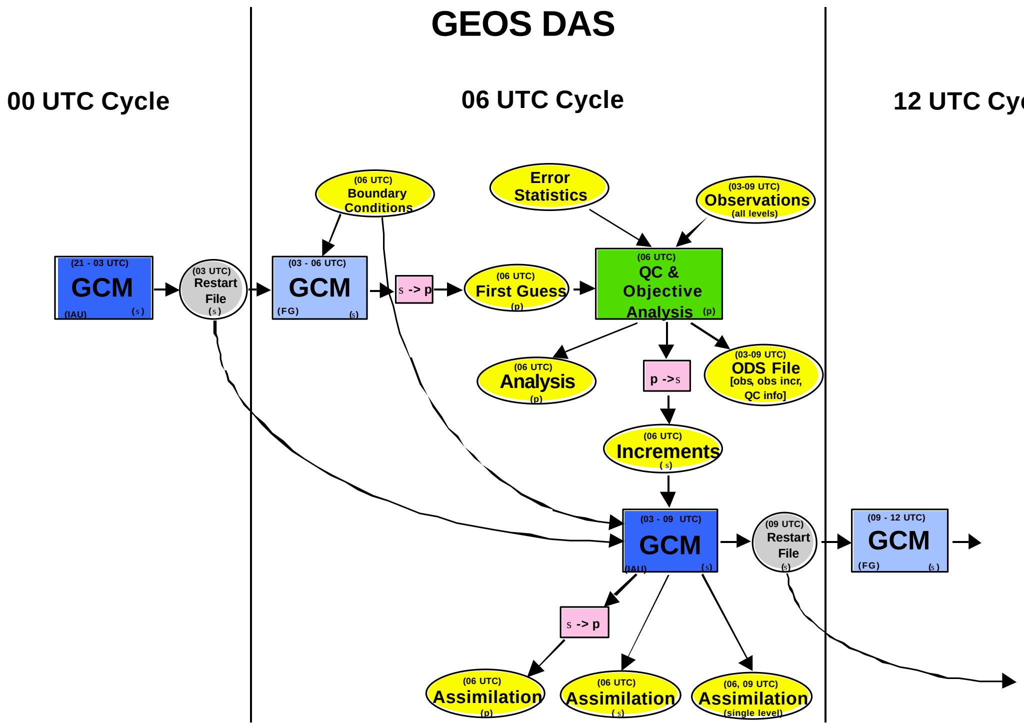
1 INTRODUCTION

This document describes the gridded output files from the version of the Goddard EOS Data Assimilation System (GEOS-Terra) which will support level-4 product generation at the time of EOS Terra launch. The intended audience is EOS instrument teams and other users of GEOS-TERRA products who will need to write software to read DAO products. The gridded data described in this document will be produced by the GEOS- Terra and a selection of the products will be available from the EOS Core System (ECS) commencing with the Terra launch in July 1999. Two production suites will run for each daily time period, the first-look assimilation and the late-look assimilation (see Appendix A for definitions). Due to performance issues, a limited set of products will be generated by the first-look assimilation while the full set will be generated by the late-look assimilation. The product descriptions in Section 6 will identify which products are generated by each run.



This figure depicts a typical 6-hour data assimilation cycle. The ovals represent data sets and the rectangles processes. The small pink rectangles represent vertical coordinate shifts between standard pressure and model sigma levels. The cycle begins with the General Circulation Model (*GCM*) (light blue rectangle) creating a *first guess*, or 3-hour forecast, using a *restart file* from the previous cycle and *boundary conditions* (sea surface temperature, terrain, etc.). Then, using *error statistics* and *observations* collected over the 6-hour window, the *QC and Objective Analysis* create corrections to the first guess. Information about the observation quality and deviation from the first guess are saved in the *ODS file*. Most assimilation systems apply the gridded corrections directly to the first guess to produce the *analysis*. In the GEOS DAS, however, an additional step is taken; the gridded corrections, or *increments*, are gradually inserted back into another integration of the *GCM* (dark blue rectangle). This is referred to as the incremental analysis update (IAU). Through the IAU process, *assimilation* data sets are put out every 6 hours on standard pressure (p) and model sigma (_) and every 3 hours for surface and vertically integrated fields (single level).

Figure 1-1. Typical 6-hour Data Assimilation Cycle

2 FORMAT AND FILE ORGANIZATION

GEOS- Terra files will use 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- Terra 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 lat/lon grid and some files will contain 3-D variables on the same lat/lon grid but with the addition of a vertical dimension. All files will also have a time dimension with the number of times in each file dependent on the file type (see Section 6). GEOS- Terra products always contain one complete day of data.

The variables are created using the **GDdeffield** function from the HDF-EOS GD 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 COARDS conventions .

ECS metadata and other information will be stored as global attributes.

