T61: SUOMI NATIONAL POLAR-ORBITING PARTNERSHIP: OZONE MAPPING AND PROFILER SUITE PRODUCT CALIBRATION, VALIDATION AND PERFORMANCE

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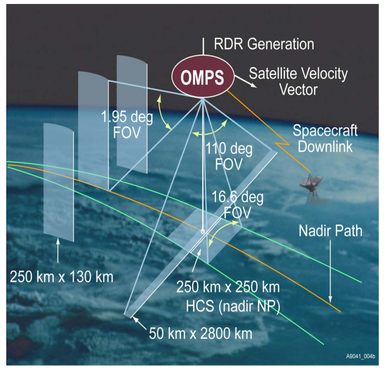
Introduction

NOAA, through the Joint Polar Satellite System (JPSS) program, in partnership with National Aeronautical and Space Administration (NASA), launched the Suomi National Polar-orbiting Partnership (S-NPP) satellite, a risk reduction and data continuity mission, on October 28, 2011. The JPSS program is executing the S-NPP Calibration and Validation (Cal/Val) program to ensure the data products comply with the requirements of the sponsoring agencies. The Ozone Mapping and Profiler Suite (OMPS) [1] consists of two telescopes feeding three detectors measuring solar radiance scattered by the Earth's atmosphere and solar irradiance by using diffusers. The measurements are used to generate estimates of total column ozone and vertical ozone profiles. The calibration and validation efforts are progressing well, and both Level 1 (Sensor Data Records/SDRs) and Level 2 (Ozone Environmental Data Records/EDRs) are advancing to release at Provisional Maturity. This poster provides information on the execution of the OMPS Cal/Val Plan with emphasis on the instrument and product performance observed over the first 18 months of the mission. The results of internal consistency analysis techniques and comparisons to other satellite instrument and ground-based products are examined.

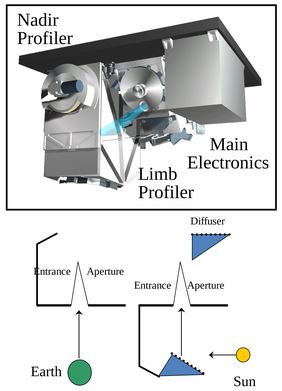
Instruments & Measurements

The total column sensor uses a single grating and a Charge-Coupled Device (CCD) array detector to make measurements every 0.42 nm from 300 nm to 380 nm with 1.0-nm resolution. It has a 110° cross-track FOV and 0.27° along-track slit width FOV. The measurements are combined into 35 cross-track bins: 3.35° (50 km) at nadir, and 2.84° at ±55°. The resolution is 50 km along-track at nadir, with a 7.6-second reporting period. (This resolution choice is changeable; we are investigating the use smaller FOVs.) The nadir profile sensor uses a double monochromator and a CCD array detector to make measurements every 0.42 nm from 250 nm to 310 nm with 1.0-nm resolution. It has a 16.6° cross-track FOV, 0.26° along-track slit width. The reporting period is 38 seconds giving it a 250 km x 250 km cell size collocated with the five central total column cells.

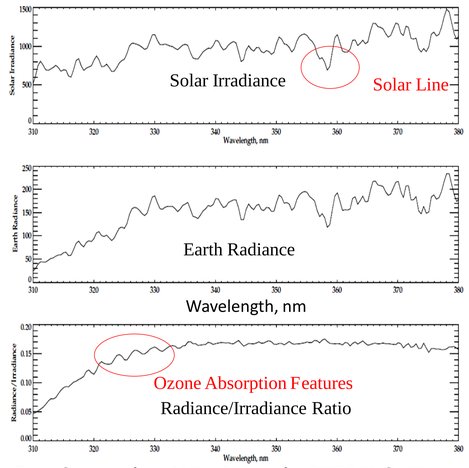
The limb profile sensor is a prism spectrometer with spectral coverage from 290 nm to 1000 nm. It has three slits separated by 4.25° with a 19-second reporting period that equates to 125 km along-track motion. The slits have 112 km (1.95°) vertical FOVs equating to 0 to 60 km coverage at the limb, plus offsets for pointing uncertainty, orbital variation, and Earth oblateness. The CCD array detector provides measurements every 1.1 km with 2.1-km vertical resolution. The products for the Limb Profiler are not discussed in detail here.



Instrument Fields of View. Schematic from Ball Aerospace and Technology Corporation.



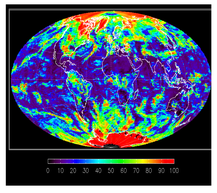
Each instrument has two solar diffusers; a working and a reference.



