Pre-Launch Radiometric Calibration of the OMPS Instruments

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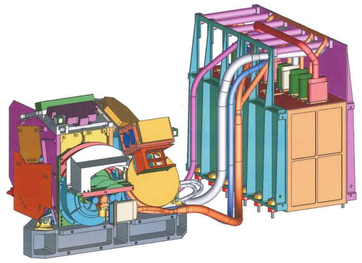
The Ozone Mapping Profiler Suite (OMPS) instrument provides long-term stratospheric ozone monitoring capability for the Joint Polar Satellite System (JPSS). The JPSS OMPS instrument consists of two nadir-viewing hyper-spectral spectrometers that provide total column ozone and ozone vertical profiler measurements. The first flight model of OMPS is currently on-orbit aboard the Suomi National Polar-orbiting Partnership satellite. The ground radiometric calibration of the OMPS instruments is discussed including an overview of techniques for transferring NIST primary standard calibration to OMPS and accounting of calibration uncertainties.



What is OMPS?

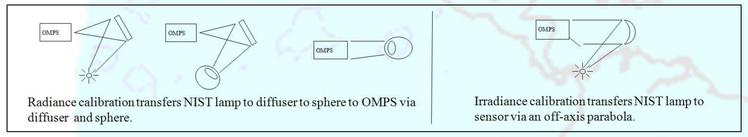
The Ozone Mapping and Profiler Suite (OMPS) is one of five instruments that launched aboard the Suomi National Polar-orbiting Partnership (S-NPP) satellite in 2011. A second OMPS flight unit built by Ball Aerospace will fly on the Joint Polar Satellite System-1 (JPSS-1) which will launch in 2017.

OMPS is a three-part instrument: a nadir mapper that will map global ozone with about 50-km ground resolution, a nadir profiler that will measure the vertical distribution of ozone in the stratosphere, and a limb profiler that measures ozone in the upper troposphere and lower stratosphere with high vertical resolution. The limb sensor is not part of the JPSS-1 OMPS flight unit.

OMPS supports operational weather capabilities by measuring atmospheric ozone and ozone concentration variability with altitude. It provides functionality comparable to both the Solar Backscatter Ultraviolet Radiometer (SBUV/2) and NASA's Total Ozone Mapping Spectrometer (TOMS) with new and improved environmental data records. OMPS collects total column and vertical profile ozone data and continues the daily global data produced by SBUV/2 and TOMS, but with higher calibration accuracy and higher spatial and spectral resolution. The collection of this data contributes to fulfilling the U.S. treaty obligation to monitor the ozone depletion for the Montreal Protocol to ensure there are no gaps in ozone coverage. OMPS data will also be used to determine if synthetic chemicals are affecting the Earth's climate and its habitability.

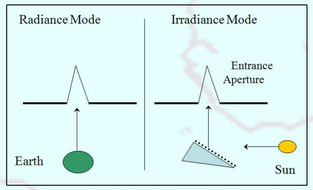
Calibration

Each OMPS spectrometer is calibrated radiometrically on the ground by transferring NIST primary standards to the sensors in both radiance mode and irradiance mode so that albedo measurements can be made on-orbit.



Radiance calibration transfers NIST lamp to diffuser to sphere to OMPS via diffuser and sphere.

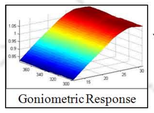
Irradiance calibration transfers NIST lamp to sensor via an off-axis parabola.



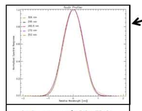
On-orbit, calibration is maintained using solar measurements. Each instrument has two diffusers - working and a reference - which allow for tracking the diffuser degradation. The solar measurements are also used to track the wavelength scale.

For pre-launch radiometric calibration, the following types of effects were considered.

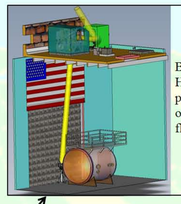
- **Sensor effects:**
  - **polarization**
  - **backgrounds**
  - **goniometric response**
  - **non-uniformity**
  - **mounting error**
  - **bandpass approximations**
  - **on-orbit glint**
  - **throughput changes**
  - **thermal vacuum sensitivities**
  - **test-as-you-fly considerations**
- **Detector effects:**
  - **linearity**
  - **non-uniformity**
  - **gain**
  - **dark current**
  - **etalon effects**



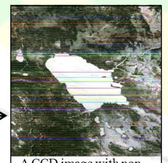
Goniometric Response



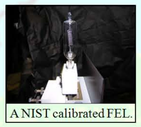
Measured OMPS Bandpasses



Ball Aerospace's Heliostat Test Facility provides solar calibration of instruments in a flight-like environment.



A CCD image with non-uniform readout (striping). Credit: USGS

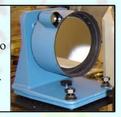


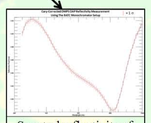
A NIST calibrated FEL.

Ball Aerospace's Stray Light Testing Facility is designed for system level stray light testing of various instruments. The facility is all black and included a cylindrical chamber to allow for excellent control of stray light.

