



Characterization of SNPP OMPS Cross-Track Uncertainty

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NOAA/NESDIS/STAR

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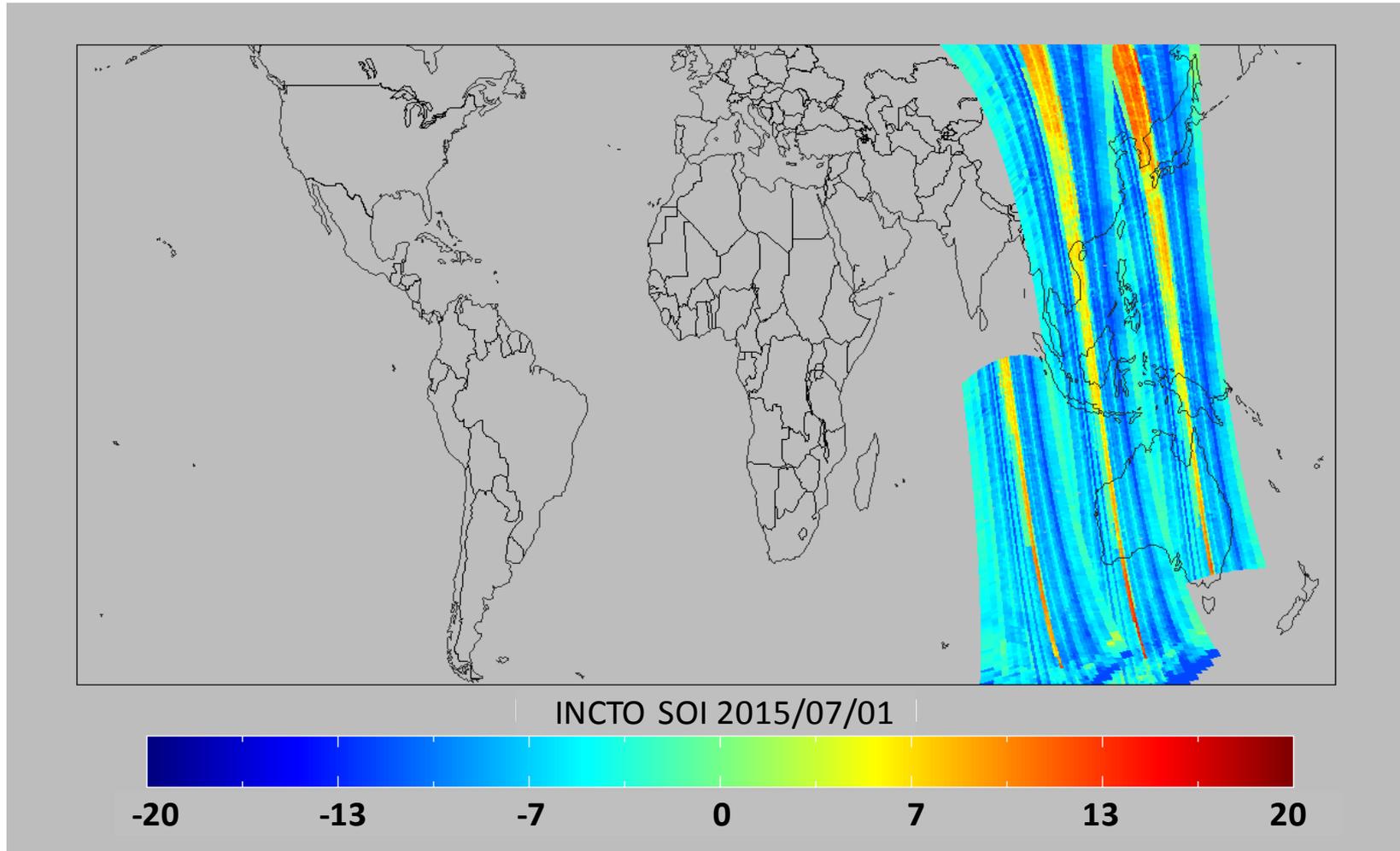
Outline



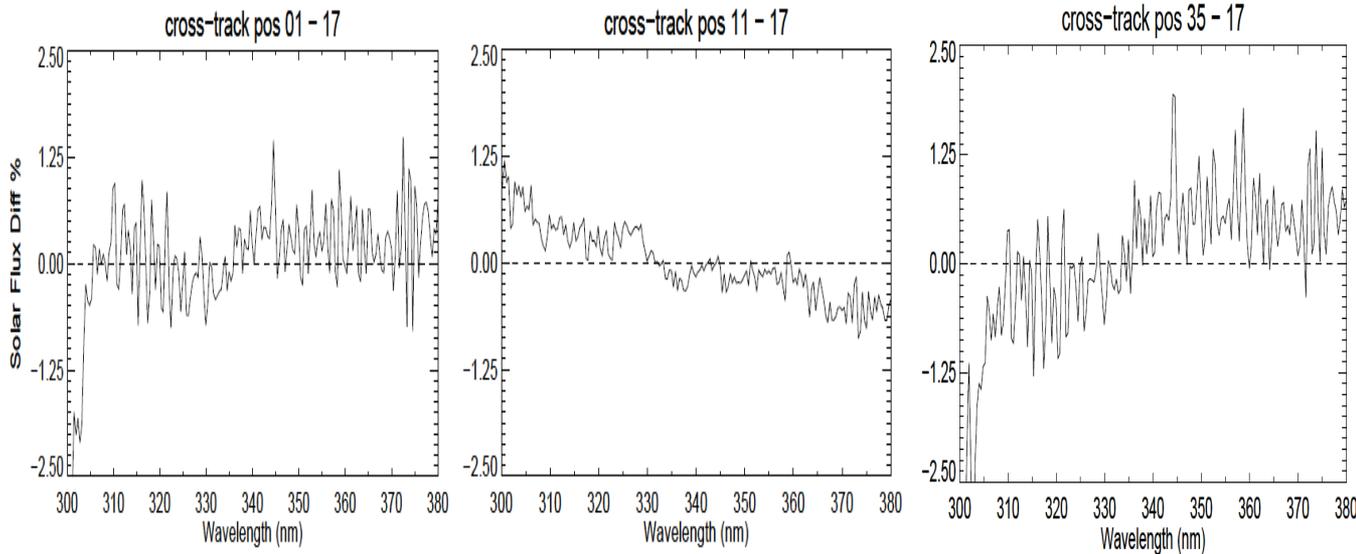
- Observed OMPS NM Cross-track Errors
- Methodology for Reducing the Cross-track Dependent Errors
- Characterization of OMPS Cross-track Error Using TOMRAD
- Impacts of Improved OMPS SDR on EDR
- Path Forward for SNPP Further Improvement

Cross-Track Dependence in SO₂ Index Derived from OMPS NM SDR

SO₂ Index Comparison before Wavelength Update



Previous wavelength LUT cause errors in cross-track position.



- Irradiance error is percent difference between observed solar flux and modeled synthetic solar flux.

$$Error = \left(1 - \frac{flux_{observed}}{flux_{synthetic}} \right) * 100$$

- Figures show the errors for 3 different cross-track position relative to the nadir position

- Solar flux and wavelength data were read from Nov. 06, 2013 SDRs to demonstrate cross-track position error.
- The OMPS NM synthetic solar flux is computed by convolving the lab band-passes with the high-resolution solar reference spectrum.



Methodology for Reducing NM Cross-Track Dependent Errors



- The cross-track errors are primarily associated with bandpass shape/bandwidth changes.
- We reduced/minimized the errors by aliased wavelength shifts.
- The new NM (TC) wavelength LUT and day-one solar LUT minimizes radiance/irradiance cross-track direction errors.
- Additionally, the new radiometric calibration LUTs improved radiance consistency between NM & NP in 300-310 nm.



LUTs Updated for NM



- NM GND-PI and LUT updates as indicated below.

The new NM (TC) wavelength minimizes radiance/irradiance cross-track direction errors. The new radiance coefficients for NM account for ground to orbit thermal loading changes, as well as radiance consistency between NM and NP in 300-310 nm. The new day one solar LUT accounts for new radiance cal coefficients.

