Describing the NPOESS Preparatory Project Ozone Mapping and Profiling Suite (OMPS) Environmental Data Records

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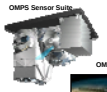
Abstract

The Ozone Mapping and Profiling Suite (OMPS) is one of the four instruments that make up the suite of sensors on the NPOESS Preparatory Project (NPP) scheduled to launch in 2010. The OMPS will produce one Environmental Data Record (EDR) - the Ozone Total Column (TC) and one deliverable Intermediate Product (IP) - the Ozone Nadir Profile (NP) to describe the ozone properties. It will also generate Raw Data Records (RDRs) from the experimental research Limb Profiler. This poster describes the OMPS algorithms used to generate the EDR and IP and provides a current estimate of performance based on pre-launch test data.

Heritage Sensors & Data Products

OMPS Sensor Suite



OMPS Fields of View

The NPOESS Total Column Ozone is obtained by matching hyperspectral UV range radiance measurements with calculated normalized radiances for wavelength pairs. The NPOESS Nadir Profile is obtained by interpreting the backscattered ultraviolet radiance measurements based on its sensitivity to ozone absorption and the understanding of UV scattering from the Earth's atmosphere as a function of solar zenith angle. The OMPS suite derives from a long heritage of extensively validated UV sensors flown on several successful satellite missions.

The TC design is based on NASA's heritage TOMS system and also draws from close heritage cousins GOME, on board the second European Remote Sensing Satellite (ERS-2) and OMI, flown on EOS Aura sensors. One of the main improvements of the OMPS TC over the heritage systems comes from the use of co-located external data, e.g. snow/ice and temperature profile provided by other NPOESS sensors VIIRS and CrIS. Additional enhancements are made possible by the OMPS TC CCDs detectors that offer a continuous coverage from 300 nm – 380 nm with a spectral resolution of 1 nm whereas the TOMS detectors are photomultipliers that allow only a discrete range of wavelengths between 250 and 360 nm. The OMPS SDR algorithm has been developed to make use of the OMPS sensor characteristics and operational design. For example, the use of sample tables to correct for bad pixel to pixel inhomogeneities or nonlinearities. The improved design and algorithm enhancements will allow the OMPS TC to satisfy the OMPS EDR requirements with margin and match or slightly exceed heritage TOMS performance.

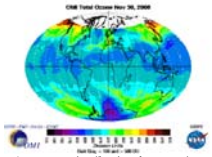


Image source: http://jwocky.gsfc.nasa.gov/

The OMPS NP is designed to provide continuity for the heritage measurements from BUV, SBUV and SBUV/2. However, the instrument also provides improvements over the heritage due to its capability of continuous range of wavelengths in the 250 nm to 300 nm range. The instrument is integrated with the TC to provide expanded wavelength coverage (to the 380 nm range) and can provide slightly better SNR than heritage. Its performance is currently expected to match that of heritage instruments, but some of the instrument improvements could be used in the future to obtain a better performance.

Algorithm Overview

Total Column EDR

- Adapted from NASA's TOMS version 7
  - Includes modular enhancements to make use of external EDRS
  - Improves O_3 estimates with use of triplets
- Initial model of the atmosphere assumes a simple Beer's Law formulation that assumes pure Rayleigh scattering atmosphere with ozone absorption:

$$I = Fe^{-s(\alpha\Omega+\beta p)}$$

I = Radiance **α = Ozone absorption coefficient**
F = Solar Flux **β = Rayleigh scattering coefficient**
Ω = Ozone amount **p = Pressure** **s = Path length**

Or

$$N = -100\log_{10}\frac{I}{F} = 43.43s\alpha\Omega + 43.43s\beta p = C_1\Omega + C_2$$

- LUT table of calculated N values (log of the normalized radiance, I/F) works well due to the linear relationship between it and the total column ozone amount.
  - LUT generated using:
    - Laboratory measurements of ozone absorption coefficients for different wavelengths
    - Pre-defined set of ozone profiles with different ozone amounts
    - Pre-defined set of temperature profiles
    - Four pressure levels (1.0, 0.7, 0.4, and 0.1 atmospheres)
    - Viewing geometries spanning the range of those seen by the sensor
- Algorithm uses 22 wavelengths from available range of measured radiances in 300 nm-380 nm range.
- Clouds in scene are accounted for using weighted average of calculated radiances for non-ozone absorbing wavelengths for a clear scene and an opaque cloud

$$f_{cld} = \frac{I_{meas} - I_{grd}}{I_{cld} - I_{grd}}$$

I_{meas} = Measured radiance
I_{grd} = Radiance from look up table assuming ground reflectivity, terrain pressure
I_{cld} = Radiance from look up table assuming cloud reflectivity from externally co-located EDR – Cloud top pressure from external EDR or UV climatology

