NPOESS PREPARATORY PROJECT OZONE MAPPER and PROFILER SUITE – Expected Performance

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Overview

The Ozone Mapping and Profiler Suite (OMPS) is a next-generation space-based system for monitoring global changes in stratospheric ozone. The suite consists of a Limb Sensor, a Nadir Sensor, and a Main Electrical Box (MEB).

The OMPS was designed and built for the National Polar-orbiting Operational Environmental Satellite System (NPOESS).

The OMPS suite has recently been completed and delivered, after a successful interagency review process, to the NPOESS Preparatory Project (NPP) prime contractor, Northrop Grumman Aerospace Systems (NGAS). It has since been integrated to the NPP spacecraft, expected to launch in mid-2011.

This poster summarizes the expected performance of OMPS as determined from the pre-launch test data and analysis. The poster also describes how potential performance deficiencies may be corrected with algorithm modifications, as well as potential improvements for the next flight model.

Glossary

SDR = Sensor Data Record
Calibrated and Geolocated radiances - Corresponds. to NASA Level 1

EDR = Environmental Data Record. Derived geophysical data product: ozone total column or profile, Aerosol Index. Corresponds to NASA Level 2

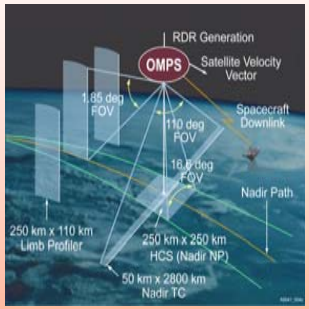
IP = Intermediate Product. Like an EDR, but research grade.

CDR = Climate Data Record. Like an EDR, but with NASA/NOAA retrospective reprocessing

Contributions from NGAS, BATC and NASA – Figures references as indicated

The suite consists of three sensors that operate synergistically:

- Nadir sensors (Nadir profiler NP and Total Column TC) determine the nadir Ozone profile and the Total Colum Ozone.
- Limb-viewing sensor (Limb profiler, LP) measures the ozone profiles between 8km-60km with finer (than NP) vertical resolution. It is an experimental sensor.
- The nadir-viewing measurements will continue the long-term data sets provided by the Total Ozone Mapping Spectrometer TOMS, the Ozone Monitoring Instrument (OMI) and the ozone profiles produced by the Solar Backscatter Ultraviolet radiometer (SBUV/2).
- The limb-viewing measurements will continue the limb scatter profile data set produced by OSIRIS and SCIAMACHY.



Coordination between organizations -

NPOESS is managed by the Integrated Program Office (IPO) as a joint Project of the Department of Commerce, the Department of Defense and NASA .

The prime contractor is Northrop Grumman Aerospace Systems (NGAS) who subcontracts BATC to construct and test the OMPS .

NASA is responsible for the satellite launch, activation and the early check of the sensors. After the initial period, NGAS is responsible for the system operation.

NGAS is responsible for the Nadir sensor Raw Data Records (RDRs), SDRs, and EDRs as well as the Limb sensor RDRs. NASA is responsible for the Limb sensor SDR and EDR.

Nadir Sensor

- Wavelength range:250 nm to 380 nm
- Two grating spectrometers w/CCD detectors
- Spectral sampling ~ .41nm, resolution ~ 1 nm
- Spectral channels: TC 196, NP 147
- Push broom 110º FOV telescope
- TC: 35 horizontal FOV (50km x 50km at nadir)
- NP: 1 horizontal FOV (250km x 250km)
- Granule: 37.44sec
- Reflective diffusers for solar calibration

Limb Sensor

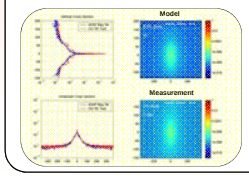
- Spectral range 290 nm to 1000 nm
- Prism spectrometer w/CCD detector
- Afocal telescope with three 1.85º vertical FOVs
- Vertical resolution 2 to 3 km
- Transmissive diffusers for solar calibration

Characterization vs requirements

Sensor level tests characterize:
- Radiometric and spectral accuracy and precision
- Stability, spatial and geolocation parameters.
- Diffuser spatial and spectral structure.
- Long and short term repeatability of the outputs.

