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File Specification for GEOS-CF Products

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Code 610.1, NASA GSFC

REVISION HISTORY

Version Number	Revision Date	Extent of Changes
1.0	09/03/2019	Baseline

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1. Introduction

The NASA Global Earth Observing System (GEOS) model has been expanded to provide global near-real-time forecasts of atmospheric composition at a horizontal resolution of 0.25 degrees (about 25 km). This GEOS Composition Forecast (GEOS-CF) system combines the GEOS weather analysis and forecasting system with the state-of-the-science GEOS-Chem chemistry module (Bey et al., 2001; Keller et al., 2014; Long et al., 2015) to provide detailed chemical analysis of a wide range of air pollutants including ozone, carbon monoxide, nitrogen oxides, and fine particulate matter (PM2.5).

1.1 Gas-phase chemistry

The main chemistry scheme in the GEOS-CF system is GEOS-Chem version 12.0.1 (http://geos-chem.org). The model chemistry scheme includes detailed HO_x-NO_x-BrO_x-VOC-O_3 chemistry as originally described by Bey et al. (2001), with addition of halogen chemistry by Parrella et al. (2012) and Sherwen et al. (2016) plus updates to isoprene oxidation as described by Mao et al. (2013) and Marais et al. (2016). GEOS-Chem includes detailed stratospheric chemistry fully coupled with tropospheric chemistry through the Unified tropospheric-stratospheric Chemistry eXtension (UCX) as described in Eastham et al. (2014).

Photolysis rates are computed online by GEOS-Chem using the Fast-JX code (Bian and Prather, 2002) as implemented in GEOS-Chem by Mao et al. (2010) and Eastham et al. (2014). The gas-phase mechanism comprises of 250 chemical species and 725 reactions and is solved using the Kinetic Pre-Processor KPP Rosenbrock solver (Sandu and Sander, 2006).

1.2. Aerosol chemistry

GEOS-CF carries two independent aerosol schemes that are run in parallel:

Scheme 1 is the Goddard Chemistry, Aerosol, Radiation, and Transport (GOCART; Chin et al., 2002; Colarco et al., 2010) bulk aerosol module which is radiatively coupled with GEOS and therefore simulates the direct and semidirect effects of aerosols (Randles et al., 2017) on the atmosphere.

Scheme 2 is the GEOS-Chem aerosol mechanism, which simulates mass concentrations of all major aerosol components – dust, black carbon (BC), organic carbon, sea salt, sulfate, nitrate, and ammonium – and provides updates to secondary organic aerosol (SOA) chemistry (Marais et al., 2016). Sulfate-nitrate-ammonium thermodynamics are computed with the ISORROPIA II thermodynamic module (Fountoukis and Nenes, 2007), as implemented in GEOS-Chem by Pye et al. (2009). Cloudwater pH for in-cloud sulfate formation is as given by Alexander et al. (2012). HOBr has been added by Chen et al. (2017) as a S(IV) oxidant. In-cloud SO_2 oxidation by transition metals is as described by Alexander et al. (2009). The BC simulation is described in Wang et al. (2014). The computation of SOA follows the simplified Volatility Basis Set (VBS) scheme of Pye et al. (2010) and the aqueous-phase isoprene SOA scheme of Marais et al. (2016) coupled to the isoprene gas-phase chemistry mechanism. The dust simulation is described by Fairlie et al. (2007), with dust size distributions from Zhang et al. (2013). The sea salt aerosol simulation in GEOS-Chem is described by Jaeglé et al. (2011).

1.3 Emissions

All model emissions related to GEOS-Chem are handled through the NASA-Harvard emissions component, HEMCO (Keller et al., 2014). Anthropogenic emissions are monthly averages from HTAP v2.2 (Janssens-Maenhout et al., 2015) and RETRO (Schultz et al., 2008), broken down into hourly values using sector-specific day-of-week and diurnal scale factors (van der Gon et al., 2011). Annual gridded scale factors based on satellite data are applied to the emissions of CO (Oda et al., 2017) and SO_2 (Liu et al., 2018). The near-real time satellite-based emissions from the Quick Fire Emission Database (QFED v2.5; Darmenov and da Silva, 2015) are used for biomass burning sources, with 35% of the fire emissions emitted above the boundary layer, evenly between 3.5 and 5.5 km altitude (Fischer et al., 2014). Volcanic emissions of SO_2 are from Carn (2019), with 5% of the sulfate emitted as SO_4. There are several natural emission sources included in the model that dynamically respond to the meteorological environment: lightning NO_x emissions are described in Murray et al. (2012); soil sources for NO_x follow Hudman et al. (2012); biogenic emissions computed online using MEGAN v2.1 (Guenther et al., 2012); sea salt aerosols (Gong, 2003; Jaeglé et al., 2011); oceanic emissions of dimethyl sulfide, acetone, acetaldehyde (Johnson, 2010; Nightingale et al., 2000) and iodine (Carpenter et al., 2013); and soil dust emissions (Zender et al., 2003).

1.4 GEOS-CF Configuration

The GEOS-CF system runs, once each day, a one-day meteorological replay and a five-day forecast. The *meteorological replay* forces the GEOS atmospheric general circulation model to the analyzed meteorological fields from an assimilated GEOS product (Orbe et al., 2017). In this case, the GEOS-CF uses the GEOS Forward Processing for Instrument Teams (FP-IT) dataset (Lucchesi, 2015) and the meteorological replay is launched as soon as the GEOS FP-IT 12z forecast run completes. The meteorological replay is coupled to the GEOS-Chem chemistry module and the GOCART aerosol module, which provides the GEOS-CF forecast with the best possible initial conditions for the chemistry and meteorology. The GOCART aerosols are replayed to GEOS FP-IT GOCART aerosols, which were constrained by satellite observations of aerosol optical depth (Buchard et al., 2017). From GEOS model level 34 (i.e., above 65 hPa/19 km; from GEOS model level 37 was used for the period January 1, 2018 to July 31, 2019 12z) to the top of the atmosphere, the GEOS-Chem ozone is nudged towards the ozone field produced by GEOS FP which were constrained by assimilating satellite observations of ozone (Wargan et al., 2015). Currently, no other direct data assimilation of chemical constituents is performed within GEOS-CF.

