National Aeronautics and Space Administration Goddard Earth Science Data Information and Services Center (GES DISC)

README Document for the Suomi-NPP OMPS LP L3 AER Monthly 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 3 aerosol extinction coefficient monthly gridded product, or OMPS_NPP_LP_L3_AER_MONTHLY (AER) for short. The AER product measures stratospheric aerosol abundance and evolution to complement the OMPS LP measurements of stratospheric and mesospheric profile ozone. This Level 3 gridded product provides spatially averaged and temporally averaged data for selected retrieved quantities (aerosol extinction coefficient, aerosol to molecular extinction ratio, number density, aerosol column optical depth).

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 multiple wavelengths. The implementation of this approach for OMPS LP is described by *Loughman et al.* [2018] and *Taha et al.* [2021].

A detailed summary of the current Level 2 retrieval algorithm is given in *Taha et al.* [2022], so only key points are discussed here.

- Aerosol extinction coefficient profiles are retrieved at six wavelengths: 510, 600, 675, 745, 869, and 997 nm.
- Profiles cover the altitude range 0.5-40.5 km, although fill values are inserted below any cloud that is detected for a given measurement event.

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 38.5 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 38.5 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 short wavelengths radiances to aerosols. This effect is caused by Rayleigh and aerosol attenuation of the limb scattered radiation, and becomes most pronounced below ~17 km and in the southern hemisphere. We advise caution in using LP aerosol extinction data below 17 km and scattering angle greater than 145 degrees for wavelengths 675 nm or shorter. The error bars provided in the daily product data files do not include this term. This error can be reduced by using 745, 869, and 997 nm wavelengths.

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.

2.0 Data Organization

These data contain a subset of the overall aerosol retrieval information generated in the daily Level 2 processing. The Level 3 monthly product averages retrieval results for all available days within each calendar month, and also creates spatial averages with bin dimensions of 5 degrees in latitude (90°-85°S, 85°-80°S,…, 85°-90°N) and 15 degrees in longitude (165°-180°W, 150°-165°W,…, 165°-180°E). Retrievals are only included for solar zenith angle SZA < 85° and extinction coefficient > 1.0×10^{-7} km^{-1} at any altitude. Only center slit measurements are used to create monthly average values. All profile data are reported for the altitude range 0.5 km-40.5 km at 1 km intervals. The total number of observations used for each month varies based on location and altitude, and is reported as a separate dataset.

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, 3
- product = EV, ANC, O3-DAILY, AER-DAILY, AER-MONTHLY
- m.n = algorithm version identifier (m = major, n = minor)
- observationDate = start date of measurements in *yyyymmdd* format
    - *yyyy* = 4-digit year number[2012-current]
    - *mm* = 2-digit month number [01-12]
    - *dd* = 2-digit day number [01-31]
- productionTime = file creation stamp in *yyyy***m***mmdd***t***hhmmss* format
    - *hhmmss* = production time [local time]

Filename example: OMPS-NPP_LP-L3-AER-MONTHLY_v1.0_2022m0101_2022m1202t212745.h5

2.2 File Format and Structure

LP-L3-AER 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 no named groups. 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 AER product are listed in this section. Important information about data temporal coverage and data quality is also provided.

Parameter
Latitude
Longitude
Altitude
ExtinctionAvg
ExtRatioAvg
NumDensAvg
StratColumn

2.3.1 Data Temporal Coverage

The first OMPS LP measurements used to create the AER 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. No LP data were taken from July 18, 2022 to August 3, 2022 while the instrument was in safe mode.

2.3.2 Data Quality

Fill values are inserted into the extinction coefficient profile for any sample where the derived aerosol scattering index (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 at low altitudes for the short wavelengths, where radiances become insensitive to aerosols due to strong Rayleigh attenuation. Extinction coefficient values less than $1x10^{-5}$ km^{-1} should be considered unreliable for evaluation of ensemble averages.

2.3.3 Measurement Flags

The Level 2 AER data product contains important information about spacecraft position and orientation for each measurement in the 'SwathLevelQualityFlags' dataset (see Section 3.3.2 of *Taha et al.* [2022] for details). 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. 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. Detailed information about these changes is not carried into Level 2 processing, although LP retrievals are most sensitive to attitude changes in the pitch direction. As a precaution, any events where this flag is set have been screened out before calculating monthly average values.

