Delta Review for SNPP OMPS SDR Earth View Products

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OMPS SDR Team

NOAA/NESDIS/STAR

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Outlines

- OMPS SDR Team Members
- Products and Users
- Past Reviews of OMPS EV SDR and Issues
- Declaring OMPS EV Validated Maturity
- Requirements and Performance
- Milestones since Provisional Maturity
- Other Accomplishments
- Path Forward for SNPP
- Supporting Materials

OMPS SDR Team

PI Name	Organization	Primary Roles
Fuzhong Weng	NOAA/STAR	Budget and coordination; instrument and product performance monitoring; TOMRAD/VLIDORT modeling
Chunhui Pan	NOAA/STAR	NOAA Technical Lead; OMPS SDR cal/val science, code development, TVAC data analysis; SDR algorithm.
Glen Jaross	NASA	Instrument scientist; TVAC data acquisition and analysis; SDR algorithm.
Maria Caponi	Aerospace	Algorithm changes coordination; DR and issues tracking
Sarah Lipscy	BATC	Instrument sciences; prelaunch test; Sensor Characterization Data Bases (SCDB)
Wael Ibrahim	Raytheon	IDPS operations

Products and Users

- Products
  - OMPS nadir mapper (NM) and nadir profiler (NP) earth view (EV) and calibration (CAL) SDR in both nominal and diagnostic mode.

- Users
  - OMPS EDR Team (NCEP assimilates OMPS EDR)
  - Broader and future users via CLASS

OMPS EV SDR Maturity Review and Issues

- Beta maturity since March 2012
- Provisional maturity since 1 March 2013
  - Resolved all three issues recommended before EV SDR became provisional – weekly update darks, resolved negative smear and applied stray light correction for NM
- Validated maturity review December, 2013 and Delta review June 2014.
  - Recommend to resolve two issues before EV SDR becomes validated:
    - *Improve cross-track effects in NM (aka scan direction dependent error).*
    - *Improve stray-light correction in NP*

Milestones since Provisional Maturity

- Improved cross-track effects in NM. The current NM normalized EV radiance meet the SDR product requirement (bias < 2.0%).
  - Updated wavelength LUT and solar flux LUT
  - Validated wavelength dependent cross-track irradiance error from solar observation data
  - Validated wavelength dependent cross-track normalized radiance error from SDR EV data via. TOMRAD
  - Validated cross-track SO2 index variation from NM EDR data
- Re-evaluated NP straylight correction. SDR and EDR teams concurs that current stray light LUT provides adequate calibration for NP.
  - The NP stray light calibration LUT was in operation in March 2014.

Other Accomplishments

- Instrument and SDR performance monitoring, characterization, and improvement.
- Improvement of EV normalized radiance consistency between NP and NM by 2-10% in 300-310 nm.
- Instrument cal/val support (e.g., orbit adjustment, anomaly resolution)
- Complete documentation (Users' Guide)
- Weekly dark LUTs update and delivery
- CCR 2546, 7825 and 7826 modified CDFCB and xml files
- CCR 2548 NP radiometric LUTs updated and delivered
- SDR software improved: stray light correction

Declaring OMPS EV SDR Validated Maturity

- **OMPS EV SDRs meet SDR performance requirement as well as EDR products requirement**
  - ✓ The cross-track direction 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 SDR should be declared as validated-maturity products, effective August 20th 2015 !***

NM Requirements and Performance

Budget Term	Requirement/Allocation	On-Orbit Performance
Non-linearity	< 2% full well	< 0.40%
Non-linearity Accuracy	< 0.2%	< 0.2%
On-orbit Wavelength Calibration	< 0.01 nm	<0.01 nm
Stray Light NM Out-of-Band + Out-of-Field Response	≤ 2	≤ 2%
Intra-Orbit Wavelength Stability	Allocation (flow down from EDR error budget) = 0.02 nm	~ 0.006 nm
SNR	1000	> 1000
Inter-Orbital Thermal Wavelength Shift	Allocation (flow down from EDR error budget) = 0.02 nm	~0.006 nm
CCD Read Noise	60 –e RMS	< 25 –e RMS
Detector Gain	46	51
Absolute Irradiance Calibration Accuracy	< 7%	< 7% for most of the channels
Absolute Radiance Calibration Accuracy	< 8%	< 8%
Normalized radiance Calibration Accuracy	< 2%	< 2%