Upon completion of the meteorological replay, a five-day free-running model forecast simulation is launched. Similar to other GEOS forecasting products, persisted sea ice concentrations, sea surface temperatures, and biomass burning emissions are used in the GEOS-CF five-day forecasts.

1.5 Spatial and temporal resolution

All fields are computed on a cubed-sphere c360 grid (approximate resolution of 25 km × 25 km) with 72 vertical model layers extending up to 0.01 hPa. The data collections are provided at ¼ degree horizontal resolution. This global grid has 1440 points in the longitudinal direction and 721 points in the latitudinal direction, corresponding to a resolution of 0.25° × 0.25°. Most collections provide model output from the lowest model layer, along with other two-dimensional (2-D) diagnostics. Two collections provide three-dimensional (3-D) model output interpolated onto 23 pressure levels. Model output is provided at 15-minute and 1-hour temporal resolution. More details on output time and grid are provided in Section 3 and Section 4, respectively.

1.6 File location

The GEOS-CF data are produced on the NCCS discover supercomputer and are available through the NCCS data portal (https://portal.nccs.nasa.gov/datashare/gmao/geos-cf). Data visualizations are available on the NASA GMAO FLUID web site (https://fluid.nccs.nasa.gov/cf/) and there are links from FLUID to the HTTPS download locations on the data portal. Additionally, clients such as the Grid Analysis and Display System (GrADS) can access data directly using the NCCS OpenDAP server (https://opendap.nccs.nasa.gov/dods/gmao/geos-cf).

2. Format and File Organization

GEOS-CF data files are provided in netCDF-4 format. Since netCDF-4 files are actually HDF-5 files that are structured in a special way, netCDF-4 files can also be read by HDF-5 tools. The data files are structured in the netCDF "classic" data model, which should allow source code written for this data model to read GEOS-CF files when compiled with the netCDF-4 and HDF-5 libraries. The data products use some of the CF ("Climate and Forecast") metadata conventions, primarily those inherited from the older COARDS conventions for NetCDF dealing with dimension scales. CF standard names for identifying parameters are not used in these data sets.

Due to the size of the GEOS-CF archive, most product collections are compressed with a GRIB-like method that is invisible to the user. This method does degrade the precision of the data, but every effort has been made to ensure that differences between the product and the original, non-degraded data are not scientifically meaningful. Once the precision has been degraded, the files are written using the standard (internal) Lempel-Ziv deflation available in netCDF-4.

GEOS-CF is run on a cube-sphere grid, but these native data are not distributed. Rather, upon output, it has been interpolated to the regular latitude-longitude grid discussed in this document. The interpolation includes two options, a conservative remapping (simply a binning routine) and a non-conservative bilinear interpolation. Most variable collections are transformed using the bilinear interpolation. The htf_inst_15mn_g1440x721_x1 collection is conservatively remapped. As a rule of thumb, only the data that have been conservatively remapped will balance to the highest precision.

2.1 Dimensions

Every GEOS-CF collection will contain variables that define the dimensions of longitude, latitude, and time. In the initial release of the GEOS-CF product, a selection of 2-D and 3-D collections are released; however, the 2-D collection may include an additional level dimension (see Section 4.2). Dimension variables 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.

Table 2.1-1. Dimension Variables Contained in GMAO NetCDF Files

Name	**Description**	**Type**	***units* attribute**
lon	Longitude	double	degrees_east
lat	Latitude	double	degrees_north
lev	Pressure, single layer index	double	hPa, or layer
time	minutes since first time in file	int	minutes

2.2 Variables

Variables are stored as HDF-5 dataset objects. GEOS-CF uses the "classic" netCDF data model and does not use any of the extensions supported by netCDF-4 and the underlying HDF-5 format. This allows applications written to read netCDF files to easily read variables without having to modify code. Variable names are listed in Section 6 along with the number and sizes of dimensions. One can quickly list the variables in the file by using common utilities such as *ncdump,* which is distributed with the netCDF-4 library. With the '-h' flag, this utility will display all information about the file and its contents, including metadata associated with each variable. A short description of the variable is provided in the *long_name* and *standard_name* metadata parameters. Please note that we do not guarantee that the value in the standard_name attribute will conform to the CF metadata conventions.

Each variable has several useful metadata attributes. Many of these attributes are required by the CF and COARDS conventions, while others are specific for GMAO products. The following table lists required attributes. Other attributes may be included for internal GMAO use and can be ignored.

Table 2.2-1 Metadata attributes associated with each SDS.

Name	Type	Description
_FillValue	32-bit float	Floating-point value used to identify missing data. Normally set to 1e15. Required by CF.
missing_value	32-bit float	Same as _FillValue. Required for COARDS backwards compatibility.
valid_range	32-bit float, array(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. These are set to -/+ _FillValue.
long_name	String	An ad hoc description of the variable as required by COARDS. It approximates the standard names as defined in an early version of CF conventions. The *Description* column from the tables of Section 6 is based on this name.
standard_name	Char String	Same as long_name
units	Char String	The units of the variable. Must be a string that can be recognized by UNIDATA's Udunits package.
scale_factor	32-bit float	If variable is packed as 16-bit integers, this is the scale_factor for expanding to floating-point. Currently data are not packed, thus value is 1.0.
add_offset	32-bit float	If variable is packed as 16-bit integers, this is the offset for expanding to floating-point. Currently, data are not packed, thus value is 0.0.