- **WAS: OMPS-TC-WAVELENGTH-GND-PI_**
npp_20141005000000Z_20140905000000Z_ee00000000000000Z_PS-1-O-CCR-14-2052-NOAA-JPSS-
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- **WAS: OMPS-TC-CALCONST-**
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LUTs Updated for NP



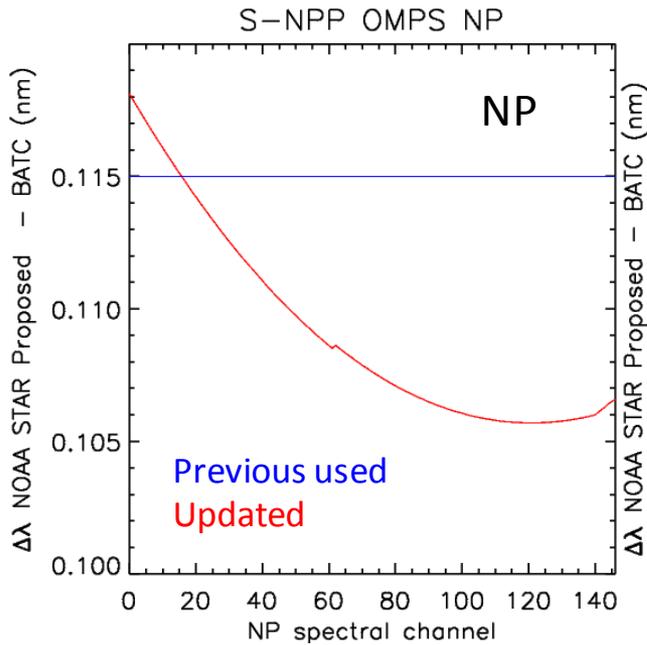
- NP GND-PI and LUT updates as indicated below.

The new radiance coefficients for NP account for ground to orbit thermal loading changes, as well as radiance consistency between NM and NP in 300-310 nm. The new day one solar LUT accounts for new radiance cal coefficients. The new NP wavelength is computed in accordance with the new day one solar LUT.

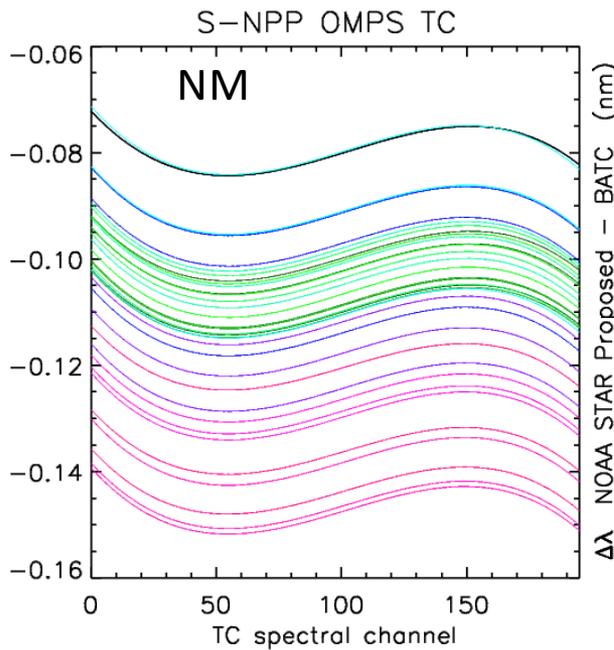
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Difference between LUTs and prelaunch data

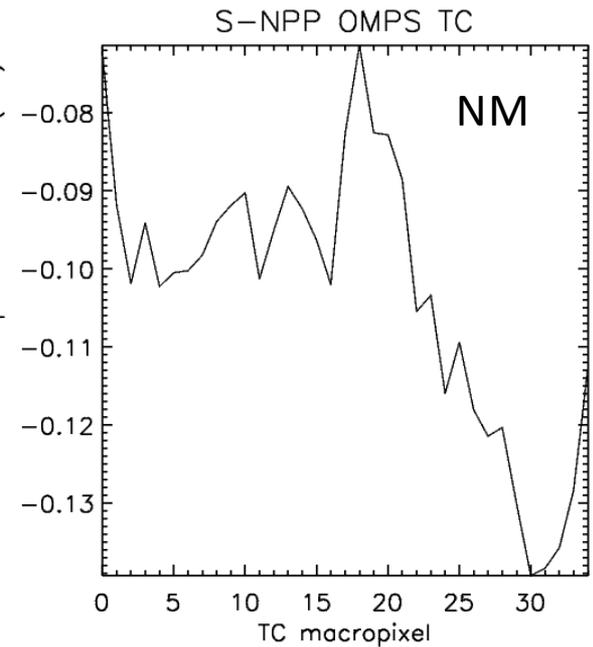
Difference between the updated and prelaunch data



Shifts vs. spectral channels



Shifts vs. spectral channels



Shifts vs. spatial 35 cells

Wavelength LUTs are modified for both NM and NP.



Building on-Orbit Truth for Estimating OMPS Earth View SDR Accuracy



- Develop the “truth” simulated from the forward radiative transfer model at OMPS EV location (Macropixel)
 - The Microwave Limb Sounder (MLS) is well calibrated
 - The temperature profile from MLS was assumed to be accurate
 - The MLS ozone profile was assumed to be accurate
 - The OMPS sensor were co-located, within 50 km, to measurements from the MLS sensor
- Radiative transfer model must include comprehensive scattering and absorption processes at UV regions
 - Roma scattering would be significant and
- Accurate understanding of atmospheric and surface status at OMPS EV location.
- The difference between observations and simulations is used as an estimate of on-board calibration accuracy



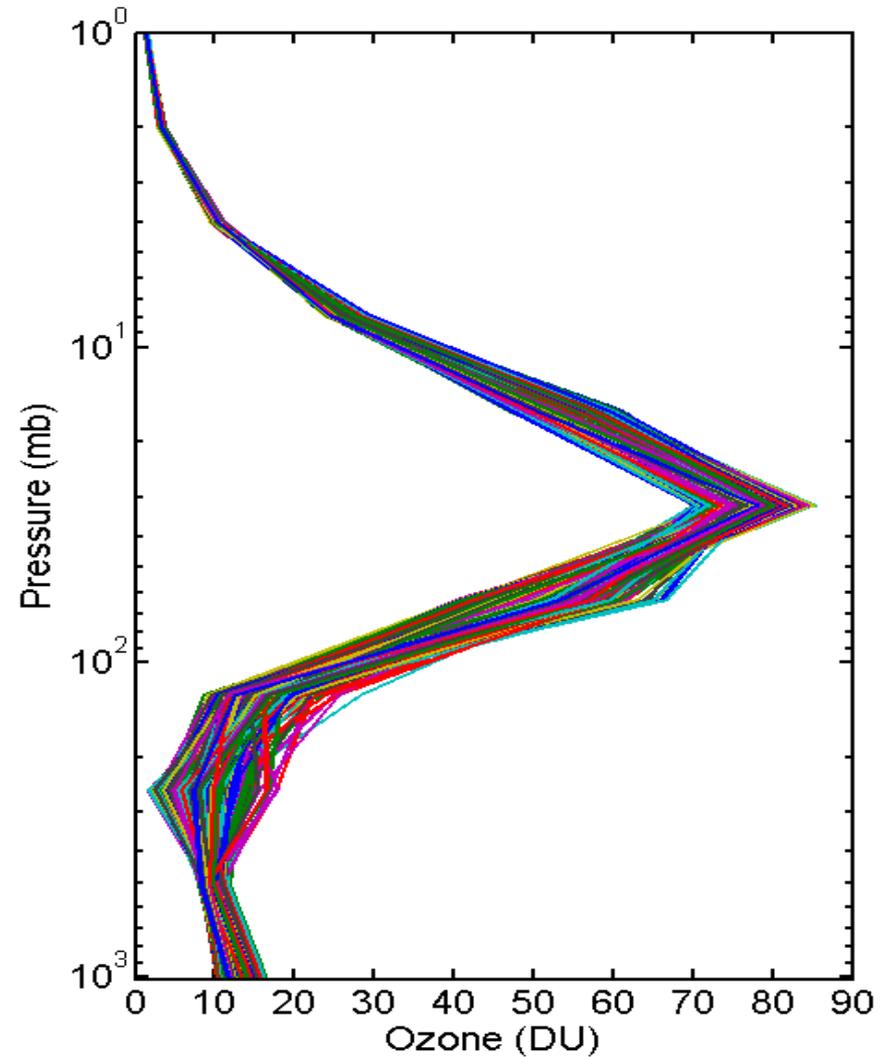
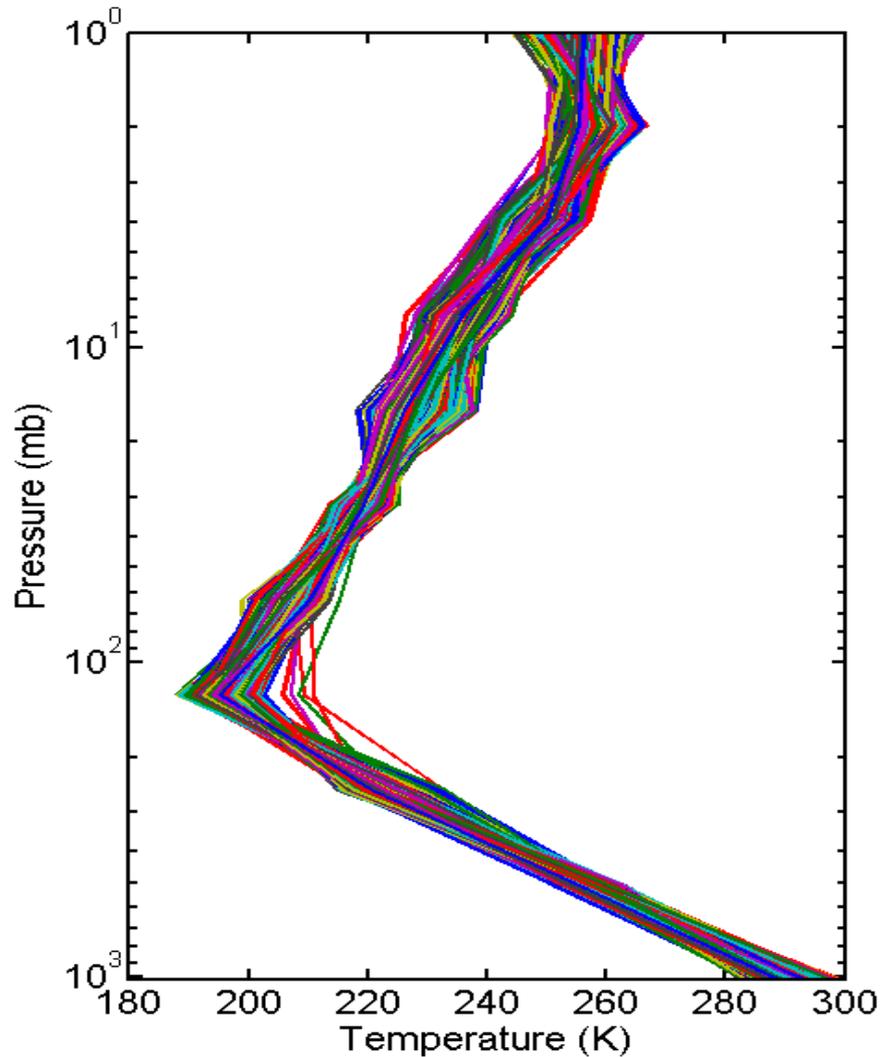
OMPS EV Radiative Transfer Simulations