3.0 Data Contents

3.1 Dimensions

The AER product includes the following dimension terms:

Name	long_name	Value
/DimAltitude	Altitude-level dimension	41
/DimLatitude	Latitude-grid dimension	36
/DimLongitude	Longitude-grid dimension	24
/DimWavelength	Wavelength dimension	6

3.2 Global Attributes

Metadata in the AER 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*4	Archive set number for processing
Conventions	String	Name of convention(s) for metadata
DOI	String	DOI value
DayNightFlag	String	Identify day or night measurements
Format	String	Data file format
LocalGranuleID	String	File name
LongName	String	Full product name
OrbitNumberStart	Integer*4	First orbit number of day
OrbitNumberStop	Integer*4	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	String	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

Dataset Name	Description	Units	Dimension
Altitude	Altitude grid for retrieved profiles	km	(41)
ExtRatioAvg	Aerosol to molecular extinction ratio average profile at each wavelength	none	(24,36,41,6)
ExtRatioStDev	Aerosol to molecular extinction ratio standard deviation at each wavelength	none	(24,36,41,6)
ExtRatioStErr	Aerosol to molecular extinction ratio standard error at each wavelength	none	(24,36,41,6)
ExtinctionAvg	Retrieved extinction coefficient average profile at each wavelength	km^{-1}	(24,36,41,6)
ExtinctionStDev	Retrieved extinction coefficient standard deviation at each wavelength	km^{-1}	(24,36,41,6)
ExtinctionStErr	Retrieved extinction coefficient standard error at each wavelength	km^{-1}	(24,36,41,6)
Latitude	Center latitude of each grid cell	degrees	(36)
Longitude	Center longitude of each grid cell	degrees	(24)
NumDensAvg	Average number density profile at each wavelength	cm^{-3}	(24,36,41)
NumGoodScreen	Number of good samples	none	(24,36,41,6)

NumSamples	Number of possible samples	none	(24,36,6)
Pressure	Average background atmosphere pressure profile	hPa	(24,36,41)
ScatteringAngle	Scattering angle at tangent point [25 km altitude]	degrees	(24,36)
StratColumn	Total column stratospheric aerosol	none	(24,36,6)
Temperature	Average background atmosphere temperature profile	K	(24,36,41]
TropopauseAltitude	Calculated tropopause altitude	km	(24,36)
Wavelength	Wavelengths for aerosol products	nm	(6)

Altitude. Altitude grid for retrieved profiles in ascending order 0.5 km-40.5 km.

ExtRatioAvg. Aerosol to molecular extinction ratio average profile at each wavelength. If a cloud is detected for any profile, all extinction values at the cloud height and below are set to -999.0.

ExtRatioStDev. Aerosol to molecular extinction ratio standard deviation at each wavelength.

ExtRatioStErr. Aerosol to molecular extinction ratio standard error at each wavelength.

ExtinctionAvg. Retrieved extinction coefficient average profile at each wavelength. If a cloud is detected for any profile, all extinction values at the cloud height and below are set to -999.0.

ExtinctionStDev. Retrieved extinction coefficient standard deviation at each wavelength.

ExtinctionStErr. Retrieved extinction coefficient standard error at each wavelength.

Latitude. Center latitude of each grid cell in degrees [-87.5, -82.5,…, 87.5]. South latitudes are negative.

Longitude. Center longitude of each grid cell in degrees [-172.5, -157.5,…, 172.5]. West longitudes are negative.

NumDensAvg. Average number density profile at each wavelength.

NumGoodScreen. The number of good samples in each grid cell and altitude (at each wavelength) after filtering for clouds and minimum extinction coefficient.

NumSamples. The number of possible samples in each grid cell after screening for valid retrievals and no spacecraft maneuver.

Pressure. Average atmospheric pressure profile calculated from GMAO forward processing data at the nearest location to each LP event, and interpolated to the corresponding measurement time.

ScatteringAngle. Single scattering angle at tangent point and 25 km altitude, averaged over all possible samples.

StratColumn. Column stratospheric aerosol above the tropopause or cloud height (whichever is higher) for each wavelength.

Temperature. Average atmospheric temperature profile calculated from GMAO forward processing data at the nearest location to each LP event, and interpolated to the corresponding measurement time.

TropopauseAltitude. Average tropopause altitude based on the lapse rate of the temperature profile, calculated from GMAO forward processing data at the nearest location to each LP event, and interpolated to the corresponding measurement time.

Wavelength. The nominal wavelengths at which extinction profiles are retrieved (510, 600, 675, 745, 869, 997 nm).

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.

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.

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:
https://omps.gesdisc.eosdis.nasa.gov/data/

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:
https://snpp-omps.gesdisc.eosdis.nasa.gov/opendap/SNPP_OMPS_Level2/OMPS_NPP_LP_L2_AER_DAILY.2/contents.html

6.0 More Information

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