2.3 Global Attributes

In addition to HDF-5 dataset variables and dimension scales, global metadata is also stored in GMAO netCDF-4 files. Some metadata are required by the CF/COARDS conventions, some are present to meet ECS requirements, and others as a convenience to users of GMAO products. A summary of global attributes present in all GEOS-CF files is shown in Table 2.3-1.

Table 2.3-1 Global metadata attributes (type character) associated with each SDS.

Name	Description
History	Production/creation date of this file.
Comment	Includes but not limited to the Internal/original GMAO filename (for provenance).
Filename	Filename of this granule.
Conventions	Identification of the file convention used, currently "CF-1"
Institution	"NASA Global Modeling and Assimilation Office"
References	"https://gmao.gsfc.nasa.gov"
Format	"NetCDF-4/HDF-5"
SpatialCoverage	Global
VersionID	The GEOS-CF version
Temporal Range	The beginning and ending dates of GEOS-CF. The ending date is assumed but may change.
Shortname	Product short name (see Section 5.2)
RangeBeginningDate	Date corresponding to the first timestep in this file.
RangeBeginningTime	Time corresponding to the first timestep in this file.
RangeEndingDate	Date corresponding to the last timestep in this file.
RangeEndingTime	Time corresponding to the last timestep in this file.

Name	Description
GranuleID	Filename for this product.
ProductionDateTime	Production date & time of this granule.
LongName	Description of product type.
Title	"GEOS CF (Composition Forecast)"
SouthernmostLatitude	"-90.0"
NorthernmostLatitue	"90.0"
WesternmostLatitude	"-180.0"
EasternmostLatitude	"179.75"
LatitudeResolution	"0.25"
LongitudeResolution	"0.25"
DataResolution	Horizontal (and vertical resolution) of granule.
Source	Software version tag associated with GEOS-CF version.
Contact	"https://gmao.gsfc.nasa.gov"

3. Instantaneous vs Time-averaged Products

Each file collection listed in Section 6 contains either instantaneous or time-averaged products, but not both.

The initial release of the GEOS-CF products only contains 15-minute and 1-hour instantaneous collections and 1-hourly time-averaged collections. Each time-averaged collection consists of a continuous sequence of data averaged over the indicated interval and time stamped with the central time of the interval. For hourly data, for example, an average from 12 UTC to 13 UTC has a time stamp of 12:30 UTC.

4. Grid Structure

4.1 Horizontal Structure

In GEOS-CF, all fields will be produced on the same ¼ degree longitude by ¼ degree latitude grid. The GEOS-CF ***native grid*** is c360 on the cubed sphere. The gridded output is on a global horizontal grid, consisting of **IMn=1440** points in the longitudinal direction and **JMn=721** points in the latitudinal direction. The horizontal native grid origin, associated with variables indexed (i=1, j=1) represents a grid point located at (180°W, 90°S). Latitude (ϕ) and longitude (λ) of grid points as a function of their indices (i, j) can be determined by:

$$\lambda_i = -180 + (\Delta\lambda)_n(i-1), \quad i = 1,\text{IMn}$$
$$\phi_j = -90 + (\Delta\phi)_n(j-1), \quad j = 1,\text{JMn}$$

Where $(\Delta\lambda)_n$=1/4° and $(Dj)_n$ = 1/4°.

4.2 Vertical Structure

The GEOS model layers used for the GEOS-CF are on a terrain-following hybrid sigma-p coordinate with 72 model layers (Table 4.1). Gridded products use four different vertical configurations: Horizontal-only (can be vertical averages, single level, or surface values), pressure-level, model-level, or model-edge. Horizontal-only data for a given variable appear as 3-dimensional fields (x, y, time), while pressure-level, model-level, or model-edge data appear as 4-dimensional fields (x, y, z, time). At this time, only 2-D fields and 3-D fields on pressure-levels (Table 4.2) are made available. For the 2-D fields, these include quantities from the lowest model layer (model level 72, Table 4.1, which is nominally 130 m in thickness, e.g. "surface" concentration of O_3), vertically integrated quantities (e.g., tropospheric O_3 column), and information with no vertical coordinate (e.g., Planetary Boundary Layer Height).

Table 4.1 Products on the native vertical grid are output on the following levels. Pressures are nominal for a 1000 hPa surface pressure and refer to the top edge of the layer. Note that the bottom layer has a nominal thickness of 15 hPa.

Lev	**P(hPa)**	**Lev**	**P(hPa)**	**Lev**	**P(hPa)**	**Lev**	**P(hPa)**	**Lev**	**P(hPa)**	**Lev**	**P(hPa)**
1	0.0100	13	0.6168	25	9.2929	37	78.5123	49	450.000	61	820.000
2	0.0200	14	0.7951	26	11.2769	38	92.3657	50	487.500	62	835.000
3	0.0327	15	1.0194	27	13.6434	39	108.663	51	525.000	63	850.000
4	0.0476	16	1.3005	28	16.4571	40	127.837	52	562.500	64	865.000
5	0.0660	17	1.6508	29	19.7916	41	150.393	53	600.000	65	880.000
6	0.0893	18	2.0850	30	23.7304	42	176.930	54	637.500	66	895.000
7	0.1197	19	2.6202	31	28.3678	43	208.152	55	675.000	67	910.000
8	0.1595	20	3.2764	32	33.8100	44	244.875	56	700.000	68	925.000

