S-NPP Ozone Mapping Profiler Suite Nadir Instrument Radiometric Calibration

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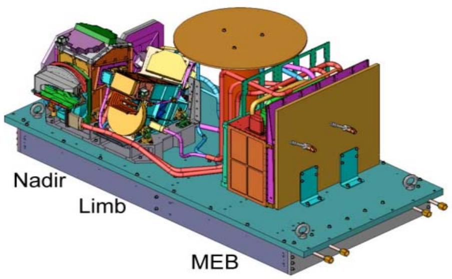
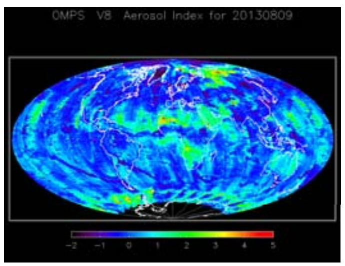
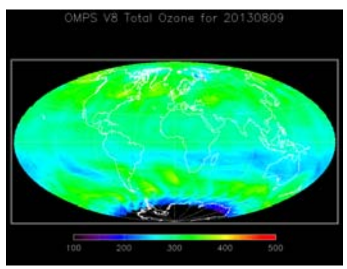


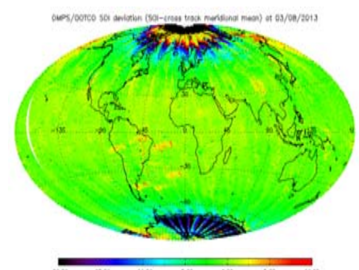
Curtsey of Ball Aerospace and Technologies Corp.



Aerosol Index



Ozone map


So2 index

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OMPS Nadir Instrument overview

• OMPS is one of four instruments on board the SNPP satellite launched in Oct. 2011. J1 OMPS will launch in early 2017.

• OMPS has three spectrometers: NP, NM and LP. Heritage from SBUV/2 and TOM, OMPS provides ozone total column and vertical profile data that continues ozone daily global data with higher calibration accuracy and higher spatial and spectral resolution.

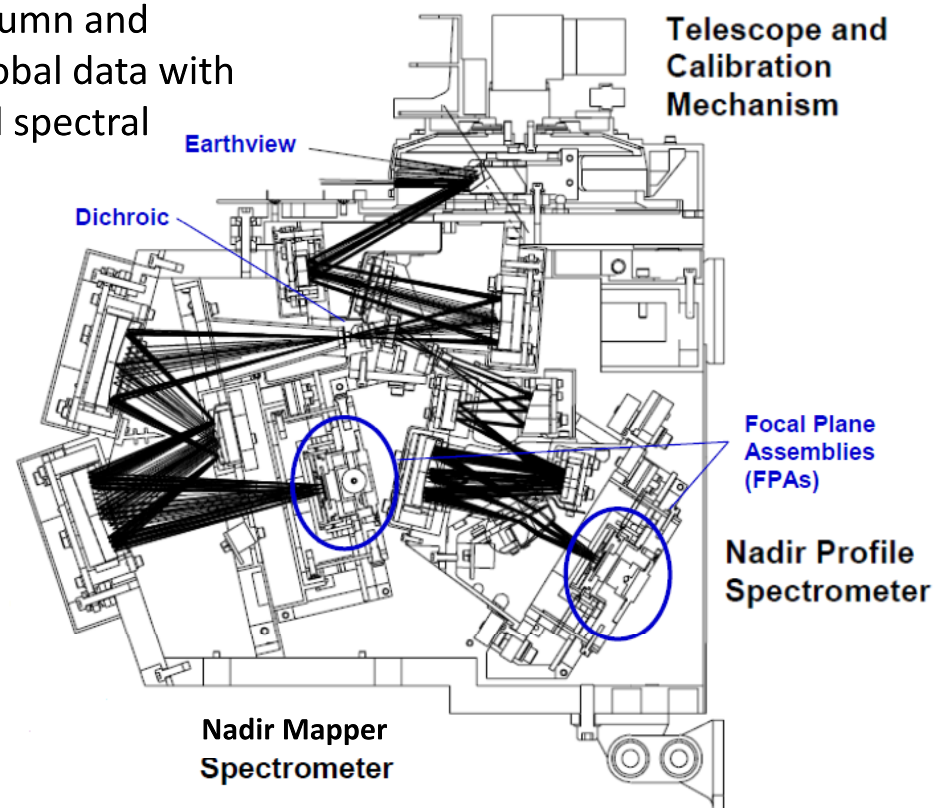
Spatial resolution can be altered to provide a smaller ground FOV that has a higher spatial resolution.

Configuration

- Push-broom 110 deg. cross-track FOV telescope
- Two grating spectrometers
  - NM covers 300 nm to 380 nm
  - NP covers 250 nm to 310 nm
- CCD optical detector for each spectrometer

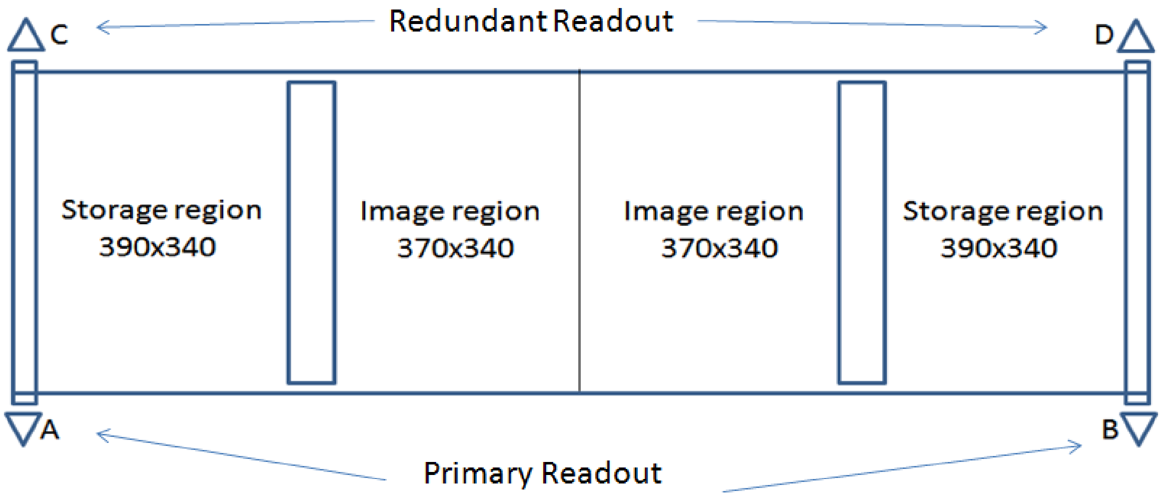
Onboard Calibrators

- Light-emitting diode provides linearity calibration
- Reflective solar diffusers maintain calibration stability

