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

README Document for the Suomi-NPP OMPS LP L2 O3 Daily Product

Version 2.5

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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 ozone daily product, or OMPS-NPP_LP_L2_O3_DAILY (O3) for short. The O3 product measures stratospheric and mesospheric profile ozone in combination with the OMPS LP measurements of stratospheric aerosol abundance.

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 OMPS Limb Profiler (LP) Version 2.5 (V2.5) daily ozone product is created using a modified version of the ozone retrieval algorithm described in *Rault and Loughman* [2013]. The algorithm generates ozone density *vs.* altitude profiles at 1 km intervals, with a vertical resolution of ~1.6-2.8 km in the central portion of each retrieval, increasing to 3-4 km at lower and higher altitudes. The V2.5 algorithm uses altitude-normalized radiances to make the retrievals insensitive to both instrument calibration errors and to the diffuse upwelling radiation (DUR) produced by surface reflection and scattering of sunlight by clouds and aerosols located below the tangent point. Table 1 provides a summary of the Level 2 (L2) algorithm-specific changes from the original algorithm that are applied for V2.5 retrievals.

Separate retrievals are performed for the middle and upper stratosphere (using UV wavelengths) and for the upper troposphere and lower stratosphere (using visible (VIS) wavelengths).

1. The UV algorithm retrieves profiles between 29.5 km and 52.5 km, using radiances measured at three wavelengths (302, 312, 322 nm) normalized at 55.5 km. Each wavelength is paired with 353 nm to make the algorithm insensitive to errors in the assumed pressure *vs.* altitude profiles p(z) used in calculating the radiances.

2. The VIS algorithm retrieves profiles from cloud top to 37.5 km, using radiances measured at 600 nm and normalized at 40.5 km. Cloud detection is based on the algorithm described by *Chen et al*. [2016]. If no cloud is identified, the VIS retrieval lower limit is set to 12.5 km. These radiances are combined with 510 nm and 675 nm to form a triplet. In addition to making the algorithm insensitive to p(z), the triplet formulation greatly reduces the sensitivity of the algorithm to aerosols. An additional correction for aerosol scattering effects is calculated using the concurrent aerosol extinction coefficient profile retrieval from the LP-L2-AER675 data product [*Johnson and DeLand*, 2017].

Table 1. Summary of key algorithm changes implemented in Version 2.5 compared to the base OMPS LP ozone algorithm described in *Rault and Loughman* [2013].

Key changes	Version 2.5
Cloud Height Detection	Use algorithm described in *Chen et al*. [2016]
Altitude Registration	Absolute adjustment applied in Level 1B (L1B) data Intra-orbital and seasonal adjustment applied in L2 processing [*Moy et al*., 2017]
Stray Light Correction	Empirical correction applied for VIS wavelengths
Wavelength Selection	**UV:** 302 nm, 312 nm and 322 nm paired with 353 nm (3 pairs) **VIS:** 600 nm combined with 510 nm and 675 nm to form a single triplet
Radiance Normalization Altitude	**UV:** 55.5 km **VIS:** 40.5 km
Aerosol Correction	Use aerosol extinction coefficient profiles retrieved from LP measurements for same event
Vertical Smoothing	2nd order Twomey-Tikhonov regularization term replaced with Rodgers minimum variance solution

Atmospheric pressure and temperature profiles used for forward model radiance calculation 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. While the LP ozone retrieval algorithm is insensitive to p(z) profiles, these profiles are used for altitude registration analysis [*Moy et al.*, 2017]. We provide these data in the LP-L2-O3-DAILY files for the convenience of users who want to convert ozone profiles from our retrieval coordinates (number density *vs*. altitude) to mixing ratio *vs*. pressure profiles.

1.2.1 Changes Between Version 2 and Version 2.5 Data Product

Several changes have been implemented for the LP V2.5 ozone product compared to the V2 product previously released in 2014. The summary listing provided below complements the L2 algorithm changes summarized in Table 1.

- The L2 algorithm now uses Sun-normalized radiances for all retrievals. The effect of this change is relatively small, since the algorithm uses altitude-normalized radiances.
- We do not combine UV and VIS ozone profiles because of unresolved bias issues in the altitude range where they overlap.
- Only center slit data are provided in the daily product, since data from the left and right slits have some quality issues.