NP Requirements and Performance

Budget Term	Requirement/Allocation	On-Orbit Performance
Non-linearity	< 2% full well	< 0.3%
Non-linearity Accuracy	< 0.2%	< 0.2%
On-orbit Wavelength Calibration	< 0.01 nm	~0.02 nm
Stray Light NP Out-of-Band + Out-of-Field Response	≤ 2	≤ 2% for most of the channels
Intra-Orbit Wavelength Stability	Allocation (flow down from EDR error budget) = 0.02 nm	~ 0.02 nm
SNR	45-400 channel dependent	meet requirement
Inter-Orbital Thermal Wavelength Shift	Allocation (flow down from EDR error budget) = 0.02 nm	~0.02 nm
CCD Read Noise	60 –e RMS	< 25 –e RMS
Detector Gain	43	47
Absolute Irradiance Calibration Accuracy	< 7%	< 7% for most of the channels
Absolute Radiance Calibration Accuracy	< 8%	< 8%
Normalized radiance Calibration Accuracy	< 2%	< 2%

Path Forward for SNPP Further Improvement

- Continue instrument and SDR performance monitoring, characterization, and improvement.
- Support instrument cal/val (e.g., orbit adjustment, anomaly resolution)
- Carry out intra-orbital wavelength correction
- Transition from CAL SDR operation to GRAVITE.
- More comprehensive radiative transfer simulations at shorter wavelengths

Supporting Materials for Declaring OMPS EV SDR Validated Maturity Products

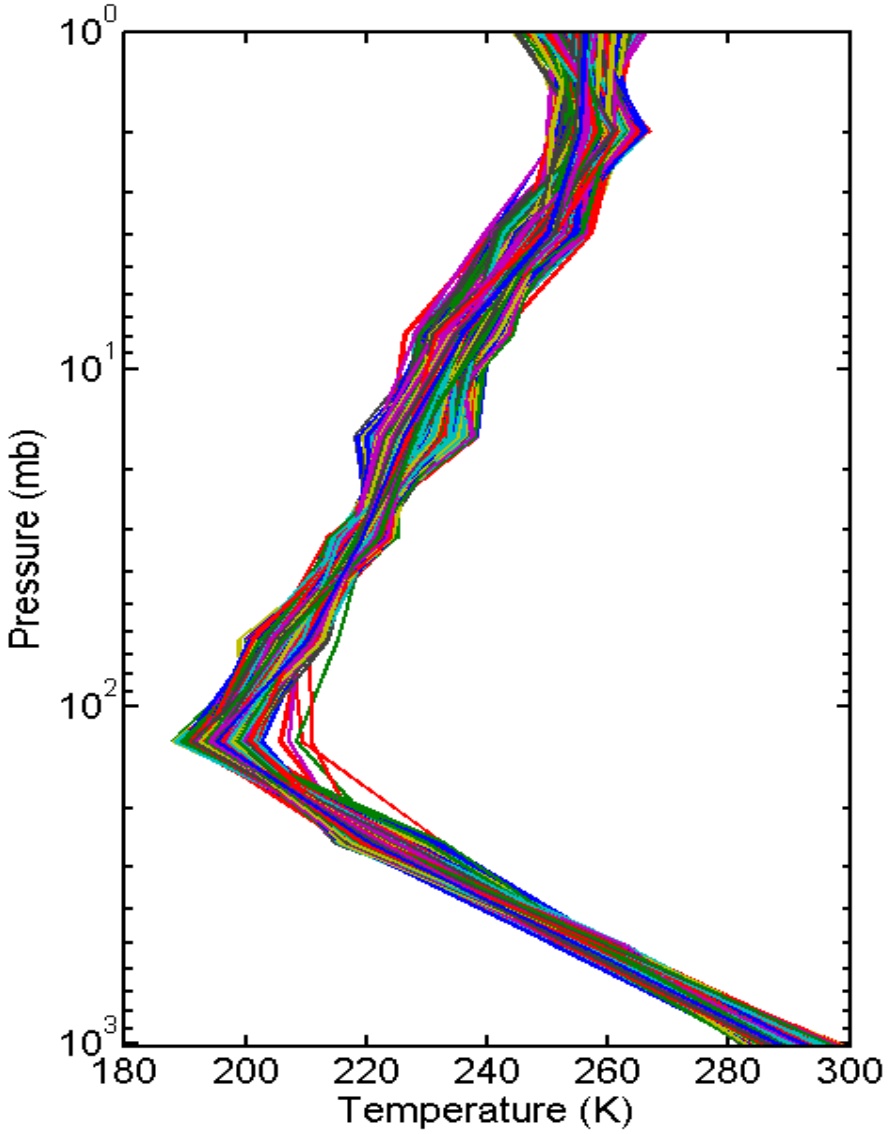
Building on-Orbit Truth for Estimating OMPS Earth View SDR Accuracy