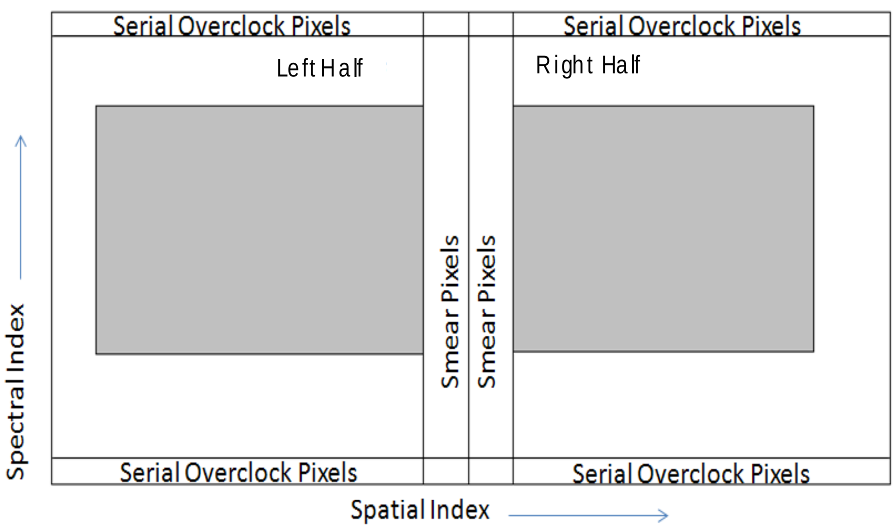


Courtesy of BATC

NM OMPS Focal Plane

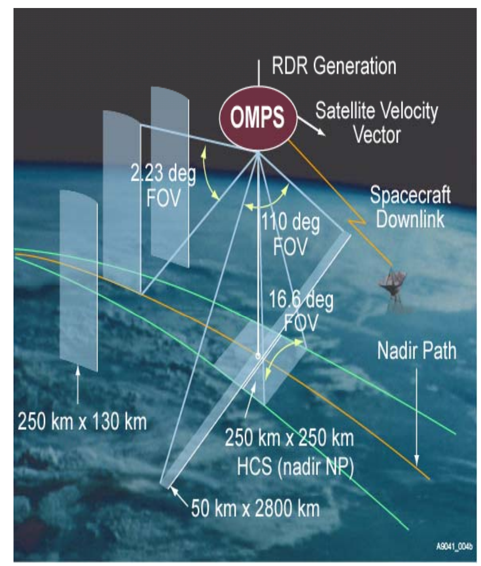


- CCD operation temperature: -30 deg. for TC and -45 deg. for NP
- Split frame transfer, two halves identical CCD



OMPS NM CCD readout full frame image format.

35 spatial cells in the cross –track direction, covers 110 deg FOV



OMPS Nadir performance specifications

Dominant contribution to accuracy

Spatial Properties

- Cross-track MTF at nadir >.5 at .01cycles/Km
- Cross-track TC macpx. IFOV nadir <3.44 degrees
- 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 OOB + OOF response <2%
- Intra-orbit wavelength stability .02 nm
- Band Pass Shape Knowledge 2%
- Solar Irradiance < 7%
- Radiance <3%

Dominant contribution to precision

Radiometric Precision Terms

- SNR 1000 for TC, varies for NP
- Inter-orbital Thermal Wavelength Shift .02 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

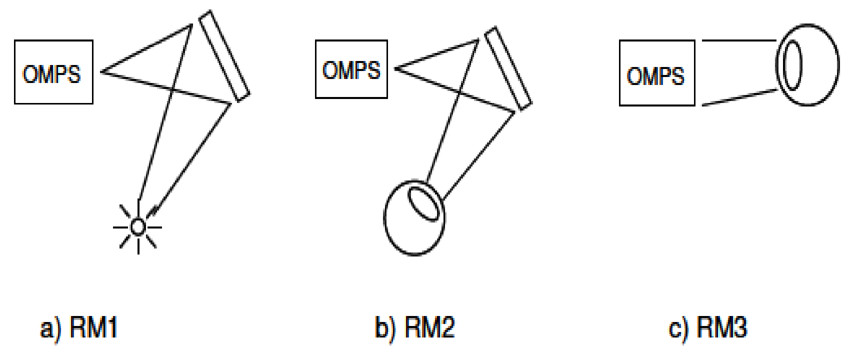
OMPS Sensor Radiometric calibration – Prelaunch calibration

•Prelaunch calibration consists of three principal phases: irradiance calibration, goniometry characterization and radiance calibration.

•Each OMPS spectrometer was calibrated by transferring NIST traceable standards to the sensors in both radiance and irradiance modes.

•The irradiance coefficients were measured using a similar method to the radiance measurement.

•OMPS radiometric calibration uncertainties come from the calibrators and the measurements, such as calibrators' stability, sphere strike-to-strike repeatability, wavelength calibration accuracy, stray light contamination, signal correction accuracy and signal to noise ratio.



Courtesy of BATC

➢ Dark
- Dark distribution
- Dark generate rates
- Electronic bias
- Hot pixels
- Dark Signal Non-uniformity (DSNU)
- Readout noise
- Dark smear

➢ Linearity
- Nonlinearity
- LED output drifts
- Dynamic range
- Calibrated accuracy
- LED lamp warm up behavior
- LED illumination uniformity
- CCD gain

OMPS Sensor Radiometric calibration – Orbital calibration

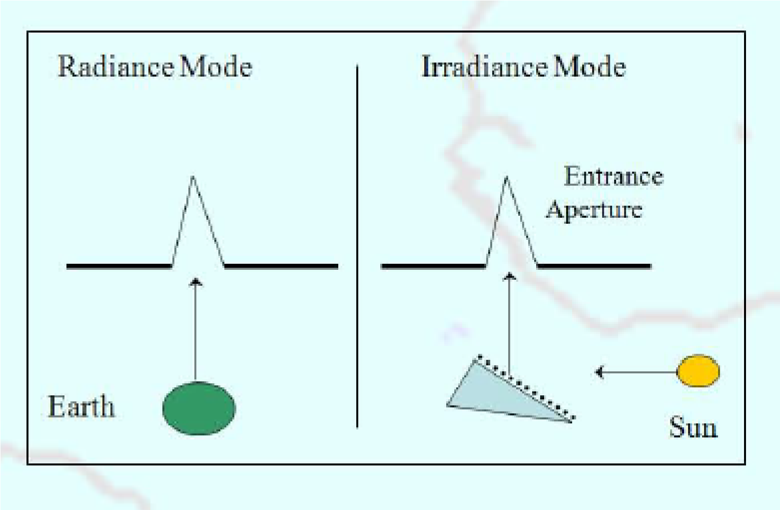
The in-flight calibration provides an observed solar irradiance spectrum along with the measured Earth radiances from Earth observation.

