Stability and Soft Calibration of the Version 8 Total Ozone and Ozone Profile Algorithms Applied to Ozone Mapping and Profiler Suite (OMPS) Measurements to Continue Ozone Climate Data Records

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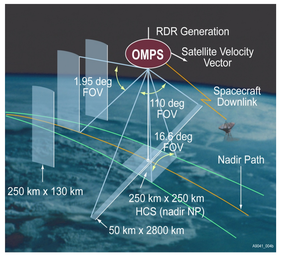
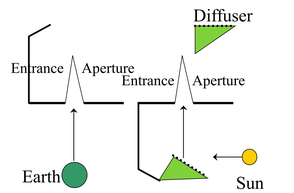
Introduction

NOAA, through the Joint Polar Satellite System (JPSS) program, is advancing its polar-orbiting satellite system with new instruments for weather forecast and climate monitoring. The first satellite, the Suomi Nation Polar-orbiting Partnership satellite (S-NPP), was launched on October 28, 2011 [in partnership with NASA)]. The second, NOAA-20, was launched on November 10, 2017. See
http://www.jpss.noaa.gov/mission_and_instruments.html
for information on the payload compliment of other instruments. The Ozone Mapping and Profiler Suite (OMPS) onboard the S-NPP satellite (and future JPSS satellites) is the next generation of US operational space-borne UV and ozone monitoring instruments.
The suite consists of two telescopes feeding three detectors measuring solar radiance scattered by the Earth's atmosphere and solar irradiance by using diffusers. The OMPS consists of three spectrometers; two nadir viewing and one limb viewing, however only the products from the nadir instruments will be discussed here. The OMPS NM (total column ozone sensor) uses a single grating and a 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 FOVs: 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/aggregation period.
The OMPS NP (nadir ozone 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 Nadir Mapper cells. The measurements are used to generate estimates of total column ozone and vertical ozone profiles.[1,2] NOAA and NASA are working to continue the Satellite BUV Climate Data Records for Total Column Ozone and Ozone Profiles with the measurements from these new instruments. The total ozone (V8TOZ) and vertical ozone profile (V8PRO) climate data records (CDRs) are long-term datasets that have been derived by applying the Version 8 retrieval algorithms[3] to measurements obtained over the last 38 years from several UV spectrometers onboard various satellites. The V8TOZ CDR is derived from measurements obtained by the SBUV, SBUV/2, TOMS, and OMI instruments. The V8PRO CDR is derived from data obtained by the SBUV and SBUV/2 instruments. The OMPS Nadir Profiler (OMPS NP) replaces the NOAA Solar Backscatter Ultraviolet (SBUV/2) series of instruments as a source of measurements for the profile CDR and the OMPS Nadir Mapper (OMPS NM) replaces the SBUV/2 and TOMS series.



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

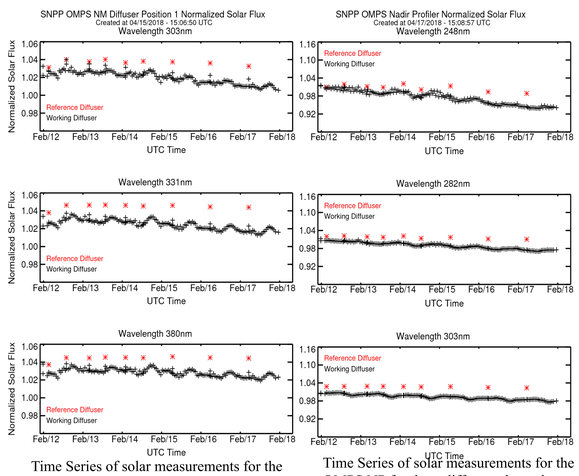


Each instrument has two solar diffusers; a working and a reference.

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.[4] 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, diffusers and spectrometers. The OMPS has multiple diffusers, one working and one reference, which allow for tracking long-term solar measurement degradation to produce a stable calibration critical for climate monitoring applications. The instrument makes additional measurements to track dark current, linearity, detector gain, and wavelength scale. These are augmented by soft calibration and internal consistency checks. The NOAA-20 OMPS does not have a Limb Profiler.

Monitoring OMPS Solar Measurements



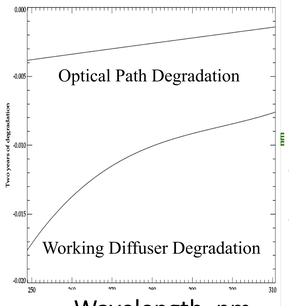
Time Series of solar measurements for the OMPS NM for three different channels.

Time Series of solar measurements for the OMPS NP for three different channels.