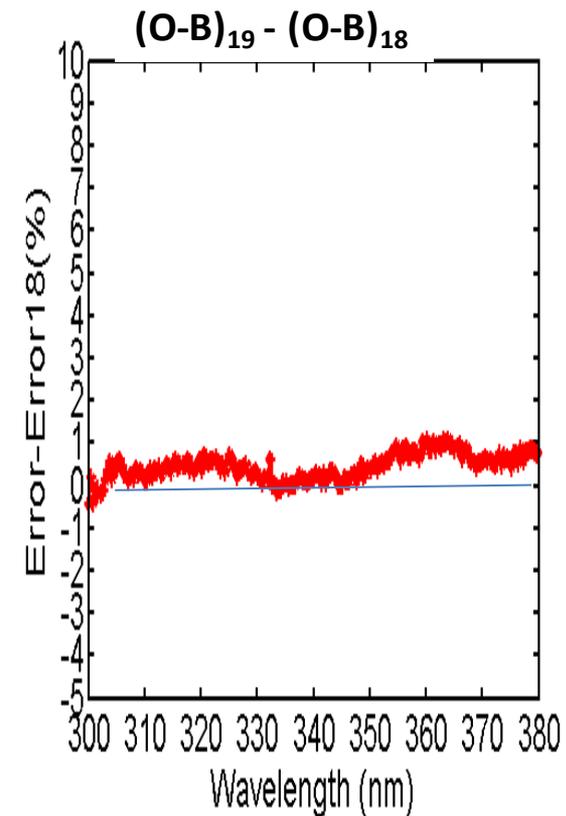
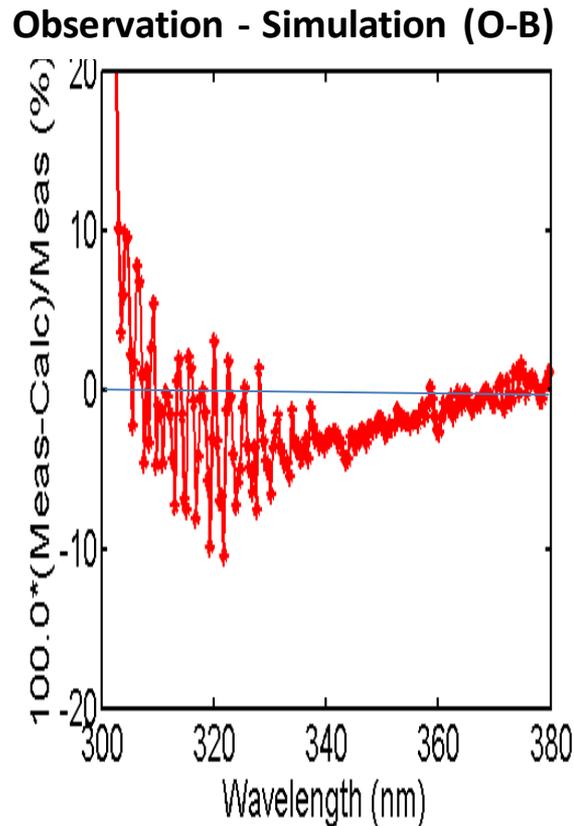
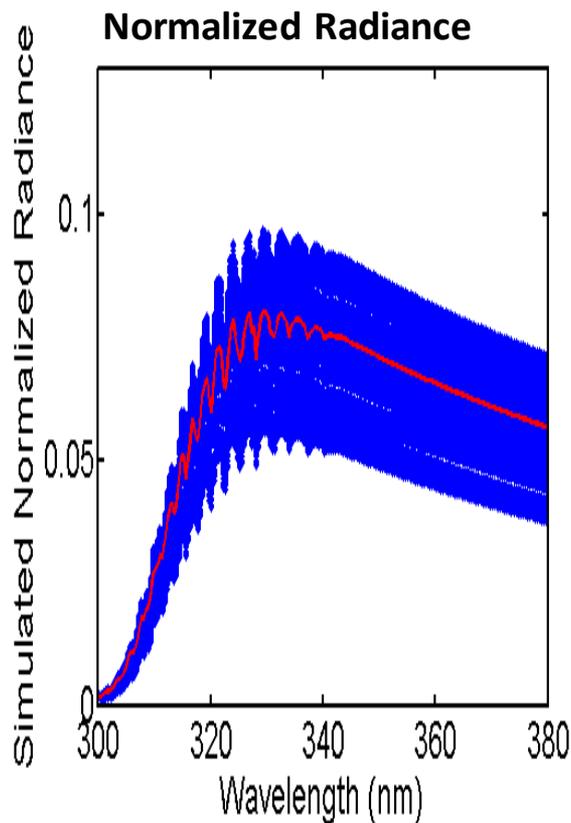
- TOMRAD-2.24: TOMS (Total Ozone Mapping Spectrometer) Radiative Transfer Model
 - Rayleigh scattering atmosphere with ozone and other gaseous absorption
 - Spherical correction for the incident light
 - Molecular anisotropy and Raman scattering
- Inputs to TOMRAD
 - Wavelength, solar and satellite viewing geometry, surface albedo, temperature and ozone profile
 - Climatology temperature profile
 - Ozone profile from Aura Microwave Limb Sounder (MLS)
 - Collocated OMPS/MLS data generated at STAR using NASA algorithm
 - a) reflectivity < 0.10 to eliminate cloud effects
 - b) Latitude: $-20 \sim 20$ degrees
- Outputs from TOMRAD
 - Normalized radiance (NR=reflected radiance/solar flux) or N-Value ($N=100*\log_{10}NR$)