Orbital calibration employed two diffusers for each spectrometer to maintain calibration stability

A working diffuser and a reference diffuser operate in a different observation frequency to tack sensor optical degradation and diffuser degradation

The solar measurement provide time-dependent solar irradiance, wavelength, and sensor stability monitoring

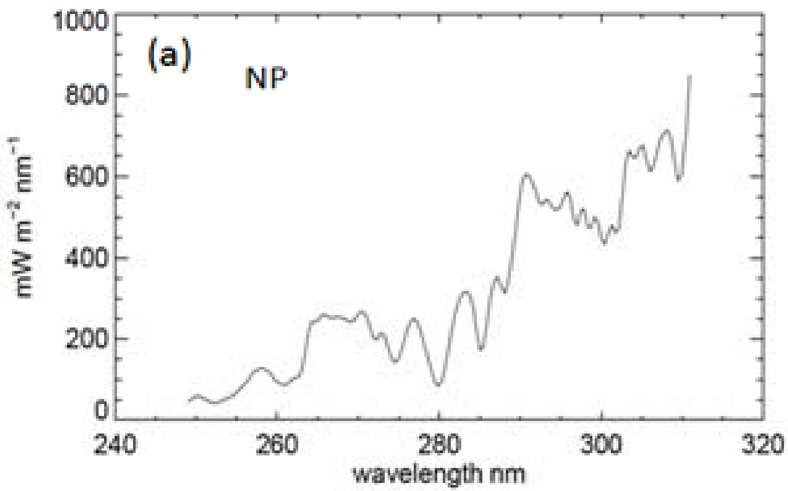
Major challenge is orbital wavelength variation: Ground-to-orbital transition, seasonal, intra-orbit, cross-track

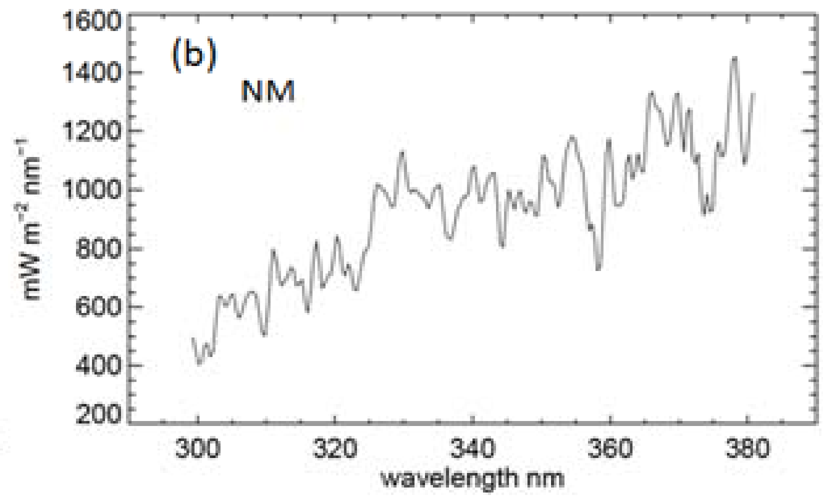


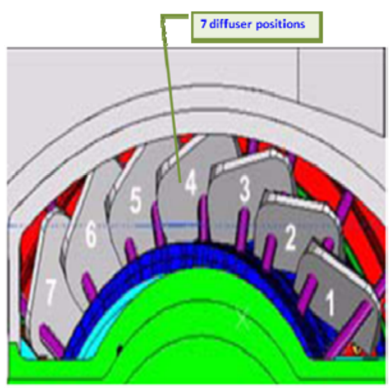
Courtesy of S. J. Lipscy from BATC

Backscatter UV retrievals use a normalized radiance, a ratio of measured Earth radiance to measured solar irradiance.