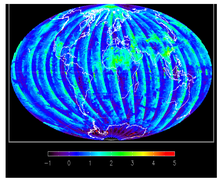
Typical spectra from 310 to 380 nm for OMPS Nadir Mapper.

Calibration System

The OMPS instruments (Nadir Mapper, Nadir Profiler, and Limb Profiler) are designed to take a set of measurements to allow analysts to maintain the instrument characterization and calibration.[2] For each of the instruments, this task can be broken into two components, tracking the performance of the CCD array detectors and electronics, and tracking the performance of the optical components, that is, the telescopes and spectrometers. The instruments make measurements on the night side of orbits with the apertures closed. One set is made without any sources and is used to track the CCD array dark currents. Another set is made with illumination by an LED and is used to track CCD non-linearity and pixel-to-pixel non-uniform response. The instruments also make solar measurements using pairs of diffusers. Judicious operation of working and reference diffusers allows analysts to track the diffuser degradation. The solar measurements also provide check on the wave-length scale and bandpass. The instruments have completed multiple passes through their internal dark and nonlinearity calibration sequences and have made an annual set of solar measurements. The instruments show little degradation in the comparisons of the working & reference diffuser measurements over the first year.

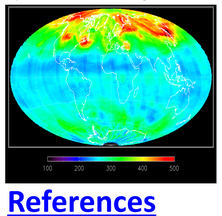


← Effective Reflectivity for the March 23, 2013 for the OMPS Nadir Mapper measurements. The quantity represents the UV reflectivity of the clouds and surface in each Field-of-View. This image shows the expected range of values over the globe with bright clouds and polar ice and dark open ocean.



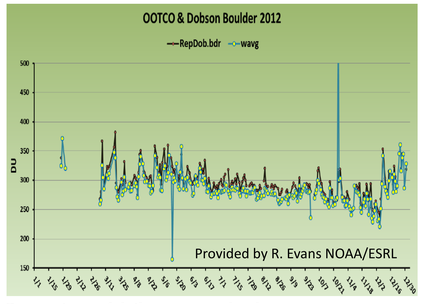
Aerosol Index from the operational algorithm in IDPS for March 23, 2013.. This quantity is derived from residuals at a longer reflectivity channel relative to a shorter channel. The range of values is as expected but there are significant cross-track biases.

Aerosol Index→



← Total Ozone from the operational multiple triplet retrieval algorithm in IDPS for March 23, 2013. The values show some cross-track variations and are offset approximately 2% from some other satellite ozone product. These uncertainty levels are consistent with the independent calibration parameters and tables currently in use in the operational system.