2.1 DIMENSIONS

DAO 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 contain an attribute named "units" with the value of an appropriate string defined by the COARDS conventions that can be used by an application to identify the dimension. The other set of dimensions 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 DAO 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	float32	millibar
TIME:EOSGRID	minutes since first time in file	float32	minutes since YYYY-MM-DD HH:MM:SS
XDim	longitude values	float64	N/A
YDim	latitude values	float64	N/A
Height (3D only)	pressure levels	float64	N/A
Time	seconds since 1/1/93	float64	N/A

The first four dimension variables have a "units" attribute that makes them COARDS-compliant, while the last four dimension variables satisfy ECS conventions.

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* . The latter utility is distributed from NCSA with the HDF library. A sample scan of one DAO HDF-EOS file is shown below:

```
unix% hdp dumpsds -h
DAS.flk.asm.tsyn3d_mis_p.AM100.1999052800.1999052818.V01 | grep Variable


Variable Name = UWND
Variable Name = VWND
Variable Name = HGHT
Variable Name = TMPU
Variable Name = SPHU
Variable Name = TKE
Variable Name = RH
Variable Name = OMEGA
Dimension Variable Name = XDim:EOSGRID
Dimension Variable Name = YDim:EOSGRID
Dimension Variable Name = Height:EOSGRID
Dimension Variable Name = TIME:EOSGRID
Variable Name = XDim
Variable Name = YDim
Variable Name = Height
Variable Name = Time
```

In Section 9 we will present sample code for reading one or more data fields from this file. The short names for all variables in all DAO data products are listed in the File Collections chapter, Section 6.

Each variable will have attributes that may be useful to some users. Many of these attributes are required by the COARDS conventions while others are for internal DAO use. A listing of attributes that are always present follows:

- _FillValue (Type = 32-bit floating point or 16-bit signed integer)
  Any missing data will be filled with this value. This attribute is generated automatically by the HDF-EOS library. It will be of the same data type as the variable, thus could be 16-bit integer if the variable is packed.
- long_name (Type = 8-bit signed char)
  Long name or description for this variable.
- units (Type = 8-bit signed char)
  The units of the geophysical variable (ud-units compliant).
- scale_factor (Type = 32-bit floating point)
  If this variable is packed into 16-bit integers, this value would be multiplied to each data value to obtain the floating point number.

- add_offset (Type = 32-bit floating point)
  For a packed variable, add this number after multiplying by the scale_factor.
- missing_value (Type = 32-bit floating point or 16-bit signed integer)
  For an unpacked variable, this is a floating-point representation of the fill value. For a packed variable, this is an integer representation of the fill value.
- fmissing_value (Type = 32-bit floating point)
  Always a floating-point representation of the fill value.
- vmin (Type = 32-bit floating point)
  For internal DAO use.
- vmax (Type = 32-bit floating point)
  For internal DAO use.

Since we are not planning to pack the products intended for use by EOS instrument teams, attributes that support packing can be ignored. There may be other attributes that are meant for internal DAO use that can also be ignored.

2.3 GLOBAL ATTRIBUTES

In addition to SDS arrays containing variables and dimension scales, there is a large amount of metadata stored in DAO HDF-EOS files. Some of this metadata is required by the COARDS conventions, some is present due to ECS requirements, and some may exist as a convenience to internal DAO users. A summary of global attributes that will exist in all DAO files follows:

- HDFEOSVersion - Version of the HDF-EOS library used to create this file.
- StructMetadata.0 - This is the GridStructure metadata that is created by the HDF-EOS library.
- CoreMetadata.0 - The ECS inventory metadata.
- ArchivedMetadata.0 - The ECS archive metadata.
- Conventions - Should always be set to "COARDS".
- Source - NASA Data Assimilation Office, GEOS-DAS Version.
- Contact - Where to send questions.
- History - Version of DAS output library.

3 SYNOPTIC VS TIME AVERAGED PRODUCTS

GEOS-Terra gridded output files are identified as either Synoptic or Time-averaged products. Synoptic products are defined in Section 6.2 while Time-averaged products are defined in Section 6.3. Additional Synoptic products associated with the ozone assimilation are defined in Section 6.4. All Synoptic products contain fields which are snapshots taken at a specific time. Time-averaged products are averaged over a 3 hour period for single level files or a 6 hour period for pressure level files. Single level products contain 8 times, with time stamps ranging from 00 GMT to 21 GMT. Each time represents an average of the previous three hours (upstream time average). It follows that the first time in each file (time stamped with 00 GMT) represents and average between 21 GMT of the previous day and 00 GMT of the current day. Time-averaged pressure level products contain 4 times with time stamps ranging from 00 GMT to 18 GMT. Each time represents an average of the 6 hour period centered on the output time. It follows that the first time in the file (time stamped with 00 GMT) represents an average between 21 GMT of the previous day and 03 GMT of the current day.

