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

Version 2.6

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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 (~12-60 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 in the stratosphere and mesosphere (~12-60 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) data were re-processed over the lifetime of the mission (from April 2012 to present) with the updated Version 2.6 (V2.6) ozone retrieval algorithm. The algorithm generates ozone number density profiles on geometrical altitude grid with 1 km intervals. The main concepts of the OMPS LP ozone retrieval algorithm are described by *Rault and Loughman* [2013]. Version 2.5 of OMPS LP dataset was thoroughly evaluated by comparing with independent ozone profile measurements [*Kramarova et al*., 2018]. The main difference of this release from previous Versions 2.0 and 2.5 is that a single ozone profile is retrieved using combined UV and VIS measurements between 12.5 km (or cloud top) and 57.5 km. The vertical resolution of LP ozone profile is ~1.9 - 2.5 km between 20-55 km, increasing to 3-4 km at lower and higher altitudes. Table 1 provides a summary of the V2.6 algorithm-specific changes from the previous publicly released versions (V2.0 and V2.5).

In Version 2.6 a single ozone profile is retrieved by combining UV and VIS wavelengths from the upper troposphere - lower stratosphere (UTLS) to lower mesosphere. The algorithm retrieves profiles between 12.5 km (or cloud top) and 57.5 km, using radiances measured at six UV ozone-sensitive wavelengths (295, 302, 306, 312, 317 and 322 nm) paired with 353 nm and one VIS wavelength at 606 nm combined with 510 nm and 675 nm to form a triplet. The approach with forming pairs or triplets - when ozone-sensitive wavelengths are combined with the reference wavelength(s) with almost no ozone absorption to form a pair or a triplet - makes the algorithm insensitive to errors in the assumed pressure *vs*. altitude profiles *p(z)* used in calculating the radiances. Pairs and triplets also help to reduce the sensitivity of the retrieval algorithm to aerosols. The V2.6 algorithm uses altitude-normalized radiances (60.5 km for UV and 40.5 km for VIS) 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. Cloud detection is based on the algorithm described by *Chen et al*. [2016]. If no cloud is identified, the retrieval lower limit is set to 12.5 km. The algorithm corrects for aerosol scattering effects using the concurrent aerosol extinction coefficient profile at 675 nm retrieved from the same LP measurements [*Loughman et al*., 2018; *Chen et al*., 2018]. The aerosol algorithm assumes the gamma-function particle size distribution, which is also used to estimate aerosol extinction at ozone sensitive wavelengths.

Table 1. Summary of key algorithm changes implemented in Version 2.6 compared to the base OMPS LP [*Rault and Loughman*, 2013] and to V2.5 [*Kramarova et al*., 2018] algorithms.

Key changes	Version 2.5	Version 2.6

Main highlights:		✓ Single profile from combined UV+VIS ✓ Increased number of wavelengths ✓ Updated O_3 cross-sections: BDM in UV (290-355 nm); and SG in VIS (500-700 nm) ✓ Updated O_3 and NO_2 climatology ✓ Limited vertical range for each wavelength pair/triplet contribution
Cloud Height Detection	Algorithm described in *Chen et al*. [2016]	Algorithm described in *Chen et al*. [2016]
Altitude Registration	Updated static TH for 3 slits Two 100-m steps (Apr. 2013 and Sep 2014) Intra-orbital, seasonally varying TH corrections of ~0.3-0.4 km [*Moy et al*., 2017]	Updated static TH for 3 slits (based on RSAS) Removed the second step in Sep. 2014 Simplified linear intra-orbital TH correction of ~ 0.5 km without seasonal component
Static Radiometric calibration		Spectrally smoothed albedo calibration Updated Day 1 goniometric corrections (orbit 1804, IRF 3-5%) Fraunhofer corrections in IRF Updated Day 1 wavelength assignment (orbit 1804) New quadratic fit to wavelength registration
Time-dependent Radiometric calibration		Wavelength shift correction CF values based on 5-pixel spectrally smoothed solar Reference measurements
Stray Light Correction	Empirical correction applied for VIS wavelengths	OOR correction 12% increase in PSF tails Modeled slit image correction (no UV change; VIS Left 1x, Center 1.5x, Right 3x)
Wavelength Selection	**UV:** 302, 312 and 322 nm paired with 353 nm (3 pairs) **VIS:** 600 nm combined with 510 nm and 675 nm to form a single triplet	**UV:** 295, 302, 306, 312, 317, 322 nm paired with 353 nm (6 pairs) **VIS:** 606 nm combined with 510 and 675 nm to form a single triplet
Normalization Altitude	**UV:** 55.5 km **VIS:** 40.5 km	**UV:** 60.5 km **VIS:** 40.5 km
Aerosol Correction	Use aerosol extinction coefficient profiles retrieved from LP measurements for same event assuming bimodal size distribution	Use aerosol extinction coefficient profiles at 675 nm retrieved from LP measurements for same event assuming gamma-function size distribution
Measurement Noise	**UV:** 1% **VIS:** 0.5%	**UV:** 1% **VIS:** 0.5% (below 27.5 km), gradually increasing from 0.5% to 1% from 27.5 km to 37.5 km
Vertical Smoothing	Optimal estimation with *a priori* covariance matrices S_a assuming 25% and 50 % ozone variability above 20 km and below 16 km,	Second order Tikhonov regularization aimed to keep the final vertical resolution ~ 2 km