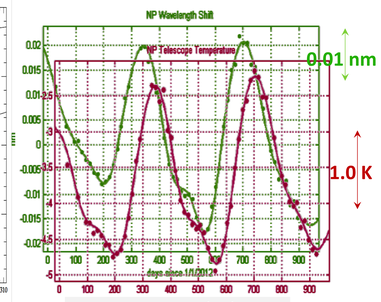
The OMPS NM has been vary stable since launch. Estimates of the changes from the working and reference diffuse measurements for three channels are shown in the plots in the figure above on the left. The plots are updated every two weeks at the NOAA ICVS website https://www.star.nesdis.noaa.gov/icvs/ . The red asterisks show the reference diffuser measurements. These reference diffuser measurements are made every six months with care taken to have the same solar viewing angles. The black plus signs show the working diffuser measurements. The annual cycles in these measurements are believed to be due to solar beta angle deficiencies in the goniometric characterization. The has been some small degradation in the working diffuser but the reference measurements are flat.
The OMPS NP has experienced greater degradation. The three plots in the figure above on the right show the times series of solar measurements for three NP channels. The working diffuser is exposed thirteen times as frequently as the reference diffuser and its measurements show significant wavelength-dependent signal degradation. The components of a model for these measurements are described in the next section.

OMPS NP Solar Model

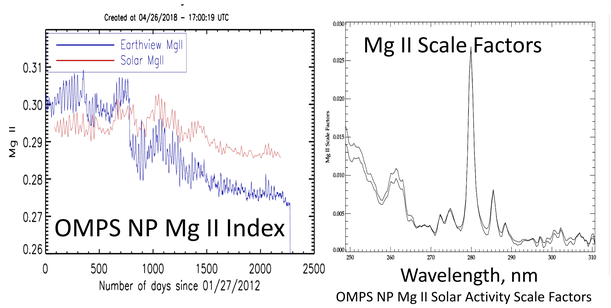
The OMPS NP solar measurements were analyzed with a model using components for solar activity, wavelength shifts and separate degradation rates for the diffusers and instrument throughput. The solar activity component used Mg II Scale Factors derived from 27-day solar rotation measurements. Mg II time series and the factors from two different analyses are shown at the top of the next column. The wavelength scale variations were determined by comparisons of working diffuser measurements. They were found to have an annual cycle well correlated with changes in the optical bench temperature. Time series of the shifts and temperature are in the plots below on the right. Estimates of the degradation of the working diffuser and of the shared optical path are shown in the plot below on the left. The curves show the expected relative changes over two years of operations.



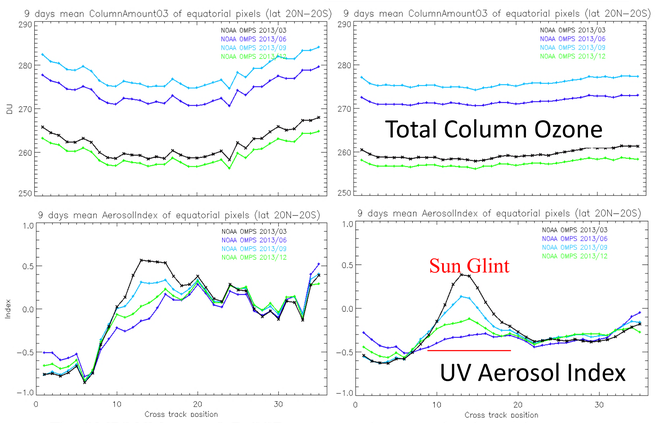
Relative Changes in OMPS NP Reference and Working Solar Measurements over two Years



Time Series of Wavelength Shifts and Telescope Temperatures



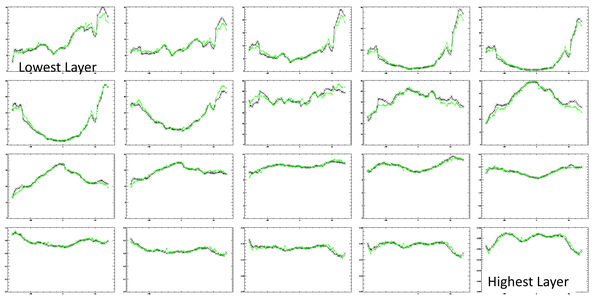
OMPS V8 Total Ozone Cross-Track Adjustments