4 GRID STRUCTURE

Most GEOS-Terra gridded output will be on a 1x1 degree global latitude-longitude horizontal grid (see Figure 4-1). Products from the DAO ozone assimilation (DFLAXCHM, DFLAPCHM, DLLAXCHM, DLLAPCHM) will be on a 2 x 2.5 degree latitude-longitude horizontal grid. The vertical structure of gridded products will have 2 different configurations: single-level (can be vertical averages) or pressure levels. Single level data for a given variable appear as 3-dimensional fields (x,y,time) while pressure level data appear as 4-dimensional fields (x,y,z,time). Pressure level data will be output on 36 pressure levels (hPa), except for DFLAPCHM and DLLAPCHM which will have 42 pressure levels (see Appendix C). The appropriate grid structure will be specified both in the filename and the metadata.

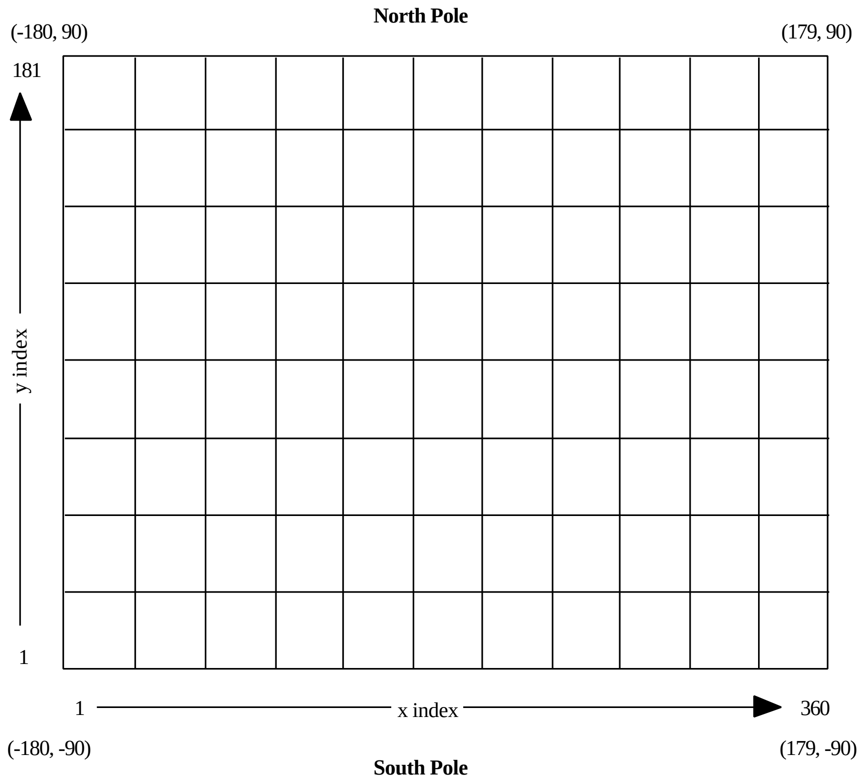


Figure 4-1. GEOS-Terra 2D Grid Structure.

This figure shows the structure of the 1 x 1 GEOS-Terra 2-dimensional grids. The origin of the grid is at the lower left-hand corner at -180 degrees longitude and -90 degrees latitude. Values in the data arrays represent values at the grid point.

Latitude or longitude as a function of the index can be determined by:

$$lon = -180 + (x-1) * dx$$
$$lat = -90 + (y-1) * dy$$

where dx = 1.0, dy = 1.0 except in the case of ozone products where dx = 2.5, dy = 2.0.

5 FILE NAMING CONVENTION

Each GEOS-Terra 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 COMPLETE FILE NAME

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

DAS.config.mode.filetype.expid.yyyymmddhh.yyyymmddhh.version

A brief description of the node fields appear below:

DAS:

Identifies output as a Data Assimilation System product.

config:
GEOS-Terra will run in two different configurations. Appendix A describes these configurations. These are the strings which can appear in the config field.

flk - First Look
llk - Late Look

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

asm - Assimilation. Uses the IAU process (initialized) to combine the general circulation model with observation-based analysis increments (see Fig 1).