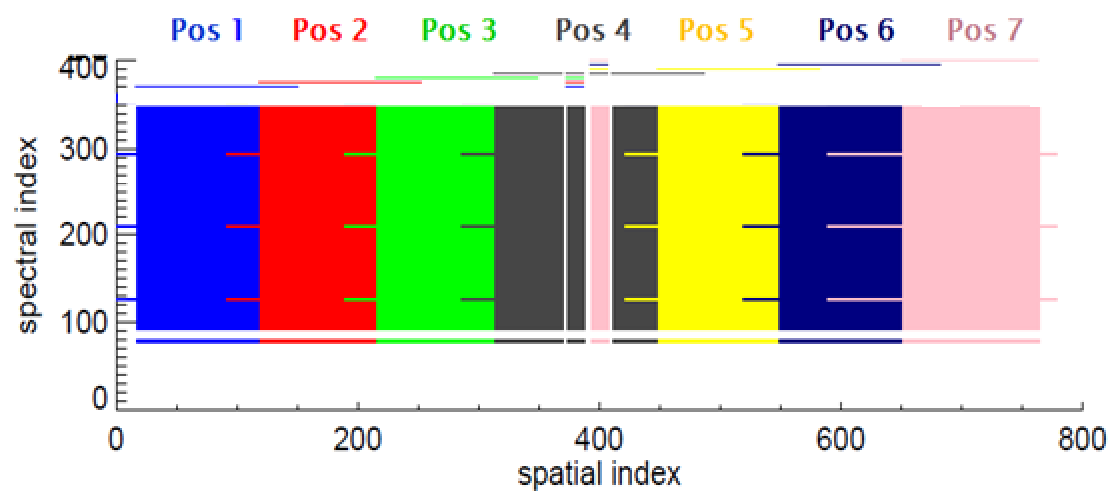
Solar irradiance measurements





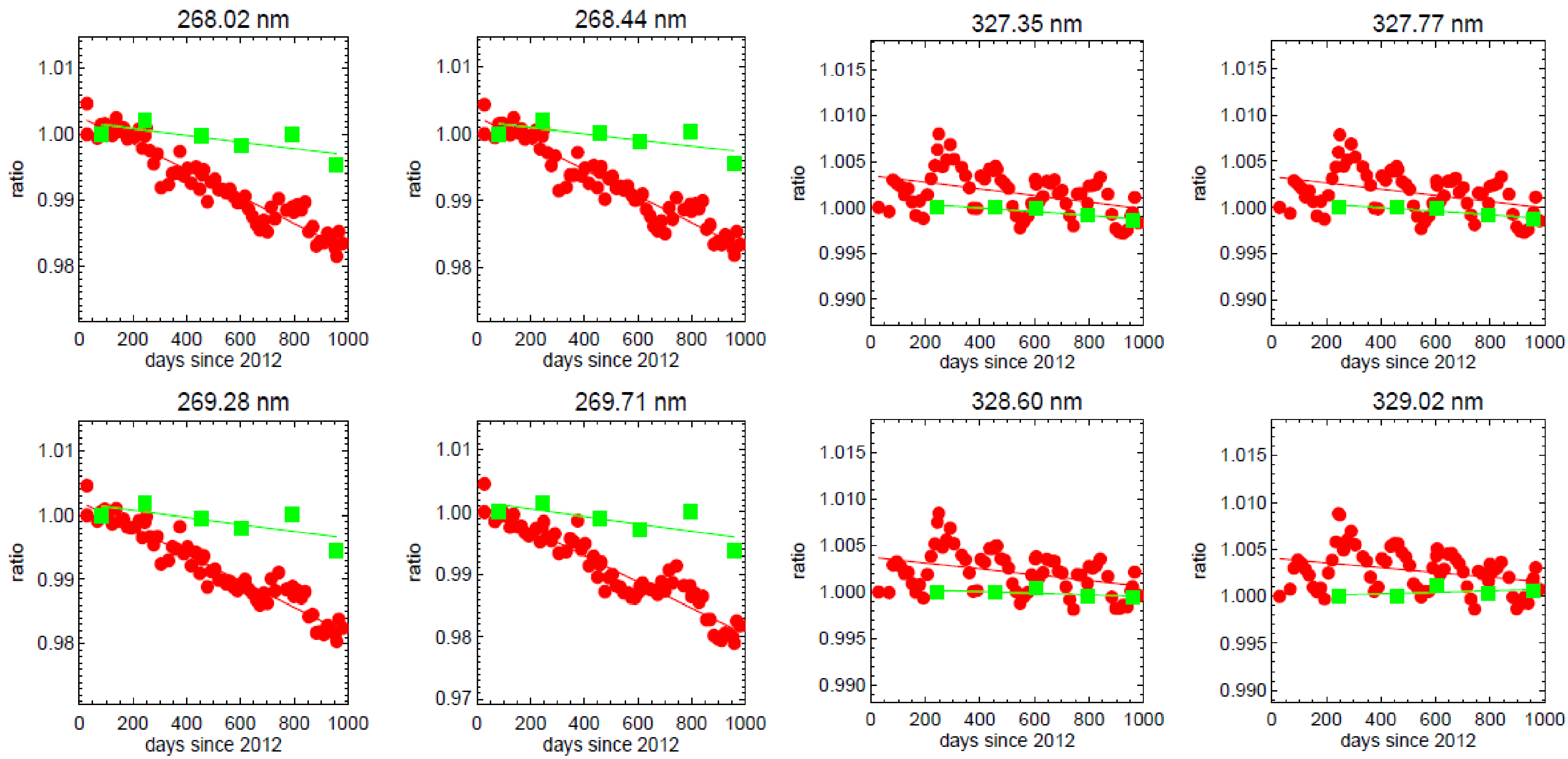


courtesy of BATC



Optical throughput change < 1%

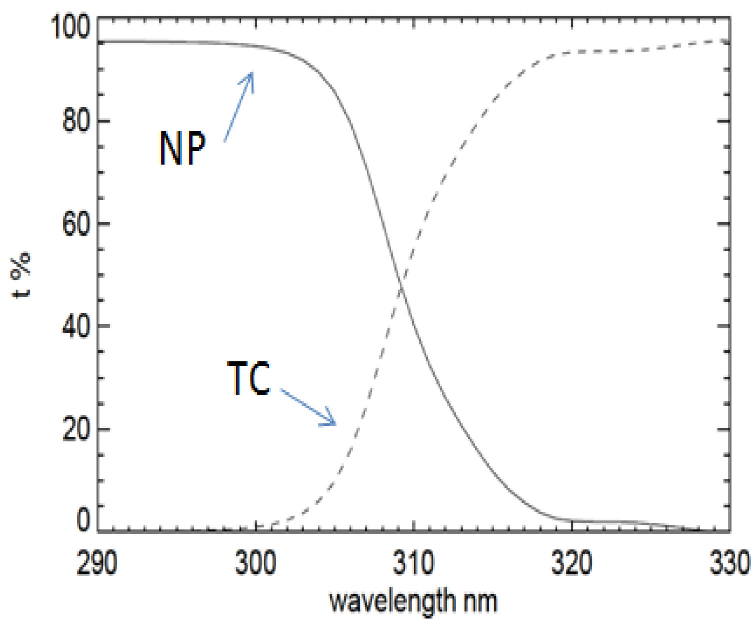
NP | Reference | Working | NM



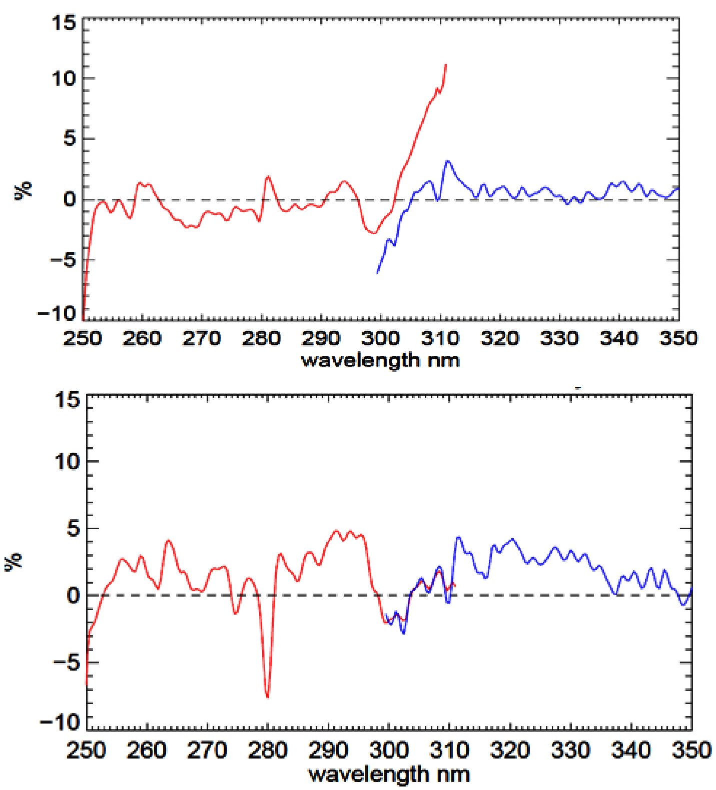
Dichroic wavelength changed ~ - 0.1 nm from ground to orbit