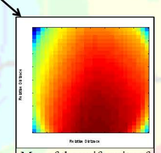
- **Calibrated Source effects:**
  - **calibration errors/uncertainties**
  - **wavelength dependence of optical elements**
  - **wavelength specific issues**
  - **wavelength calibration**
  - **source non-uniformity**
  - **BRDF uncertainty**
  - **strike-to-strike repeatability**
  - **stray light**
  - **stability**
  - **distances**
  - **unresolved wavelength features**
  - **wavelength region specific issues**

The off-axis parabola used to calibrate the OMPS sensors.





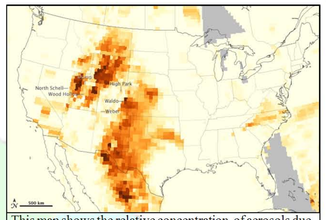
Spectral reflectivity of the off-axis parabola.



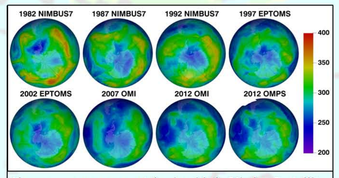
Map of the uniformity of the off-axis parabola.

S-NPP OMPS Performance

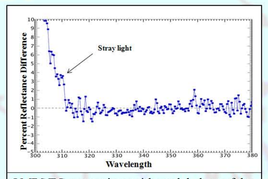
S-NPP OMPS has been acquiring data since January 2012 and is performing well. OMPS total column measurements have been compared to Aura OMI and EOS MLS results. The OMPS ozone map measurements after one month of operation were consistent with OMI and OMPS data were in agreement with MLS calculated reflectances to within 1% for wavelengths > 312 nm. A unique capability of the OMPS is the ability to combine the limb and nadir sensor data to allow a better understanding of the ozone total column as a function of altitude. Also, OMPS has also been used to measure aerosols in the upper atmosphere including smoke from the western US fires in summer 2012.



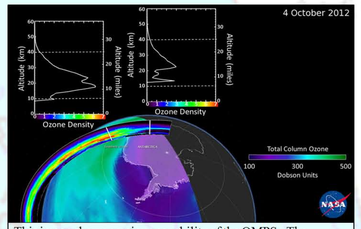
This map shows the relative concentration of aerosols due to forest fires as measured by OMPS on June 26, 2012 in the United States. Credit: NASA



These ozone measurements begin with the Nimbus 7 satellite; continue with the Earth Probe Total Ozone Mapping Spectrometer (EP TOMS); the Ozone Monitoring Instrument (OMI) above the Aura satellite; and the most recent, the OMPS aboard the S-NPP satellite. Credit: NASA/NOAA



OMPS TC comparison with modeled top of the atmosphere reflectances from EOS MLS. There is stray light consistent with pre-launch OMPS characterization at wavelengths <312 nm. At longer wavelengths, the agreement is within 1%. Credit: NASA



This image shows a unique capability of the OMPS. The measured total column ozone is shown during the Antarctic ozone minimum with the curtain plot showing the ozone profile from 10 to 40 km (blown up by a factor of 30). The combination of measurements indicate the altitude at which the ozone is depleted in the total column measurement. Credit: NASA

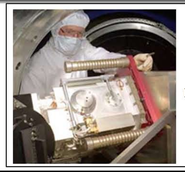
Summary

The S-NPP OMPS was calibrated on the ground prior to launch with NIST traceable sources and has been returning high quality data from on-orbit since January 2012. The JPSS-1 OMPS is currently undergoing calibration and will launch in 2017.

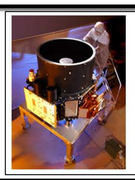
A well calibrated sensor can result in superior performance on-orbit after a short commissioning time. We present a range of factors that should be considered when calibrating UV/optical sensors with NIST standards and demonstrate the capabilities Ball Aerospace has to offer when calibrating such sensors.

Ball Aerospace supports operational weather with the S-NPP and JPSS-1 spacecrafts as well as the OMPS instruments.

This work is funded by a contract to Ball Aerospace from NASA. The authors wish to thank and congratulate all the NASA, NOAA, and Ball Aerospace folks who have worked on OMPS and helped to make it a successful sensor.



Solar Backscatter Ultraviolet Radiometer (SBUV/2)



Cloud-Aerosol LIDAR and Infrared Pathfinder Satellite Observations (CALIPSO)

QuickBird

Ball Aerospace has extensive experience with space-qualified hardware assembly, integration, and test. Our philosophy of building a strong relationship with the science investigators, applying solid systems engineering practices to translate the science objectives into requirements, and using integrated tools for design and modeling has led to the success of S-NPP-OMPS, NPP, SBUV/2, CALIPSO, and QuickBird and the future successes of OLI, GMI, JPSS-1 OMPS, and JPSS.

S-NPP Spacecraft

Operational Land Imager (OLI)

GPM Microwave Imager (GMI)

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