Additional tests:
- Environmental and functional tests for the main electronics box.
- Environmental, functional and limited performance tests (irradiance and trending) for the integrated sensor suite.

Sensor performance:
- Tests verified all performance parameters satisfy specification.
- Critical parameters identified with little or no margin:
  - Initial albedo calibration wavelength - dependent uncertainty: less than 1% margin.
    - Main contributors to this error:
      - Lab diffuser BRDF - .5 % fractional uncertainty
      - Mounting error/Goniometry - .38% fractional uncertainty
  - TC Stray light: compliant for a global average. At wavelengths below 320nm and larger than 360nm might exceed allocation for the low TC Ozone bins and impact EDR precision error.
    - Extensive stray light characterization test, analysis and modeling program carried out by BATC, surpassing heritage BUV-detailed measurements of point spread functions (PSFs) using tunable point-source laser.



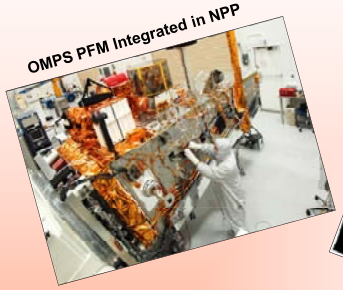
Sensor Requirements

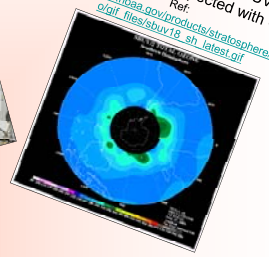
Spatial Properties`	
Cross-track MTF at nadir	>.5 at .01cycles/Km
Cross-track TC macpx. IFOV nadir	<3.44
Cross-track TC FOV	>110 degrees
Radiometric Accuracy	
Pixel-pixel radiometric calibration	<.5%
Non linearity	2% full well
NL knowledge	<.5%
On-orbit wavelength calibration	.01 nm
Stray Light	
TC out of band + out of field response	<2%
Intra-orbit wavelength stability	.02 nm
Band Pass Shape Knowledge	2%
Bandpass limits TC	50%<1.05 nm; 10%<1.9 nm; 1%<3.1 nm
Albedo Calibration Accuracy	
Wavelength independent	<2%
Wavelength dependent	<.5%
Linear polarization sensitivity	<5%
Radiometric Precision Terms	
SNR	1000
Inter-orbital Thermal Wavelength Shift	.01 nm
Geolocation Error Terms	
Boresight alignment knowledge uncertainty between nadir instrument interface and nadir alignment reference	<160 arcsec
Total cumulative boresight alignment shift (between final ground calibration and on-orbit operations	<500 arcsec
Database interpolation error	40 arcsec

Dominant contributors to EDR accuracy
Dominant contributors to EDR precision

- Total Column PSFs matched predictions with some differences near the peak
- Nadir Profiler PSFs exhibit more scatter than predictions

REF: NASA briefing Polar Max - 2006

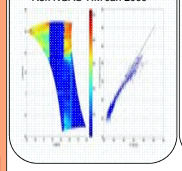

OMPS PFM Integrated in NPP


Total Ozone Map
Results obtained with SBUV/2 – Improved results expected with OMPS
Ref: http://www.cpc.noaa.gov/products/stratosphere/sbuv2t/gif_files/sbuv18_sh_latest.gif

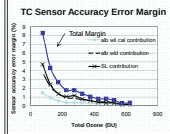
Expected performance

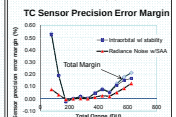
TC Sensor and SDR performance

SDR: functional performance verified using OMPS proxy data with LUT's from sensor characterization testing results
- SDR calibration match the truth with residual errors <.02% excluding BRDF interpolation error
- EV SDRs match the truth within .02% for all channels used by the EDR
- Ref: NGAS TIM Jan 2009