Co-located OMPS/MLS Temperature and Ozone Profiles

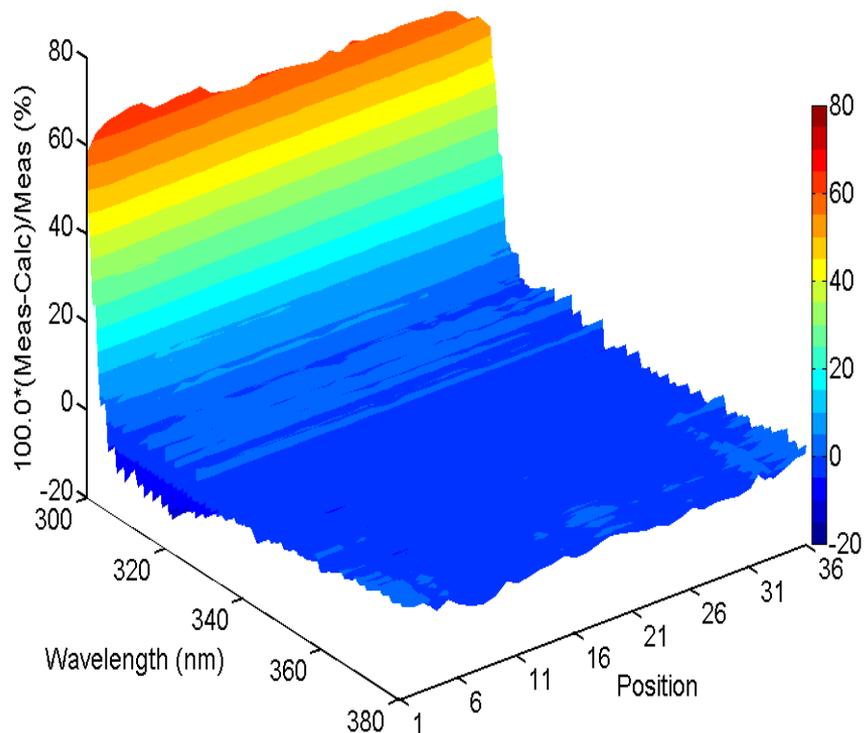


Simulated Normalized Radiance at OMPS Macropixel Position 19

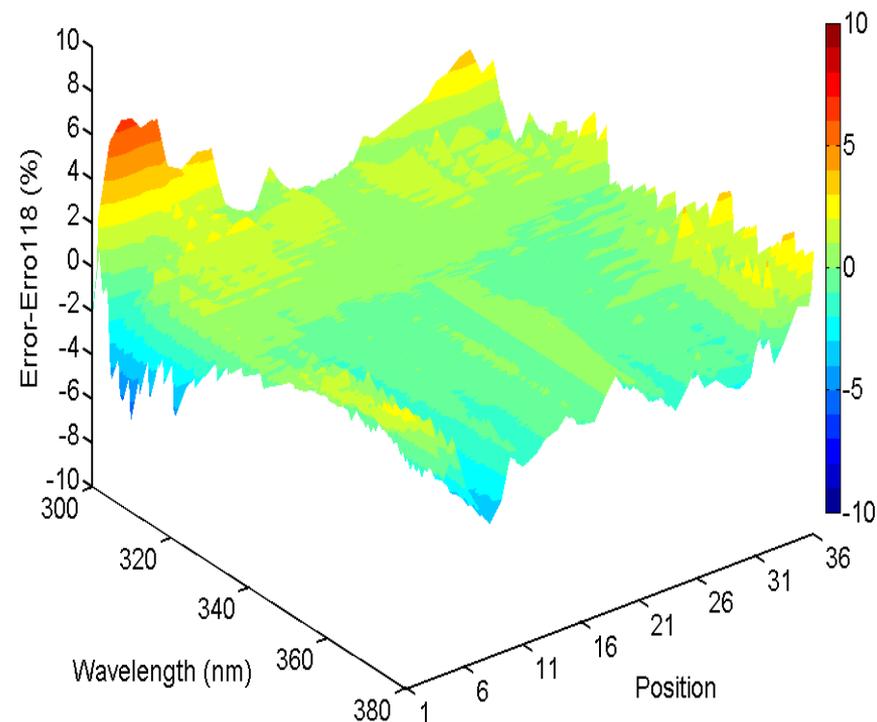


The left plot shows the calculated OMPS normalized radiance using MLS ozone and temperature profiles collocated with OMPS for cross-track position 19. The middle plot shows the percent difference between observed and calculated data. In the right plot, the relative percent difference between position 19 and 18.

Relative Error

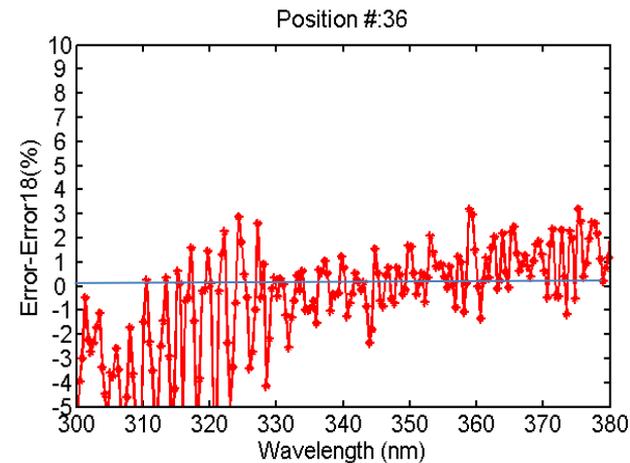
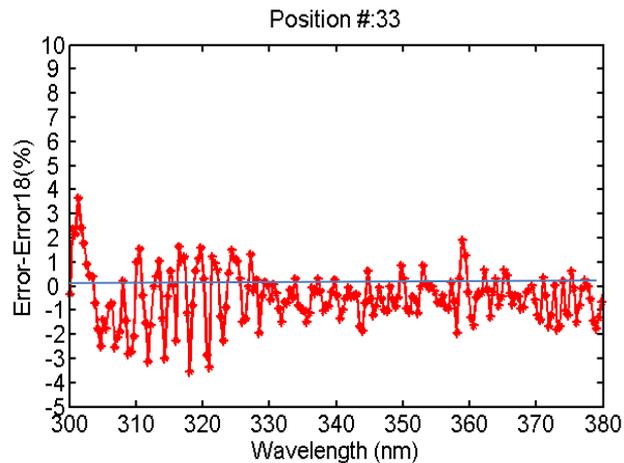
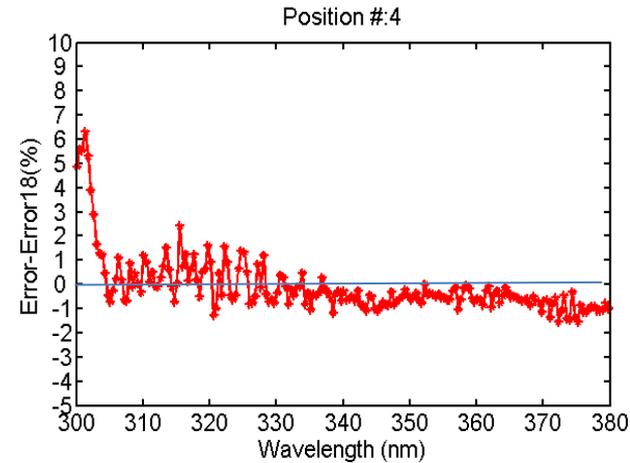
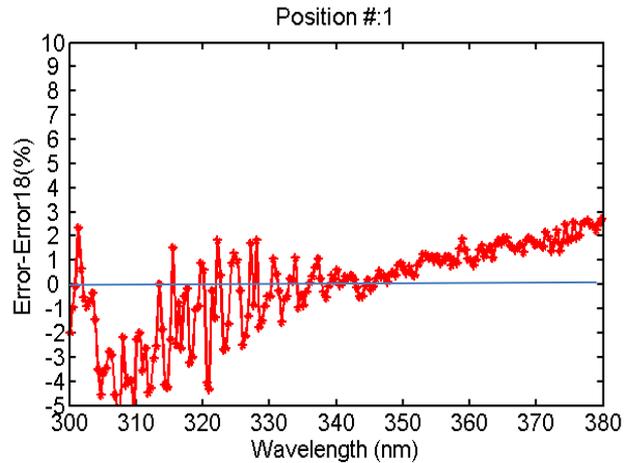


Relative error wrt to Position 18 (nadir)

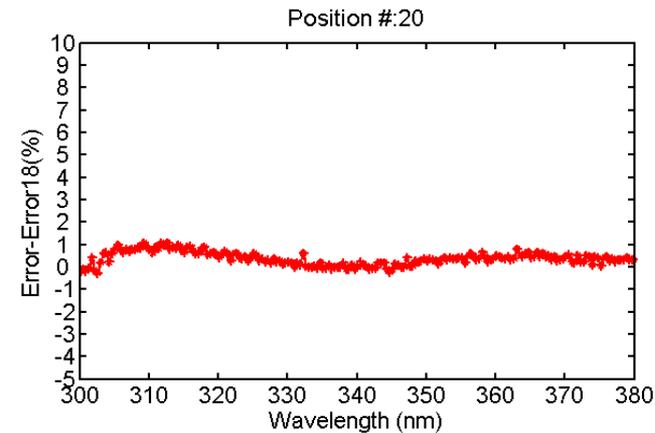
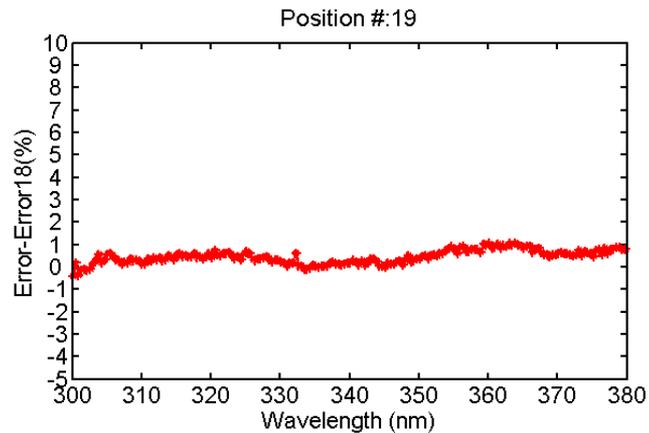
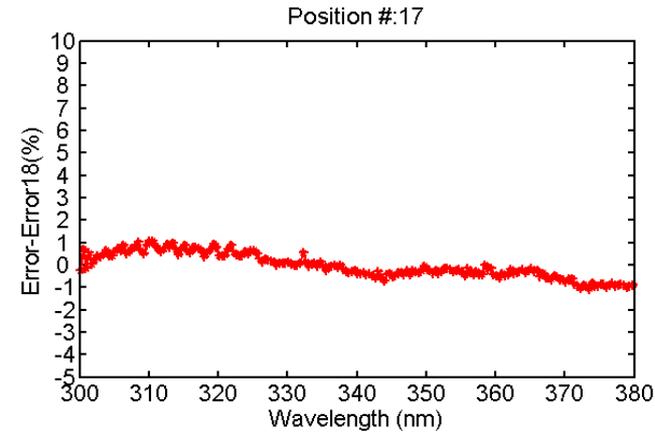
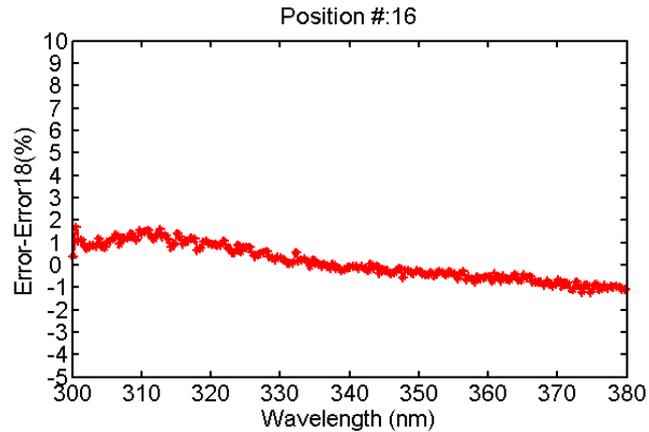