	respectively, with 5 km inter-level correlation

Atmospheric air pressure and temperature profiles, used for forward model radiance calculation in this retrieval algorithm, are taken from NASA GSFC Global Modeling Assimilation Office (GMAO) Forward Processing for Instrument Team (FP-IT) data processed with version GEOS 5.12.4. The nearest spatial grid points (Δlatitude = 0.5°, Δlongitude = 0.625°) to each SNPP OMPS LP profile are identified, and the temperature and pressure profiles for time steps bracketing the LP measurement (Δt = 3 hours) are interpolated to the LP observation time and location. The tropopause altitude is calculated from GMAO FP-IT temperature profiles using the standard WMO definition of the lowest altitude at which the lapse rate is less than 2 K/km [*e.g.* *Reichler et al*., 2003]. The co-located GMAO FP-IT temperature and pressure profiles, along with the derived tropopause altitude, are provided in the LP-L2-O3-DAILY files for the convenience of users who may wish to create mixing ratio profiles on a pressure scale.

1.2.1 Changes Between Version 2.5 and Version 2.6 Data Product [December 2022]

Numerous changes have been implemented for the LP V2.6 ozone product compared to the V2.5 product released in 2017. The summary listing provided below complements the algorithm changes summarized in Table 1.

- The Level 2 (L2) algorithm now retrieves a single ozone density profile combining UV and VIS measurements, while in previous versions two separate ozone profiles were derived from UV and VIS measurements independently.
- Only center slit data are provided in the V2.6 daily product (same as in V2.5). Internal analysis shows that radiances measured in the left and right slits and ozone profiles retrieved from those slits have systematic biases compared to the center slit data and to each other. These biases show a complex dependence on multiple factors (calibration, altitude registration, stray light etc.). Based on these results, we provide only center slit data in the V2.6 LP-L2-O3-DAILY product.
- The assumed aerosol size distribution was changed from bimodal (used in V2.5 [*Loughman et al*., 2018]) to gamma-function in V2.6 [*Chen et al*., 2018]. The ozone retrievals are corrected for the effects of aerosols using the aerosol extinction coefficient profile for each event derived from concurrent aerosol retrieval at 675 nm derived from the same LP measurements. The radiance adjustment at ozone sensitive wavelengths is computed using the gamma-function particle size distribution assumed for that product.
- The number of wavelengths used to retrieve ozone profiles has increased in V2.6 compared to V2.5. The algorithm uses six ozone sensitive wavelengths (295, 302, 306, 312, 317, and 322 nm) in UV range and one ozone sensitive wavelength in VIS (606 nm) combined with one reference wavelength (353 nm) in UV and two reference

wavelengths (510 and 675 nm) in VIS. Increased number of wavelengths allows the algorithm to keep a similar sensitivity to changes in ozone over the entire vertical range.