Sensor: positive margins demonstrated for most conditions

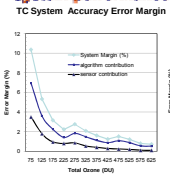


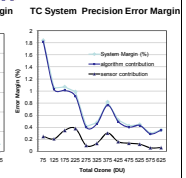


Margin (%) defined as: (Allocation – Prediction)/Total Ozone

Similar margins obtained for the NP

System performance





Performance results derived from BATC measurements and analysis, but do not include additional errors associated with UV vs IR differences in cloud top pressure, and assume on orbit SL and diffuser goniometry is similar to ground analysis.
See the next panel →

Issues and Planned Improvements

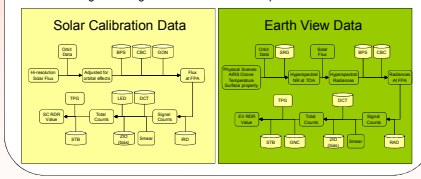
Cloud Top Pressure (CTP)
OMPS CTP obtained from IR measurements by VIIRS. Used for estimating the ozone profile. But UV penetrates deeper into clouds than does IR.
- Accuracy and precision errors using CTP from VIIRS IR are therefore underestimated.
- Current analysis indicates that the resulting bias may not drive the system outside its accuracy specifications.
- The decrease in precision may be worse. Regions with TC = 300DU or 600DU TC may not satisfy the spec.
- Effects as well as mitigation approaches are being investigated:
  - OMI based climatology of UV cloud top pressures can be used to correct accuracy errors
  - Spectral resolution of OMPS may allow UV cloud-top altitudes to be estimated from the filling-in of Fraunhofer lines by rotational Raman scattering (Ref: Vasilkov, A., J. Joiner, R. Spurr, P. K. Bhartia, P. Levelt, and G. Stephens (2008), *J. Geophys. Res.*, 113, D15S19, doi:10.1029/2007JD008689.)

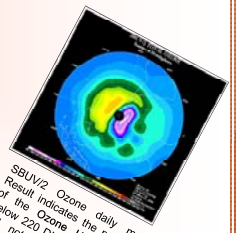
Ionizing Radiation
- Spurious signals from the CCDs when traversing the South Atlantic Anomaly.
- Exacerbated by on-board binning of data from the two Nadir instruments.
- Might be mitigated for the Ozone Total Column with CrIS Ozone measurements based on absorption by ozone at 9.6 microns.

Diffuser interference features
- Spatial non uniformities driven by diffuser surface roughness and optical path of the instrument
- Features on the order of CCD pixel size, affect pre and post launch sensor calibration
- OMPS current mitigation uses a detailed pre launch characterization and analysis – High spatial sampling rate - Non-heritage ground calibration method.
- Improvements planned for FM2: easier removal, new grind technique. Quartz volume diffuser being investigated as potential alternative.

Stray Light (SL)
Stray Light corrections may be needed. SL from longer wavelengths affect ozone retrievals that use shorter wavelengths. Without correction there would be little margin at shorter wavelengths. Characterization of PSFs permits implementation of corrections in the SDR algorithm. NGAS is working with BATC on developing a correction matrix.

SDRs and EDRs were tested at NGAS with proxy data.
Cal and Earth view (EV) data use BATC sensor characterization data bases.
EV test data uses TOA hyperspectral radiances generated by GMU Sensor TVAC test data is being used to generate RDRs and test operational SDR.





SBUV/2 Ozone daily map. Result indicates the presence of the Ozone Hole (values below 220 DU). Notice OMPS will not have the hole of missing data at the South Pole in October. Ref.: NOAA/Flynn

Nadir and Limb sensors currently integrated in NPP – Expected to meet most performance requirements
– Main concern: stray light for Limb and TC – Good SL characterization and algorithm corrections will mitigate risk.