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

type/dimension_group_level

type/dimension:

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

tsyn2d - 2-dimensional instantaneous fields at synoptic times (no time averaging).
tsyn3d - 3-dimensional instantaneous fields at synoptic times (no time averaging).

tavg2d - 2-dimensional 3-hour upstream time averaged fields. For example, 6z output would be a 3z-6z time average).

tavg3d - 3-dimensional 6-hour time averaged fields where the average is centered on the 6-hour synoptic time (e.g. 0z, 6z, 12z, 18z). For example, 6z output would be a 3z-9z time average.

group (for files which contain 2-dimensional fields):

str: stress related fields
eng: energy related fields
cld: cloud related fields
lsm: land surface model related fields
chm: chemical related fields (e.g. ozone)
mis: mixture of prognostic and diagnostic fields

group (for files which contain 3-dimensional fields):

mis: mixture of prognostic and diagnostic fields
mom: momentum profile fields
tmp: temperature profile fields
mst: moisture profile fields
cld: cloud profile related fields
trp: transport profile fields (e.g. eddy diffusivity)
chm: chemical profile fields

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

x: single level data (surface, column integrated, single level)
p: pressure level data (see Appendix D for pressure levels)

expid:
Experiment Identification. The Terra GEOS DAS data sets will be numbered:

AM1# #

where # # begins at 00 for the test data produced prior to the launch of the Terra satellite. The data produced by the GEOS DAS after launch will be numbered with the AM101 experiment identification. Any changes to the GEOS DAS due to improvements or corrections after the launch will subsequently increase the ## sequentially. Thus all configurations which use identical versions of the GEOS DAS will have the same expid.

yyyymmddhh.yyyymmddhh:

This group defines the valid beginning date and synoptic time as well as the valid ending date and synoptic time of the fields from the assimilation. The first date and time refer to the beginning date and time while the second date and time refer to the ending date and time.

yyyy - year string (e.g. "1997")
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 - time (synoptic hour, e.g. "18" for 18:00 Greenwich Mean Time)

version:
This group 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".

EXAMPLE:

DAS.flk.asm.tavg3d_mom_p.AM100.1997061500.1997061518.V01

This example defines a Data Assimilation System file. It is a first look assimilation configuration product. The data are 6-hour time averaged output on pressure levels in 3 dimensions. The filetype consists of momentum fields. The experiment is numbered 'AM100' indicating these data to be test data (see explanation of expid above). The valid beginning date and time of this dataset is Jun 15, 1997 at 00Z. The valid ending date and time of this dataset is June 15, 1997 at 18Z.

5.2 EARTH SCIENCE DATA TYPES (ESDT) OR ABBREVIATED INDEXING

To accomodate EOSDIS toolkit requirements, GEOS-Terra complete filenames are associated to 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-Terra gridded ESDTs. The standard ESDT naming convention for the GEOS-Terra gridded output will have the form:

DGGMVCCC

D: DAS identifier. Always "D"

GG: Product

FL = First Look
LL = Late Look

M: Mode

A = Assimilation
F = Forecast
N = Analysis

V: Vertical Coordinate:

X = Single-Level
P = Pressure

CCC: Filetype

MIS = misc
ENG = energy
LSM = land surface model
STR = stress
CHM = chemical
CLD = cloud
MOM = momentum
MST = moisture
TMP = temperature
TRP = transport fields

Example:

Abbreviated Name: DFLAPMOM

Complete Name: DAS.flk.asm.tavg3d_mom_p.AM100.1997091500.1997091518.V01

6 FILE COLLECTIONS

The contents of the Data Assimilation System file collections are described in sections 6.2, 6.3 and 6.4 while the sizes of each file are discussed in Section 6.1.

6.1 FILE SIZES

With the exception of chm products, the file sizes listed below reflect the GEOS-Terrra file sizes for 1 day of data on a 1 degree x 1 degree lat-lon grid using 32-bit storage for the assimilation mode only. Chm products are stored on a 2 degree by 2.5 degreee lat-lon grid. See Appendix C for details about vertical levels. File sizes are approximate as they do not include the space used by metadata.

The file sizes for the First-look Assimilation Mode are:

Filetype Group	Single Level (MB/day) (360,181,1) 8X/day	Pressure Levels (MB/day) (360,181,36) 4X/day
mis	45.9 (DFLAXMIS)	300.3 (DFLAPMIS)
eng	58.4 (DFLAXENG)	N/A
lsm	25.0 (DFLAXLSM)	N/A
str	33.4 (DFLAXSTR)	N/A
chm	0.4 (DFLAXCHM) *	8.8 (DFLAPCHM) **
cld	29.2 (DFLAXCLD)	Not produced
mom	N/A	Not produced
mst	N/A	Not produced
tmp	N/A	Not produced
trp	N/A	Not produced
Totals	200.6	309.1

The file sizes for the Late-look Assimilation Mode are:

Filetype Group	Single Level (MB/day) (360,181,1) 8X/day	Pressure Levels (MB/day) (360,181,36) 4X/day
mis	45.9 (DLLAXMIS)	300.3 (DLLAPMIS)
eng	66.7 (DLLAXENG)	N/A
lsm	25.0 (DLLAXLSM)	N/A
str	33.4 (DLLAXSTR)	N/A
chm	0.4 (DLLAXCHM) *	8.8 (DLLAPCHM) **
cld	29.2 (DLLAXCLD)	112.6 (DLLAPCLD)
mom	N/A	375.3 (DLLAPMOM)
mst	N/A	225.2 (DLLAPMST)
tmp	N/A	412.9 (DLLAPTMP)
trp	N/A	150.1 (DLLAPTRP)
Totals	200.6	1547.6

* = (144, 91, 1) ** = (144, 91, 42)

6.2 ASSIMILATED SYNOPTIC FILES

Below are the variables which are output into each syn 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 x F = bytes/day

where:

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

The method for calculating sizes is the same in 6.2, 6.3, and 6.4.

