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README Document for the Suomi-NPP OMPS LP L2 AER675 Daily Product

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1.0 Introduction

This document provides basic information for using the Suomi National Polar-orbiting Partnership (NPP) Ozone Mapping and Profiling Suite (OMPS) Limb Profiler (LP) Level 2 aerosol extinction coefficient daily product, or OMPS-NPP_LP_L2_AER675_DAILY (AER675) for short. The AER675 product measures stratospheric aerosol abundance and evolution to complement the OMPS LP measurements of stratospheric and mesospheric profile ozone.

1.1 OMPS Instrument Description

The Ozone Mapping and Profiling Suite (OMPS) is designed to measure the global distribution of total column ozone on a daily basis, as well as the vertical distribution of ozone in the stratosphere and lower mesosphere (~15-60 km). OMPS on the Suomi NPP satellite consists of three instruments:

Nadir Mapper (NM) – The Nadir Mapper measures total column ozone using backscattered UV radiation between 300-380 nm. A wide field-of-view telescope enables full daily global coverage using 50 km x 50 km pixels. Other quantities, such as aerosol index and column SO_2 abundance, can be derived from NM measurements.

Nadir Profiler (NP) – The Nadir Profiler measures stratospheric profile ozone with moderate vertical resolution (6-8 km) using backscattered UV radiation between 250-310 nm. The along-track footprint of NP is 250 km x 250 km.

Limb Profiler (LP) – The Limb Profiler measures limb scattered radiation in the UV, visible, and near-IR spectral regions to retrieve ozone density and aerosol extinction coefficient profiles from the lower stratosphere (10-15 km) to the upper stratosphere (55 km).

Only OMPS LP measurements and products will be described here.

1.1.1 Limb Profiler

The OMPS Limb Profiler (LP) views the Earth's limb looking backwards along the orbit track, using three parallel vertical slits. One slit is aligned with the orbit track, and the other two slits are pointed 4.25° to each side, giving an effective cross-track separation of approximately 250 km at the tangent point. Each profile measurement takes approximately 19 seconds to complete, corresponding to along-track sampling of approximately 125 km. OMPS LP uses a 2-dimensional CCD detector that records atmospheric spectra covering the wavelength range 290-1000 nm at 1 km altitude intervals between 0 km and 80 km. These spectra are primarily used to retrieve vertical profiles of ozone and aerosol extinction coefficient. The vertical resolution of the retrieved profiles is approximately 1.8 km. Additional description of the LP instrument is given in *Jaross et al*. [2014].

1.2 Algorithm Background

The aerosol extinction coefficient retrieval algorithm used with OMPS LP measurements for this product applies a version of the Chahine non-linear relaxation technique [*e.g*. *Chahine*, 1968] to retrieve the aerosol extinction profile from radiance measurements at 675 nm. An extensive description as it was developed for the previous LP V1.0 aerosol product is given by *Loughman et al*. [2018], and we summarize that description here. The measurement vector used in this retrieval is called the aerosol scattering index (ASI), which is defined as follows:

$$ASI(\lambda,z) = [I_m(\lambda,z) - I_{c0}(\lambda,z)] / I_{c0}(\lambda,z) \qquad [1]$$

where I_m is altitude-normalized measured radiance, and I_{c0} is calculated assuming a pure Rayleigh scattering atmosphere, bounded by a Lambertian reflecting surface at 1013 hPa. Both measured and calculated radiances are normalized at 40.5 km to reduce sensitivity to instrument calibration and multiple scattering. This choice of altitude is intended to minimize both errors in the meteorological data used in the calculation of radiances and possible aerosol contamination.

In the single-scattering approximation the numerator of ASI in Equation [1] is called the path radiance, which is proportional to line-of-sight aerosol extinction and aerosol scattering phase function. However, when multiple scattering of the diffuse upwelling radiation (DUR) emanating from the lower atmosphere is considered, ASI becomes less dependent on the aerosol scattering phase function. Since the effect of DUR is relatively small, we estimate it approximately assuming a Lambertian reflector model. In this model one assumes a Rayleigh scattering atmosphere bounded at 1013 hPa by a Lambertian reflecting surface. The reflectivity of this surface, called Lambert-equivalent reflectivity (LER), is calculated from un-normalized measured radiance at 675 nm and 40.5 km. We adjust the calibration to ensure that the minimum LER value observed in the tropics is approximately 0.03.