- The VIS retrieval radiances are corrected for the effects of aerosols. The aerosol extinction coefficient profile for each event is taken from the LP-L2-AER675 product retrieved for the same event.
- The UV retrieval wavelength selection has been reduced from 43 wavelengths in V2 (all available values between 289-325 nm, excluding 306.5-311.0 nm) to three wavelengths in V2.5 (302, 312, 322 nm). Each wavelength is paired with 353 nm and used from 52.5 km down to a specific lower altitude level (44.5 km, 38.5 km, 29.5 km respectively). This change simplifies the evaluation of radiance error effects by reducing the size of the measurement vector by approximately a factor of 20.
- The VIS retrieval wavelength selection has been reduced from 17 wavelengths in V2 (all available values between 549-633 nm) to one wavelength in V2.5 (600 nm). This wavelength is combined with 510 nm and 675 nm in a triplet. As with the UV algorithm, this reduction in the number of wavelengths simplifies the error analysis.
- The UV retrieval normalization altitude has been changed from 65.5 km to 55.5 km to reduce possible effects from PMC contamination.
- The VIS retrieval normalization altitude has been changed from 45.5 km to 40.5 km to reduce possible effects from residual stray light.
- An empirical stray light correction for visible wavelength data was developed from radiance measurements. High altitude non-zero signals were extrapolated down to 76 km, and the adjustment required to produce agreement with the prelaunch stray light model was calculated. These spectrally dependent scale factors are applied to L1B radiances.
- L1B data contain new adjustments for altitude registration: A static correction of 1.37 km is applied to all center slit data, and an additional +0.1 km adjustment is applied on 25 April 2013 to correct for a S-NPP spacecraft pitch maneuver, as described in *Moy et al*. [2017]. A separate adjustment of +0.1 km is made in L2 processing on 5 September 2014.
- Analysis of ARRM data presented by *Moy et al*. [2017] indicates a remaining altitude registration error that varies by approximately 300-400 m along each orbit, with additional seasonal components. We have developed a correction function that is applied in Level 2 processing. The specific dependence on event number and day of year is shown in Figure 1.