NOTE: All HDF variable names are UPPERCASE.

tsyn2d_mis_x (nominally 8 times per day)

ESDTs: DFLAXMIS, DLLAXMIS

360 x 181 x 1 x 22 x 8 x 4 = 45.9 MB/day

PHIS	Surface Geopotential Height (m/s)^2
ALBEDO	Surface Albedo (0-1)
PS	Surface Pressure (hPa)
SLP	Sea Level Pressure (hPa)
SURFTYPE	Surface Types
VAVEU	Vertically Averaged Zonal Wind (m/s)
VAVEV	Vertically Averaged Meridional Wind (m/s)
VAVET	Vertically Averaged Temperature (K)
TPW	Total Precipitable Water (g/cm^2)
GWET	Soil Moisture (percent of field capacity)
SNOW	Snow Depth (mm water equivalent)
TGROUND	Ground temperature, skin temperature of the surface [SST over water] (K)
T2M	Temperature Interpolated to 2 meters (K)
T10M	Temperature Interpolated to 10 meters (K)
Q2M	Specific Humidity Interpolated to 2 meters (g/kg)
Q10M	Specific Humidity Interpolated to 10 meters (g/kg)
U2M	Zonal Wind Interpolated to 2 meters (m/s)
V2M	Meridional Wind Interpolated to 2 meters (m/s)
U10M	Zonal Wind Interpolated to 10 meters (m/s)
V10M	Meridional Wind Interpolated to 10 meters (m/s)
TROPP	Tropopause Pressure (hPa)
TROPT	Tropopause Temperature(K)

tsyn3d_mis_p (nominally 4 times per day)

ESDTs: DFLAPMIS, DLLAPMIS

360 x 181 x 36 x 8 x 4 x 4 = 300.3 MB/day

UWND	Zonal Wind (m/s)
VWND	Meridional Wind (m/s)
HGHT	Geopotential Height (Virtual) (m)
TMPU	Temperature (K)
SPHU	Specific Humidity (g/kg)
TKE	Turbulent Kinetic Energy (m/s)^2
RH	Relative Humidity (%)
OMEGA	Vertical Velocity (hPa/day)

6.3 ASSIMILATED TIME AVERAGED FILES

Below are the variables which 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_eng_x (nominally 8 times per day)

ESDTs: DFLAXENG, DLLAXENG

360 x 181 x 1 x 28 x 8 x 4 = 58.4 MB/day

PREACC	Total Precipitation (mm/day)
PRECON	Convective Precipitation (mm/day)
EVAP	Surface Evaporation (mm/day)
HFLUX	Sensible Heat Flux (pos. upward)(W/m^2)
QICE	Heat conduction through Sea-Ice (W/m^2)
CT	Surface Drag Coefficient for Scalars (m/s)
TGROUND	Ground temperature, skin temperature of the surface (SST over water)(K)
T2M	Temperature Interpolated to 2 Meters (K)
T10M	Temperature Interpolated to 10 Meters (K)
Q2M	Specific Humidity Interpolated to 2 Meters (g/kg)
Q10M	Specific Humidity Interpolated to 10 Meters (g/kg)
RADLWG	Net Upward Longwave Flux at the Ground (W/m^2)
RADSWG	Net Downward Shortwave Flux at the Ground (W/m^2)
ALBEDO	Surface Albedo (0-1)
ALBVISDR	Direct Beam VIS Surface Albedo (0-1)
ALBVISDF	Diffuse Beam VIS Surface Albedo (0-1)
ALBNIRDR	Direct Beam NIR Surface Albedo (0-1)
ALBNIRDF	Diffuse Beam NIR Surface Albedo (0-1)
LWGCLR	Clear Sky Net Longwave Flux at the Ground (W/m^2)

SWGCLR	Clear Sky Net Downward Shortwave Radiation at the Ground (W/m^2)
VAVEUQ	Vertically Averaged UWND*SPHU (m-g/s-kg)
VAVEVQ	Vertically Averaged VWND*SPHU (m-g/s-kg)
VAVEUT	Vertically Averaged UWND*TMPU (m-K/s)
VAVEVT	Vertically Averaged VWND*TMPU (m-K/s)
TPW	Total Precipitable Water (g/cm^2)
VAVEQIAU	Vertically Averaged QIAU (mm/day)
VAVEQFIL	Vertically Averaged QFILL (mm/day)
VAVETIAU	Vertically averaged TIAU (K/day)

tavg2d_lsm_x (nominally 8 times per day)