9	0.2113	21	4.0766	33	40.1754	45	288.083	57	725.000	69	940.000
10	0.2785	22	5.0468	34	47.6439	46	337.500	58	750.000	70	955.000
11	0.3650	23	6.2168	35	56.3879	47	375.000	59	775.000	71	970.000
12	0.4758	24	7.6198	36	66.6034	48	412.500	60	800.000	72	985.000

Table 4.2 Pressure-level data is output on the following 23 pressure levels:

Level	**P(hPa)**	**Level**	**P(hPa)**	**Level**	**P(hPa)**	**Level**	**P(hPa)**	**Level**	**P(hPa)**	**Level**	**P(hPa)**
1	1000	5	900	9	700	13	500	17	300	21	100
2	975	6	850	10	650	14	450	18	250	22	50
3	950	7	800	11	600	15	400	19	200	23	10
4	925	8	750	12	550	16	350	20	150		

5. File Naming Conventions

The filename of each GEOS product will be stored in the metadata parameter GranuleID (Table 2.3-1). Each product also has a "Shortname" (maximum 30 characters) which is specified in the metadata and is often called an Earth Science Data Type (ESDT). In GEOS-CF each file collection has a unique ESDT index. The ESDT index convention is described in Section 5.2.

5.1 File Names

The standard full name for the GEOS-CF products will consist of five dot-delimited nodes:

runid.version.mode.collection.timestamp.nc4

The node fields, which vary from file to file, are defined as follows:

runid

All GEOS-CF files will begin with the runid = "GEOS-CF"

version

If there are major updates to either the GEOS model or the GEOS-Chem model, the version number will change, beginning with "v01"

mode

There are three possible options: "ana", "rpl" and "fcst", where ana stands for data assimilation analysis, rpl for meteorological replay, and fcst for forecast. At this time, "ana" is not used since there is no direct data assimilation of chemical constituents.

***collection*:**

All GEOS-CF data are organized into file *collections* that contain fields with common characteristics. These collections are used to make the data more accessible for specific purposes. Fields may appear in more than one collection. Collection names are of the form *grp_time_Ftt_hIxJ_vL*, where the five attributes are:

grp: A three-letter mnemonic for the type of fields in the collection. It is used also for the group designation in the ESDT name, as in the next section.

htf = high-temporal frequency

chm = chemistry fields

met = meteorology fields

xgc = extra GEOS-Chem chemistry fields

time: Either instantaneous **(inst)** or time-average (**tavg**)

Ftt: The frequency or averaging time interval, including the time unit tt:

mn = minutes

hr = hour

hIxJ: Grid domain and size of the grid

h is the horizontal grid domain. It can be global or regional:

g: Global

r: Subset of the global resolution

IxJ is the horizontal resolution in number of longitude points x number of latitude points.

vL: Vertical resolution, where

v can be:

p: Pressure levels

v: Native vertical grid

x: Single-level, where fields in the collection are not exclusively the lowest model layer (e.g. vertically-integrated quantities, quantities with no vertical coordinate).

L is the number of vertical levels in the collection.

timestamp:

This node defines the date and time associated with the data in the file. It has the form *yyyymmdd_hrmn* for either instantaneous or time-averaged daily files.

yyyy - year string (e.g., "2002")

mm - month string (e.g.., "09" for September)

dd - day of the month string

hr – hour (UTC indicated by the 'z')

mn – minute

The forecast files have two date nodes separated by a '+'. For forecast files, the final timestamp of the meteorological replay used to initialize the forecast is first (*yyyymmdd_hr+*) followed by the valid time for the forecasted data within the file (*yyyymmdd_hrmn*). A forecast time-series will contain numerous files with the same initial node while the second node progresses through the time-span of the forecast (5 days).

nc4:

All files are in NetCDF-4 format, thus the suffix ".nc4".

EXAMPLE 1:

GEOS-CF.v01.rpl.htf_inst_15mn_g1440x721_x1. 20190101_0015z.nc4

This is an example of a GEOS-CF replay filename ("GEOS-CF.v01.rpl"). The data are the high-temporal-frequency ("htf") instantaneous ("inst"), 15-minute ("15mn") global 1/4° ("g1440x721") product. This is a mix of single-level and surface level data ("x1"). The file is for a single timestamp ("20190101_0015z") and is in "nc4" format.

EXAMPLE 2:

GEOS-CF.v01.fcst.chm_tavg_1hr_g1440x721_v1. 20190309_12z+20190314_0730z.nc4

This is an example of a GEOS-CF forecast filename ("GEOS-CF.v01.fcst"). The data are chemical species ("chm") time-averaged ("tavg") for a 1-hour period ("1hr") at the global 1/4° horizontal resolution ("g1440x721") for a single model layer data ("v1"). This file is for a forecast for a single timestamp ("20190314_0730z") which was initialized from the 20190309_12z replay timestamp. The file is in "nc4" format.