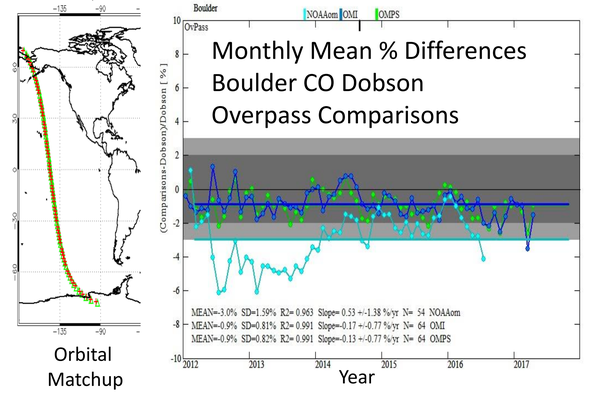
The OMPS NM uses a 2-D CCD array to make spectral and spatial measurements. The spatial pixels are aggregated to make 35 cross-track Fields of View. Since each pixel can be regarded as an individual instrument, it is necessary to cross-calibrate the different cross-track results. To do this, data are examined over various Earth targets and regions and the measurements are adjusted to produce consistent results. The figures above show the before and after for this process. The data for March 2013 were used to find adjustments to remove the cross-track bias. The figures on the left show the "before" and the figures on the right show the "after" for 9-day means for March, June, September and December 2013 for total column ozone (top) and the Absorbing UV Index (bottom). The remaining cross-track features around Position 14 in the Aerosol Index curves are created by open ocean sun glint.

OMPS V8 Profile Adjustments

In order to create a consistent long-term record, the OMPS NP was adjusted to agree with NOAA-19 SBUV/2. A well-matched orbit on March 20, 2013 (The map at the top of the next column shows the S-NPP and NOAA-19 orbital tracks which were within 20 km and 15 minutes of each other at the Equator.) was used to estimate calibration offsets and adjustments. The adjustments vs wavelength are [0.0, -0.3,1.0, 0.7,1.0, 2.5, 6.7, 4.0, 0.7, 0.1,-1.0,0.0] % for channels at [253,273,282,288,292,298,302,306,312,317,331,340] nm. The figure below shows the layer ozone amounts from the Version 8 Ozone Profile Retrieval Algorithm for the SBUV/2 and OMPS NP as a function of Latitude after applying the adjustments.



Comparisons



The first five years of OMPS NM and NP Sensor Data Records have been reprocessed with the latest calibration coefficients and corrections for dark current, stray light and nonlinearity. The V8 total ozone and V8 ozone profile algorithms have been applied with adjustments to the absolute calibration to make create new components of the long-term ozone records. The figure above shows comparisons of the OMPS NP V8Pro ozone profile total to the Dobson station record at Bolder CO. The figure shows the percent differences between monthly average overpass values for three satellite data sets. The light blue line connects the operational OMPS NP V8Pro results. They show the effects of poor updates to the dark current producing an initial drift and then improvements as these move to weekly updates and a new stray light correction is introduced.[5] Calibration adjustment to SBUV/2 and the estimate of optical path degradation explain the additional differences with the dark blue line connecting the reprocessed OMPS NP V8Pro. The green line connects the EOS Aura OMI V8TOz data. The latter two track very well.

Conclusions

- ❑ The OMPS Nadir Mapper has had stable performance in orbit. Soft calibration adjustments to remove cross tack biases produce consistent products for all FOVs.
- ❑ The OMPS Nadir Profiler has had a small amount of degradation which can be estimated from the reference solar measurements. After soft calibration adjustments to agree with NOAA-19 SBUV/2, its record provides a continuation of the long-term ozone profile record.

Acknowledgment and Disclaimer

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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, DOI: 10.1117/12.467525.

[2] *Earth Science Satellite Remote Sensing Vol.1: Science and Instruments*, Qu, J.J, et al. (Eds.), 2006, Springer Verlag, ISBN: 978-3-540-35606-6. "Chapter 21: Introduction to the Ozone Mapping and Profiler Suite (OMPS)," L. Flynn, C. Seftor, J. Larsen, and P. Xu, Springer Verlag, July 2004.

[3] *Solar Backscatter Ultraviolet Instrument (SBUV/2) Version 8 Ozone Retrieval Algorithm Theoretical Basis Document (V8 ATBD),* Edited by L. Flynn (Last Revision February 2, 2007)
star.nesdis.noaa.gov/smcd/spb/calibration/icvs/sbuv/doc/SBUV2_V8_ATBD_020207.pdf

[4] Quinn P. Remund, et al., "The ozone mapping and profiler suite (OMPS): on-orbit calibration design," *Proc. SPIE*, 5652, pp.165-173. December 2004.

[5] Flynn, L., et al. (2014), Performance of the Ozone Mapping and Profiler Suite (OMPS) products, J. Geophys. Res. Atmos., 119, 6181–6195, doi:10.1002/2013JD020467.

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