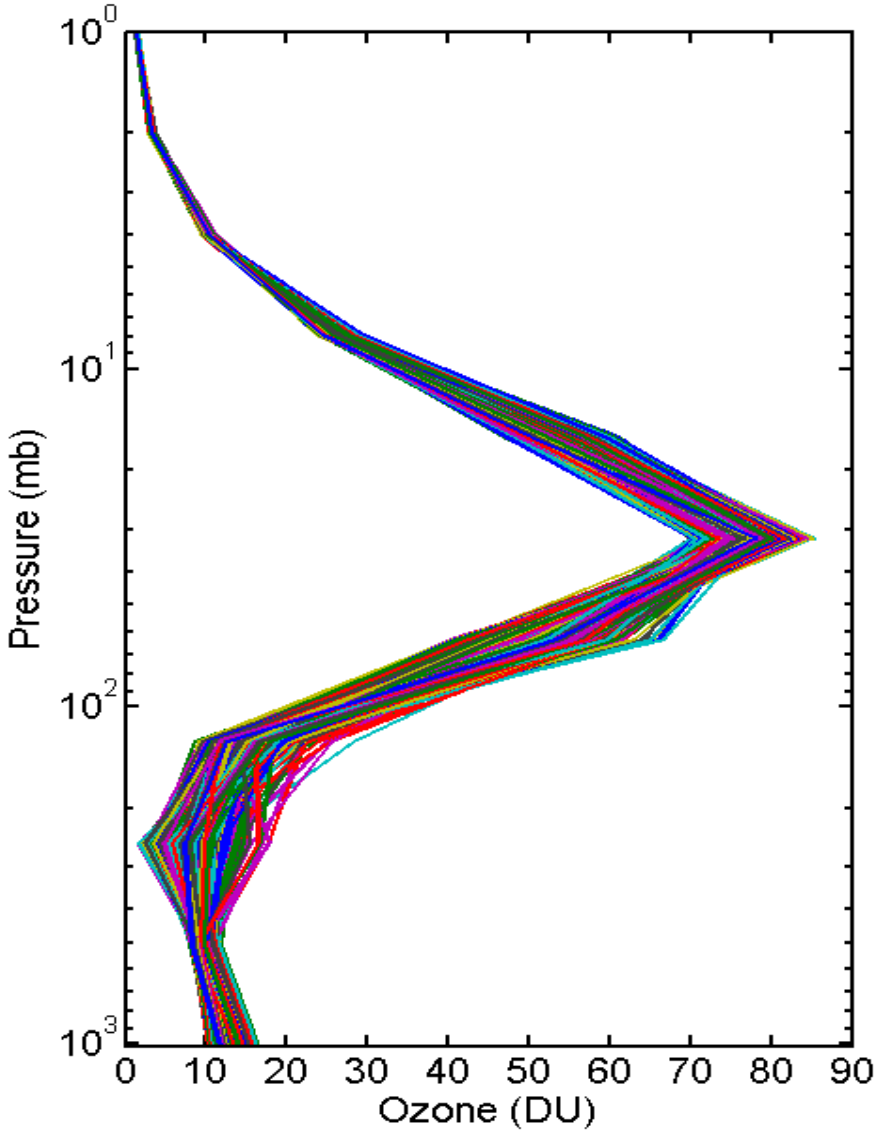
- Develop the “truth” simulated from the forward radiative transfer model at OMPS EV location (Macropixel)
- Radiative transfer model must include comprehensive scattering and absorption processes at UV regions
- Accurate understanding of atmospheric and surface status at OMPS EV location.
- The difference between observations and simulations is used as an estimate of on-board calibration accuracy