5.2 Earth Science Data Types (ESDT) Name

To accommodate EOSDIS toolkit requirements, all GEOS-CF files are associated with a maximum of 30-character ESDT. The ESDT is designed for users to access sets of files. In GEOS-CF, the ESDT will be used to identify the *Mainstream collections* and consists of a compressed version of the collection name of the form:

IDVVMgrp_FttT_hIxJ_VL

where

ID: Reduced runid to "CF"

VV: Reduced version number to simply the number, e.g., "01" for v01

M: Mode

A = Analysis

R = Replay

F = Forecast

grp: Group

htf = high-temporal frequency

chm = chemistry fields

met = meteorology fields

xgc = extra GEOS-Chem chemistry fields

Ftt: The frequency or averaging interval, including the time unit tt:

mn = minutes

hr = hour

T: Time description

I = Instantaneous

T = Time-average

h: Grid

g = Global

r = subset region

IxJ: Horizontal resolution, number of longitude points x number of latitude points

V: Vertical resolution

P = Pressure levels

V = model layer center

X = Two-dimensional

L: Number of vertical levels or layers

EXAMPLE 1:

CF01Rhtf_15mnI_g1440x720_X1

This is an example of a GEOS-CF version 01 replay shortname ("CF01R") for the high temporal frequency diagnostics ("htf"). The data are 15-minute ("15mn") instantaneous ("I") on the global 1/4° ("g1440x721") resolution. This is a mix of single-level and lowest model layer data ("X1").

EXAMPLE 2:

CF01Fchm_1hrT_g1440x721_V1

This is an example of a GEOS-CF version 01 forecast shortname ("CF01F") for chemistry fields ("chm"). The data are 1-hourly time-averaged ("1hrT") at the global 1/4° horizontal resolution ("g1440x721") for a single model layer ("v1").

6. GEOS-CF data collections

This section lists the variables in each data collection. The definition of the chemical species is given in the "Description".

Instantaneous Two-Dimensional Collections

htf_inst_15mn_g1440x721_x1: High Temporal Frequency Chemistry and Meteorology Fields

Frequency: *15-minute from 00:00 UTC (instantaneous)*

Spatial Grid: *2D, single-level, full horizontal resolution*

Dimensions: *longitude=1440, latitude=721, level=1, time=1*

vertical level: *[72.] (layer)*

Granule Size: *~17 MB*

Shortname: CF01Rhtf_15mnI_g1440x721_X1

Name	*Dim*	*Description*	*Units*
CO	tzyx	Carbon monoxide (CO, MW = 28.00 g mol-1) volume mixing ratio dry air	mol mol-1
NO2	tzyx	Nitrogen dioxide (NO2, MW = 46.00 g mol-1) volume mixing ratio dry air	mol mol-1
O3	tzyx	Ozone (O3, MW = 48.00 g mol-1) volume mixing ratio dry air	mol mol-1
PM25_RH35_GCC	tzyx	Particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25_RH35_GOCART	tyx	Total reconstructed PM2.5 RH 35	kg m-3
Q	tzyx	specific humidity	kg kg-1
RH	tzyx	relative humidity after moist	1
SLP	tyx	sea level pressure	Pa
SO2	tzyx	Sulfur dioxide (SO2, MW = 64.00 g mol-1) volume mixing ratio dry air	mol mol-1
T	tzyx	air temperature	K
U	tzyx	eastward wind	m s-1
V	tzyx	northward wind	m s-1

Time-Averaged Two-Dimensional Collections

chm_tavg_1hr_g1440x721_v1: Chemistry Fields

Frequency: *1-hourly centered on 00:30 UTC (time-averaged)*
Spatial Grid: *2D, surface-layer, full horizontal resolution*
Dimensions: *longitude=1440, latitude=721, level=1, time=1*
vertical level: *[72.] (layer)*
Granule Size: *~81 MB*
Shortname: CF01Rchm_1hrT_g1440x721_V1

Name	*Dim*	*Description*	*Units*
ACET	tzyx	Acetone (CH3C(O)CH3, MW = 58.08 g mol-1) volume mixing ratio dry air	mol mol-1
ALD2	tzyx	Acetaldehyde (CH3CHO, MW = 44.05 g mol-1) volume mixing ratio dry air	mol mol-1
ALK4	tzyx	Lumped >= C4 Alkanes (MW = 58.12 g mol-1) volume mixing ratio dry air	mol mol-1
BCPI	tzyx	Hydrophilic black carbon aerosol (MW = 12.01 g mol-1) volume mixing ratio dry air	mol mol-1
BCPO	tzyx	Hydrophobic black carbon aerosol (MW = 12.01 g mol-1) volume mixing ratio dry air	mol mol-1
BENZ	tzyx	Benzene (C6H6, MW = 78.11 g mol-1) volume mixing ratio dry air	mol mol-1
C2H6	tzyx	Ethane (C2H6, MW = 30.07 g mol-1) volume mixing ratio dry air	mol mol-1
C3H8	tzyx	Propane (C3H8, MW = 44.10 g mol-1) volume mixing ratio dry air	mol mol-1
CH4	tzyx	Methane (CH4, MW = 16.00 g mol-1) volume mixing ratio dry air	mol mol-1
CO	tzyx	Carbon monoxide (CO, MW = 28.00 g mol-1) volume mixing ratio dry air	mol mol-1
DST1	tzyx	Dust aerosol, Reff = 0.7 microns (MW = 29.00 g mol-1) volume mixing ratio dry air	mol mol-1
DST2	tzyx	Dust aerosol, Reff = 1.4 microns (MW = 29.00 g mol-1) volume mixing ratio dry air	mol mol-1

