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

README Document for Suomi-NPP OMPS NPBUVO3-L2 Product

Version 2.8

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Revision History

Revision Date	*Changes*	*Author*
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Table of Contents

1.0 Introduction

This document provides basic information for using the Suomi National Polar-orbiting Partnership (NPP) Ozone Mapping and Profiling Suite (OMPS) Nadir Profiler (NP) Ozone Profile Level 2 product, or OMPS-NPP_NPBUVO3-L2 for short. OMPS-NPP_NPBUVO3-L2 provides ozone profile retrievals determined from normalized radiance measurements taken by both the NP and Nadir Mapper (NM) sensor. Each file contains one orbit's worth of data.

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 NPBUVO3 L2 retrievals and products will be described here.

1.1.1 Nadir Profiler

The OMPS nadir module is composed of two spectrometers that share the same telescope. A dichroic filter downstream of the telescope redirects photons into either the NM or the Nadir Profiler (NP) spectrometer. The telescope itself has a 110° total across-track field of view (FOV), resulting in 2800 km instantaneous coverage at the Earth's surface; this is sufficient to provide daily full global coverage at the equator for the NM sensor. The telescope includes a pseudo depolarizer designed to minimize the system's sensitivity to incoming polarization. The dichroic filter is optimized to reflect most of the 250–310 nm light to the NP spectrometer and transmit most of the 300–380 nm light to the NM spectrometer.

Once split, the light from the NM spectrometer is dispersed via a diffraction grating onto one dimension of a two dimensional charge-coupled device (CCD) located at the spectrometer's focal plane. The second dimension reflects the cross-track spatial coverage provided by the slit aperture and optics. The CCD consists of 340 pixels along the spectral dimension and 740 pixels in the across-track spatial dimension.

Measurements meeting the 300–380 nm wavelength range specification required by the NM sensor are obtained by illuminating 196 of the 340 pixels in the spectral dimension. In the across-track dimension, 708 pixels are illuminated. For nominal operations, the pixel signals are summed into 35 separate "macropixel" FOVs; all but the two outer FOVs contain 20 pixels per macropixel; the left outermost macropixel contains 26 pixels, while the right outermost contains 22. Since the readout of the CCD is split in the center, measurements comprising the central

FOV are actually split (although not symmetrically). Rather than rebinning these measurements in ground processing, they remain split, resulting in 36 cross-track FOVs. In this case, the central two FOVs comprise 12 pixels (30 × 50km) and 8 pixels (20 × 50 km), respectively.

For the NP sensor, 147 of the 340 spectral pixels are illuminated, resulting in the 250–310 nm range specified in Table 1. The NP entrance slit illuminates only 93 of the available spatial pixels. All of the pixels are on the same side of the CCD, and they are subsequently combined into a single macropixel. The 147 × 93 pixels are exposed for 38 s, which yields a 250 km × 250 km nadir-looking FOV that is somewhat larger than the SBUV/2 FOV. As with the NM sensor, the NP sensor can be configured to provide higher-resolution measurements by changing the along-track timing and across-track binning (again at the expense of downlinking fewer wavelengths due to bandwidth constraints).

Since the ozone profile algorithm relies on measurements from 250 to 380 nm, data from both the NM and NP sensors are needed. In order to use the NM data, measurements from the central 6 FOVs and 5 along-track swaths are combined together to match the NP FOV.

1.2 Algorithm Background

The Version 8.7 O3 ozone profile algorithm is the latest in a series of BUV (backscattered ultraviolet) vertical profile O3 algorithms that were originally developed for the SBUV and follow on SBUV/2 instruments. It uses an Optimal Estimation retrieval algorithm combining OMPS measurements (from NM and NP) with a priori O3 profile information. The core of the retrieval algorithm remains the same as in the previous version 8.6 described by Bhartia et al. [2013]. The longer channel measurements are used to provide an initial total O3 estimate (used to select the first guess ozone profile) and a cloud/surface reflectivity estimate. The measurement vector is represented by Y_M and contains the natural logarithm of the Top of the Atmosphere Albedos (TOAAs). The number of channels used varies with solar zenith angle and total O_3 column. The unknown O_3 profile is represented by a vector X and its components are the layer O_3 amounts in Dobson Units [DU] for each of 21 pressure layers. The vector X_A corresponds to the 21-layer a priori O_3 profile.