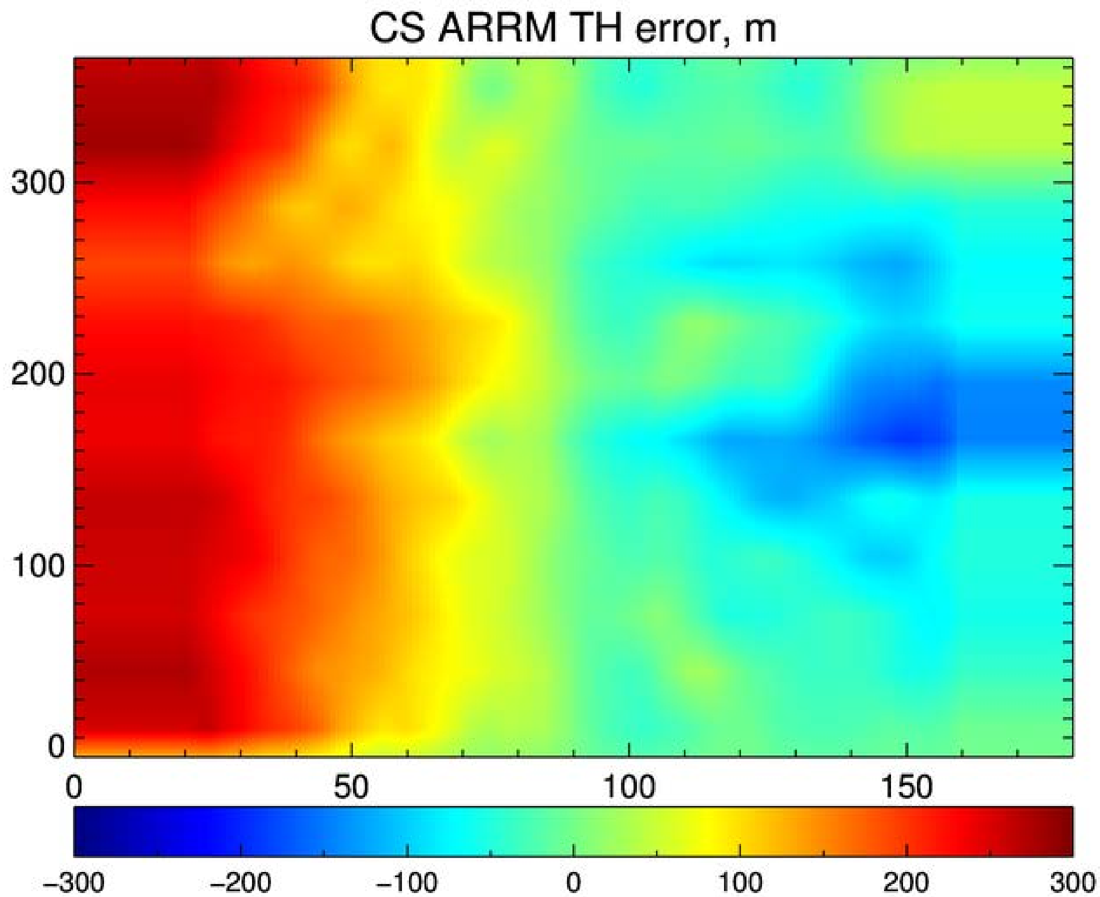

Figure 1. Altitude registration correction applied in V2.5 Level 2 processing as a function of event number and season. The X-axis scale shows event number along the orbit, and the Y-axis scale shows day of year. The Southern Hemisphere terminator crossing occurs at event 0. The color scale shows calculated tangent height error, ranging from -300 m [*blue*] to +300 m [*red*].

1.3 Data Disclaimer

We have made uncertainty estimates for LP V2.5 ozone retrievals, based on our evaluation of the retrieval algorithm and radiance residuals. We have verified that these estimates are reasonable, based on comparisons of the LP V2.5 ozone data product against other data sets (*e.g.* Aura MLS, Odin OSIRIS, ACE FTS). Our initial assessment of LP data quality is given in this section, followed by a discussion of specific features that users should be aware of.

1.3.1 Accuracy

The accuracy of LP retrieved ozone profiles depends on the combination of many individual factors. The relationship between uncertainty of any factor and a corresponding ozone profile error may depend on altitude, latitude, season, wavelength, or other parameters. A summary of known uncertainties is given below. Table 2 lists estimated ozone profile errors at selected altitudes due to these uncertainties.

- Altitude Registration (absolute). Since the ozone profile varies by up to 30%/km at some altitudes, small errors in altitude registration of radiances can produce large errors in retrieved ozone. Since the shape of the ozone profile changes considerably with altitude, latitude, and season, this error pattern can be quite complex. However, for any given ozone profile, or zonally averaged profile, this uncertainty can be estimated accurately if the altitude registration uncertainty is known. Our current best estimate is that our altitude registration accuracy is ±200 m [*Moy et al.*, 2017], which can produce up to 6% uncertainty in ozone density in the upper stratosphere, reducing to zero uncertainty near the density peak, and reversing in sign below the peak.
- Altitude Registration (drift). Analysis of V2.5 data suggests that there may be a small drift (16 m/year) in LP altitude registration. This produces about +0.5%/year drift in ozone in the upper stratosphere, decreasing to zero near the density peak. This drift has been observed in MLS comparisons.
- Bias at Normalization Altitude. Ozone values assumed by the V2.5 algorithm show a bias of -10% compared to MLS data at 55.5 km, where UV radiances are normalized. If MLS data are assumed to be correct, this bias will produce a small bias in LP retrieved ozone at nearby altitudes (48-52 km).
- Systematic Errors. LP radiances show quasi-systematic errors of 1-3% that vary between CCD pixels. These errors produce approximately ±3% errors in retrieved ozone that vary with altitude, latitude, and season. The cause of these systematic errors is under investigation. Some errors appear to be caused by small uncorrected wavelength shifts with altitude.
- Precision. Random noise in LP measured radiances is much smaller than the quasi-systematic errors discussed in the previous item, so we do not consider this effect here.
- Aerosol Correction. Our experience with the LP V2 data product, where no explicit aerosol correction was applied in the retrieval algorithm, suggests that any remaining errors due to aerosols in V2.5 retrieved ozone profiles are quite small.
- Polar Mesospheric Cloud (PMC) Contamination. While these clouds exist at 80-85 km and high latitudes (> 50°), they can affect the measured radiances as low as 50 km if they are in the line of sight (LOS) of the LP instrument. Although lowering the UV normalization altitude has reduced the overall impact, Northern Hemisphere measurements can still be affected because forward-scattered PMC photons have not