DST3	tzyx	Dust aerosol, Reff = 2.4 microns (MW = 29.00 g mol-1) volume mixing ratio dry air	mol mol-1
DST4	tzyx	Dust aerosol, Reff = 4.5 microns (MW = 29.00 g mol-1) volume mixing ratio dry air	mol mol-1
EOH	tzyx	Ethanol (C2H5OH, MW = 46.07 g mol-1) volume mixing ratio dry air	mol mol-1
H2O2	tzyx	Hydrogen peroxide (H2O2, MW = 34.00 g mol-1) volume mixing ratio dry air	mol mol-1
HCHO	tzyx	Formaldehyde (CH2O, MW = 30.00 g mol-1) volume mixing ratio dry air	mol mol-1
HNO3	tzyx	Nitric acid (HNO3, MW = 63.00 g mol-1) volume mixing ratio dry air	mol mol-1
HNO4	tzyx	Peroxynitric acid (HNO4, MW = 79.00 g mol-1) volume mixing ratio dry air	mol mol-1
ISOP	tzyx	Isoprene (CH2=C(CH3)CH=CH2, MW = 68.12 g mol-1) volume mixing ratio dry air	mol mol-1
MACR	tzyx	Methacrolein (CH2=C(CH3)CHO, MW = 70.00 g mol-1) volume mixing ratio dry air	mol mol-1
MEK	tzyx	Methyl Ethyl Ketone (RC(O)R, MW = 72.11 g mol-1) volume mixing ratio dry air	mol mol-1
MVK	tzyx	Methyl vinyl ketone (CH2=CHC(=O)CH3, MW = 70.00 g mol-1) volume mixing ratio dry air	mol mol-1
N2O5	tzyx	Dinitrogen pentoxide (N2O5, MW = 108.00 g mol-1) volume mixing ratio dry air	mol mol-1
NH3	tzyx	Ammonia (NH3, MW = 17.00 g mol-1) volume mixing ratio dry air	mol mol-1
NH4	tzyx	Ammonium (NH4, MW = 18.00 g mol-1) volume mixing ratio dry air	mol mol-1
NIT	tzyx	Inorganic nitrates (MW = 62.00 g mol-1) volume mixing ratio dry air	mol mol-1
NO	tzyx	Nitrogen oxide (NO, MW = 30.00 g mol-1) volume mixing ratio dry air	mol mol-1
NO2	tzyx	Nitrogen dioxide (NO2, MW = 46.00 g mol-1) volume mixing ratio dry air	mol mol-1

NOy	tzyx	Reactive nitrogen = NO NO2 HNO3 HNO4 HONO 2xN2O5 PAN OrganicNitrates AerosolNitrates	mol mol-1
O3	tzyx	Ozone (O3, MW = 48.00 g mol-1) volume mixing ratio dry air	mol mol-1
OCPI	tzyx	Hydrophilic organic carbon aerosol (MW = 12.01 g mol-1) volume mixing ratio dry air	mol mol-1
OCPO	tzyx	Hydrophobic organic carbon aerosol (MW = 12.01 g mol-1) volume mixing ratio dry air	mol mol-1
PAN	tzyx	Peroxyacetyl nitrate (CH3C(O)OONO2, MW = 121.00 g mol-1) volume mixing ratio dry air	mol mol-1
PM25_RH35_GCC	tzyx	Particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25_RH35_GOCART	tyx	Total reconstructed PM2.5 RH 35	kg m-3
PM25bc_RH35_GCC	tzyx	Black carbon particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25du_RH35_GCC	tzyx	Dust particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25ni_RH35_GCC	tzyx	Nitrate particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25oc_RH35_GCC	tzyx	Organic carbon particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25soa_RH35_GCC	tzyx	Secondary organic aerosol particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25ss_RH35_GCC	tzyx	Seasalt particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25su_RH35_GCC	tzyx	Sulfate particulate matter with diameter below 2.5 um RH 35	ug m-3
PRPE	tzyx	Lumped >= C3 alkenes (C3H6, MW = 42.08 g mol-1) volume mixing ratio dry air	mol mol-1
RCHO	tzyx	Lumped aldehyde >= C3 (CH3CH2CHO, MW = 58.00 g mol-1) volume mixing ratio dry air	mol mol-1
SALA	tzyx	Fine (0.01-0.05 microns) sea salt aerosol (MW = 31.40 g mol-1) volume mixing ratio dry air	mol mol-1

SALC	tzyx	Coarse (0.5-8 microns) sea salt aerosol (MW = 31.40 g mol-1) volume mixing ratio dry air	mol mol-1
SO2	tzyx	Sulfur dioxide (SO2, MW = 64.00 g mol-1) volume mixing ratio dry air	mol mol-1
SOAP	tzyx	SOA Precursor - lumped species for simplified SOA parameterization (MW = 150.00 g mol-1) volume mixing ratio dry air	mol mol-1
SOAS	tzyx	SOA Simple - simplified non-volatile SOA parameterization (MW = 150.00 g mol-1) volume mixing ratio dry air	mol mol-1
TOLU	tzyx	Toluene (C7H8, MW = 92.14 g mol-1) volume mixing ratio dry air	mol mol-1
XYLE	tzyx	Xylene (C8H10, MW = 106.16 g mol-1) volume mixing ratio dry air	mol mol-1

met_tavg_1hr_g1440x721_x1: Meteorological Fields

Frequency: *1-hourly centered on 00:30 UTC (time-averaged)*

Spatial Grid: *2D, surface-layer, full horizontal resolution*

Dimensions: *longitude=1440, latitude=721, level=1, time=1*

vertical level: *[72.] (layer)*

Granule Size: *~28 MB*

Shortname: CF01Rmet_1hrT_g1440x721_X1

Name	***Dim***	***Description***	***Units***
CLDTT	tyx	total cloud area fraction	1
PHIS	tyx	surface geopotential height	m+2 s-2
PS	tyx	surface pressure	Pa
Q	tzyx	specific humidity	kg kg-1
Q10M	tyx	10-meter specific humidity	kg kg-1
Q2M	tyx	2-meter specific humidity	kg kg-1
RH	tzyx	relative humidity after moist	1
SLP	tyx	sea level pressure	Pa
T	tzyx	air temperature	K