The bias in cross-track direction is generally less than 2% except at shorter wavelengths where simulations may become less accurate due to complex scattering process. The bias is also larger in side pixel locations

Observation minus Simulation at Wing Positions

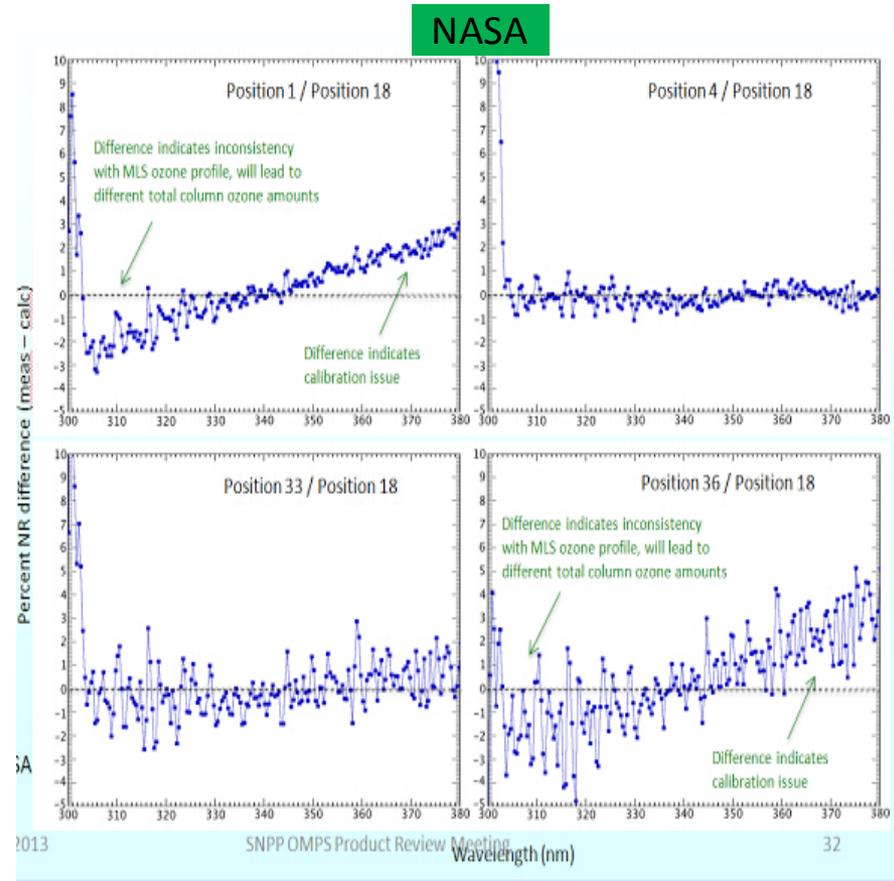
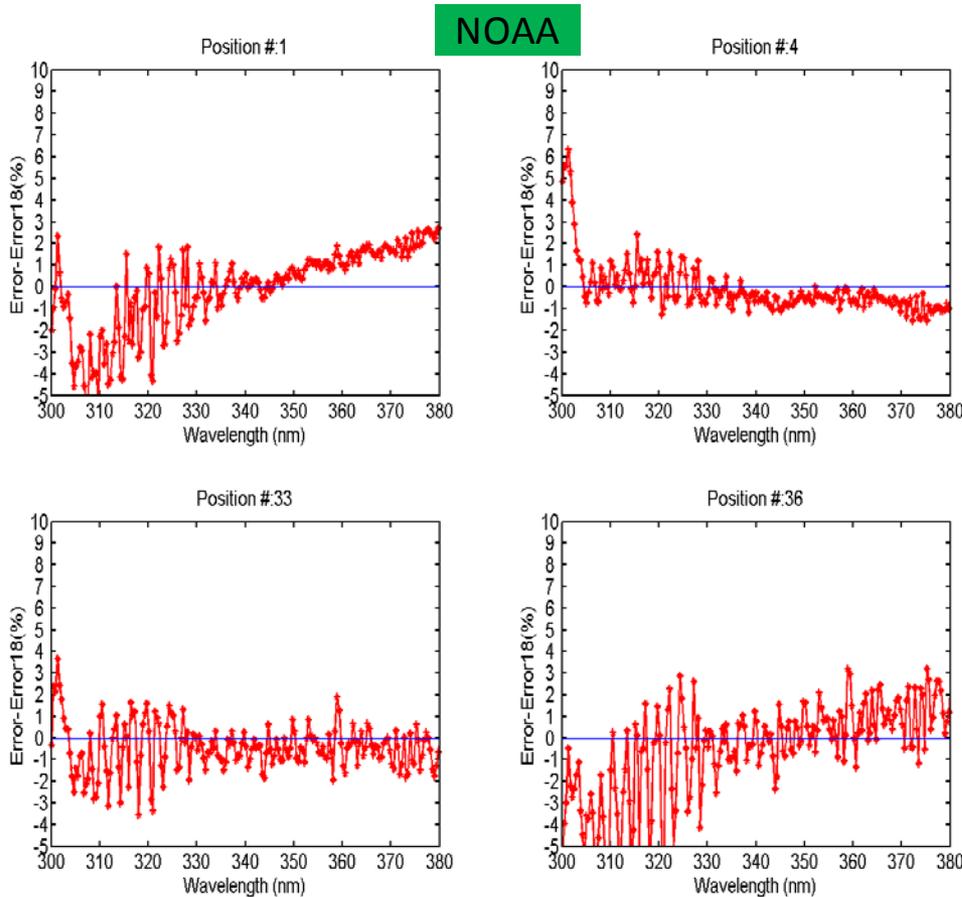


The biases at far wing positions (1-4 and 33-36) are out of specifications at wavelengths less than 320 nm. The causes can be related to complex RT processes, etc.