- Each wavelength pair or triplet is used over a limited range of tangent point altitudes determined from the vertical profile of measured radiances Y_m normalized at altitude z_n and paired with the reference wavelength λ_0 for each event. We use the threshold of -0.8 to determine the appropriate range for each wavelength pair and do not include that pair when $Y_m(z, \lambda) < -0.8$ (where $Y_m(z, \lambda) = \{\ln(I_m(z,\lambda))-\ln(I_m(z_n,\lambda))\} - \{\ln(I_m(z,\lambda_0))-\ln(I_m(z_n,\lambda_0))\}$ and λ_0 = 353 nm and z_n = 60.5 km). We found that the tangent points determined using this threshold correspond to altitudes where sensitivity kernels $dY(z,\lambda)/dO_3$ starts to decrease as well. We limit the range for each pair to keep consistent sensitivity of the algorithm to changes in ozone over the entire profile.
- The UV normalization altitude has been changed from 55.5 km to 60.5 km to extend ozone retrievals at upper altitudes. The VIS normalization altitude remains at 40.5 km as in V2.5.
- Tikhonov regularization is employed in the V2.6 retrieval algorithm to vertically smooth retrieved ozone profiles and to keep the vertical resolution close to ~2 km through the middle stratosphere.
- Ozone absorption cross-sections were updated in V2.6. In UV spectral range (295-355 nm) Brion-Dumont-Mallicet (BDM) [*Brion et al*., 1993] cross sections provide more accurate ozone absorption coefficients at longer UV channels (λ > 320 nm) compared to the previous cross-sections [*Bass and Paur*, 1985] used in V2.5. BDM cross-sections are also used in ozone retrievals from OMPS Nadir Mapper and Nadir Profiler. In VIS range, Serdyuchenko-Gorshelev (S-G) cross-sections [*Gorshelev et al*., 2014] replaced those by *Burkholder and Talukdar* [1994] used in V2.5. We expect small changes (<1%) in the ozone products due to updates in ozone absorption cross sections.
- Nitrogen dioxide (NO_2) cross sections based on *Mérienne et al*. [1995] in V2.5 were replaced with *Vandaele et al*. [1998]. This has very small effect on ozone retrievals since NO_2 absorption is relatively low at the wavelengths we use in the retrieval algorithm.
- Ozone and nitrogen dioxide (NO_2) profile climatologies, used in the forward model to simulate limb scattered radiances, were updated in V2.6. The seasonal ozone climatology is described in *Ziemke et al*. [2021] and is based on multi-year averaged MLS ozone profiles in the stratosphere. In V2.6 we use model-based GEOS GMI NO_2 climatology [*Nielsen et al*., 2017; *Orbe et al*., 2017] that accounts for changes in the local time of LP measurements. We also found that the new climatology agrees better with satellite-based NO_2 retrievals [*e.g. Rivas et al*., 2014] in terms of absolute values, latitudinal distribution and seasonal variations. In V2.5 the NO_2 climatology was based on the PRATMO (PRather ATmospheric Model) photochemical box model [*Prather and Jaffe*, 1990; *Brohede et al*., 2007]. Note that OMPS LP ozone retrievals are not sensitive to O_3 or/and NO_2 climatologies. Therefore, these changes will not affect retrieved ozone profiles directly. However, simulated radiances used to evaluate the LP altitude registration or LP instrument performance will benefit from these updates.
- The stray light correction has been updated in V2.6. The out-of-range (OOR) correction includes a 12% increase in the tails of the pixel spread function (PSF). The modeled slit image correction is unchanged for UV wavelengths, and has been increased by a factor of 1.5 for the center slit at visible wavelengths. These spectrally dependent scale factors are applied to L1B radiances.

- Level 1B data contain new adjustments for altitude registration. A static correction of 1.58 km is used for center slit data, and a single +0.1 km adjustment on 25 April 2013 is applied to correct for a S-NPP spacecraft pitch maneuver.
- The intra-orbital tangent height adjustment is simplified in V2.6. The correction is expressed as a linear function of event number without seasonal dependence. The intra-orbital correction was applied to L1B radiances in V2.6. The magnitude of this adjustment (from peak to peak) is ~ 650 m over the entire orbit.
- The LP static radiometric calibration for V2.6 has been revised to use spectrally smoothed albedo (radiance/irradiance) prelaunch data. The “Day 1” goniometric correction has been updated to use irradiance (IRF) measurements from orbit 1804 in February 2012. Fraunhofer line corrections have been applied to the reference IRF. The “Day 1” wavelength scale assignment has also been updated based on measurements from orbit 1804, using a quadratic fit to the dispersion relation.
- The V2.6 ozone product uses two time-dependent (dynamic) calibration corrections. Wavelength registration uses a seasonally varying correction derived from analysis of measurements over selected spectral regions. Radiometric calibration factor (CF) corrections are determined from solar reference diffuser measurements taken at 6-month or 12-month intervals, and smoothed over 5 spectral pixels.