T10M	tyx	10-meter air temperature	K
T2M	tyx	2-meter air temperature	K
TPREC	tyx	total precipitation	kg m-2 s-1
TROPPB	tyx	tropopause pressure based on blended estimate	Pa
TS	tyx	surface skin temperature	K
U	tzyx	eastward wind	m s-1
U10M	tyx	10-meter eastward wind	m s-1
U2M	tyx	2-meter eastward wind	m s-1
V	tzyx	northward wind	m s-1
V10M	tyx	10-meter northward wind	m s-1
V2M	tyx	2-meter northward wind	m s-1
ZL	tzyx	mid layer heights	m
ZPBL	tyx	planetary boundary layer height	m

xgc_tavg_1hr_g1440x721_x1: Extra GEOS-Chem Field

Frequency: *1-hourly centered on 00:30 UTC (time-averaged)*
Spatial Grid: *2D, surface-layer, full horizontal resolution*
Dimensions: *longitude=1440, latitude=721, time=1*
Granule Size: *~101 MB*
Shortname: CF01Rxgc_1hrT_g1440x721_X1

Name	*Dim*	*Description*	*Units*
AOD550_BC	tyx	Black carbon optical depth at 550nm	1
AOD550_CLOUD	tyx	Cloud optical depth	1
AOD550_DST1	tyx	Dust bin1 optical depth at 550nm	1
AOD550_DST2	tyx	Dust bin2 optical depth at 550nm	1
AOD550_DST3	tyx	Dust bin3 optical depth at 550nm	1
AOD550_DST4	tyx	Dust bin4 optical depth at 550nm	1
AOD550_DST5	tyx	Dust bin5 optical depth at 550nm	1

AOD550_DST6	tyx	Dust bin6 optical depth at 550nm	1
AOD550_DST7	tyx	Dust bin7 optical depth at 550nm	1
AOD550_DUST	tyx	Dust optical depth at 550nm	1
AOD550_OC	tyx	Organic carbon optical depth at 550nm	1
AOD550_SALA	tyx	Accumulation mode sea salt optical depth at 550nm	1
AOD550_SALC	tyx	Coarse mode sea salt optical depth at 550nm	1
AOD550_SULFATE	tyx	Sulfate optical depth at 550nm	1
DRYDEPFLX_BCPI	tyx	Hydrophilic black carbon aerosol (MW = 12.01 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_BCPO	tyx	Hydrophobic black carbon aerosol (MW = 12.01 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_DST1	tyx	Dust aerosol, Reff = 0.7 microns (MW = 29.00 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_DST2	tyx	Dust aerosol, Reff = 1.4 microns (MW = 29.00 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_DST3	tyx	Dust aerosol, Reff = 2.4 microns (MW = 29.00 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_DST4	tyx	Dust aerosol, Reff = 4.5 microns (MW = 29.00 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_HCHO	tyx	Formaldehyde (CH2O, MW = 30.00 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_HNO3	tyx	Nitric acid (HNO3, MW = 63.00 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_NH3	tyx	Ammonia (NH3, MW = 17.00 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_NH4	tyx	Ammonium (NH4, MW = 18.00 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_NIT	tyx	Inorganic nitrates (MW = 62.00 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_NO2	tyx	Nitrogen dioxide (NO2, MW = 46.00 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_O3	tyx	Ozone (O3, MW = 48.00 g mol-1) dry deposition flux	molec cm-2 s-1

DRYDEPFLX_OCPI	tyx	Hydrophilic organic carbon aerosol (MW = 12.01 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_OCPO	tyx	Hydrophobic organic carbon aerosol (MW = 12.01 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_SALA	tyx	Fine (0.01-0.05 microns) sea salt aerosol (MW = 31.40 g mol-1) dry deposition flux	molec cm-2 s-1
DRYDEPFLX_SALC	tyx	Coarse (0.5-8 microns) sea salt aerosol (MW = 31.40 g mol-1) dry deposition flux	molec cm-2 s-1
TOTCOL_BrO	tyx	Bromine monoxide (BrO, MW = 96.00 g mol-1) total column density	1.0e15 molec cm-2
TOTCOL_CO	tyx	Carbon monoxide (CO, MW = 28.00 g mol-1) total column density	1.0e15 molec cm-2
TOTCOL_HCHO	tyx	Formaldehyde (CH2O, MW = 30.00 g mol-1) total column density	1.0e15 molec cm-2
TOTCOL_IO	tyx	Iodine monoxide (IO, MW = 143.00 g mol-1) total column density	1.0e15 molec cm-2
TOTCOL_NO2	tyx	Nitrogen dioxide (NO2, MW = 46.00 g mol-1) total column density	1.0e15 molec cm-2
TOTCOL_O3	tyx	Ozone (O3, MW = 48.00 g mol-1) total column density	dobsons
TOTCOL_SO2	tyx	Sulfur dioxide (SO2, MW = 64.00 g mol-1) total column density	1.0e15 molec cm-2
TROPCOL_BrO	tyx	Bromine monoxide (BrO, MW = 96.00 g mol-1) tropospheric column density	1.0e15 molec cm-2
TROPCOL_CO	tyx	Carbon monoxide (CO, MW = 28.00 g mol-1) tropospheric column density	1.0e15 molec cm-2
TROPCOL_HCHO	tyx	Formaldehyde (CH2O, MW = 30.00 g mol-1) tropospheric column density	1.0e15 molec cm-2
TROPCOL_IO	tyx	Iodine monoxide (IO, MW = 143.00 g mol-1) tropospheric column density	1.0e15 molec cm-2
TROPCOL_NO2	tyx	Nitrogen dioxide (NO2, MW = 46.00 g mol-1) tropospheric column density	1.0e15 molec cm-2
TROPCOL_O3	tyx	Ozone (O3, MW = 48.00 g mol-1) tropospheric column density	dobsons
TROPCOL_SO2	tyx	Sulfur dioxide (SO2, MW = 64.00 g mol-1) tropospheric column density	1.0e15 molec cm-2