We assume spherical Mie scattering particles of refractive index 1.448 + 0*i* to calculate the effect of aerosols on LP radiance. The LP V1.0 product used a bi-modal log-normal size distribution based on aircraft measurements. For the V1.5 product, we have revised the size distribution to use a gamma function formulation as determined by Equation [2]:

$$n(r) = \frac{dN(r)}{dr} = \frac{N_0 \beta^{\alpha} r^{\alpha-1}}{\Gamma(\alpha)} \exp(-r\beta) \qquad [2]$$

where *n(r)* is the number of particles N (r) per unit volume with a size between radius *r* and *r+dr* ($cm^{-3}\mu m^{-1}$), N_0 is the total number density of aerosols (cm^{-3}), α and β (μm^{-1}) are the fitting parameters, and Γ is Euler's Gamma function. At small radii this function follows a power law, while at large radii it follows an exponential function. Further discussion of the rationale for this change is given in *Chen et al*. [2018]. The gamma function has only two parameters to be specified, the shape parameter α and the scale parameter β. The values used here for these parameters (α = 1.8, β = 20.5) were determined from a cumulative distribution fit to CARMA aerosol microphysical model output coupled to the GEOS-5 atmospheric model, and sampled for specific conditions (June-July-August average, 41°N, 20 km) corresponding to long-term balloon particle size measurements.

The retrieval algorithm starts from a nominal first guess aerosol profile and refines the solution iteratively. The maximum number of iterations is set to four. The maximum allowed change in the retrieved extinction is set to a factor of three per iteration, or a factor of 81 in four iterations. We estimate ozone absorption at 675 nm in two steps. Initially, we use an ozone climatology from *McPeters and Labow* [2012], which is updated in the final step by estimating a correction derived from a Chappius band wavelength triplet (510, 600, 675 nm). The magnitude of this correction rarely exceeds 5%.

We identify the peak altitude of any cloud that may be present, using the cloud detection algorithm described in *Chen et al*. [2016]. We replace extinction coefficient values at and below this level with fill values (-999.) for the retrieval product 'RetrievedExtCoeff' that we recommend to most users. However, this algorithm also flags aerosols from fresh volcanic eruptions, which tend to be thicker and more difficult to retrieve accurately. We now provide an additional dataset ('RetrievedExtCoeff_NOFILT') that contains these flagged data for special studies. Users may wish to compare filtered and unfiltered extinction coefficient data to determine the most appropriate choice for their situation.

Atmospheric pressure and temperature profiles used in this retrieval algorithm are derived from NASA GSFC Global Modeling Assimilation Office (GMAO) Forward Processing-Instrument Team (FP-IT) GEOS 5.12.4 data. The nearest spatial grid point (Δlatitude = 0.5°, Δlongitude = 0.625°) to each LP profile is identified, and the temperature and pressure profiles for time steps bracketing the LP measurement (Δt = 3 hours) are interpolated to the observation time.

Additional changes for the V1.5 product that have less effect on the retrieved extinction values include the use of vector radiative transfer calculations and the implementation of intra-orbit tangent height adjustments as described by *Kramarova et al*. [2018]. The tangent height adjustments are positive at high SH latitudes, which can increase the altitude of a detected cloud by 1 km relative to the V1.0 product. Changes in the absolute frequency of cloud detection are less common. In addition, the V1.0 retrievals only allowed a factor of two change in extinction for each iteration and executed three iterations, rather than the larger values (factor of five change, four iterations) given in *Loughman et al*. [2018]. Based on inspection of test results, we revised those parameters for the V1.5 algorithm to allow a factor of three change in extinction for each iteration and four iterations of the retrieval.