The retrieval formulation begins with a linearization of the discretized forward model about a first guess for the O_3 profile, X_0. This first guess profile is chosen from the 21 standard profiles based on the estimated total O_3 column and latitude. The forward radiative transfer model (TOMRAD) is used to calculate TOAAs. In the operational code, only single scattering calculations are done online, while the multiple scattering adjustments for TOAAs are pre-calculated for the set of standard O_3 profiles and stored in look-up-tables. The initial TOAAs Y_0 are calculated using the single scattering model with X_0 ozone profile for the measurement viewing conditions, and then adjusted to account for multiple scattering using the factors from the look-up tables. The linearization is given by

$$Y = Y_n + K_n (X - X_n) \quad n=0,1,\ldots$$

where Y_n is the forward model estimate after iteration n, X_n is the O3 profile estimate after iteration n, and K_n is the Jacobian matrix of partial derivatives of the components of Y with respect to the components of X ($\partial y_i/\partial x_j$ where individual y_i and x_j represent sensitivity of log of TOAA for wavelength channel *i* to changes in O_3 layer amount in layer *j*, respectively) evaluated at X_n.

The partial derivative coefficients in K are calculated by using the O_3 profile from the previous iteration (X_n) and constitute the weighting function. They measure the sensitivity of the radiance at a particular wavelength to changes in O_3 in the different layers in the profile.

The iterative solution proceeds by generating the optimal estimation solution for the current linearized problem by using the following calculation

$$X_{n+1} = X_A + S_A K^T [K_n S_A K_n^T + S_M]^{-1}[(Y_M - Y_n) - K_n (X_A - X_n)]$$

Where X_n is the discrete O_3 profile derived in previous iteration n, X_{n+1} is the new O_3 profile estimate, X_A is the a priori O_3 profile, Y_M is the vector of measured TOAAs; Y_n and K_n are the calculated TOAAs and Jacobian for an atmosphere containing layer O_3 amounts, X_n ; and S_A and S_M are the a priori and measurement covariance matrices, respectively. The algorithm uses the root mean square (RMS) change in X from one iteration to the next as a convergence criterion. For a more detailed description of the algorithm see Bhartia et al. [2013].

The SBUV algorithm uses climatological ozone profiles as a priori to constrain retrievals. In the new version 8.7 algorithm, the ozone climatology has been updated. In the troposphere, a sonde-based ozone climatology was replaced with a climatology derived from GMI model simulations to account for variability that cannot be sampled by the relatively sparse sonde network [Ziemke et al., 2021]. In addition, the a priori ozone profiles include a correction factor for the diurnal ozone effect. This correction factor depends on local solar time of the measurement, and is derived based on the Goddard Diurnal Ozone Climatology [Frith et al., 2020]. The diurnal corrections are especially important for SBUV-2 instruments that were launched on board of satellites with drifting orbits when the measurements were acquired at different local times over the lifetime of the mission. The corrections are negligibly small for Suomi NPP OMPS between 60°S-60°N, but at high latitudes where measurements are acquired at different local solar times these corrections provide a better a priori constrains.

The version 8.7 processing also includes updated soft calibrations for OMPS channels, which are derived by comparing OMPS NP radiances with SBUV/2 instruments, particularly NOAA-19 (see table 1). This was done to ensure consistency between the long-term SBUV record and OMPS.

1.3 Data Disclaimer

Special high resolution diagnostic NM data were taken every Sunday from the beginning of the mission until 4 August 2013. Between 4 August 2013 and 25 June 2016, these data were taken every Saturday. During these times, no NP data were taken.