ESDTs: DFLAXLSM, DLLAXLSM

360 x 181 x 1 x 12 x 8 x 4 = 25.0 MB/day

RAINCON	Convective rainfall (liquid precipitate) (mm/day)
SNOWFALL	Total snowfall (solid precipitate) (mm/day)
RAINLSP	Large-scale Rainfall (liquid precipitate) (mm/day)
LWGDOWN	Downward Longwave Radiation at the Ground (W/m^2)
LWGUP	Upward Longwave Radiation at the Ground (W/m^2)
PARDF	Diffuse-beam Photosynthetically Active Radiation (W/m^2)
PARDR	Direct-beam Photoshynthetically Active Radiation (W/m^2)
LAI	Leaf Area Index (%)
GREEN	Green-ness Index (%)
DLWDTC	Derivative of LW Radiation wrt TGROUND (W/m^2 /degK)
DTG	Total Change in Ground Temperature (K/s)
SNOW	Snow Depth (mm water equivalent)

tavg2d_str_x (nominally 8 times per day)

ESDTs; DFLAXSTR, DLLAXSTR

360 x 181 x 1 x 16 x 8 x 4 = 33.4 MB/day

PS	Time Averaged Surface Pressure (hPa)
UFLUX	Zonal Wind Surface Stress (N/m^2)
VFLUX	Meridional Wind Surface Stress (N/m^2)
GWDUS	Zonal Wind Gravity Wave Surface Stress (N/m^2)
GWDVS	Meridional Wind Gravity Wave Surface Stress (N/m^2)
GWDUT	Zonal Wind Gravity Wave Stress at Model Top (N/m^2)
GWDVT	Meridional Wind Gravity Wave Stress at Model Top (N/m^2)
CU	Surface Drag Coefficient for Winds (non-dimensional)
USTAR	Friction Velocity (m/s)
Z0	Surface Roughness (m)
PBL	Estimated PBL Depth (hPa)

U2M	Zonal Wind Interpolated to 2 Meters (m/s)
V2M	Meridional Wind Interpolated to 2 Meters (m/s)
U10M	Zonal Wind Interpolated to 10 Meters (m/s)
V10M	Meridional Wind Interpolated to 10 Meters (m/s)
PIAU	Surface Pressure Tendency due to Analysis (hPa/day)

tavg2d_cld_x (nominally 8 times per day)

ESDTs: DFLAXCLD, DLLAXCLD

360 x 181 x 1 x 14 x 8 x 4 = 29.2 MB/day

OLR	Outgoing Longwave Radiation (W/m^2)
OLRCLR	Clear Sky Outgoing Longwave Radiation (W/m^2)
RADSWT	Incident Shortwave Radiation at TOA (W/m^2)
OSR	Outgoing Shortwave Radiation (W/m^2)
OSRCLR	Clear Sky Outgoing Shortwave Radiation (W/m^2)
CLDFRC	2-D Total Cloud Fraction (0-1)
TAULOW	Low-Level (1000-700 hPa) Optical Depth
TAUMID	Mid-Level (700-400 hPa) Optical Depth
TAUHI	High-Level (above 400 hPa) Optical Depth
CLDLOW	Low-Level (1000-700 hPa) Cloud Fraction (0-1)
CLDMID	Mid-Level (700-400 hPa) Cloud Fraction (0-1)
CLDHI	High-Level (above 400 mb) Cloud Fraction (0-1)
CLDTMP	Cloud Top Temperature (when cloudy)(K)
CLDPRS	Cloud Top Pressure (when cloudy) (hPa)

tavg3d_cld_p (nominally 4 times per day)

ESDT: DLLAPCLD

360 x 181 x 36 x 3 x 4 x 4 = 112.6 MB/day

TAUCLD	Cloud Optical Depth (non-dimensional)
CLDTOT	3-D Total Cloud Fraction (0-1)
CLDRAS	Convective Cloud Fraction (0-1)

tavg3d_mom_p (nominally 4 times per day)

ESDT: DLLAPMOM

360 x 181 x 36 x 10 x 4 x 4 = 375.3 MB/day

TURBU	Zonal Wind Tendency due to Turbulence (m/s/day)
TURBV	Meridional Wind Tendency due to Turbulence (m/s/day)
GWDU	Zonal Wind Tendency due to Gravity Wave Drag (m/s/day)

GWDV	Meridional Wind Tendency due to Gravity Wave Drag (m/s/day)
RFU	Zonal Wind Tendency due to Rayleigh Friction (m/s/day)
RFV	Meridional Wind Tendency due to Rayleigh Friction (m/s/day)
UIAU	Zonal Wind Tendency due to Analysis (m/s/day)
VIAU	Meridional Wind Tendency due to Analysis (m/s/day)
DUDT	Total Zonal Wind Tendency (m/sec/day)
DVDT	Total Meridional Wind Tendency (m/sec/day)

tavg3d_mst_p (nominally 4 times per day)