Wavelength shifted ~ - 0.1 nm from ground to orbit. The figure shows percent difference between observed and synthetic solar flux

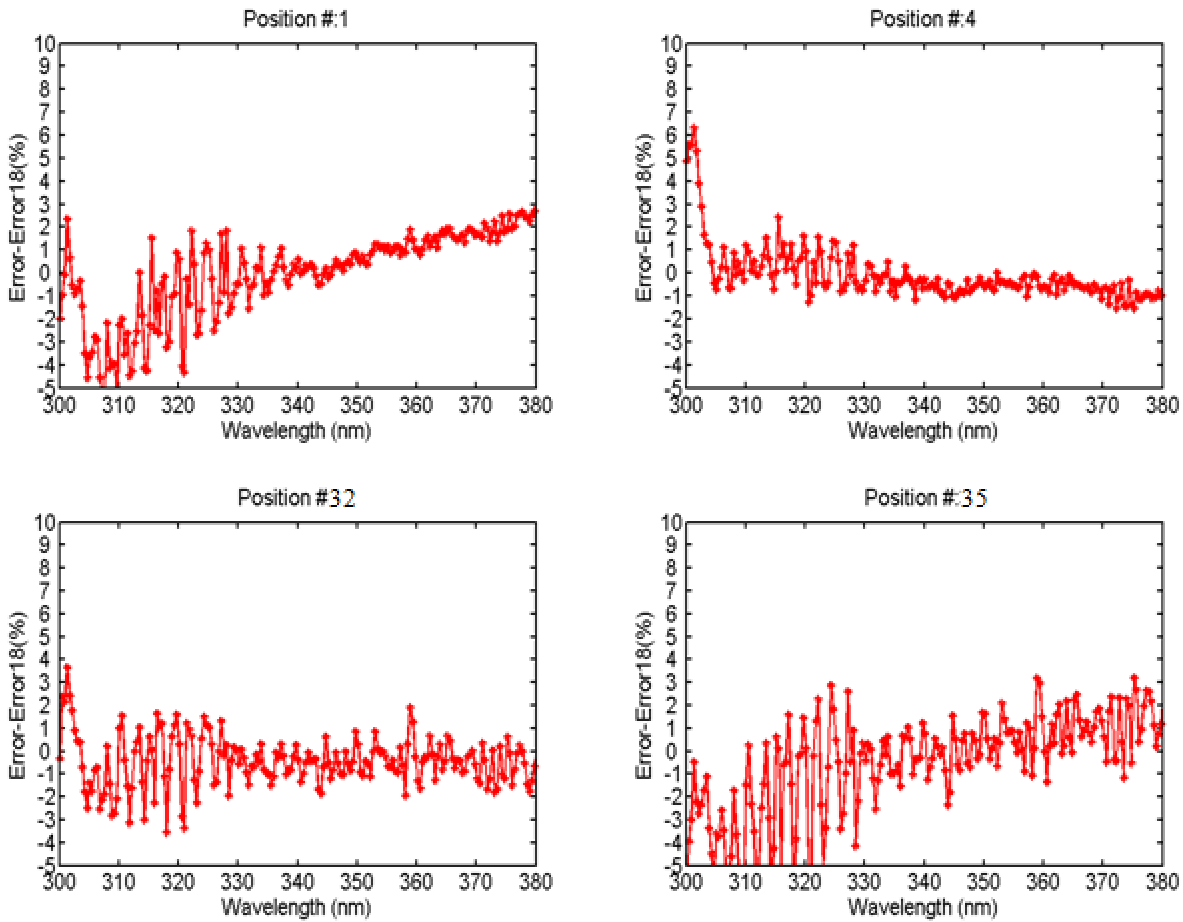
Percent transmittance



Measured vs. Synthetic Solar Flux



Cross-track position pattern from normalized radiance

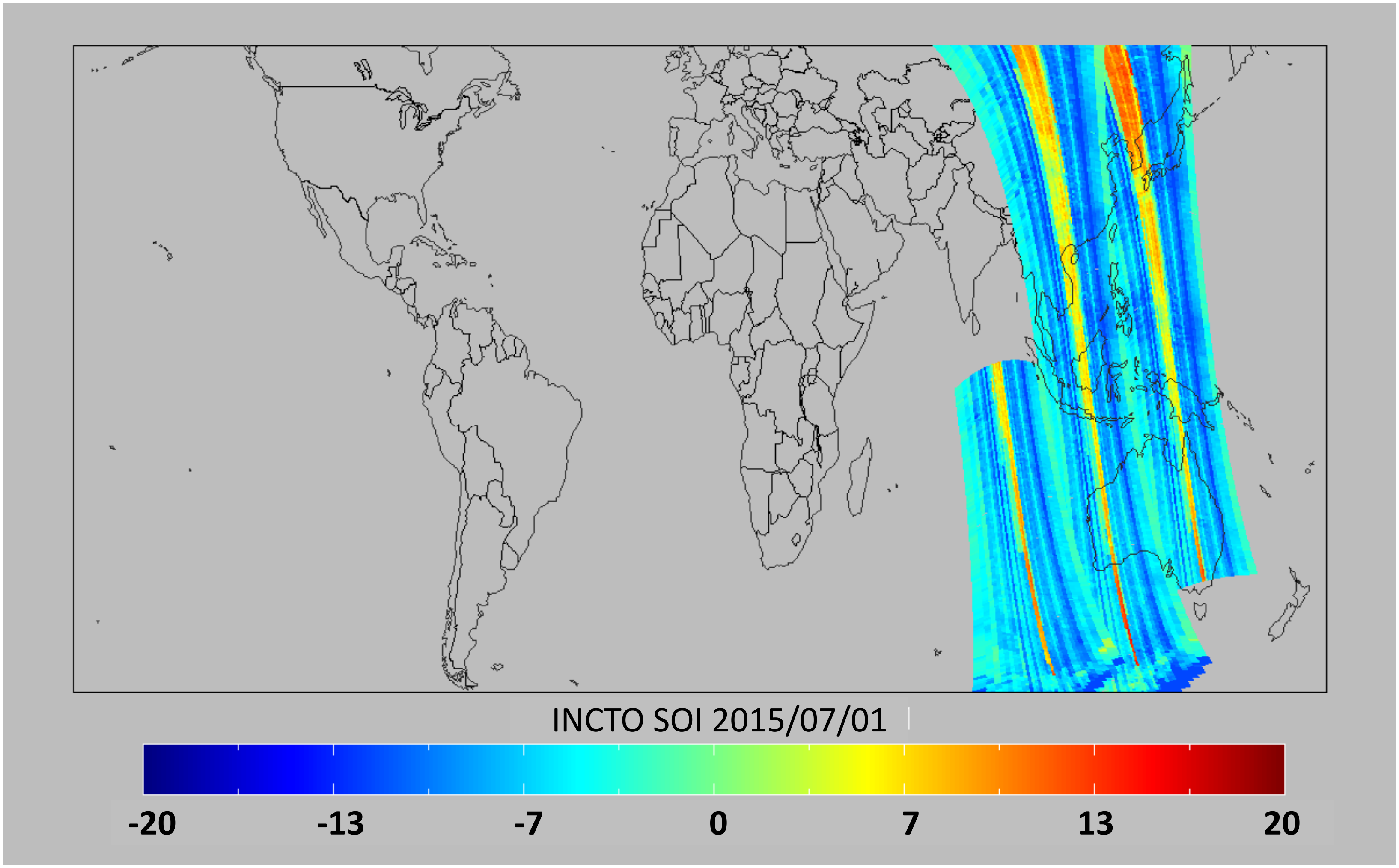


- OMP data is compared with data from the well calibrated Microwave Limb Sounder (MLS)
- Using MLS ozone and temperature profiles colocated with OMPS retrievals under the OMPS viewing conditions, a calibration standard is established through radiative transfer model TOMRAD.
- The model computes the normalized radiance (NR) that represents what OMPS should provide

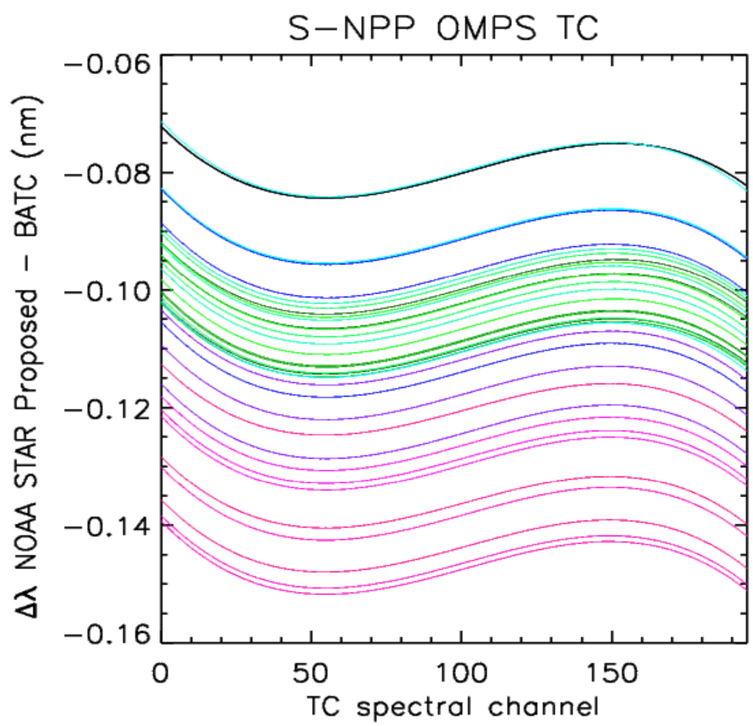
Wavelength dependent accuracy in cross-track scan direction exceed our expectation but can be corrected. The figure shows percent difference between OMPS and MLS before SDR validated maturity