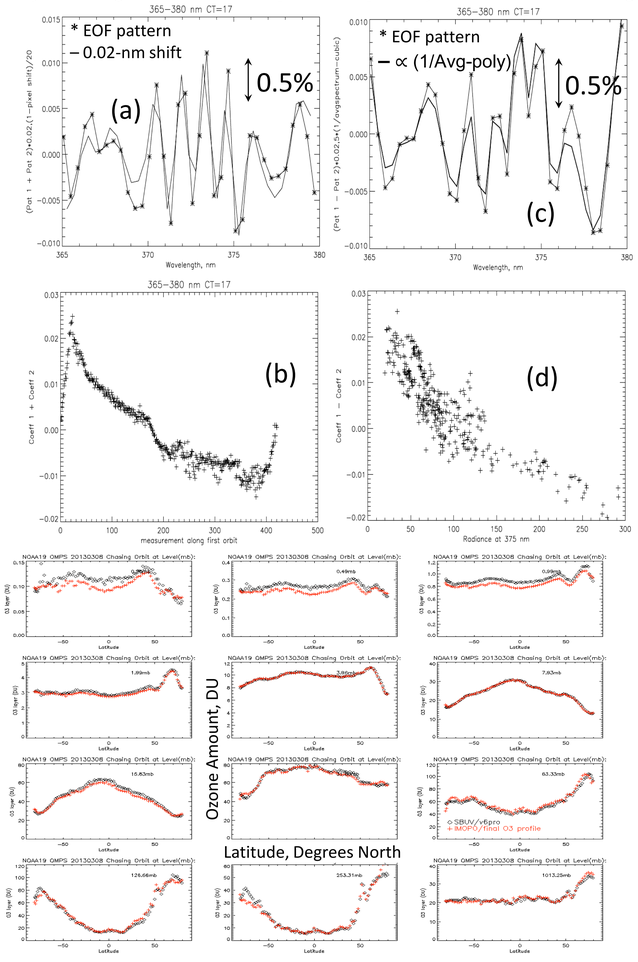
Current Products are Provisional



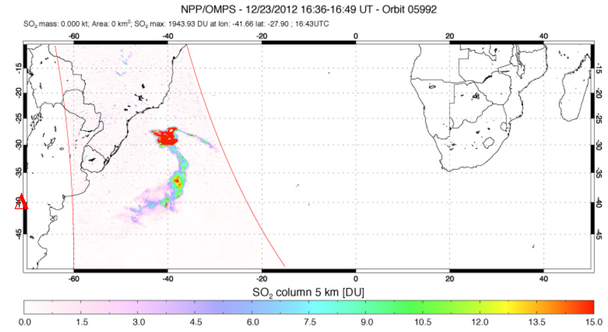
Comparison of daily mean total column ozone estimates from NPP OMPS Green and the Dobson Instrument in Boulder Colorado. The OOTCO are weighted averages of overpass data near the station location. They had been running approximately 4% low but this difference has been reduced after changes in the algorithm cloud pressure data and adjustments for Sun/Earth Distance in the last six months.

Internal Consistency and Measurement Information Content

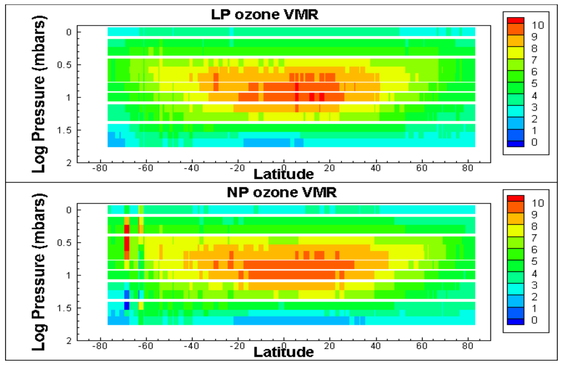
The product retrieval algorithms are designed to use ratios of Earth radiance to solar irradiance, to make use of pairs and triplets of measurements, and, in the case of the Limb profiler, to use normalization to measurements at reference tangent heights, greatly reducing sensitivity to instrument throughput changes [3]. The hyperspectral nature of the detectors provides information at wavelengths not used directly in the retrieval algorithm. Residuals for these measurements are used to check the consistency of the retrieved quantities. For example, differences in the ozone absorption cross-section for channels between 306 nm and 313 nm provide a test of the retrievals for equatorial viewing conditions. The differential sensitivity of the top of atmosphere radiances at reflectivity channels from 340 nm to 360 nm to satellite viewing angles and solar zenith angles provide opportunities to check the calibration by comparisons of derived cross track minimum reflectivity estimates. Empirical Orthogonal Function (EOF) analysis was conducted on the covariance matrix for spectra for the central cross-track position for the 365 nm to 380 nm wavelength range for parts of six orbits on 1/28/2012. The first two patterns contain 90% of the variability after removing a 3rd order polynomial from Radiance divided by the Average Radiance. The two patterns are primarily combinations of Wavelength Scale Shift and Ring Effect/Stray Light variations.



Figures (a) and (b) show the sum of the first two EOF patterns (a) and the coefficients (b) for the first orbit. (a) also has the computed variations expected from a 0.02-nm wavelength scale shift. The two curves agree very well. The pattern of the coefficients in (b) may be related to wave-length scale changes produced by intra-orbital variations in the optical bench temperatures. While the shifts are small, we plan to implement a correction/adjustment to improve the ozone products. Figure (c) shows the differences of the first two EOF patterns. Now the additional curve is a scaled reciprocal of the average spectrum pattern. Again, the two curves agree very well. One would expect this pattern to be produced by inelastic scattering (Ring Effect) or out-of-band stray light. The figure on the Bottom Right tests this by looking at the dependence of the coefficients (y-axis) with the 375 nm radiances (x-axis). The inverse relationship between the two suggest that the major source of these variations is the Ring Effect – not Stray Light. The OMPS NPP Science Team has plans to exploit this signal to create UV cloud optical centroid estimates. Given the radiance levels, a 0.01 pattern in values in figures (a) and (c) equates to approximately a 1% radiance variations.



The figure above displays the results of an off-line processing of OMPS Nadir Mapper data to show its capability for monitoring atmospheric SO_2. The false color image captures an SO_2 plume originating from Mount Copahue (▲ Location of SO_2 Source) as it moves out into the South Atlantic off the coast of South America. (Processed by the NASA OMPS NPP Science Team.)