1.4 What's New?

V2.1 was the first version of the dataset released through the GES DISC in 2017. The previous V1.0 dataset was available through NASA's OMPS science team's web site: https://ozoneaq.gsfc.nasa.gov/omps

1.4.1 Version 2.1

<u>Changes from V1.0 to V2.1 included:</u>

Non-science-related changes

Nomenclature and Naming Convention

1) The naming convention for the L1B dataset has been changed from NP_EDR_EV_NASA to NPBUVO3-L2. Specifically, NOAA nomenclature (EDR) has been replaced by

NASA nomenclature (L2).

2) All capitalization of names within the file has been replaced by camel casing.

3) Underlines in all names have been eliminated.

Science-related changes:

1) The V2.1 dataset uses V2.0 of NPEV-L1B and NMEV-L1B as input. The V2.0 L1Bs provide improved radiance calibration.

2) SurfaceCategory has been added to the AncillaryData group. It is based on the International Geosphere–Biosphere Programme (IGBP) surface classification.

3) GroundPixelQualityFlags and InstrumentQualityFlags have been added to the GeolocationGroup.

4) A TrendingData group has been added.

   a) QualityFlagsFrequency provides the percent frequency of occurrence for each of the defined Algorithm Quality Flags.

1.4.2 Version 2.8

The intermediate version 2.6 had been released in 2019 (McPeters et al., 2019) and was available at https://ozoneaq.gsfc.nasa.gov/omps

Changes from v2.1 to v2.6:

1) In v2.6 the prelaunch absolute calibrations for NM were adjusted by +2%, based on the polar snow/ice reflectivity). Comparisons with coincident N19 measurements allowed cross-calibration of NP ozone absorbing channels to be consistent with the SBUV historical record (see Table 1).
2) OMPS NP solar measurements were analyzed to derive the drift in sensor sensitivity. The sensor drift was fitted and linearly extrapolated for the NP albedo calibration adjustments. After 9 years of operation, radiance sensitivity degradation of the NP is ~1% for shorter UV channels (272 nm) and ~0.5 % at 300 nm. The sensor drift for the longest channels used in SBUV algorithm, which come from OMPS NM measurements, were small at the tenths of a percent level. Therefore, no adjustments has been applied at those wavelengths ($\lambda > 310$ nm).
3) Solar activity correction for Day-1 solar irradiance measurements of OMPS NP has been implemented. The Mg II index was computed using available NP solar irradiance measurements. The spectral dependence of solar activity factor was also derived from these OMPS NP solar measurements. Then daily Mg II index from GOME-2 solar measurements (available at https://www.iup.uni-bremen.de/gome/gomemgii.html) was adjusted to OMPS NP Mg II index and applied to Day-1 solar irradiance measurements.
4) In order to match the OMPS NP footprint, several OMPS NM pixels are combined. There was a bug in the composing of the NP footprint from NM pixels that produced a large scene noise. The bug was fixed in v2.6.

5) The SBUV algorithm was originally designed to work with discrete wavelength measurements. OMPS is a hyperspectral instrument, and an intermediate interpolation step is needed to find the required wavelength. The wavelength interpolation procedure was changed in v2.6 processing from linear interpolation to cubic spline. The linear interpolation can produce an undesirable latitude dependent offset compared to a more accurate cubic spline.
6) The wavelength dependent constant adjustments for Raman scattering have been included. Those corrections are based on radiative transfer simulations with elastic and inelastic scattering for the OMPS wavelengths used in the retrieval algorithm.

Changes from V2.6 to V2.8 include:
7) The ozone a priori profiles have been updated in v2.8 (see Sec. 1.2 above for more details) and include corrections for the ozone diurnal cycle based on local solar time of measurements.

8) OMPS channels have been adjusted based on comparisons with the previous SBUV instruments, particularly NOAA 19 (see column 4 in Table 1). The adjustments were derived from the analysis of initial residuals calculated with climatological ozone profiles. This was done to keep OMPS NP calibrations consistent with the historical SBUV record.