passed through the ozone molecules in the LOS. This leads to an underestimate of the ozone profile (see also Section 4.5).

Table 2. Summary of estimated OMPS LP ozone profile errors due to uncertainties discussed in Section 4.1.

Altitude	16.5 km	24.5 km	32.5 km	40.5 km	48.5 km	52.5 km
Alt. Reg. (abs.)	5%	0%	3-4%	6%	6%	6%
Alt. Reg. (drift)	0.6%/yr	< 0.2%/yr	0.5%/yr	0.5%/yr	0.5%/yr	0.5%/yr
Bias at 55.5 km	–	–	–	-0.5%	-3%	-5%
System. Error	±3%	±3%	±3%	±3%	±3%	±3%

1.3.2 LP UV Profiles and MLS Comparisons

- The mean differences between LP and MLS ozone profiles are within ±5% between 29.5 km and 43.5 km. This agreement is well within the combined uncertainty of LP retrievals and MLS retrievals (quoted accuracy of 5-7%).
- Average LP ozone values tend to be 5-15% smaller than MLS above 45 km, with clear seasonal biases. These biases are still within the combined systematic error bars for MLS and LP instruments. Possible causes of these larger biases are discussed in Section 4.1, and are currently under investigation.
- Relative drift between LP and MLS ozone time series of ~0.3-0.8%/year is observed at altitudes above 33 km. The vertical pattern of the observed ozone drift is consistent with possible altitude registration drift in one of these instruments.

1.3.3 LP VIS Profiles and MLS Comparisons

- Biases between LP and MLS ozone profiles are generally less than ±5% for all altitudes between 18-30 km. Larger biases observed at Northern Hemisphere high latitudes (> 50°N) may be caused by residual errors in the LP stray light correction at VIS wavelengths.
- Significant negative LP biases of ~10-30% are observed in the lower stratosphere (< 18 km) in the southern mid-latitudes (40°S-60°S).
- Larger ozone differences between LP and MLS are observed in the tropical upper troposphere/lower stratosphere (UT/LS), with negative LP biases (up to -30%) in the

upper troposphere and smaller positive biases (~10%) in the lower stratosphere. LP and MLS ozone variability are also higher in this region.

- Negative drifts of 0.3-0.6%/year in LP VIS data are consistent with the altitude registration drift errors described in Section 4.1. Selected altitude and latitude regions can exhibit positive drifts in LP ozone.

1.3.4 LP UV/VIS Bias

- LP UV and VIS ozone retrievals overlap between 29.5 km and 35.5 km. We find that VIS and UV retrievals agree quite well (±3-5%) between ~30-33 km in the tropics (30°S-30°N). At mid- and high latitudes, UV retrievals systematically give larger ozone values than VIS retrievals (~5-7% differences in the Southern Hemisphere, up to 10-20% differences in the Northern Hemisphere). Comparisons with MLS also confirm that VIS retrievals are lower.

1.3.5 Data Product Features

<u>1. Inter-Slit Differences.</u> Internal analysis shows that radiances measured in the left slit and right slit still contain some biases relative to center slit data. These biases show a complex dependence on multiple factors (event number, tangent height adjustment, stray light). The center slit data show essentially no tangent height offset when evaluated using the ARRM method described by *Moy et al*. [2017]. Based on these results, we provide only center slit data in the V2.5 LP-L2-O3-DAILY product.