1.3 Data Disclaimer

The LP retrieved aerosol extinction data can include contributions from four types of errors.

1) Error in calculating Rayleigh scattering. This error is determined at the 40.5 km normalization altitude, using meteorological pressure and temperature profiles supplied by GMAO. The extinction error bars provided in the daily product data file include only this quantity. It is estimated by assuming a 1% error (±1 σ) in calculating 675 nm scattered radiances at 40.5 km.

2) Error in assumed aerosol microphysical parameters. These parameters include the real and imaginary refractive indices, as well as the two parameters that define our assumed gamma function size distribution. The errors in these parameters may vary with season, altitude, and latitude, and may change significantly after a volcanic eruption. The error bars provided in the daily product data files do not include this term. *Chen et al*. [2018] present approximate changes in phase function and retrieved extinction for specified changes of ±10%

in α and β. The calculated changes vary with scattering angle, and thus with season and latitude, in the LP data product.

3) Loss of sensitivity of 675 nm radiances to aerosols. This effect is caused by Rayleigh and aerosol attenuation of the limb scattered radiation, and becomes most pronounced below ~17 km. We advise caution in using LP aerosol extinction data below 17 km. The error bars provided in the daily product data files do not include this term. This error can be reduced by using longer wavelength radiances already measured by the LP instrument in the aerosol retrieval.

4) Clouds and thick aerosols. The LP extinction retrieval becomes unreliable in the presence of clouds and thick aerosols. The cloud height detection flag described above identifies most of these cases, including fresh volcanic plumes that are too optically thick for accurate aerosol extinction retrieval. The residual uncertainty flag described in Section 2.3.2 may also help to indicate where caution is appropriate.

2.0 Data Organization

These data contain a subset of the overall aerosol retrieval information generated in the orbital Level 2 processing. The daily product is an aggregation of retrieval results for all orbits whose starting time falls within a single calendar day. There are typically 180 observations (or "events") during a single orbit, although measurements at the start or end of an orbit may not be useful for science products. For the AER675 product, retrievals are only performed for observations with solar zenith angle SZA < 88°. There are *Ntime* total observations from all orbits during a complete day. Data fields with dimensions [*Ntime*, 3] use the following convention for slit identification of event *i* (looking backward along the orbit track):

X(*i*,0) = left slit X(*i*,1) = center slit X(*i*,2) = right slit

All profile data are reported for the altitude range 10.5 km-40.5 km at 1 km intervals.

2.1 File Naming Convention

The OMPS Limb Profiler data products use the following file name convention:

OMPS-satellite_sensor-**L**level-product_**v**m.n_observationDate_productionTime.**h5**

Where:

- satellite = NPP
- sensor = LP
- level = 1G, 1, 2
- product = EV, ANC, O3-DAILY, AER675-DAILY
- m.n = algorithm version identifier (m = major, n = minor)
- observationDate = start date of measurements in *yyyymmdd* format
  - o *yyyy* = 4-digit year number[2012-current]
  - o *mm* = 2-digit month number [01-12]
  - o *dd* = 2-digit day number [01-31]
- productionTime = file creation stamp in *yyyy***m***mmdd***t***hhmmss* format
  - o *hhmmss* = production time [local time]

Filename example: OMPS-NPP_LP-L2-AER675-DAILY_v1.5_2012m0412_2018m1219t160142.h5

2.2 File Format and Structure

LP-L2-AER675 data files are provided in the HDF5 format (Hierarchical Data Format Version 5), developed at the National Center for Supercomputing Applications, now the HDFGroup (). These files use the Swath data structure format, with four primary groups: AerosolParameters, AncillaryData, GeolocationFields, and ProfileFields. Section 3.0 describes the dimensions, global attributes, and data fields in more detail.

2.3 Key Science Data Fields

The data fields most likely to be used by typical users of the AER675 product are listed in this section. Important information about data temporal coverage and data quality is also provided.