9) An error in the v2.7 software was found that was related to a wavelength index in constructing the measurement covariance matrix S_M. The index had been determined by looking at the sensitivity matrix K calculated for the apriori profile X_a instead of the initial state X_0. This error affected a small fraction of data (less than 2% at a given day) mostly at high latitudes in winter hemisphere where significant differences between X_a and X_0 can be expected. That is the only change between versions 2.7 and 2.8.

Table 1. Absolute calibration adjustments (in N-values) applied to OMPS NP with respect to pre-launch calibrations (Day-1 calibrations) in v2.6 and v2.8.

Channels	V2.6 adjustments based on coincident NP/N19 comparisons and snow/ice calibrations	Analysis of Initial Residuals NP/N19	Total adjustments applied in v2.8
252.0 nm	1.44	0.0	1.44
273.7 nm	0.29	-0.16	0.13
283.2 nm	0.18	-0.20	-0.02
287.7 nm	0.30	-0.21	0.09
292.4 nm	0.65	-0.01	0.64
297.6 nm	1.17	-0.14	1.03
302.0 nm	1.44	-0.38	1.06
305.9 nm	0.60	-0.26	0.34
312.7 nm	-1.22	0.61	-0.61
317.6 nm	-0.00	-0.13	-0.13
331.3 nm	0.11	0.0	0.11
339.9 nm	0.11	0.0	0.11
378.8 nm	0.11	0.0	0.11

2.0 Data Organization

The V2.8 file contains radiance data for the daylit part of one orbit. There is typically one measurement at nadir taken at 80 positions along the orbit.

2.1 File Naming Convention

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

OMPS-satellite_sensorproduct-**L**level_**v**m.n_observationDate_productionTime.**h5**
Where:

- satellite = NPP
- sensorproduct = NPBUVO3
- level = 2
- 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_NPBUVO3-L2_v2.8_2017m0608t041839_o29082_2017m0608t074932.h5

2.2 File Format and Structure

NPBUVO3-L2 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.

2.3 Key Science Data Fields

The data fields most likely to be used by typical users of the NPBUVO3-L2 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
BandCenterWavelengths	CalibrationData
SolarFlux	CalibrationData
SolarFluxWavelengths	CalibrationData
ColumnAmountO3	ScienceData
UVAerosolIndex	ScienceData
Reflectivity331	ScienceData

2.3.1 Data Temporal Coverage

The first OMPS measurements used to create the NMEV-L1B and NPEV-L1B product used to create the NPBUVO3-L2 product were taken on January 28, 2012. Data for February-March 2012 have numerous gaps due to variations in instrument operations. Regular operations began on April 2, 2012. Note that the OMPS Nadir Mapper conducted high-resolution measurements approximately one day per week from April 2012 to June 2016: NP data were not taken during these measurements.

3.0 Data Contents

3.1 Dimensions

NPBUVO3-L2 includes the following dimension terms:

Name	long_name	Value
DimAlongTrack	Along-track dimension	80
DimCrossTrack	Cross-track dimension	1
DimMixingRatioPressureLevel	Pressure Levels for Mixing Ratio Profile	15
DimNvalueResidueWavelength	Wavelengths for Reporting Residues	10
DimNvalueWavelength	Wavelengths for Reporting N Values	12
DimPressureLevel	Pressures at Bottoms of Solution Pressure Levels	21
DimPressureLevel81	Pressures at Bottoms of Fine Layers 81 Pressure Levels	81
DimPressureLevel80	Pressures at Bottoms of Fine Layers (except for the top layer) 80 Pressure Levels	80
DimSurfaceSensitiveWavelength	Wavelengths for Surface Sensitive Channels	8
DimUmkehr11Level	Umkehr layer base pressures for layers 0 - 10	11
DimUmkehr13Level	Umkehr layer base pressures for layers 12 - 0	13
DimWavelength	Wavelengths Used For Retrievals	13