<u>2. Profile Quality Flag</u>. The LP retrieval algorithm creates radiance residuals (difference between measurement vector and forward model calculation) at each altitude level for every event. We define a profile quality flag (Q_UV, Q_VIS) based on the root-sum-square (RSS) of all residuals for that profile. Q_retrieval = 0, which we believe represents the best profiles, corresponds to an RSS residual < 0.05. A typical day has 90-95% of all profiles with Q_UV = 0, most of the remainder with Q_UV = 1, and less than 1% with Q_UV ≥ 2. Figure 2 shows the geographic distribution of Q_UV = 1 profiles for a single day. Almost all VIS profiles achieve the best quality flag. A typical day has < 0.2% of profiles with Q_VIS ≥ 1.

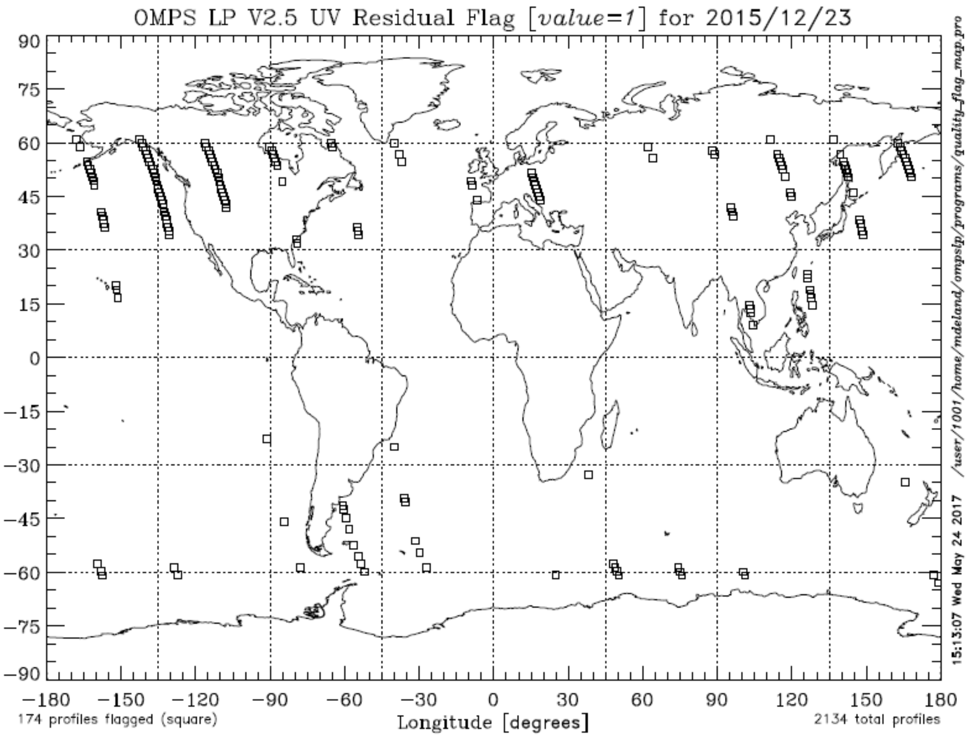

Figure 2. Geographic distribution of UV profile residual quality flag Q_UV = 1 for 23 December 2015.

3. Polar Mesospheric Clouds. We include a flag in the V2.5 data product to identify the most significant instances of PMC contamination in the ozone retrieval. The occurrence frequency of this flag (primarily during June-August in NH data, and December-February in SH data) varies from 5-10% of events at 60°-65° latitude to 85-90% of events at 75°-80° latitude. We recommend that the measurements identified by the PMC flag should not be used in data analysis.

4. Data Sampling. Data rate limitations on the Suomi NPP satellite prevent collection of the full wavelength and altitude range observed by LP for every event. The selection of pixels to be downloaded is specified by the Sample Table, which can be reprogrammed on-orbit. Table 3 gives a list of the main sample tables used by the LP instrument since launch. During the time period covered by Sample Table (STB) v0.5 (11/26/2013 – 01/23/2014), the altitude coverage of short wavelength radiance data causes problems in the UV retrieval algorithm. As a result, we have replaced all UV retrieval density values with fill values during this period, and set the corresponding retrieval quality flag to -999. We do not believe that the VIS retrievals are

impacted by this issue, but we have not fully verified this statement. We therefore set the VIS retrieval quality flag to 2 during the STB v0.5 period as a caution to users.