Parameter	Group
Date	GeolocationFields
Latitude	GeolocationFields
Longitude	GeolocationFields
CloudHeight	GeolocationFields
Altitude	ProfileFields
RetrievedExtCoeff	ProfileFields
RetrievedExtCoeff_NOFILT	ProfileFields
ExtCoeffError	ProfileFields
ResUncertFlag	ProfileFields

2.3.1 Data Temporal Coverage

The first OMPS LP measurements used to create the AER675 product were taken on February 7, 2012. LP data for February-March 2012 have numerous gaps due to variations in instrument operations and changes in sample tables. Regular operations began on April 2, 2012. Note that there is very little or no LP data on days when the OMPS Nadir Mapper conducts high-resolution measurements. This sequence occurred approximately one day per week from April 2012 to June 2016.

2.3.2 Data Quality

Fill values are inserted into the standard and unfiltered extinction coefficient array for any sample where the derived ASI value is less than 0.01, since the retrieval error is inversely proportional to ASI. Such values typically occur at high altitudes where the aerosol amounts are too small, but they can also occur below 12 km where 675 nm radiances becomes insensitive to aerosols due to strong Rayleigh attenuation. Extinction coefficient values less than $1x10^{-5}$ km^{-1}

should be considered unreliable for evaluation of both individual profiles and ensemble averages. We also flag each sample at any altitude where the ASI value is greater than 0.10 and the relative magnitude of the retrieval residual is greater than 0.30, but do not remove these samples, in order to help identify possible retrieval convergence problems at higher signal levels. This flag is frequently set at or below the altitude of a cloud detection, but may also be set in situations where no cloud has been indicated by our current algorithm.

2.3.3 Measurement Flags

The AER675 data product contains important information about spacecraft position and orientation for each measurement in the 'SwathLevelQualityFlags' dataset (see Section 3.3.2 for details). Two flags are particularly relevant for data users.

- The 'SAA' value of this dataset indicates the probability of South Atlantic Anomaly (SAA) charged particle effects on raw CCD data. A particle hit on a pixel used in the retrieval process can cause a spurious cloud detection at a high altitude (*e.g*. 30-40 km) that does not reflect real geophysical behavior, in addition to possibly producing erroneous extinction values at lower altitudes.

- The 'NonNominalAttitude' value of this dataset indicates changes to the S-NPP spacecraft orientation. Continuous sequences of this flag (up to 30-40 events) correspond to planned spacecraft activity, such as monthly roll maneuvers for VIIRS lunar calibration, that frequently result in failed retrievals for one or more LP slits. Successful retrievals during these sequences should be examined carefully before any use. Isolated occurrences of this flag (e.g. 1-3 consecutive events) represent a change in spacecraft flight control software that induces a small change in one or more spacecraft attitude Euler angles (> 0.015° in yaw or roll, > 0.0075° in pitch) during the 18.72 second integration period of a single LP event. We do not currently carry more detailed information about these changes into Level 2 processing, although LP retrievals are most sensitive to attitude changes in the pitch direction. Users should be aware that increased extinction profile noise is possible when this flag is set.

Both flags indicate an increased possibility of abnormal aerosol extinction profiles. Users should check these flags when selecting observations for their analysis to ensure maximum data quality.

3.0 Data Contents

3.1 Dimensions

The AER675 product includes the following dimension terms:

Name	long_name	Value
DimAlongTrack	Along-track dimension	1980 (nTime samples)
DimAltitudeLevel	Altitude-level dimension	31
DimCrossTrack	Cross-track dimension	3

3.2 Global Attributes

Metadata in the AER675 product data files includes attributes whose value is constant for all files and attributes whose value is unique to each individual file. Table 3.2.1 summarizes these global attributes.