3.2 Global Attributes

Metadata in NPBUV-L2 data files includes attributes whose value is constant for all files and attributes whose value is unique to each individual file. The table below 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
DATA_QUALITY	Integer	Data quality
DOI	String	DOI value
DayNightFlag	String	Identify day or night measurements
EquatorCrossingDate	String	Date of equator crossing
EquatorCrossingLongitude	Real*4	Longitude of equator crossing
EquatorCorssingTime	String	Time of equator crossing
Format	String	Data file format
LocalGranuleID	String	File name
LongName	String	Full product name
OrbitNumber	Integer*4	Number of the orbit
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
SAMP_TBL	Integer	Number of sample table used to take data
SAMP_TBL_VER	Integer	Version of the sample table used to take data
ShortName	String	Short product name
VersionID	String	Version ID for this product
VersionNumber	String	Version number for this product
acknowledgement	String	Acknowledgement of data producer
comment	String	Any additional comments
contributor_name	String	Name of data creator
contributor_role	String	Role of data creator
creator_email	String	e-mail address of data creator
creator_institution	String	Organization of data creator
creator_name	String	Name of data creator
creator_type	String	Type of data creator (e.g. person, organization)
date_created	String	Date of file creation
history	String	History of file
id	String	Short product name
institution	String	Producer of data
instrument	String	Instrument making measurements
instrument_vocabulary	String	Source of instrument terms
keywords	String	Identifying keywords
keywords_vocabulary	String	Source of keywords used in metadata
license	String	Source of data information regulations
metadata link	String	Web address for metadata DOI
naming_authority	String	Organization providing naming information
platform	String	Platform for measuring instrument
processing_level	String	Level of data product (e.g. L1B, L2)
program	String	Type of measurement program

project	String	Name of project
publisher_email	String	e-mail address of data publisher
publisher_institution	String	Organization of data publisher
publisher_name	String	Name of data publisher
publisher_type	String	Organization type of data publisher
publisher_url	String	URL of data publisher
references	String	Reference material for data product
source	String	Source of measurement data
summary	String	Any additional summary
time_coverage_end	String	Ending data and time of data
time_coverage_start	String	Starting date and time of data
title	String	Title of data product

3.3 Products/Parameters

3.3.1 AncillaryData Group

Dataset Name	Description	Dimensions	Units
CloudPressure	Optical centroid pressure	DimAlongTrack	hPa
PressureLevels	Pressure at bottom of 21 layers used in retrieval	DimPressureLevel	hPa
PressureLevelsMixingRatio	Pressures of 15 mixing ratio layers	DimMixingRatioPressureLevel	hPa
ProfileO3APrioriLayer	A priori profile for the 21 layers used in retrieval	DimAlongTrack DimPressureLevel	Dobson Units
SnowIceIndicator	Snow/ice indicator	DimAlongTrack	(no units)
SurfaceCategory	Surface category	DimAlongTrack	(no units)
TemperatureProfile	Temperature profile climatology	DimAlongTrack DimUmkehr13Level	K
TerrainPressure	Terrain pressure	DimAlongTrack	hPa
ProfileO3APrioriLayer81	A priori ozone profiles at 81 layers	DimAlongTrack DimPressureLevel81	Dobson Units
ProfileO3QBO81	Correction for interannual ozone variability in a priori profiles at 81 layers	DimAlongTrack DimPressureLevel81	Dobson Units
ProfileTempAPrioriLayer81	Climatological temperature profiles at 81 layers	DimAlongTrack DimPressureLevel81	K
NValueResidualsaPriori	N value residuals calculated with a priori profiles	DimAlongTrack DimNvalueResidueWavelength	1 (unitless)
O3MixingRatio80	Retrieved ozone profiles in units of mixing ratio reported for 80 layers	DimAlongTrack DimPressureLevel80	ppmv
ProfileO3FirstGuess81	First guess ozone profile at 81 layers	DimAlongTrack DimPressureLevel81	Dobson Units
ProfileO3Retrieved81	Retrieved ozone profiles reported for 81 layers	DimAlongTrack DimPressureLevel81	Dobson Units

3.3. 2 CalibrationData Group

(currently empty and may be used in future release)