1.2.2 Changes Between Version 2 and Version 2.5 Data Product [July 2017]

Several changes were implemented for the LP V2.5 ozone product compared to the V2 product previously released in 2014. These changes are summarized below. Please note that some items have been superseded by the changes described in Section 1.2.1.

- 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 which depends on event number and day of year.

1.2.3 Changes Between Version 1 and Version 2 Data Product [July 2014]

Numerous changes were implemented for the LP V2 ozone product compared to the V1 product. These changes are summarized below. Please note that some items have been superseded by the revisions described in Section 1.2.2.

- The baseline wavelength registration has been revised. In addition, spectral shifts due to temperature variations are now corrected using a seasonal term (based on the day of year for each measurement) and an intra-orbit term (applied within each orbit).
- The *a priori* data set is now based on 2012 MLS observations.
- An estimated instrument error of 1% has been incorporated in the retrieval procedure to reduce high frequency vertical oscillations in the retrieved profiles.
- Radiance samples between 306.5-311 nm are excluded from the UV ozone retrieval to avoid contamination from OH dayglow emission at high altitudes.
- Data are reported from all three LP slits.
- The normalization altitude for radiance data used in the UV ozone retrieval has been lowered from 68.5 km to 65.5 km.
- No aerosol correction is applied in the ozone retrieval based on external aerosol profile data.
- The combined ozone profile does not apply any merging procedure in the altitude region where the UV and visible retrievals overlap. UV ozone data are used from 60.5 km down to 27.5 km, and visible ozone data are used from 26.5 km down to the lowest altitude retrieved for that event.

1.3 Data Disclaimer

We report several quality flags in Version 2.6 daily files that are based on our evaluation of the retrieval algorithm and radiance residuals. These flags are aimed to characterize the quality of ozone retrievals and help users to filter data. We evaluated a limited subset of the LP V2.6 ozone data product against other data sets (*e.g*. Aura MLS, SAGE III). 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. In Section 1.3.4. we provide recommended values for the various flags to filter out low-quality retrievals.

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). The absolute uncertainty quoted in *Moy et al*. [2017] is ±200 m. Validation results suggest that the current performance is well within this estimated range.
- Altitude Registration (inter-orbital). While the Suomi NPP spacecraft has a star tracker that provides accurate pointing information, it is located near the VIIRS instrument at the opposite end of the spacecraft from the OMPS sensors. Our current analysis indicates that the flexure of the spacecraft bus may be causing up to 20 arc-sec errors in determining the spacecraft pitch angle at the OMPS LP location on the spacecraft, producing up to 300 m error in the LP altitude registration along the orbit. These errors may vary with latitude and season, and can produce approximately 5-7% errors in retrieved ozone density above 35 km. In V2.6 we simplified the intra-orbital TH corrections, expressing them as a linear function of event number only and removing the seasonal component. The intra-orbital corrections in V2.6 are implemented in L1B processing.
- Altitude Registration (drift). Analysis of V2.5 data [*Kramarova et al*., 2018] revealed a drift in ozone time series with the patterns consistent with an altitude registration drift of ~100-200 m. This drift was primarily caused by the +100 m adjustment erroneously applied in V2.5 in September 2014. After analyzing LP altitude registration (using the RSAS method described in *Moy et al*. [2017]), we concluded that this 100-m step in Sep. 2014 led to a drift in the altitude registration, producing a drift in the O_3 time series. In V2.6 this step has been removed, and drifts in both quantities – LP altitude registration and ozone record – have been reduced by a factor of 2.

- Retrieval Precision. This quantity is calculated using diagonal elements of the solution covariance matrix. Precision values in V2.6 range between 3-4% between 20 and 52 km (compared to 6-8% in V2.5). Larger precision values occur in the tropical upper troposphere and lower stratosphere (UT/LS) and in the mesosphere.
- Systematic Errors. Quasi-systematic patterns are observed in LP radiance residuals that vary with wavelength, altitude, event number, and season. These patterns are consistent with individual pixel calibration errors at the < ±1% level. We estimate that the pixel errors can produce retrieved ozone errors of ~ ±3%.
- Background Aerosol. Residual, non-linear errors may be present in ozone profile retrievals in the UT/LS after applying the aerosol correction based on retrieved aerosol. Potential errors due to aerosol contamination are larger below ~18 km in the tropics (20°S-20°N) and below ~15 km in the subtropics (20°-40° latitude).
- 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. Measurements in Northern Hemisphere are particularly affected because forward-scattered PMC photons have not passed through the ozone molecules in the LOS. The magnitude of the excess radiance signal is also greater in the NH because PMC particles have an increased phase function in forward-scattering geometry [*DeLand and Gorkavyi*, 2020]. This effect leads to an underestimate of the ozone profile (see also Section 1.3.3).
- South Atlantic Anomaly. Charged particles can contaminate LP measurements when the satellite flies over the South Atlantic Anomaly (SAA) region. Any pixel on the LP CCD detector can be affected by these particles. The swath-level quality flag (see Section 1.3.4, item #6) contained in V2.6 files identifies geographic regions with increased chances of SAA effects based on climatology. The Measurement Vector Quality (QMV) flag provides a quantitative estimate of SAA effects on individual profiles (see Section 1.3.4, item #3).