Global Attribute	Type	Description
APPName	String	Software name
APPVersion	String	Software version
ArchiveSetName	String	Archive set name for processing
ArchiveSetNumber	Integer*8	Archive set number for processing
Conventions	String	Name of convention(s) for metadata
DOI	String	DOI value
DayNightFlag	String	Identify day or night measurements
DayOfYear	String	Day of year for data
Format	String	Data file format
LocalGranuleID	String	File name
LongName	String	Full product name
OrbitNumberStart	Integer*8	First orbit number of day
OrbitNumberStop	Integer*8	Last orbit number of day
PGEVersion	String	Software version (same as APPVersion)
ProductDateTime	String	Time of file creation
RangeBeginningDateTime	String	Starting date and time of data
RangeEndingDateTime	String	Ending date and time of data
ShortName	String	Short product name
VersionID	Integer*4	Version ID for this product
VersionNumber	String	Version number for this product
acknowledgement	String	Acknowledgement of data producer
comment	String	Any additional comments
contributor_name	String	Name of data creator

contributor_role	String	Role of data creator
creator_email	String	e-mail address of data creator
creator_institution	String	Organization of data creator
creator_name	String	Name of data creator
creator_type	String	Type of data creator (e.g. person, organization)
date_created	String	Date of file creation
history	String	History of file
id	String	Short product name
institution	String	Producer of data
instrument	String	Instrument making measurements
instrument_vocabulary	String	Source of instrument terms
keywords	String	Identifying keywords
keywords_vocabulary	String	Source of keywords used in metadata
license	String	Source of data information regulations
metadata link	String	Web address for metadata DOI
naming_authority	String	Organization providing naming information
platform	String	Platform for measuring instrument
processing_level	String	Level of data product (e.g. L1B, L2)
program	String	Type of measurement program
project	String	Name of project
publisher_email	String	e-mail address of data publisher
publisher_institution	String	Organization of data publisher
publisher_name	String	Name of data publisher
publisher_type	String	Organization type of data publisher
publisher_url	String	URL of data publisher
references	String	Reference material for data product
source	String	Source of measurement data
summary	String	Any additional summary
time_coverage_end	String	Ending data and time of data
time_coverage_start	String	Starting date and time of data
title	String	Title of data product

3.3 Products/Parameters

3.3.1 AerosolParameters Group

Dataset Name	Description	Units	Dimension
Alpha	Size parameter for gamma function particle size distribution	none	(1)
AngstromExponent	Angstrom exponent for particle size distribution	none	(1)
Beta	Shape parameter for gamma function particle size distribution	none	(1)
EffectiveRadius	Calculated effective radius for assumed particle size distribution	µm	(1)
NumDenToExtRatio	Conversion coefficient from number density to extinction	km/cm^3	(1)
RefractiveIndex	Refractive index components (real, imaginary) used in aerosol retrieval	none	(2)
Wavelength	Wavelength used for aerosol extinction retrieval	nm	(1)

Alpha. Size parameter of the gamma function particle size distribution.

AngstromExponent. The Angstrom exponent of the particle size distribution.

Beta. Shape parameter of the gamma function particle size distribution.

EffectiveRadius. The effective radius calculated for the overall aerosol particle population.

NumDenToExtRatio. Coefficient used to convert from number density to extinction coefficient.

RefractiveIndex. Refractive index components used in aerosol extinction retrieval.

Wavelength. Wavelength used for aerosol extinction retrieval.

3.3.2 AncillaryData Group

Dataset Name	Description	Units	Dimension
Pressure	Background atmosphere pressure profile for measurement conditions	hPa	(nTime, 3, 31)
Temperature	Background atmosphere temperature profile for measurement conditions	K	(nTime, 3, 31)
TropopauseAltitude	Calculated tropopause altitude	km	(nTime, 3)

Pressure. Atmospheric pressure profile from GMAO forward processing data at the nearest grid cell to each LP event, and interpolated to the corresponding measurement time.

Temperature. Atmospheric temperature profile from GMAO forward processing data at the nearest grid cell to each LP event, and interpolated to the corresponding measurement time.

TropopauseAltitude. Calculated tropopause altitude based on the temperature profile.