Table 3. OMPS LP Sample Table list as loaded on the Suomi NPP spacecraft for Earth view data collection. Note that during early instrument operations (through February 2012), there was more frequent switching between different sample tables.

Version	Orbits	Start Date	End Date	Comments
1.2	1-1581 3735-3737	10/28/2011	02/16/2012	BATC sample table
84.4	1043-1072	01/09/2012	01/11/2012	Initial sample table for regular science operations (ST 5A)
84.3	1279-1298	01/26/2012	01/27/2012	Left slit only (all pixels)
84.1	1299-1386	01/27/2012	02/03/2012	Right slit only (all pixels)
84.2	1387-1438	02/03/2012	02/06/2012	Center slit only (all pixels)
84.5	1439-3734 3738-4658	02/06/2012	09/20/2012	Minor smear pixel revision to operational table
0.4	4659-10788	09/20/2012	11/26/2013	Minor revision to move wavelength registration columns
0.5	10789-11612	11/26/2013	01/23/2014	First revision for improved spectral coverage
0.6	11613-12010	01/23/2014	02/20/2014	Second revision for spectral coverage
0.7	12011-13101	02/20/2014	05/08/2014	Third revision for spectral coverage
0.8	13102-current	05/08/2014	current	Small changes to improve IR coverage

5. Data Coverage. The first OMPS LP measurements were taken on January 10, 2012. LP data for January-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.

6. Solar Intrusion. LP radiance data near the end of the orbit can show anomalous values at high altitude. This behavior begins at approximately event 170, and has a seasonal variation with maximum effects in July [minimum solar β angle] and minimum effects in November. We believe that this behavior is caused by solar radiation that enters the instrument when the Sun illuminates the spacecraft insulation at high solar zenith angle at the end of the orbit. Users should be cautious with data taken during these situations.

7. Measurement Flags. The O3-DAILY data product contains important information about spacecraft position and orientation for each measurement in the 'SwathLevelQualityFlags' dataset of the GeolocationFields group (see Section 3.3.3 for details). The 'SAA' value of this dataset indicates the probability of South Atlantic Anomaly (SAA) charged particle effects on raw CCD data. The 'NonNominalAttitude' value of this dataset indicates when the S-NPP spacecraft orientation is temporarily changed, such as during roll maneuvers for VIIRS lunar calibrations. Both flags indicate an increased possibility of abnormal ozone profiles. Users should check these flags when selecting observations for their analysis to ensure maximum data quality.

2.0 Data Organization

These data files contain a subset of the overall ozone 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 O3 product, retrievals are only performed for observations with solar zenith angle SZA < 85°. These files contain two ozone density profiles (UV and VIS) for each event, along with geolocation information and informational flags. There are *Ntime* total observations from all orbits during a complete day. Only center slit data are provided in the daily product. All profile data are reported for the altitude range 0.5 km-55.5 km at 1 km intervals.

2.1 File Naming Convention

The OMPS Limb Profiler data product uses 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
    - *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-L2-O3-DAILY_v2.5_2012m0412_2017m0719t201536.h5

2.2 File Format and Structure

LP-L2-O3 data files are provided in the HDF5 format (Hierarchical Data Format Version 5), developed at the National Center for Supercomputing Applications http://www.hdfgroup.org/. These files use the Swath data structure format, with three primary groups: AncillaryData, DataFields, and GeolocationFields. The InputPointers group contains only data processing provenance information, and is not relevant for science users. 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 O3 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
Altitude	DataFields
CloudHeight	DataFields
O3UvValue	DataFields
O3UvPrecision	DataFields
O3VisValue	DataFields
O3VisPrecision	DataFields

2.3.1 Data Temporal Coverage

The first OMPS LP measurements used to create the O3 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 VIS retrieved profile for all altitudes below the cloud detection height if a cloud is identified.