Table 2. Summary of estimated OMPS LP ozone profile errors due to uncertainties discussed in Section 1.3.1.

Altitude	**16.5 km**	**24.5 km**	**32.5 km**	**40.5 km**	**48.5 km**	**52.5 km**
Alt. Reg. (abs.)	5-10%	0%	3-4%	5%	5%	5%
Alt. Reg. (drift)	0.6%/yr	< 0.2%/yr	0.4%/yr	0.4%/yr	0.4%/yr	0.4%/yr
Retrieval Precision	10-20(50)%	3-4%	3-4%	3-4%	3-4%	5%
System. Error	±3%	±3%	±3%	±3%	±3%	±3%
Background Aerosol	10-20%	1-2%	< 1%	< 1%	–	–

1.3.2. Ozone Profiles Assessment

Based on preliminary comparisons with MLS version 5 data we found:

- Mean biases are within ±5% between 20-45 km (Figure 1). In the upper stratosphere around 45-53 km, LP has systematic negative biases (-5% → -10%).
- Biases in UTLS region (12-18 km) are larger (up to ±20-30%) and mostly positive in the tropics. Smaller but persistent negative biases are also observed at these altitudes in the southern hemisphere between 40°-60°S.
- Seasonal biases are seen in LP retrieved ozone profiles between ~25-30 km in the northern hemisphere (also observed in V2.5) with smaller biases in summer and larger biases in winter.
- Systematic patterns in biases. There are persistent patterns in the mean differences between LP and MLS (also seen in comparisons with other independent instruments) that are about ±2-3% in magnitude. Similar patterns were seen in V2.5 [*Kramarova et al*., 2018]. The patterns (Figure 1) repeat from orbit to orbit with remarkable precision. They are caused by subtle systematic errors (<1%) in measured radiances. These errors are most likely due to small variations in CCD pixel-to-pixel calibration in both the vertical and spectral dimensions. The geometry of LP observations changes over the orbit such that the same CCD pixel sees different altitudes along the orbit; this effect is more prominent in the Southern Hemisphere. As a result, systematic measurement errors lead to artificial latitudinal structures in the LP ozone data.
- Relative drift between LP and MLS has reduced in V2.6 to +0.3-0.6%/year (down from 0.6-1.2%/year in V2.5). The drift is observed in upper stratosphere above ~35 km.