3.3.3 GeolocationFields Group

Dataset Name	Description	Units	Dimension
CloudHeight	Derived cloud height for event	km	(Ntime, 3)
Date	Date in ISO format YYYYMMDD	none	(1)
EventNumber	Event index within orbit for each event	none	(Ntime)
Latitude	Latitude at tangent point [25 km altitude]	degrees	(Ntime, 3)
Longitude	Longitude at tangent point [25 km altitude]	degrees	(Ntime, 3)
OrbitNumber	Orbit number for Suomi NPP spacecraft	none	(Ntime)
Reflectance675	Lambert-equivalent reflectivity	none	(Ntime, 3)
RetrievalFlag	Quality flag for successful retrieval	none	(Ntime, 3)
SingleScatteringAngle	Scattering angle at tangent point [25 km altitude]	degrees	(Ntime, 3)
SolarZenithAngle	Solar zenith angle at tangent point [25 km altitude]	degrees	(Ntime, 3)
SwathLevelQualityFlags	Flags for satellite location and orientation	none	(Ntime)
Time	Measurement time of event [UT]	seconds	(Ntime)

CloudHeight. If a cloud is identified for any event, the altitude of the cloud is recorded. The minimum valid cloud height is 4.5 km. If no cloud is detected, a default value of 1.0 is reported.

Date. The date of each observation in this file in year/month/day format (YYYYMMDD).

EventNumber. The event number represents the position of each event during each orbit sequence, beginning at 1 and ending at the last event for that orbit. A typical orbit contains 180 events.

Latitude. The latitude for each event where the tangent point altitude corresponds to 25 km.

Longitude. The longitude for each event where the tangent point altitude corresponds to 25 km.

OrbitNumber. The orbit number for the Suomi NPP spacecraft since its launch on 28 October 2011.

Reflectance675. The calculated Lambert-equivalent reflectivity at the nominal wavelength.

RetrievalFlag. A non-zero value means that no valid aerosol profile was retrieved for that event.

SingleScatteringAngle. The single scattering angle for each event where the tangent point altitude corresponds to 25 km.

SolarZenithAngle. The solar zenith angle for each event where the tangent point altitude corresponds to 25 km.

SwathLevelQualityFlags. The swath level quality flag contains five values packed into a 2-byte (16-bit) integer, with the following definitions.

Bits 0-1: SAA (South Atlantic Anomaly)

0 = estimated SAA effects at satellite location are < 5% of nominal maximum value, based on OMPS LP climatology

1 = estimated SAA effects are 5-40% of nominal maximum value

2 = estimated SAA effects are 40-75% of nominal maximum value

3 = estimated SAA effects are > 75% of nominal maximum value

Bits 2-3: Moon

0 = does not appear in any slit (based on calculated ephemeris)

1 = appears in left slit

2 = appears in center slit

3 = appears in right slit

Bit 4: SolarEclipse

0 = none

1 = solar eclipse on day side of Earth at time of measurement

Bits 5-6: OtherPlanets

0 = does not appear in any slit (based on calculated ephemeris)

1 = appears in left slit

2 = appears in center slit

3 = appears in right slit

Bit 7: NonNominalAttitude

0 = nominal spacecraft attitude

1 = attitude shift due to planned spacecraft maneuver (such as roll or yaw) or other reason

<u>Time</u>. Measurement time of each event.

3.3.4 ProfileFields Group

Dataset Name	Description	Units	Dimension
Altitude	Altitude levels for profile data sets	km	(31)
ExtCoeffError	Calculated error for retrieved extinction profile	km^{-1}	(nTime, 3, 31)
MeasurementVector	Measured ASI at 675 nm	none	(nTime, 3, 31)
ResUncertFlag	Residual uncertainty flag at 675 nm	none	(nTime, 3, 31)
Residual675	Measured ASI – Calculated ASI	none	(nTime, 3, 31)
RetrievedExtCoeff	Extinction coefficient profile at 675 nm with cloud filtering	km^{-1}	(nTime, 3, 31)
RetrievedExtCoeff_NOFILT	Extinction coefficient profile at 675 nm with no cloud filtering applied	km^{-1}	(nTime, 3, 31)

<u>Altitude</u>. Tangent height altitude levels between 10.5-40.5 km in 1 km intervals for profile data sets.

<u>ExtCoeffError</u>. The calculated uncertainty in the retrieved extinction coefficient.