3.3.3 GeolocationData Group

Dataset Name	Description	Dimensions	Units
DayOfYear	Day of year	DimAlongTrack	(no units)
GroundPixelQualityFlags	Ground FOV quality flag	DimAlongTrack	(no units
InstrumentQualityFlags	Error flags for each FOV	DimAlongTrack	(no units)
Latitude	Ground FOV latitude	DimAlongTrack,	Degrees
Longitude	Ground FOV longitude	DimAlongTrack,	Degrees
OrbitNumber	Number of the orbit	DimAlongTrack	(no units)
SecondsInDay	Time when measurement was taken (in number of seconds since beginning of the day)	DimAlongTrack,	Seconds
SolarZenithAngle	Solar zenith angle of each FOV	DimAlongTrack,	Degrees
UTC_CCDSDS_A	Twenty-seven character UTC date-and-time string	DimAlongTrack	(no units)
Year	Year when measurement was taken	DimAlongTrack	(no units

Definition of bit-packed GroundPixelQualityFlags

0-3	Unused		
4-5	SAA Flag	WARNING	Indicates location of spacecraft w.r.t. SAA 0 = outside SAA boundaries 1 = <5% of nominal maximum SAA effect 2 = between 5% and 40% of nominal maximum SAA effect 3 = >40% of nominal maximum SAA effect
6-19	Unused		
20	Maneuver Flag	WARNING	Indicates a spacecraft attitude maneuver was in progress during the measurement
21	Attitude Threshold Flag	WARNING	Indicates when any of the 3 geodetic spacecraft attitude Euler angles exceeds a defined threshold
22-31	Unused		

Definition of InstrumentQualityFlags

0-7	Unused		
8	Eclipse Flag	WARNING	Indicates ground pixel is within umbra or penumbra of the moon
9-15	Unused		

3.3.4 ScienceData Group

Dataset Name	Description	Dimensions	Units
AveragingKernel	20 layer averaging kernel	DimAlongTrack DimPressureLevel	1 (unitless)
CloudFraction	MLER (Mixed Lambertian Reflecting Surface) cloud fraction	DimAlongTrack	1 (unitless)
IndexLongestProfile Channel	Index of longest channel used in profile retrieval	DimAlongTrack	No units
KMatrix	Jacobian matrix, dN/dx (where N is N value, x is layer ozone amount)	DimAlongTrack DimPressureLevel DimNvalueResidueWavelength	No units
LayerEfficiency	N value [-100*log10(normalized radiance)]	DimAlongTrack DimUmkehr11Level	No units
NValue	N value = [-100*log10(normalized radiance)]	DimAlongTrack DimWavelength	1 (unitless)