WETDEPFLX_ BCPI	tyx	Hydrophilic black carbon aerosol (MW = 12.01 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ BCPO	tyx	Hydrophobic black carbon aerosol (MW = 12.01 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ DST1	tyx	Dust aerosol, Reff = 0.7 microns (MW = 29.00 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ DST2	tyx	Dust aerosol, Reff = 1.4 microns (MW = 29.00 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ DST3	tyx	Dust aerosol, Reff = 2.4 microns (MW = 29.00 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ DST4	tyx	Dust aerosol, Reff = 4.5 microns (MW = 29.00 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ HCHO	tyx	Formaldehyde (CH2O, MW = 30.00 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ HNO3	tyx	Nitric acid (HNO3, MW = 63.00 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ NH3	tyx	Ammonia (NH3, MW = 17.00 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ NH4	tyx	Ammonium (NH4, MW = 18.00 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ NIT	tyx	Inorganic nitrates (MW = 62.00 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ OCPI	tyx	Hydrophilic organic carbon aerosol (MW = 12.01 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ OCPO	tyx	Hydrophobic organic carbon aerosol (MW = 12.01 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1

WETDEPFLX_ SALA	tyx	Fine (0.01-0.05 microns) sea salt aerosol (MW = 31.40 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ SALC	tyx	Coarse (0.5-8 microns) sea salt aerosol (MW = 31.40 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ SO2	tyx	Sulfur dioxide (SO2, MW = 64.00 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1
WETDEPFLX_ SO4	tyx	Sulfate (SO4, MW = 96.00 g mol-1) vertical integrated loss due to wet scavenging	kg m-2 s-1

Instantaneous Three-Dimensional Collections

chm_inst_1hr_g1440x721_p23: Chemistry Fields

Frequency: *1-hourly from 00:00 UTC (instantaneous)*

Spatial Grid: *3D, pressure-level, full horizontal resolution*

Dimensions: *longitude=1440, latitude=721, level=23, time=1*

vertical level: *[1000. 975. 950. 925. 900. 850. 800. 750. 700. 650. 600. 550. 500. 450. 400. 350. 300. 250. 200. 150. 100. 50. 10.] (hPa)*

Granule Size: *~413 MB*

Shortname: CF01Rchm_1hrI_g1440x721_P23

Name	*Dim*	*Description*	*Units*
CO	tzyx	Carbon monoxide (CO, MW = 28.00 g mol-1) volume mixing ratio dry air	mol mol-1
NO2	tzyx	Nitrogen dioxide (NO2, MW = 46.00 g mol-1) volume mixing ratio dry air	mol mol-1
NOy	tzyx	Reactive nitrogen = NO NO2 HNO3 HNO4 HONO 2xN2O5 PAN OrganicNitrates AerosolNitrates	mol mol-1
O3	tzyx	Ozone (O3, MW = 48.00 g mol-1) volume mixing ratio dry air	mol mol-1
PM25_RH35_G CC	tzyx	Particulate matter with diameter below 2.5 um RH 35	ug m-3

PM25bc_RH35_GCC	tzyx	Black carbon particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25du_RH35_GCC	tzyx	Dust particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25ni_RH35_GCC	tzyx	Nitrate particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25oc_RH35_GCC	tzyx	Organic carbon particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25soa_RH35_GCC	tzyx	Secondary organic aerosol particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25ss_RH35_GCC	tzyx	Seasalt particulate matter with diameter below 2.5 um RH 35	ug m-3
PM25su_RH35_GCC	tzyx	Sulfate particulate matter with diameter below 2.5 um RH 35	ug m-3
SO2	tzyx	Sulfur dioxide (SO2, MW = 64.00 g mol-1) volume mixing ratio dry air	mol mol-1

met_inst_1hr_g1440x721_p23: Meteorology Fields

Frequency: *1-hourly from 00:00 UTC (instantaneous)*

Spatial Grid: *3D, pressure-level, full horizontal resolution*

Dimensions: *longitude=1440, latitude=721, level=23, time=1*

vertical level: *[1000. 975. 950. 925. 900. 850. 800. 750. 700. 650. 600. 550. 500. 450. 400. 350. 300. 250. 200. 150. 100. 50. 10.] (hPa)*

Granule Size: *~317 MB*

Shortname: CF01Rmet_1hrI_g1440x721_P23

Name	***Dim***	***Description***	***Units***
AIRDENS	tzyx	moist air density	kg m-3
AIRVOL_CHEM	tzyx	GEOS-Chem chemistry box volume	km3
EPV	tzyx	ertels potential vorticity	K m+2 kg-1 s-1
ETH	tzyx	potential temperature	K
H	tzyx	edge heights	m
OMEGA	tzyx	vertical pressure velocity	Pa s-1

PS	tyx	surface pressure	Pa
Q	tzyx	specific humidity	kg kg-1
RH	tzyx	relative humidity after moist	1
SLP	tyx	sea level pressure	Pa
T	tzyx	air temperature	K
TH	tzyx	potential temperature	K
U	tzyx	eastward wind	m s-1
V	tzyx	northward wind	m s-1

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Web Resources

GMAO web site: https://gmao.gsfc.nasa.gov/

OpeNDAP Software Description: https://www.opendap.org/

CF NetCDF Standard Description: https://cf-trac.llnl.gov/trac

COARDS Description: https://ferret.pmel.noaa.gov/Ferret/documentation/coards-netcdf-conventions