2.3.3 Measurement Flags

The O3 data product contains important information about spacecraft position and orientation for each measurement in the 'SwathLevelQualityFlags' dataset (see Section 3.3.2 for details). The 'SAA' value of this dataset indicates the probability of South Atlantic Anomaly (SAA) charged particle effects on raw CCD data. The 'NonNominalAttitude' value of this dataset indicates when the S-NPP spacecraft orientation is temporarily changed, such as during roll maneuvers for VIIRS lunar calibrations. Both flags indicate an increased possibility of abnormal ozone density 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 O3 product includes the following dimension terms:

Name	long_name	Value
DimAlongTrack	Along-track dimension	2430 (nTime samples)
DimAltitudeLevel	Altitude-level dimension	56

3.2 Global Attributes

Metadata in the O3 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
platform_vocabulary	String	Source of platform name
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 AncillaryData Group

Dataset Name	Description	Units	Dimension Size
Pressure	Background atmosphere pressure profile for measurement conditions	hPa	[nTime,56]
Temperature	Background atmosphere temperature profile for measurement conditions	K	[nTime,56]
TropopauseAltitude	Calculated tropopause altitude	km	[nTime]

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.

3.3.2 DataFields Group

Dataset Name	Description	Units	Dimension Size
ASI_PMCFlag	Flag to indicate possible PMC impact on UV ozone retrieval	none	[nTime]
Altitude	Reference altitude grid	km	[56]
CloudHeight	Observed cloud height for each event from aerosol retrieval	km	[nTime]
O3UvPrecision	Calculated precision for UV ozone density profile	cm^{-3}	[nTime,56]
O3UvQuality	Quality flag for UV ozone retrieval	none	[nTime]
O3UvValue	UV retrieval ozone density profile	cm^{-3}	[nTime,56]
O3VisPrecision	Calculated precision for VIS ozone density profile	cm^{-3}	[nTime,56]
O3VisQuality	Quality flag for VIS ozone retrieval	none	[nTime]
O3VisValue	VIS retrieval ozone density profile	cm^{-3}	[nTime,56]
Q_UV	Quality flag calculated from residuals for UV retrieved profile	none	[nTime]
Q_VIS	Quality flag calculated from residuals for VIS retrieved profile	none	[nTime]
VertRes_O3UV	Calculated vertical resolution of UV retrieval	km	[nTime,56]
VertRes_O3Vis	Calculated vertical resolution of VIS retrieval	km	[nTime,56]
eventNumber	Event index for current orbit	none	[nTime]
sfcReflValue	Retrieved surface reflectivity at 675 nm	none	[nTime]

ASI PMC Flag. This flag is set to 1, indicating possible polar mesospheric cloud (PMC) effects in the UV ozone retrieval, if ASI(353 nm, 65.5 km) > 0.20. The aerosol scattering index (ASI) represents the difference between measured and calculated radiances, normalized at 45.5 km.

Altitude. Tangent height altitude levels between 0.5-55.5 km in 1 km intervals for profile data sets.

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.

O3UvPrecision. Estimated standard deviation profile derived from the diagonal of the covariance matrix of the Rodgers optimal estimation solution for each UV retrieval.

O3UvQuality. The UV profile quality flag is set to 1.0 for a successful retrieval, or -999.0 for an unsuccessful retrieval. This flag is also set to -999.0 during the period 11/26/2013-01/23/2014, when the LP sample table data coverage caused many UV retrievals to fail, and produced large data anomalies in UV retrievals that did succeed.

O3UvValue. Ozone density profile from UV retrieval. Valid data are provided for the altitude range 29.5 km – 52.5 km.

O3VisPrecision. Estimated standard deviation profile derived from the diagonal of the covariance matrix of the Rodgers optimal estimation solution for each VIS retrieval.

O3VisQuality. The VIS profile quality flag is set to 1.0 for a successful retrieval, or -999.0 for an unsuccessful retrieval. This flag is set to 2.0 as a cautionary note during the period 11/26/2013-01/23/2014, when the LP sample table data coverage caused most UV retrievals to fail.

O3VisValue. Ozone density profile from VIS retrieval. Valid data are provided for the altitude range cloud top – 37.5 km. If no cloud is identified above 12.5 km, the lowest valid altitude is set to 12.5 km.