OMPS EV Radiative Transfer Simulations

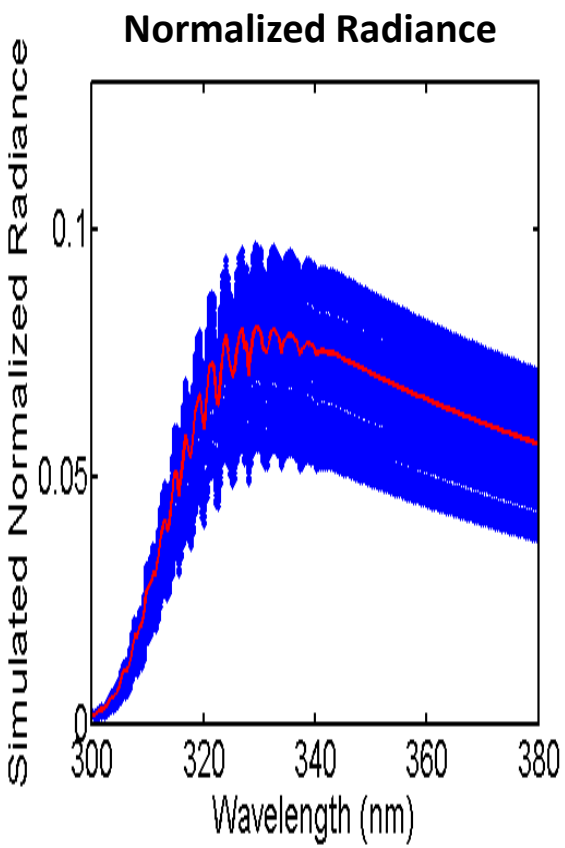
- TOMRAD-2.24: TOMS (Total Ozone Mapping Spectrometer) Radiative Transfer Model
  - Rayleigh scattering atmosphere with ozone and other gaseous absorption
  - Spherical correction for the incident team
  - Molecular anisotropy and Raman scattering
- Inputs to TOMRAD
  - Wavelength, solar and satellite 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 NASA
- Outputs from TOMRAD
  - Normalized radiance (NR=reflected radiance/solar flux) or N-Value ($N=-100*\log_{10}NR$)

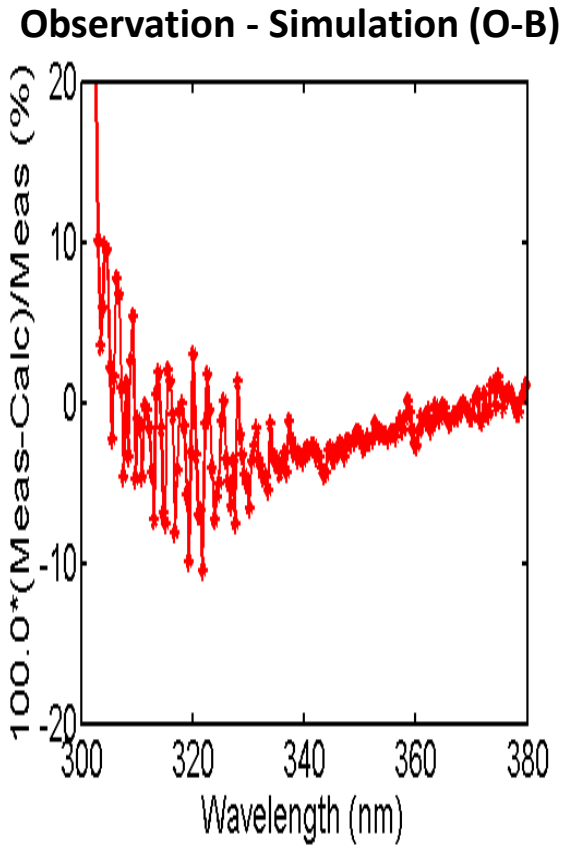
Co-located OMPS/MLS Temperature and Ozone Profiles