Cross-track position pattern from EDR data

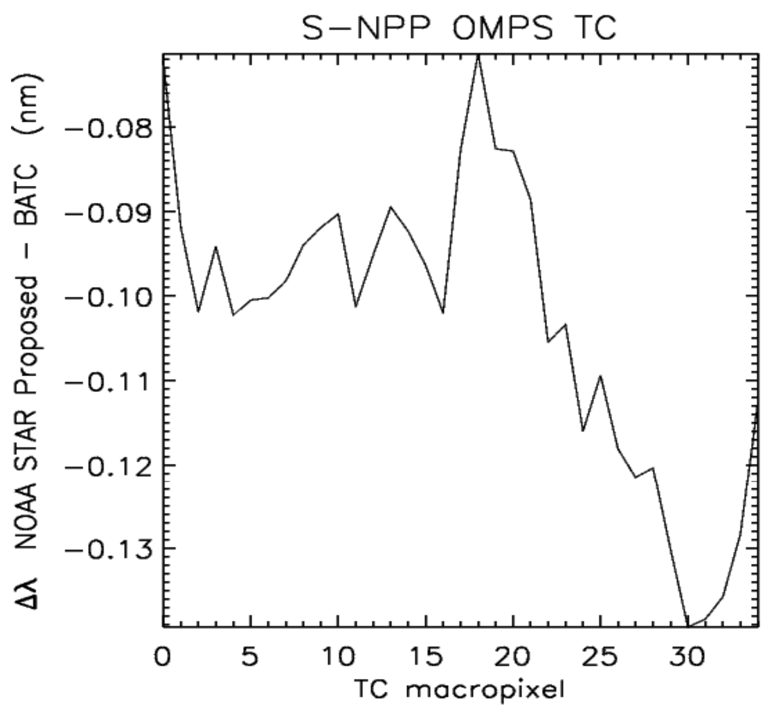
SO2 Index before wavelength update



Wavelength changed spectrally and spatially



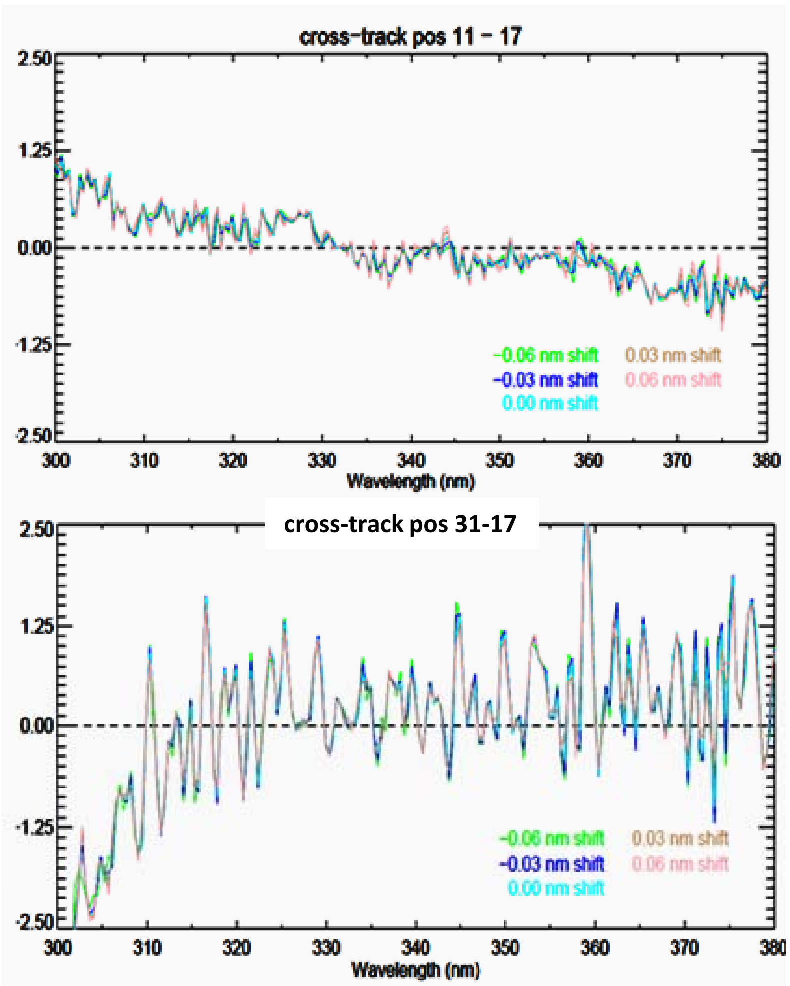
Shifts vs. spectral channels



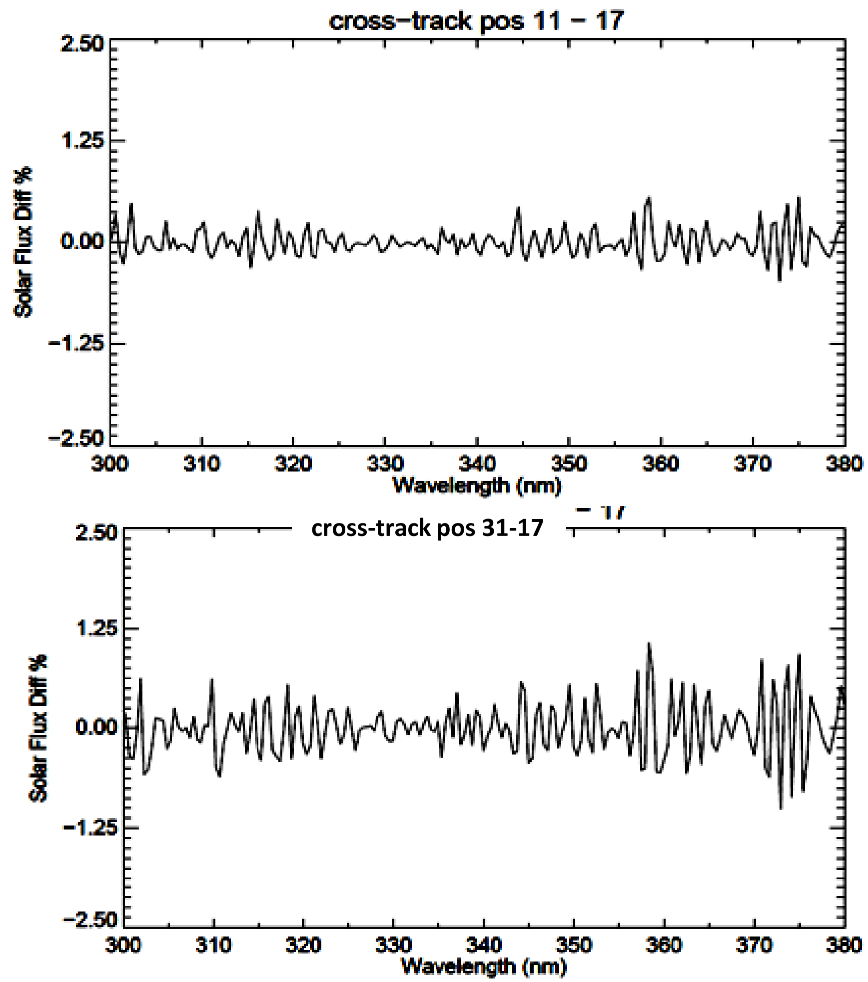
Shifts vs. spatial 35 cells

Cross-track position pattern from Solar data

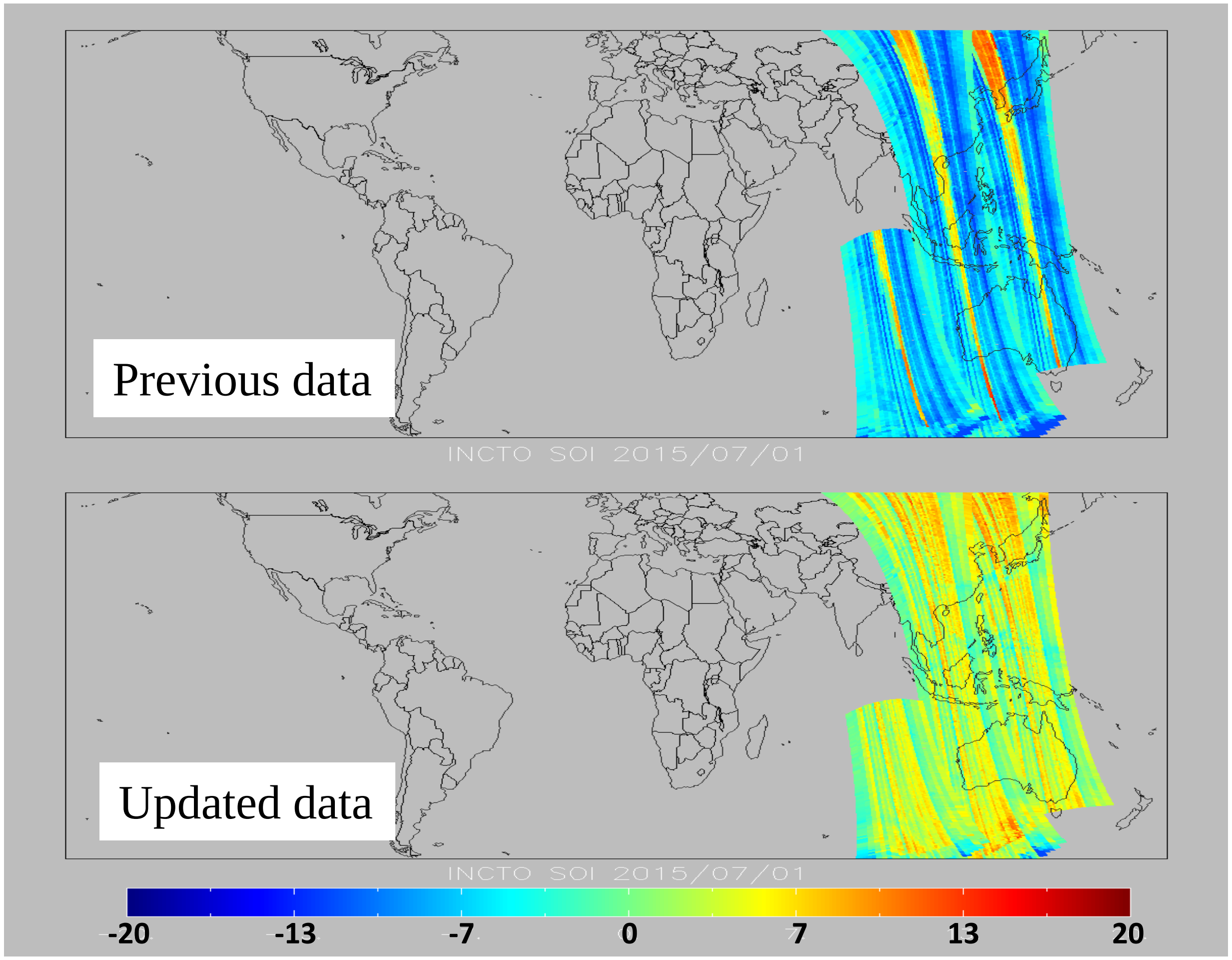
before adjustment



After adjustment

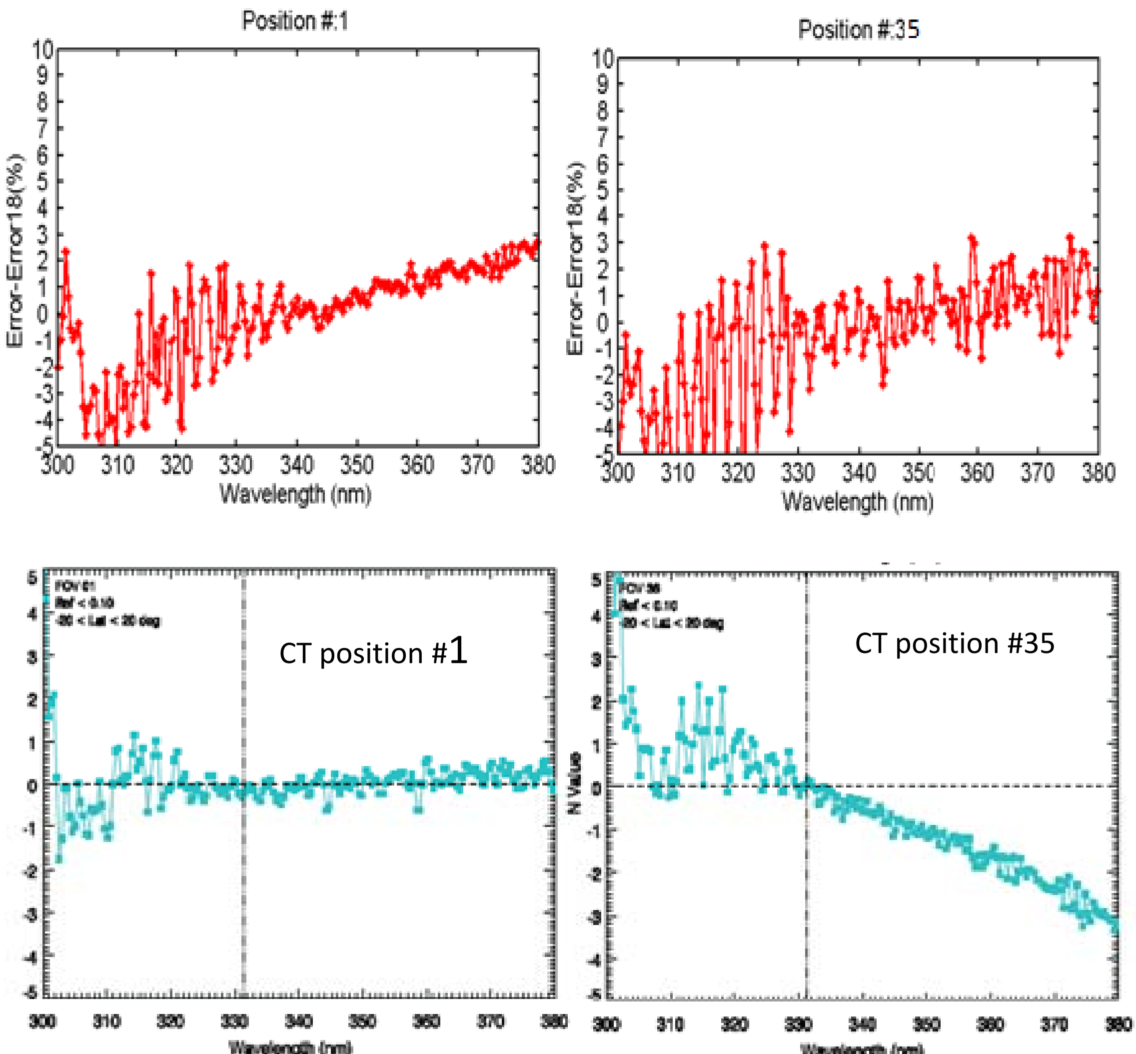


SO2 Index Comparison before and after Wavelength Update



- SO2 index cross-track variation was minimized from -13 ~ 13 to 6~7/8.
- Residual error are caused by EDR V7 TOZ algorithm, that inappropriately exaggerates the impact of wavelength variation.
- The residual error can be corrected by EDR V8 algorithm with an appropriate n-value adjustment.
- Data comes from OMPS NM EDR products INCTO SO2 2015/07/01

Wavelength-dependent Cross-Track Normalized Radiance Error Meets Requirement



Courtesy of NASA

- Normalized radiance error is percent difference between Observed and Calculated N-values

- Figures shows the errors for 6 different cross-track (CT) positions

- Errors were minimized < 2% for most of the channels.

- Except ion is CT#36 on wavelength > 360 nm. Soft calibration are being implemented to eliminate this residual error.

Summary

- Sensor orbital performance is stable and meet our expectation
- Radiometric calibration includes dichroic adjustments, stray light correction, wavelength shift corrections and radiance/irradiance calibration coefficients modification
- The cross-track direction normalized radiance accuracy meets spec and the error is less than 2.0% with updated wavelength and day one solar LUTs
- The NM and NP consistency in 300-310 nm has been improved by 2-10% with updated radiance calibration coefficients
- Newly established calibration validation method via radiative transfer model is critical for SDR products assessment