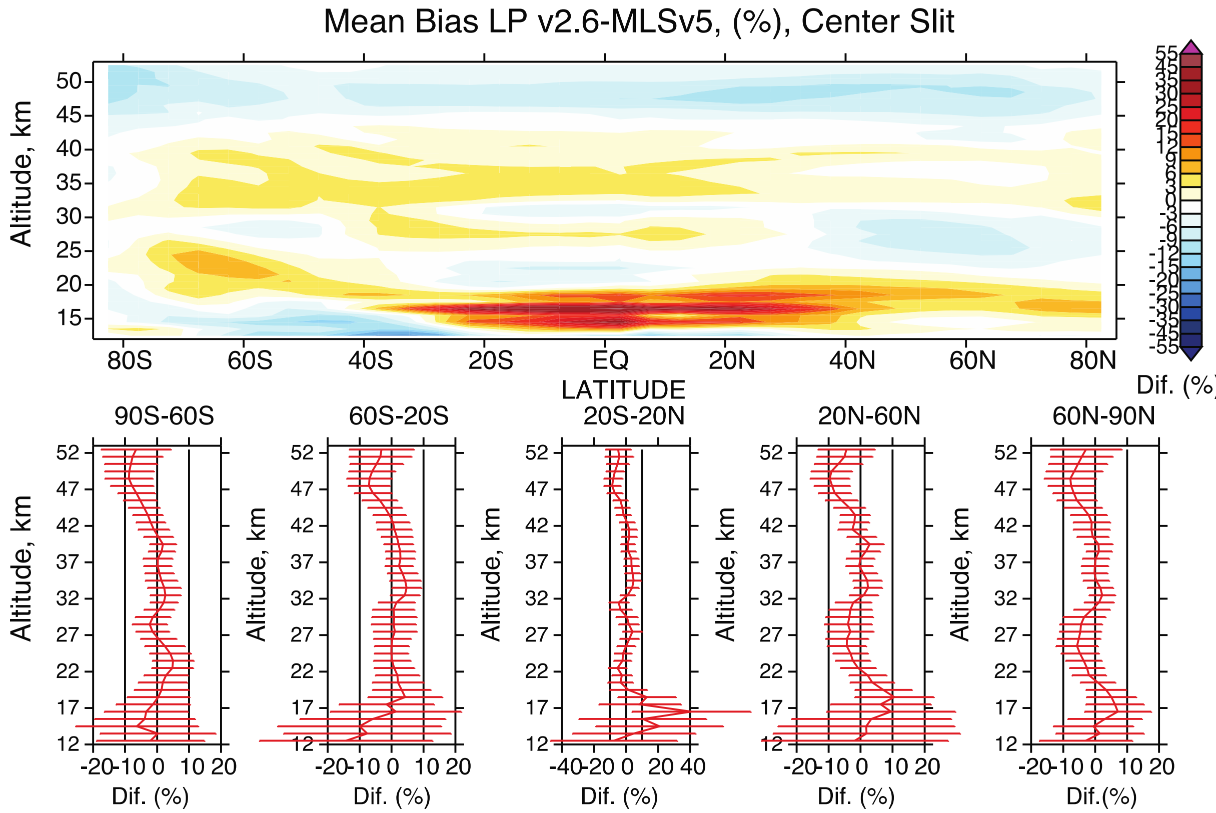

Figure 1. Mean biases between OMPS LP v2.6 and MLS v5 as a function of altitude and latitude (top panel) based on a subset of 112 days between April 2012 and August 2020 (with a sample of one day per month). Mean biases with 1-sigma standard deviations (horizontal bars) are shown on the low panels for five wide latitude zones.

1.3.3. Data Product Features

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 the 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 ozone retrieval algorithm. As a result, we have replaced all ozone retrieval density values with fill values during this period, and set the corresponding retrieval quality flag to -999.

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

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. The data before April 2012 are not well calibrated. 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 (on Sundays) from April 2012 to June 2016.

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.

Increased stratospheric aerosol concentrations. Recent years have had several unprecedented events, such as the Australian New Year fires in 2020 and the Hunga-Tonga volcanic eruption in January 2022, that disturbed stratospheric composition and increased the stratospheric aerosol optical depth. The aerosol concentration in SH has increased substantially [*Taha et al*., 2022]. The high aerosol concentration, particularly at altitudes above ~20 km, can be mistakenly identified as a cloud by the LP cloud detection algorithm, forcing the ozone retrieval to be cut off below the altitude marked as a cloud top. The OMPS team is working on evaluation of ozone retrievals for this type of conditions.

1.3.4. Recommended Data Quality Filters

1. Convergence. The algorithm requires a convergence test that determines when the iterations no longer improve retrievals and can be stopped. In V2.6 we choose the convergence test that minimizes the cost function (see eq. 5.29 in *Rodgers* [2000]). We recommend using profiles with reported convergence (O3Convergence) less than 10.

2. Number of Iterations. The number of iterations for each retrieval is reported in the output file (O3Status). If after 7 iterations the convergence criterion is still greater than 10, we assume that the retrieval did not converge and set the O3Status flag to 0. For events where we did not attempt to retrieve (*e.g*. high SZA > 85°), we set the O3Status flag to the fill value of “-999”. We recommend using profiles with reported number of iterations (O3Status) ranging from 2 to 7.

3. Quality Measurement Vector Flag. 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 Measurement Vector Quality flag (QMV) based on the root-sum-square (RSS) of all residuals for that profile, using data from each wavelength pair only for the altitude range over which it is used in the retrieval. We scale the summed residual so that QMV = 0, which we believe represents the best profiles, corresponds to an RSS residual < 0.08. This flag identifies ozone profiles affected by the SAA and other anomalies in measured radiances. A typical day has >99% of all profiles with QMV = 0 outside the SAA region, gradually increasing to 50-60% of profiles with QMV > 0 in the core of the SAA region. Figure 2 shows the distribution of QMV > 0 profiles for a single day. Note that the location of most flagged events is shifted relative to the actual SAA because the LP tangent point is 3300 km away from the S-NPP spacecraft. We recommend using profiles with reported QMV = 0.