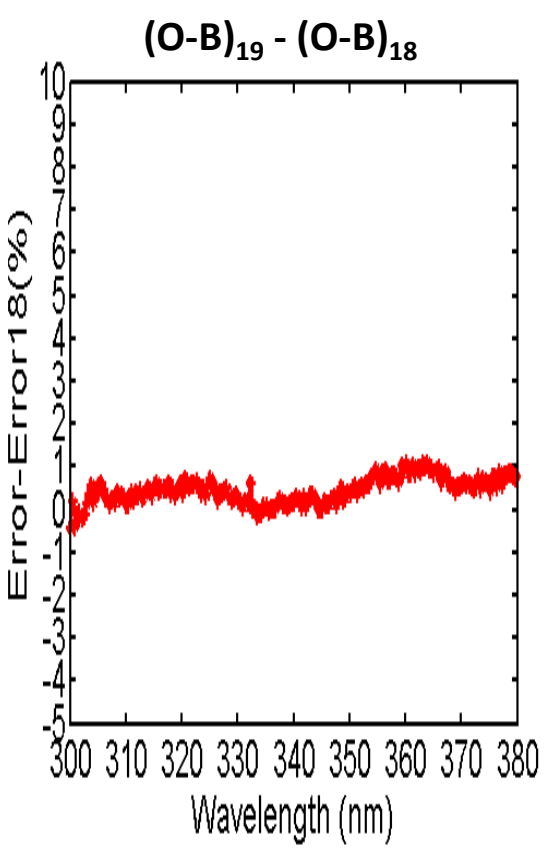




Simulated Normalized Radiance at OMPS Macropixel Position 19

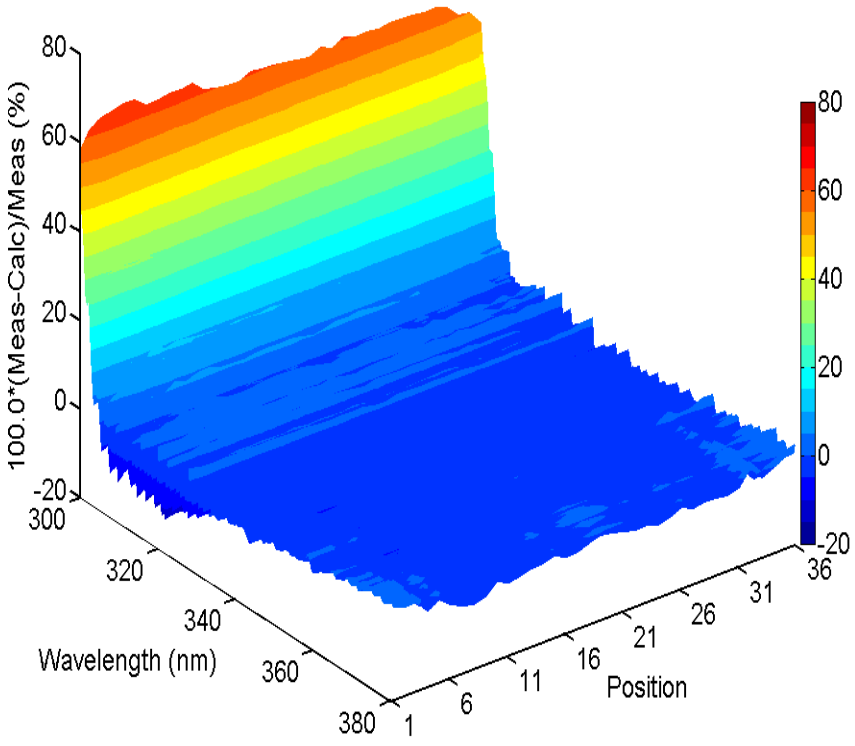




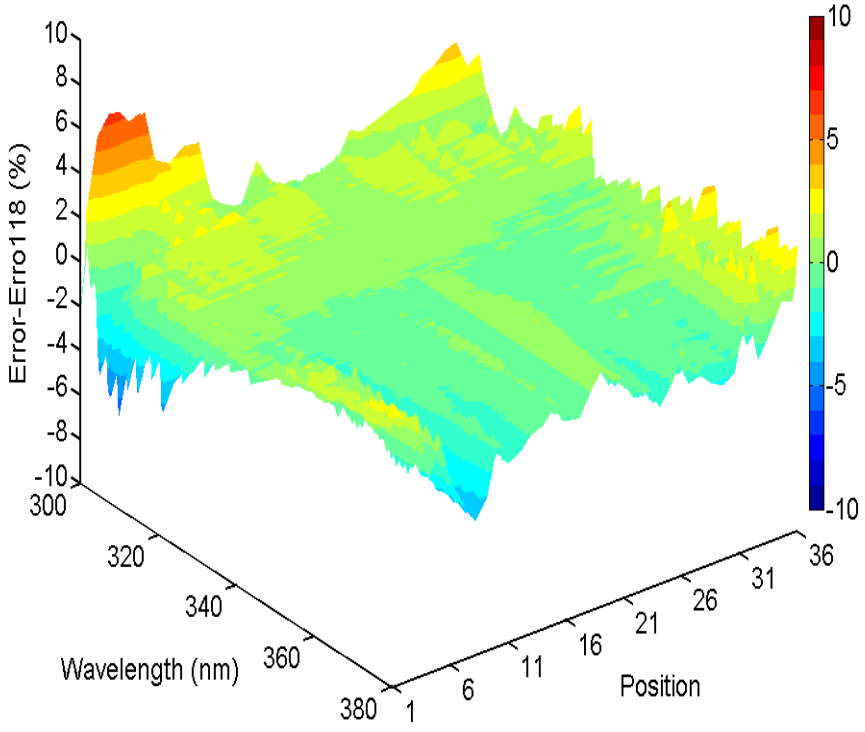