<u>MeasurementVector</u>. Aerosol scattering index (ASI) profile, calculated from LP radiance data normalized at 40.5 km.

<u>Residual675</u>. Difference between measured ASI and calculated ASI.

<u>ResUncertFlag</u>. This flag is set to 1 at any altitude if the magnitude of the ASI measurement vector is greater than 0.10 and the relative magnitude of the ASI residual [Residual675/MeasurementVector] is greater than 0.30. A fill value of -999 indicates that no flag is defined.

<u>RetrievedExtCoeff</u>. The retrieved extinction coefficient profile at 675 nm for each event. If a cloud is detected for any event, all extinction values at the cloud height and lower are set to -999.

<u>RetrievedExtCoeff_NOFILT</u>. The retrieved extinction coefficient profile at 675 nm for each event. No samples are filtered out based on cloud detection.

4.0 Options for Reading the Data

There are many tools and visualization packages (free and commercial) for viewing and dumping the contents of HDF5 files. Libraries are available in several programming languages for writing software to read HDF5 files. A few simple to use command-line and visualization tools, as well as programming languages for reading the L2 HDF5 data files are listed in the sections below. For a comprehensive list of HDF5 tools and software, please see the HDF Group's web page at .

4.1 Command Line Utilities

4.1.1 h5dump (free)

The h5dump tool, developed by the HDFGroup, enables users to examine the contents of an HDF5 file and dump those contents, in human readable form, to an ASCII file, or alternatively to an XML file or binary output. It can display the contents of the entire HDF5 file or selected objects, which can be groups, datasets, a subset of a dataset, links, attributes, or datatypes. The h5dump tool is included as part of the HDF5 library, or separately as a stand-alone binary tool:

4.1.2 ncdump (free)

The ncdump tool, developed by Unidata, will print the contents of a netCDF or compatible file to standard out as CDL text (ASCII) format. The tool may also be used as a simple browser, to display the dimension names and lengths; variable names, types, and shapes; attribute names and values; and optionally, the values of data for all variables or selected variables. To view HDF5 data files, version 4.1 or higher is required. The ncdump tool is included with the netCDF library. **NOTE: you must include HDF5 support during build.**

4.1.3 H5_PARSE (IDL/commercial)

The H5_PARSE function recursively descends through an HDF5 file or group and creates an IDL structure containing object information and data values. You must purchase an IDL package, version 8 or higher, to read the L2 HDF5 data files.

4.2 Visualization Tools

4.2.1 HDFView (free)

HDFView, developed by the HDFGroup, is a Java-based graphic utility designed for viewing and editing the contents of HDF4 and HDF5 files. It allows users to browse through any HDF file, starting with a tree view of all top-level objects in an HDF file's hierarchy. HDFView allows a user to descend through the hierarchy and navigate among the file's data objects. Editing features allow a user to create, delete, and modify the value of HDF objects and attributes. For more info see:

4.2.2 Panoply (free)

Panoply, developed at the Goddard Institute for Space Studies (GISS), is a cross-platform application which plots geo-gridded arrays from netCDF, HDF and GRIB dataset required. The tool allows one to slice and plot latitude-longitude, latitude-vertical, longitude-vertical, or time-latitude arrays from larger multidimensional variables, combine two arrays in one plot by differencing, summing or averaging, and change map projections. One may also access files remotely into the Panoply application.

4.2.3 H5_BROWSER (IDL/commercial)

The H5_BROWSER function presents a graphical user interface for viewing and reading HDF5 files. The browser provides a tree view of the HDF5 file or files, a data preview window, and an information window for the selected objects. The browser may be created as either a selection dialog with Open/Cancel buttons, or as a standalone browser that can import data to the IDL main program. You must purchase an IDL package, version 8 or higher to view the L2 HDF5 data files.