Q_UV. This flag indicates the magnitude of the root-sum-square (RSS) radiance residual from the UV retrieval. It is scaled so that Q_UV = 0 corresponds to RSS residual < 0.05, Q_UV = 1 corresponds to RSS residual = 0.05-0.10, and so on.

Q_VIS. This flag indicates the magnitude of the root-sum-square (RSS) radiance residual from the VIS retrieval. It is scaled so that Q_VIS = 0 corresponds to RSS residual < 0.05, Q_VIS = 1 corresponds to RSS residual = 0.05-0.10, and so on.

VertRes_O3UV. The calculated vertical resolution of the UV retrieval at each altitude level using the reciprocal value of the diagonal elements of the averaging kernels. Results are only reported for the altitude range of each density profile.

VertRes_O3Vis. The calculated vertical resolution of the VIS retrieval at each altitude level using the reciprocal value of the diagonal elements of the averaging kernels. Results are only reported for the altitude range of each density profile.

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.

sfcReflValue. Retrieved scene reflectance at 675 nm, considering any clouds as being present at the terrain height.

3.3.3 GeolocationFields Group

Dataset Name	Description	Units	Dimension Size
AscendingDescendingFlag	Indicates ascending node or descending node	none	[nTime]
Date	Date [format = YYYYMMDD]	none	[1]
Latitude	Latitude at tangent point altitude of 25 km	degrees North	[nTime]
Longitude	Longitude at tangent point altitude of 25 km	degrees East	[nTime]

OrbitNumber	Orbit number	none	[nTime]
SingleScatterAngle	Single scattering angle at tangent point altitude of 25 km	degrees	[nTime]
SolarZenithAngle	Solar zenith angle at tangent point altitude of 25 km	degrees	[nTime]
SwathLevelQualityFlags	Flags for satellite location and orientation.	none	[nTime]
Time	Seconds since midnight [UT]	seconds	[nTime]

AscendingDescendingFlag. Flag to identify orbit node of Suomi NPP spacecraft for each event. Ascending node = 0, descending node = 1.

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

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.

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 in the form '*abcde*', with the following definitions.

a: 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

b: 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

c: SolarEclipse

0 = none

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

d: 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

e: NonNominalAttitude

0 = nominal spacecraft attitude

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

Time. Measurement time of each event.

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 https://support.hdfgroup.org/products/hdf5_tools/.

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:

https://support.hdfgroup.org/HDF5/release/obtain5.html

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.**

http://www.unidata.ucar.edu/downloads/netcdf/

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.

http://www.harrisgeospatial.com/ProductsandTechnology/Software/IDL.aspx

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:

https://support.hdfgroup.org/products/java/hdfview/

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.

https://www.giss.nasa.gov/tools/panoply/

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.

http://www.harrisgeospatial.com/ProductsandTechnology/Software/IDL.aspx

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 libraries (https://support.hdfgroup.org/HDF5/)

Java (https://support.hdfgroup.org/products/java/)

Python (http://www.h5py.org/)

GrADS (http://cola.gmu.edu/grads/)

Commercial:

IDL (http://www.harrisgeospatial.com/ProductsandTechnology/Software/IDL.aspx)

Matlab (http://www.mathworks.com/products/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:

https://disc.gsfc.nasa.gov/

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://snpp-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/

6.0 More Information

Contact Information

Name: GES DISC Help Desk
URL: https://disc.gsfc.nasa.gov/
E-mail: gsfc-help-disc@lists.nasa.gov
Phone: 301-614-5224
Fax: 301-614-5228
Address: Goddard Earth Sciences Data and Information Services Center
Attn: Help Desk
Code 610.2
NASA Goddard Space Flight Center
Greenbelt, MD 20771 USA

Additional OMPS and ozone data products

https://ozoneaq.gsfc.nasa.gov/

Suomi-NPP mission web page

https://jointmission.gsfc.nasa.gov/suomi.html

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> Matthew DeLand (2017), OMPS-NPP LP L2 Ozone Vertical Profile swath daily 3slit V2.5, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), accessed ***[data access date]***, doi:10.5067/X1Q9VA07QDS7.

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