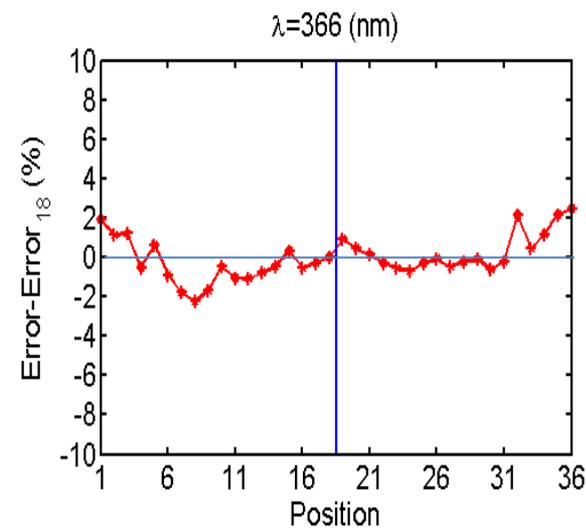
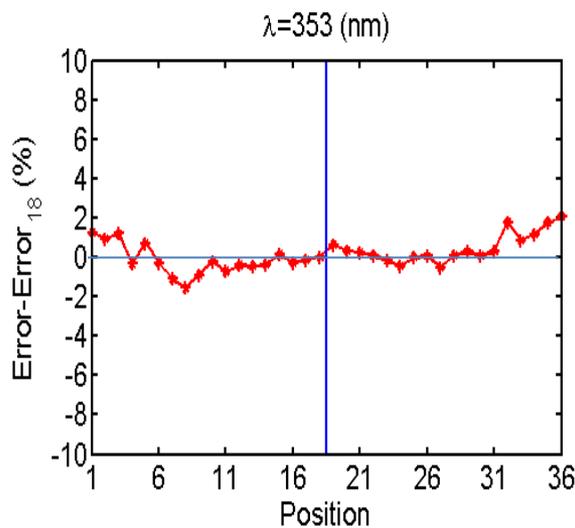
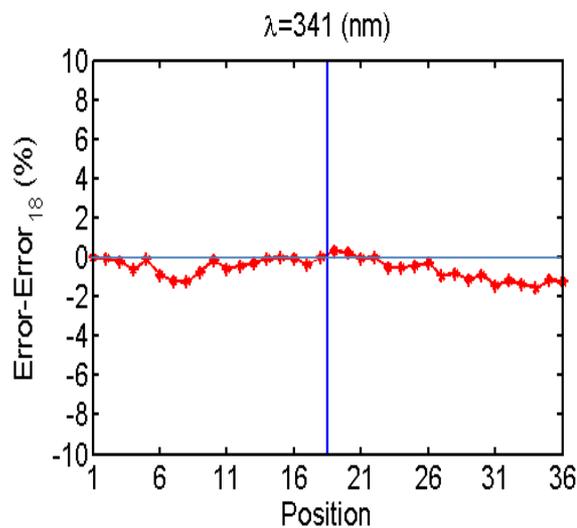
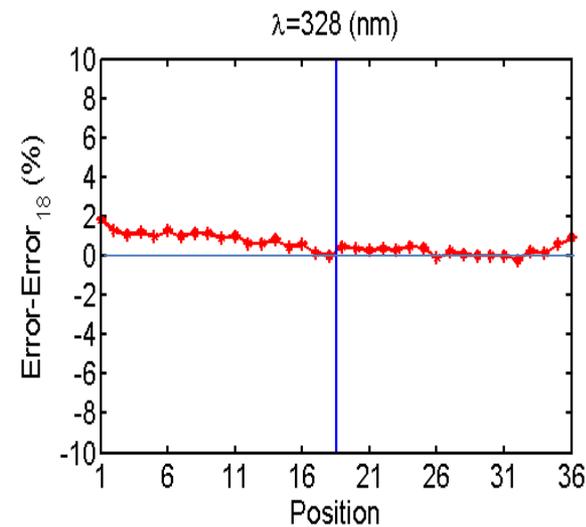
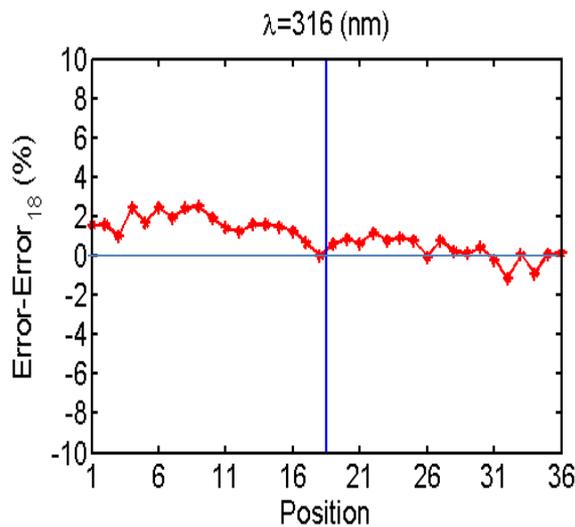
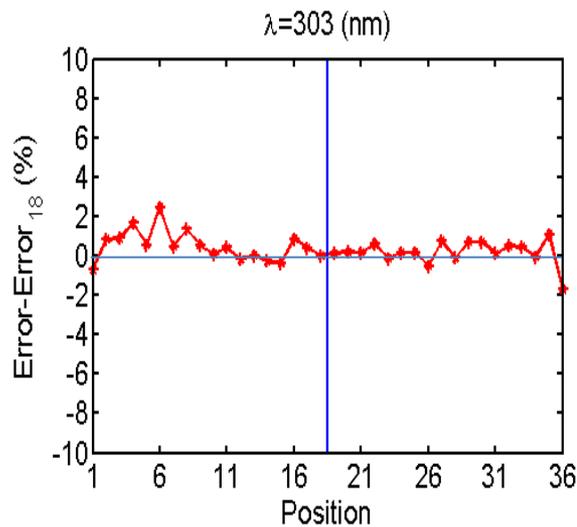
The biases near center all meet specifications at all wavelengths

Observation minus Simulation (NOAA vs. NASA)



The bias characteristics simulated from NOAA (left red curves) and NASA (left blue curves) are consistent in cross-track direction and wavelength domain.

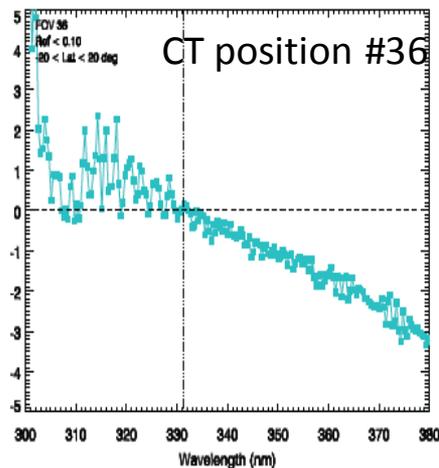
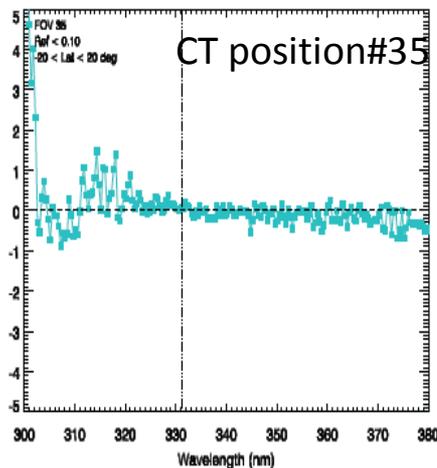
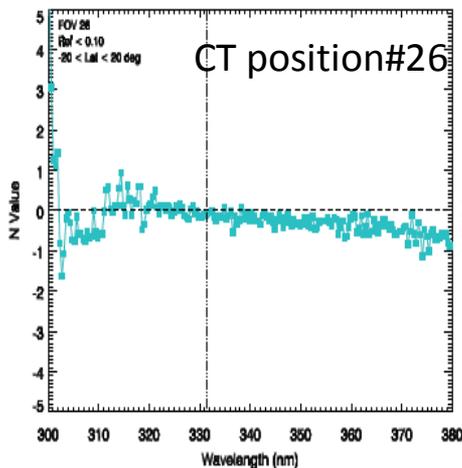
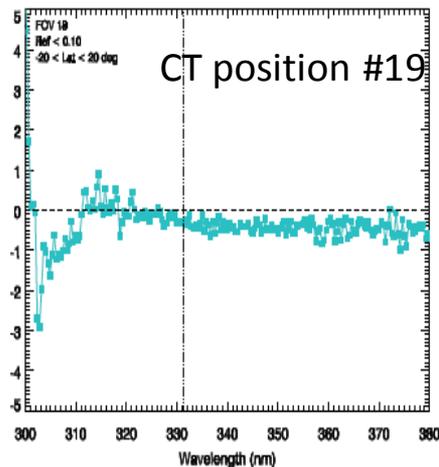
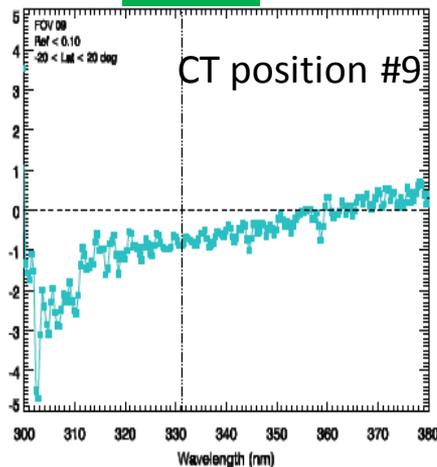
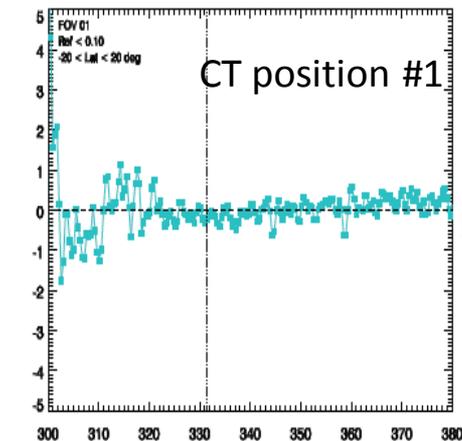
Error vs. Scan Position



Cross-Track Difference for Earth View N-Value or Radiance

Wavelength-dependent Cross-Track Normalized Radiance Error Meets Requirement

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.