The figures above have comparisons of the ozone profile retrievals between the OMPS Nadir Mapper operational (Currently Version 6) ozone profiles and the NOAA-19 SBUV/2 processed with the Version 6 ozone profile retrieval algorithm. The data are from a single pair of orbits on March 8, 2013 where the two satellites are flying in formation (orbital tracks within 50 KM and sensing times with 10 minutes). The ozone profile retrievals are reported in Dobson units for 12 pressure layers. They are plotted here versus Latitude. The 12 Umkehr layers boundaries are at: [0.0,0.25,0.50,0.99,1.98,3.96,7.92,15.8,31.7,63.3,127.0,253.0,1013] hPa.

The top three layers' results are in the top row with the topmost layer on the upper left. The lowest layer's results are in the figure on the bottom right. The **OMPS Nadir Profiler values are in Red/Orange** and the **SBUV/2 are shown in Black**. The figures show general agreement between the retrievals for the two instruments but with the OMPS NP retrieving smaller values at the top of the profiles. This is probably due to inaccuracies in the initial calibration of the shorter wavelength channels but could also be symptomatic of stray light.

Rapid Comparison to Other Products

The ozone products from the OMPS Nadir Profiler are compared to similar products from the operational Solar Backscatter Ultraviolet instruments (SBUV/2) and ground-based Dobson and Brewer instruments operated in the Umkehr mode. Comparisons of the OMPS NP zonal means of ozone profiles and initial measurement residuals with the currently monitored set of results for the SBUV/2 instruments on NOAA-16, -17 -18, and -19 are taking place. Of particular interest are those computed for instruments in similar orbits (NOAA-19 and NOAA-18 SBUV/2s) at all latitudes and for those computed for NOAA-17 SBUV/2 in a morning orbit for no-local-time difference latitudes. (If one examines a pair of ascending and descending polar-orbiting satellites, they will find two latitudes where the nadir views are at the same local time of day for both. One on the day side and the other 180 degrees away on the night side with a 12-hour difference in local time.) For the OMPS Nadir Mapper, we are making comparisons of its global ozone, effective reflectivity and aerosol products to similar ones from the Ozone Monitoring Instrument (OMI) and to the Global Ozone Monitoring Experiment (GOME-2). Sets of overpass match up values for the satellite instruments with ground-based locations have been expanded to include OMPS products.

The figures above compare the OMPS Nadir Profiler and Limb Profiler data for September 6, 2012. The Limb data has been smoothed vertically to be similar to the Nadir resolution. Refinement of both products is continuing. (Limb Profiler data were processed by the NASA OMPS NPP Science Team.)

Related talks & posters at the NSC

Session 2.0 POES/JPSS
Poster T-52 On the Provisional S-NPP Ozone Mapping and Profiler Suite SDR
Poster T-60 Ozone Instrument Calibration and EDR Products Validation with STAR ICVS
Poster W-85 Operational Ozone Products Available from NOAA/NESDIS

References

[1] Juan V. Rodriguez, et al., "An overview of the nadir sensor and algorithms for the NPOESS ozone mapping and profiler suite (OMPS)," *Proc. SPIE*, 4891, April 2003,.
[2] Quinn P. Remund, et al., "The ozone mapping and profiler suite (OMPS): on-orbit calibration design," *Proc. SPIE*, 5652, pp.165-173. December 2004,.
[3] *Earth Science Satellite Remote Sensing Vol.1: Science and Instruments*, Qu, J.J.; Gao, W.; Kafatos, M.; Murphy, R.E.; Salomonson, V.V. (Eds.), 2006, Springer Verlag,. "Chapter 21: Introduction to the Ozone Mapping and Profiler Suite (OMPS)," L. Flynn, C. Seftor, J. Larsen, and P. Xu, Springer Verlag, July 2004.

Satellite Monitoring http://www.star.nesdis.noaa.gov/icvs/PROD/proComparison.php
OMPS NM and NP Data archive http://www.nsof.class.noaa.gov/saa/products/search?datatype_family=OMPS
Operational BUFR ozone products http://projects.osd.noaa.gov/NDE/index.htm
Ground-based http://www.esrl.noaa.gov/gmd/grad/neubrew/ProductDisplays.jsp

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OMPS data are at provisional maturity levels; General research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing.
The OMPS SDR and EDR data sets are available to the public at http://www.nsof.class.noaa.gov .