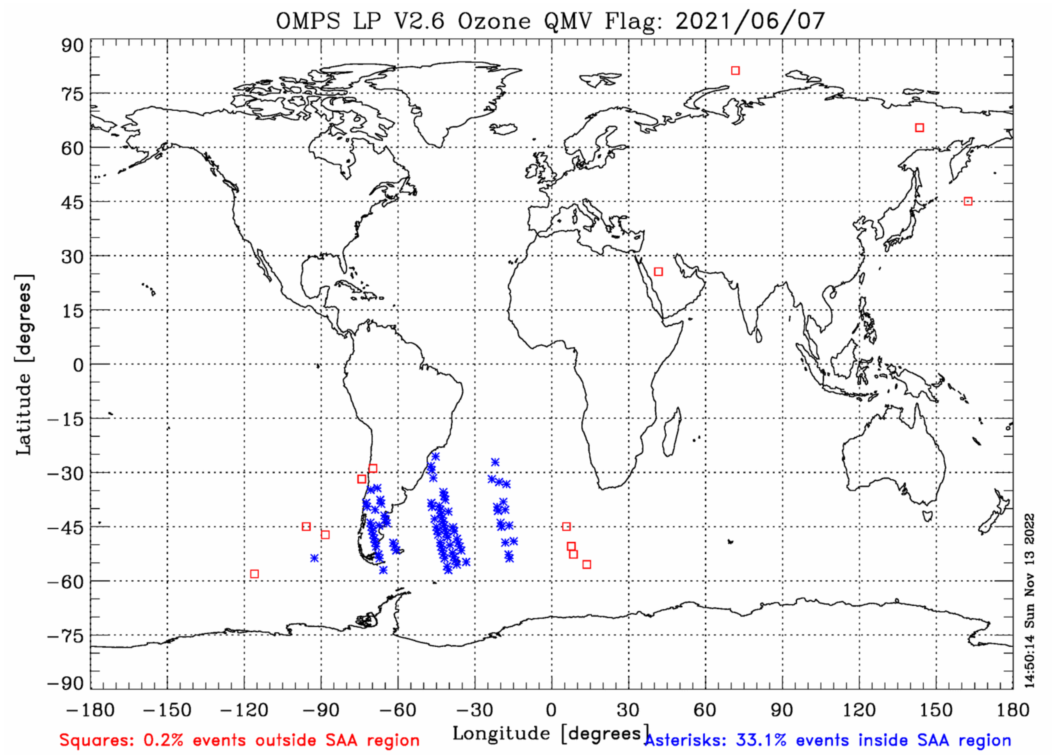

Figure 2. Geographic distribution of ozone profiles with quality flag QMV > 0 for 6 April 2021. *Blue* = satellite within climatological SAA region, *red* = satellite outside SAA region.

<u>4. Polar Mesospheric Clouds</u>. The ozone retrieval algorithm is sensitive to the presence of polar mesospheric clouds (ASI_PMCFlag). While these clouds exist at 80-85 km, their radiance can affect the retrieved ozone densities to altitudes as low as 40 km, if they are in the line of sight (LOS) of the LP instrument. We include a flag 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. Daily zonal mean ozone changes at 50 km due to PMC contamination can reach ±3-5%, and significantly larger changes are possible for individual profiles. The measurements identified by the PMC flag should not be used in data analysis. We recommend using profiles with reported PMC Flag (ASI_PMCFlag) equal to 0.

<u>5. Ozone Quality Flag</u>. The retrieval algorithm is designed to use a pre-defined set of wavelengths. The wavelengths selected in the O_3 algorithm are typically available in L1G data for each event over the lifetime of the mission. However, occasionally the requested wavelengths are not available. For the V2.6 ozone product, the algorithm looks for the nearest wavelength within $\pm$0.4 nm in the UV region and $\pm$2.0 nm in the visible region from the

nominal wavelength. If the nearest available wavelength exceeds this range, the ozone quality flag (O3Quality) is set. The format of this flag is 'bcdefg.i', where b=1 means a shift from the nominal wavelength for 295 nm pair, c=1 for 302 nm, d = 306 nm, e = 312 nm, f = 317 nm, g = 322 nm, and i = 606 nm. We recommend using profiles with no wavelength shift (O3Quality = 0.0).