ESDT: DLLAPMST

360 x 181 x 36 x 6 x 4 x 4 = 225.2 MB/day

TURBQ	Specific Humidity Tendency due to Turbulence (g/kg/day)
MOISTQ	Specific Humidity Tendency due to Moist Processes (g/kg/day)
DQLS	Specific Humidity Tendency due to Stratiform Processes (g/kg/day)
QIAU	Specific Humidity Tendency due to Analysis (g/kg/day)
QFILL	Filling of Negative Specific Humidity (g/kg/day)
DQDT	Total Specific Humidity Tendency (g/kg/day)

tavg3d_tmp_p (nominally 4 times per day)

ESDT: DLLAPTMP

360 x 181 x 36 x 11 x 4 x 4 = 412.9 MB/day

TURBT	Temperature Tendency due to Turbulence (K/day)
MOISTT	Temperature Tendency due to Moist Processes (K/day)
DTLS	Temperature Tendency due to Stratiform Processes (K/day)
RADLW	Temperature Tendency due to Longwave Radiation (K/day)
RADSW	Temperature Tendency due to Shortwave Radiation (K/day)
RFT	Temperature Tendency due to Rayleigh Friction (K/day)
GWDT	Temperature Tendency due to Gravity Wave Drag (K/day)
TIAU	Temperature Tendency due to Analysis (K/day)
DTDT	Total Temperature Tendency (K/day)
LWCLR	Clear Sky Longwave Radiation Heating Rates (K/day)
SWCLR	Clear Sky Shortwave Heating Rates (K/day)

tavg3d_trp_p (nominally 4 times per day)

ESDT: DLLAPTRP

360 x 181 x 36 x 4 x 4 x 4 = 150.1 MB/day

KH	Eddy Diffusivity Coefficient for Scalars (m^2/s)

KM	Eddy Diffusivity Coefficient for Momentum (m^2/s)
CLDMAS	Cloud Mass Flux (kg/m^2)
DTRAIN	Detrainment Cloud Mass Flux (kg/m^2)

6.4 ASSIMILATED CHEMISTRY FILES

The following variables are generated by the DAO Ozone Assimilation System. These are instantaneous fields (no time averaging). These products are produced from an offline (OL) ozone assimilation (reference TBD) which uses the wind data from the DAS as input. The ozone assimilation operates at a coarser resolution than the DAS, thus these products have horizontal resolution of 2 x 2.5 degrees. In addition, the vertical structure of the 3-D ozone products is different than other 3-D DAS products. See Appendix C for details.

The ozone mixing ratio fields in the tavg3d_chm_p product at the following levels: 1000, 975, 950, 925, 900, and 875 hPa are provided at the request of users. The ozone values provided at these levels are identical to the values at 850 hPa. Ozone data are assimilated between 850 and 0.2 hPa. No geophysical significant should be attributed to the 1000, 975, 950, 915, 900, and 875 hPa levels.

tsyn2d_chm_x (nominally 8 times per day)

144 x 91 x 1 x 1 x 8 x 4 = 0.4 MB/day

ESDTs: DFLAXCHM, DLLAXCHM

OZONE	Total Ozone (DU)

tsyn3d_chm_p (nominally 4 times per day)

144 x 91 x 42 x 1 x 4 x 4 = 8.8 MB/day

ESDTs: DFLAPCHM, DLLAPCHM

OZONE	Ozone mixing ratio (ppmv)

7 METADATA

GEOS-Terra gridded output files will be associated with two types of metadata. Depending on the utility you use to access the file, one set of metadata will be read and the other ignored.

7.1 EOSDIS METADATA

If you are using the EOSDIS toolkit you 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 is like a library card catalog. Each ESDT has a "card" 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:

a) file name (local granule ID)

b) grid structure

c) number of times per day fields are stored in this file

d) number of vertical levels for each variable in this file

e) names of variables in this file

f) variable format (32-bit floating point, 16-bit integer, etc.)

g) 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

a) "missing" value for each variable

b) unpacking scale factor for each packed variable (see section 8)

c) unpacking off-set value for each packed variable (see section 8)

7.2 COARDS METADATA

If you use GRADS or FERRET to view GEOS-Terra gridded data sets you will only use the COARDS metadata. These metadata will comply with the COARDS convention and include the following information:

a) space-time grid information (dimension variables)

b) variable long names (descriptions)

c) variable units

d) "missing" value for each variable

e) unpacking scale factor for each packed variable (see section 8)

f) unpacking off-set value for each packed variable (see section 8)

8 PACKING

The data format used by the DAO supports storage of gridded output fields in 16-bit integers by packing 32-bit floating point data using a simple linear mapping algorithm. While some output fields from GEOS-Terra could be stored in packed format without significant loss of accuracy, we do not plan to pack our standard products that are archived at ECS and used by instrument teams. We may pack data that is archived internal to the DAO. For users, who might at some time have a need to read packed data from a DAO product, the method for unpacking fields is presented here. Further information can be obtained from the COARDS documentation (see references).