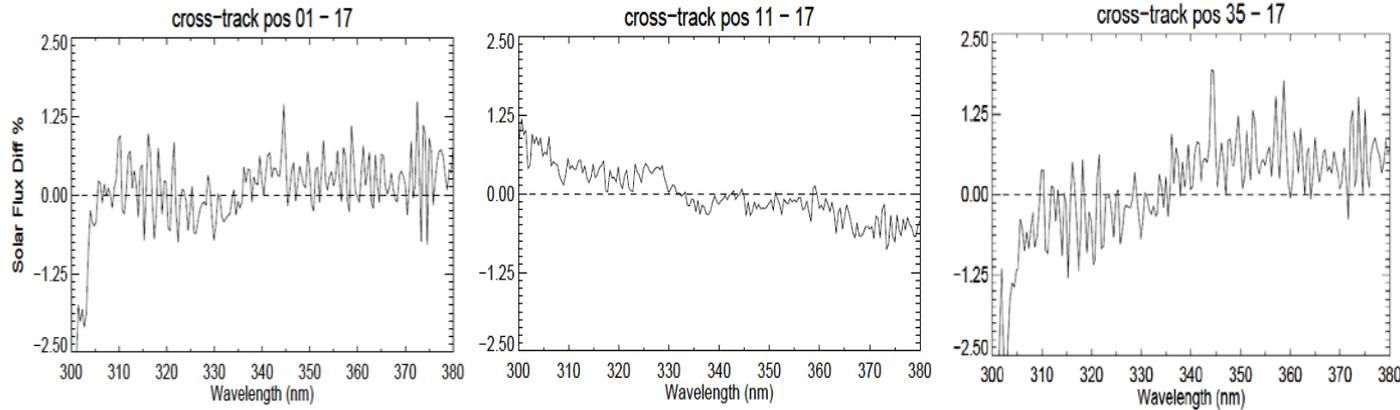
- Exception is CT#36 on wavelength > 360 nm. Soft calibration are being implemented to eliminate this residual error.

Wavelength-dependent normalized radiance errors are within 2% (except for FOV 36) which meets the performance requirement.

Solar Irradiance (Flux) Cross-Track Difference for NM

Wavelength Dependent Cross-Track Solar Irradiance Error Was Eliminated

Previous wavelength LUT cause errors in cross-track position.

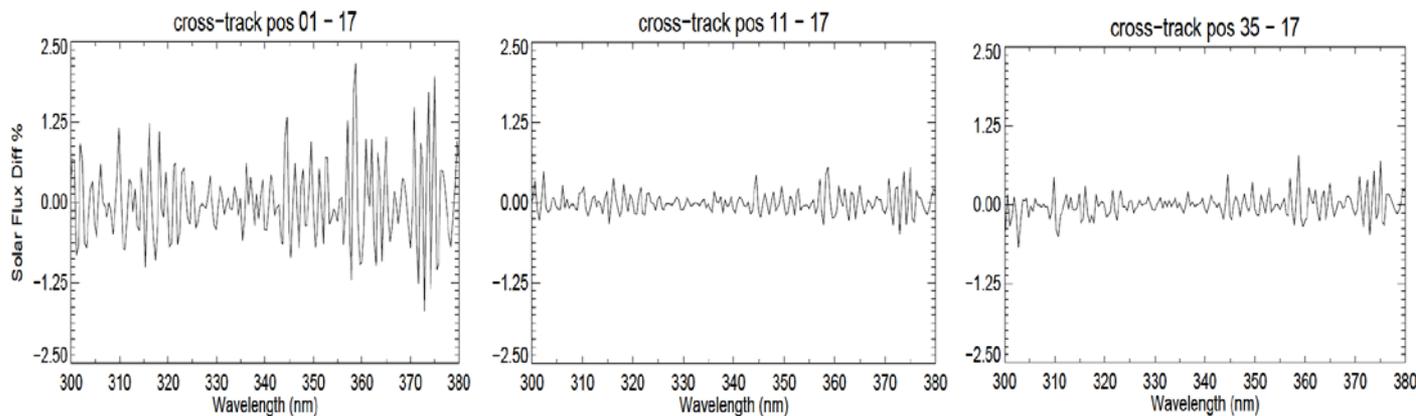


- Irradiance error is percent difference between observed solar flux and modeled solar synthetic flux.

$$Error = \left(1 - \frac{flux_{observed}}{flux_{synthetic}} \right) * 100$$

- Figures show the errors for 6 different cross-track position relative to the nadir position

Updated wavelength LUT eliminates errors in cross-track position.

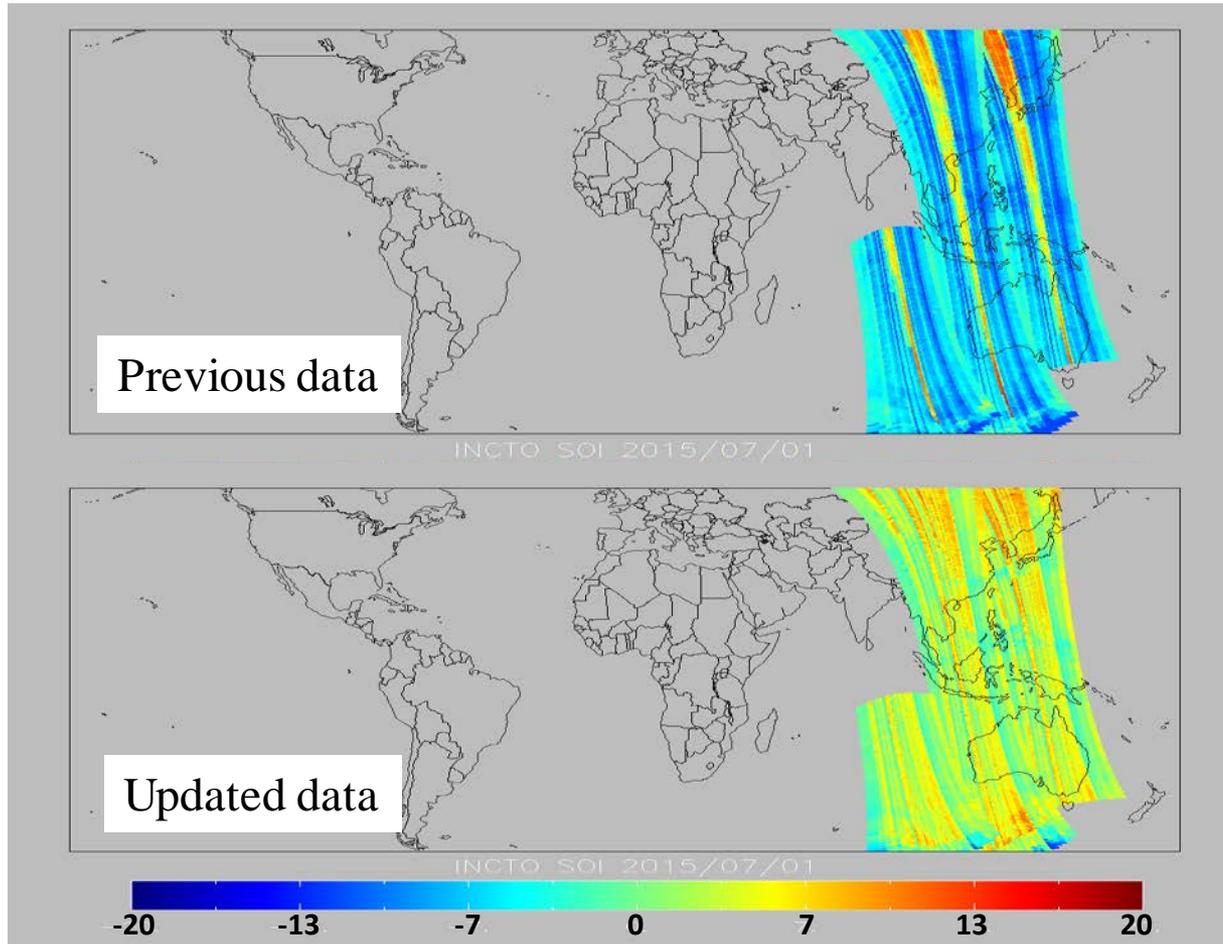


- Updated wavelength and solar flux LUTs have eliminated cross-track irradiance error .

- Up to 2.5 -3.0 % improvement has been achieved

Solar irradiance error in cross-track direction is eliminated.