NValueAdjustmentFactors	Soft calibration applied to N values	DimWavelength	1 (unitless)
Nvalue380	N value of 380 reflectivity channel	DimAlongTrack	1 (unitless)
NValueResidualsFinal	Final N value residuals	DimAlongTrack DimNvalueResidueWavelength	1 (unitless)
NValueResidualsInitial	Initial N value residuals	DimAlongTrack DimNvalueResidueWavelength	unitless
NValueSingleScattering	Single scattering N values	DimAlongTrack DimNvalueResidueWavelength	No units
NumberOfIterations	Number of retrieval iterations	DimAlongTrack	No units
O3BelowCloud	Estimate of ozone amount below cloud	DimAlongTrack	Dobson Units
O3MixingRatio	Retrieved ozone profile in units of mixing ratio	DimAlongTrack DimMixingRatioPressureLeve	ppmv
O3MixingRatioError	Error in retrieved ozone profile in units of mixing ratio	DimAlongTrack DimMixingRatioPressureLeve	ppmv
ProfileO3ErrorFlag	Estimate of O3 contamination	DimAlongTrack	Dobson Units
ProfileO3FirstGuess	First guess ozone profile	DimAlongTrack DimPressureLevel	Dobson Units
ProfileO3Retrieved	Retrieved ozone profile	DimAlongTrack DimPressureLevel	Dobson Units
ProfileO3RetrievedError	Estimated error of retrieved ozone profile	DimAlongTrack DimPressureLevel	Percent
ProfileTotalO3	Sum of retrieved ozone profile	DimAlongTrack	Dobson Units
ProfileTotalO3Error	Estimated error of the sum of the retrieved ozone profile	DimAlongTrack	Percent
QualityFitParameter	Quality of the fit parameters (average final residual)	DimAlongTrack	1 (unitless)
Reflectivity	Reflectivity of the 331 nm channel	DimAlongTrack	1 (unitless)
ReflectivityCorrection	Reflectivity correction for the 331 nm channel	DimAlongTrack	1 (unitless)
Reflectivity380	Reflectivity of the 380 nm channel	DimAlongTrack	1 (unitless)`
Residual	Final residuals for the 8 longest (surface sensitive) wavelengths	DimAlongTrack DimSurfaceSensitiveWavelength	1 (unitless)
Reflectivity380	Reflectivity of the 380 nm channel	DimAlongTrack	1 (unitless)`
ResidualStep1	Step 1 residuals for the 8 longest (surface sensitive) wavelengths	DimAlongTrack DimSurfaceSensitiveWavelength	1 (unitless)
ResidualStep2	Step 2 residuals for the 8 longest (surface sensitive) wavelengths	DimAlongTrack DimSurfaceSensitiveWavelength	1 (unitless)
Sigma	Sigma	DimAlongTrack	1 (unitless)
SigmaE	Measurement error covariance initialization parameter	DimAlongTrack	1 (unitless)
SigmaQ	A priori covariance initialization parameter	DimAlongTrack	1 (unitless)
StepOneO3	Retrieved step 1 ozone	DimAlongTrack	Dobson Units
StepTwoO3	Retrieved step 2 ozone	DimAlongTrack	Dobson Units
TotalO3	Retrieved total ozone	DimALongTrack	Dobson Units
TotalO3AprioriProfile	A priori profile used in total ozone part of retrieval	DimAlongTrack DimUmkehr11Level	Dobson Units
TotalO3AlgorithmFlag	Total ozone algorithm flag 0 - skipped	DimAlongTrack	No units

	1 - standard 2 - adjusted for profile shape 3 - based on C-pair (331 and 360 nm) Add 10 for snow/ice.		
TotalO3ErrorFlag	Total ozone error flag 0 - good sample 1 - glint contamination (corrected) 2 - sza > 84 (degree) 3 - 360 residual > threshold 4 - residual at unused ozone wavelength > 4 sigma 5 - SOI > 4 sigma (SO2 present) 6 - non-convergence 7 - abs(residual) > 16.0 (fatal) Add 10 for descending data	DimAlongTrack	No Units
UVAerosolIndex	Aerosol Index	DimAlongTrack	1 (unitless)
dN_dOmega	Sensitivity of N value to change in ozone	DimAlongTrack DimSurfaceSensitiveWavelength	1 (unitless)
dN_dR	Sensitivity of N value to change in reflectivity	DimAlongTrack DimSurfaceSensitiveWavelength	1 (unitless)
dN_dR_380	Sensitivity of 380 nm N value to change in reflectivity	DimAlongTrack	1 (unitless)

3.3.5 SensorData Group

Dataset Name	Description	Dimensions	Units
ChannelWavelengths	Wavelengths used in the retrieval	DimWavelength	nm
Gain	Unused for OMPS		
GratingDrivePositionError	Unused for OMPS		

3.3.6 TrendingData Group

Dataset Name	Description	Dimensions	Units
NValueResidualsFinal	Final N value residuals	DimAlongTrack DimNvalueResidueWavelength	1 (unitless)
NValueResidualsInitial	Initial N value residuals	DimAlongTrack DimNvalueResidueWavelength	1 (unitless)

The TrendingData group contains values that are used to monitor trends in the data over time; they are identical to the values in the ScienceData group but are separated for convenience.

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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Natalya Kramarova (2021), OMPS-NPP NPBUVO3 L2 V2.8, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), accessed ***[data access date]***, doi: 10.5067/B8A796JV7GGZ.

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Algorithms Based on Aura MLS Measurements and the MERRA-2 GMI Simulation, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2021-159, in review, 2021.