The two important parameters for reading a packed field (stored as an SDS) are the scale_factor and add_offset attributes. These attributes are attached to every field. If the field is unpacked, scale_factor=1 and add_offset=0. The HDF call **SDreadattr** can be used to read these attributes. Once an application reads the 16-bit packed data values, the scale_factor attribute, and the add_offset attribute, it can unpack the data into 32-bit floating point numbers.

For each 16-bit integer value in the packed field array:

32-bit float = (16-bit int)*scale_factor + add_offset

9 SAMPLE SOFTWARE

Presented here is software that illustrates using the standard HDF library or the ECS HDF-EOS library to read GEOS-Terra 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 anonymous-ftp directory:

ftp://dao.gsfc.nasa.gov/pub/assimilation/AM-1/format.

```
/****************************************************************************/
/* This program demonstrates how to read a field from a DAO 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@dao.gsfc.nasa.gov      */
/*                                                      2/12/1999            */
/****************************************************************************/

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

#define XDIM 360
#define YDIM 181
#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 DAO 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 DAO 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@dao.gsfc.nasa.gov              */
/*                                               2/12/1999                  */
/***************************************************************************/

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

#define XDIM 360
#define YDIM 181
#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

Figure 1-1 depicts the basic GEOS DAS configuration and its products. This configuration can be modified to satisfy a variety of scientific needs. Described below are the configurations that could be used to satisfy specific EOS requirements. Only the first-look analysis and late-look analysis will be used to support EOS-Terra instrument teams.

First Look Assimilation. This is identical to the basic GEOS DAS configuration shown in Figure 1-1. The first look analysis will run 4 times/day, 6 to 10 hours after the 4 analysis times (0Z, 6Z, 12Z, 18Z). It will run using whatever conventional and satellite observations are available before the data cut-off time. Even though first-look will run as 4 distinct segments, the DAO will only distribute products that contain one complete day.

Late Look Assimilation. The software configuration is identical to the first look assimilation but, due to a delay of at least two weeks, a more complete set of input observations can be used. Unlike the first look analysis, the late look analysis will process one day at a time.

GCM Forecast/Simulation. This looks like the basic GEOS DAS except the objective analysis portion is turned off. The only outside data that enters the system are the boundary conditions such as sea surface temperature. This configuration is used to produce forecasts. It is also used to produce multi-year simulations to investigate the climatology of the GCM.

Final Platform Analysis. This is just like the basic configuration in Figure 1-1 except it adds new EOS observations. It is called a final "platform" analysis because it will be tailored to the observations from a given EOS platform such as Terra or CHEM.

Off-line Analysis. This uses information from the atmospheric data assimilation system (GEOS DAS) as input to another assimilation system. This input is assimilated with EOS and/or other observations to produce special off-line analysis products. An example of this is the current constituent assimilation effort that uses winds from the GEOS DAS to drive a tracer model for off-line ozone assimilation.

Pocket Analysis. Pocket analyses look just like the final platform analyses except selected instrument data are excluded from the assimilation. By excluding a given instrument type from the assimilation, its impact on the climatic signal of the overall system can be assessed. Pocket analyses are important to determine if certain short-lived instruments produce artificial climate signals within the GEOS DAS, and if so how these artificial signals might be reduced.

Reanalysis. Reanalyses will look exactly like the corresponding original analyses. For example, a platform reanalysis will be done just like a final platform analysis except that it covers a longer period with a fixed DAS version and observing system.

Appendix B
Collection Metadata

GEOS-Terra collection metadata will contain the following:

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 DAAC)

Storage Medium

Appendix C
Vertical Grid Structure

Pressure level data will be output on the following 36 pressure levels for all 3-D products except chemistry:

Level	Pressure (hPa)	Level	Pressure (hPa)	Level	Pressure (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

Due to the scientific characteristics of the ozone assimilation, 3-D chemistry products (DFLAPCHM, DLLAPCHM) will have a different set of pressure levels:

Level	Pressure (hPa)	Level	Pressure (hPa)	Level	Pressure (hPa)
1	1000	15	500	29	50
2	975	16	450	30	40
3	950	17	400	31	30
4	925	18	350	32	25
5	900	19	300	33	20
6	875	20	250	34	15
7	850	21	200	35	10
8	825	22	170	36	7
9	800	23	150	37	5
10	750	24	130	38	3
11	700	25	115	39	2
12	650	26	100	40	1
13	600	27	85	41	0.4
14	550	28	70	42	0.2

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