4.3 Programming Languages

Advanced users may wish to write their own software to read HDF5 data files. The following is a list of available HDF5 programming languages:

Free:

- C/C++ ()
- Fortran ()
- Java ()
- Python ()
- GrADS ()

Commercial:

- IDL ()
- Matlab ()

5.0 Data Services

Access of GES DISC data now requires users to register with the NASA Earthdata Login system and to request authorization to "NASA GESDISC DATA ARCHIVE Data Access". Please note that the data are still free of charge to the public.

5.1 GES DISC Search

The GES DISC provides a keyword, spatial, temporal and advanced (event) searches through its unified search and download interface:

The interface offers various download and subsetting options that suit the user's needs with different preferences and different levels of technical skills. Users can start from any point where they may know little about a particular set of data, its location, size, format, etc., and quickly find what they need by just providing relevant keywords, such as a data product (e.g. "OMPS"), or a parameter such as "ozone".

5.2 Direct Download

The OMPS data products may be downloaded in their native file format directly from the archive using https access at:

5.3 OPeNDAP

The Open Source Project for a Network Data Access Protocol (OPeNDAP) provides remote access to individual variables within datasets in a form usable by many OPeNDAP enabled tools, such as Panoply, IDL, Matlab, GrADS, IDV, McIDAS-V, and Ferret. Data may be subsetted dimensionally and downloaded in a netCDF4, ASCII or binary (DAP) format. The GES DISC offers the OMPS data products through OPeNDAP:

6.0 More Information

Contact Information

Name: GES DISC Help Desk
URL:
E-mail:
Phone: 301-614-5224
Fax: 301-614-5228
Address: Goddard Earth Sciences Data and Information Services Center
Attn: Help Desk
Code 610.2
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Additional OMPS and ozone data products

Joint Polar Satellite System mission web page

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> Matthew DeLand (2018), OMPS-NPP LP L2 Aerosol Extinction Vertical Profile swath daily 3slit Collection 1.5 V1.5, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), accessed ***[data access date]***, doi:10.5067/GZJJYA7L0YW2.

References

Chahine, M. T. (1968), Determination of the temperature profile in an atmosphere from its outgoing radiance, *J. Opt. Soc. Amer.*, *58*, 1634-1637.

Chen, Z., M. DeLand, and P. K. Bhartia (2016), A new algorithm for detecting cloud height using OMPS/LP measurements, *Atmos. Meas. Tech.*, *9*, 1239-1246, doi:10.5194/amt-9-1239-2016.

Chen, Z., P. K. Bhartia, R. Loughman, P. Colarco, and M. DeLand (2018), Improvement of stratospheric aerosol extinction retrieval from OMPS/LP using a new aerosol model, *Atmos. Meas. Tech.*, *11*, 6495-6509, doi.org/10.5194/amt-11-6495-2018.

Jaross, G., P. K. Bhartia, G. Chen, M. Kowitt, M. Haken, Z. Chen, P. Xu, J. Warner, and T. Kelly (2014), OMPS Limb Profiler instrument performance assessment, *J. Geophys. Res. Atmos.*, *119*, doi:10.1002/2013JD020482.

Kramarova, N. A., P. K. Bhartia, G. Jaross, L. Moy, P. Xu, Z. Chen, M. DeLand, L. Froidevaux, N. Livesey, D. Degenstein, A. Bourassa, K. A. Walker, and P. Sheese (2018), Validation of ozone profile retrievals derived from the OMPS LP version 2.5 algorithm against correlative satellite measurements, *Atmos. Meas. Tech.*, *11*, 2837-2861, doi.org/10.5194/amt-11-2837-2018.

Loughman, R., P. K. Bhartia, Z. Chen, P. Xu, E. Nyaku, and G. Taha (2018), The Ozone Mapping and Limb Profiler Suite (OMPS) Limb Profiler (LP) Version 1 aerosol extinction algorithm: theoretical basis, *Atmos. Meas. Tech*., *11*, 2633-2651, doi.org:10.5194/amt-11-2633-2018.

McPeters, R. D., and G. J. Labow (2012), Climatology 2011: An MLS and sonde derived ozone climatology for satellite retrieval algorithms, *J. Geophys. Res.*, *117*, D10303, doi:10.1029/2011JD017006.