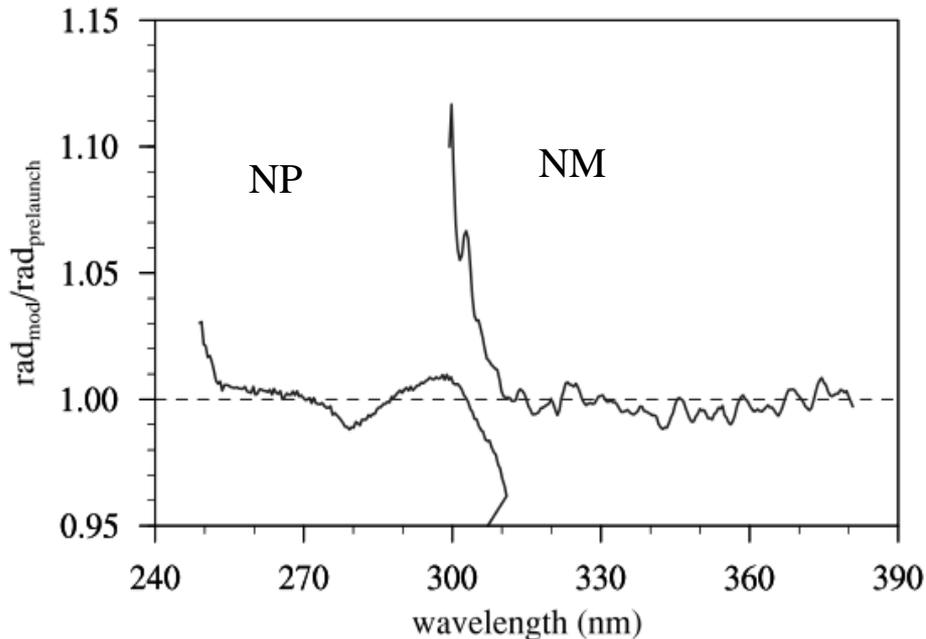
SO₂ Index Comparison before and after Wavelength Update



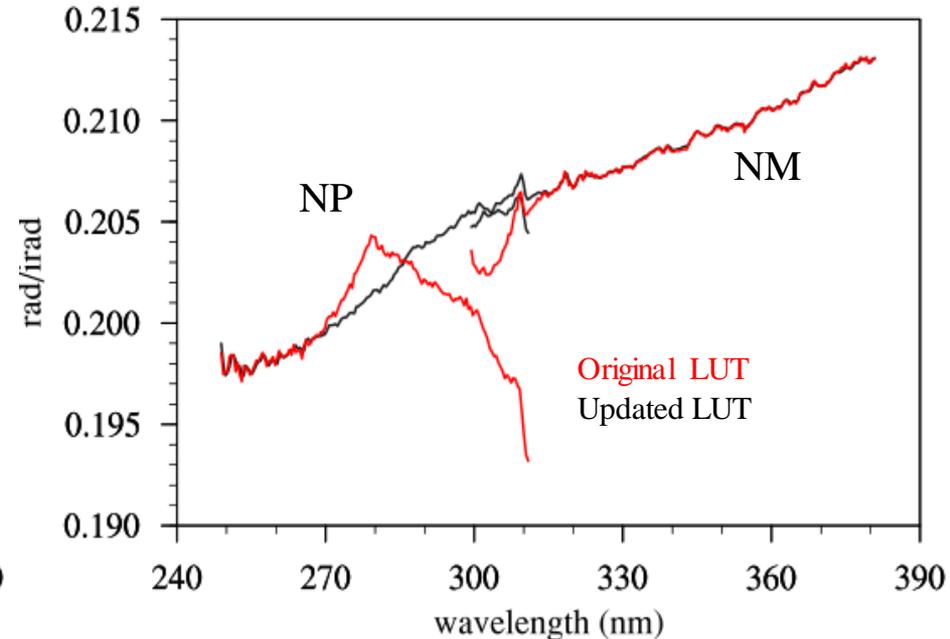
- SO₂ index cross-track variation was minimized from -13 ~ 13 to 6~7/8.
- Residual error are caused by EDR V7 TOZ algorithm, that inappropriately exaggerates the impact of wavelength variation.
- The residual error can be corrected by EDR V8 algorithm with an appropriate n-value adjustment.
- Data comes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

- Radiance/irradiance coefficients were modified to account for ground to orbit wavelength shifts, as well as normalized radiance consistency between NP and NM
- Updated day-one solar LUT accounts for updated irradiance cal coefficients.

Radiance Ratio before/after Updates

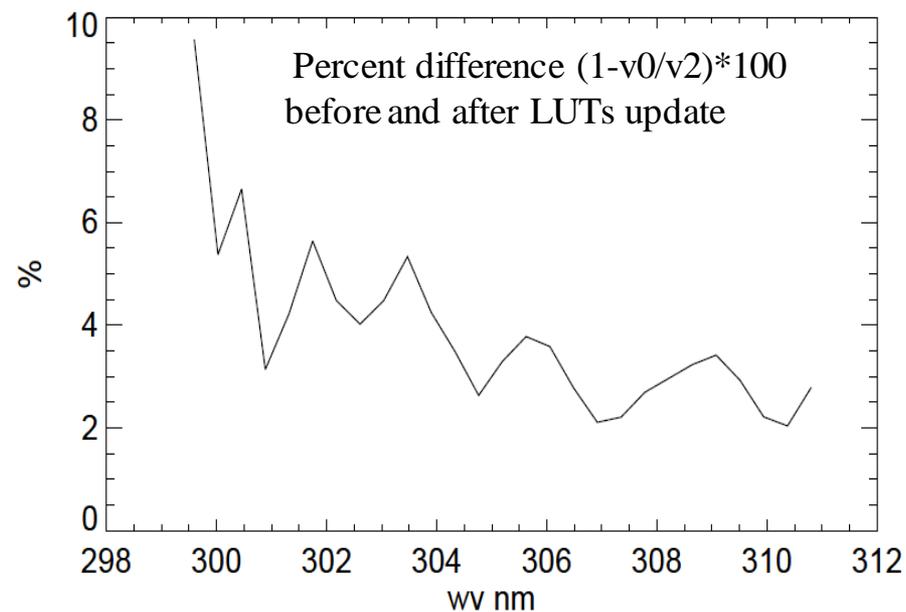
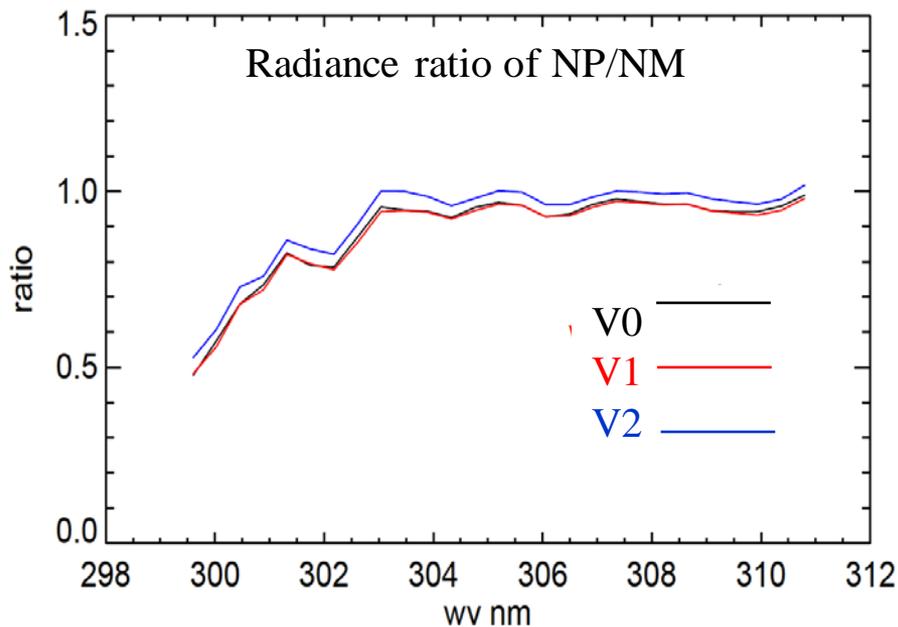


Ratio of Radiance/irradiance coefficients



Updated radiance coefficient LUTs improve normalized radiance consistency up to ~10% between NP and NM in 300-310 nm.

Improvement in the Spectral Range of 300 - 310 nm



- The improvement was validated via SDR products from both NP and NM.
- EV Radiance from NP and NM are collocated spatially and spectrally
- 1174 granules (globe coverage) were used for validation
- Radiance is computed via old LUTs (V0), updated wavelength & day one solar (V1) and updated wavelength, day one solar, radiance/irradiance LUTs (V2)

NM & NP consistency in SDR radiance is improved by ~2-10%.



Summary



- **OMPS EV SDRs meet SDR performance requirement as well as EDR products requirement**
 - ✓ 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
 - ✓ Sensor orbital performance is stable and meet expectation
- **OMPS EV SDRs have following features**
 - ✓ On-orbit sensor performance is characterized
 - ✓ SDR product uncertainties are defined for representative conditions
 - ✓ Calibration parameters are adjusted according to EDR requirement
 - ✓ High quality documentation is completed
 - ✓ SDR data is ready for applications and scientific publication
- ***Both OMPS NM and NP EV SDRs are declared as validated-maturity products***