6. 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 aerosol extinction profiles. Users should check these flags when selecting observations for their analysis to ensure maximum data quality.

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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 a single ozone density profile 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-60.5 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
- 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-O3-DAILY_v2.6_2016m1012_2022m1230t070142.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 (now the HDFGroup). 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
O3Value	DataFields
O3Precision	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 retrieved ozone 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	61
Dim7WLPairAndTriplet	Wavelength_Pair_Triplet_Dimension	7

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 atmospheric pressure profile for measurement conditions	hPa	[nTime,61]
Temperature	Background atmospheric temperature profile for measurement conditions	K	[nTime,61]
TropopauseAltitude	Calculated tropopause altitude	km	[nTime]

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

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

<u>TropopauseAltitude</u>. Tropopause altitude calculated based on WMO definition (lowest level at which temperature lapse rate is less than 2 K/km).

3.3.2 DataFields Group

Dataset Name	Description	Units	Dimension Size
ASI_PMCFlag	Flag to indicate possible PMC impact on ozone retrieval	none	[nTime]
A_priori_O3	A priori ozone density profile used for each retrieval	cm^{-3}	[nTime,61]
Altitude	Reference altitude grid	km	[61]
AveKernel_O3	Averaging kernel for each retrieval	none	[nTime,61,61]
CloudHeight	Observed cloud height for each event from aerosol retrieval	km	[nTime]
O3Convergence	Calculated convergence coefficient	none	[nTime]
O3Precision	Calculated precision for ozone density profile	cm^{-3}	[nTime,61]
O3Quality	Flag indicating wavelength shift for ozone channels	none	[nTime]
O3Status	Number of iterations for retrieval	none	[nTime]
O3Value	Retrieved ozone density profile	cm^{-3}	[nTime,61]
QMV	Quality flag calculated from measurement vector residuals for retrieved profile	none	[nTime]
UvVisLowCut	Lowest altitude for each pair (or triplet) used in retrieval	km	[nTime,7]
VertRes_O3	Calculated vertical resolution of retrieval	km	[nTime,61]
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 (assuming no aerosol), normalized at 45.5 km.

A_priori_O3. The a priori ozone density profile used for each retrieval.

Altitude. Tangent height altitude levels between 0.5-60.5 km in 1 km intervals for profile data sets.

AveKernel_O3. The averaging kernel calculated for each retrieval.

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.

O3Convergence. Convergence coefficient is determined for each retrieval using Eq. 5.29 of *Rodgers* [2000].

O3Precision. Estimated standard deviation profile derived from the diagonal elements of the solution covariance matrix *[Rodgers, 2000]*.

O3Quality. Encoded flag to indicate possible wavelength shift (>±0.4 nm in UV or ±2 nm in VIS) from the nominal value for each ozone channel. Format is bcdefg.i, where b = 1 means shift at 295 nm, c = 302 nm, d = 306 nm, e = 312 nm, f = 317 nm, g = 322 nm, i = 606 nm.

O3Status. Number of iterations for retrieved ozone profile.

O3Value. Retrieved ozone density profile. Valid data are provided for the altitude range from cloud top to 57.5 km. If no cloud is identified above 12.5 km, the lowest valid altitude is set to 12.5 km.

QMV. Quality flag calculated from the root-sum-square (RSS) of the measurement vector residual for each wavelength pair (or triplet) over the altitude range where it is used in the retrieval. It is scaled so that QMV = integer[RSS(residual)*12.5].

UvVisLowCut. The lowest altitude (z_{low}) at which each wavelength pair or triplet is used in the retrieval. For UV pairs, z_{low} is defined by

$$Ym(z_{low},\lambda) = [Ln(Im(z_{low},\lambda)- Ln(Im(z_n,\lambda)] - [Ln(Im(z_{low},\lambda_0)- Ln(Im(z_n,\lambda_0)] = -0.8$$

with λ_0 = 353 nm, z_n = 60.5 km. For the VIS triplet, z_{low} is the higher value of 12.5 km or cloud top height.

VertRes_O3. The calculated vertical resolution of the 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]
SecondsInDay	Seconds since midnight [UT]	seconds	[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]

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.

SecondsInDay. Measurement time of each 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

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 libraries
- 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://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://www.nasa.gov/mission-pages/NPP/main/index.html

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