- Initial ozone estimate made by performing table look-up using f_{cld} and difference in N value between two closely-separated wavelengths
  - Use of a ratio between two such wavelengths reduces wavelength independent calibration effects
- Taylor series expansion is performed around ozone estimate:

$$N = N_0 + (\Omega - \Omega_0)\frac{dN}{d\Omega}$$

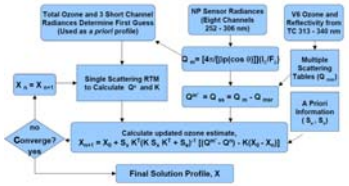
- Any residual calibration errors not in model are corrected (to first order) by adding term that is linear in wavelength:

$$N = N_0 + (\Omega - \Omega_0)\frac{dN}{d\Omega} + a + b\lambda$$

- Three unknowns (Ω, a, and b) require a **wavelength triplet** to solve for total ozone
  - Triplet consists of reflectivity wavelength and pair used to determine the original ozone estimate
- Corrections applied to account for differences between atmospheric conditions and model
- Retrieval is flagged if volcanic SO2 present

Nadir Profile IP

- Adaptation of SBUV/2 Version 6
- Uses 12 channels to derive profile
  - Shortest 8 are provided by NP spectrometer
    - Each wavelength has a contribution function that peaks at different altitude in atmosphere
  - Longest 4 provided by TC spectrometer
    - Used to derive a priori information and some scattering corrections
  - SDR approach to merging the NP and TC measurements is important component to production of quality retrievals

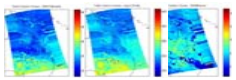


Q describes the ratio of backscattered to incident radiation

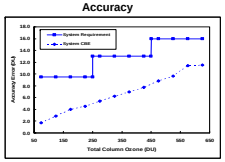
Predicted Performance

- BATC predicted TC performance for sell off indicates that specifications will be satisfied with margin.
- BATC performance is predicted on sensitivity tests, and RSS of sensor and algorithm errors, no end-to-end performance.

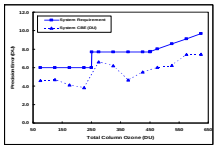
Functional end–to-end test performed in 2005 with unmodified codes and good match with truth data obtained . However SDR and input data were inconsistent with sensor characterization. (NGST – Oct. 2007 – TIM presentation -SDR delivery to IDPS)



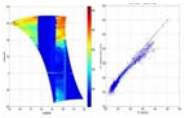
Accuracy



Precision



TC SDR code modified in 2008 to include sensor characterization databases. Preliminary results indicate consistent results. (NGST- O3OATmeeting presentation – Nov. 19, 08)



End- to-end performance pre-launch will be verified by NGST by 2010

BATC predicted NP performance for OMPS sell off indicates that specs are satisfied outside SAA. Slight increase over requirements is obtained when SAA is included.

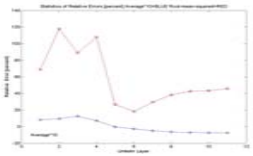
System Accuracy at 1mb
CBE = 5.9% - Requirement = 7%

System Precision at 30mb
CBE = 10.3% - Requirement = 10%

NP SDR (unmodified for consistency with current sensor characterization) and NP product were tested with limited Build 1.3 Raw data. (NGST – Test Report – NP Chain Delivery 3.2.1 - 2005)

NP SDR data converted into the SBUV/2 standard format (pmf) and Ozoned profiles retrieved and compared to input truth.

Sample is small with identified geolocation errors resulting in worse than expected performance .Tests tests will be repeated with appropriately updated NP SDR and synthetic RDRs in 2009.



End- to-end performance pre-launch will be verified by NGST by 2010

Total Column Ozone Specification Table

EDR/Attribute	Appendix B EDR Requirements
Horizontal Cell Size	
1. Total Column	50 km @Nadir
Horizontal Reporting Interval	
1. Total Column	50 km @Nadir
Vertical Cell Size	
1. Total Column	60 km
Solar Zenith Angle (SZA) Coverage	SZA < 80 deg
Vertical Coverage	
1. Total Column	0 to 60 km
Measurement Range	
1. Total Column	50 - 650 milli-atm-cm
Measurement Accuracy	
1. Total Column, Total Column > 450 milli-atm-cm	16 milli-atm-cm
2. Total Column, 250 milli-atm-cm < Total Column < 450 milli-atm-cm	13 milli-atm-cm
3. Total Column, Total Column < 250 milli-atm-cm	9.5 milli-atm-cm
Measurement Precision	
1. Total Column, Total Column > 450 milli-atm-cm	7.75 milli-atm-cm + 1.1% of Measured Ozone over 450 milli-atm-cm
2. Total Column, 250 milli-atm-cm < Total Column < 450 milli-atm-cm	7.7 milli-atm-cm
3. Total Column, Total Column < 250 milli-atm-cm	6.0 milli-atm-cm
Long Term Stability	
1. Total Column	1%
Mapping Uncertainty, 3 Sigma	
1. Total Column, at Nadir	5 km
Maximum Local Average Revisit Time	
1. Total Column	34 hrs
Latency	NPP - 140 min., NPOESS - 26 min.
Measurement Degradation Conditions (OMPS Degradations)	
1. Total Column Accuracy if Sulfur Dioxide Index > 6 milli-atm-cm	15 milli-atm-cm + 3SOI
2. Total Column Precision if Sulfur Dioxide Index > 6 milli-atm-cm	6 milli-atm-cm + 1.5SOI

01/09