Observation minus Simulation (O-B)

Relative Error

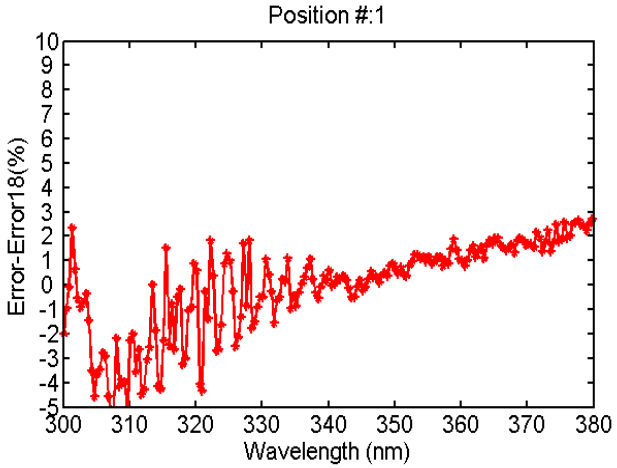


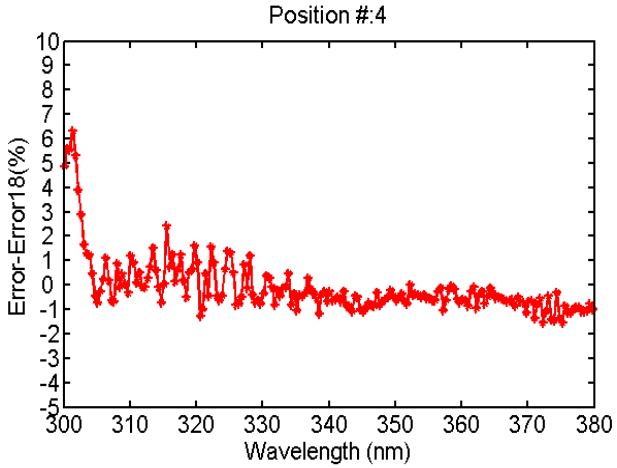
Relative error wrt to Position 18 (nadir)

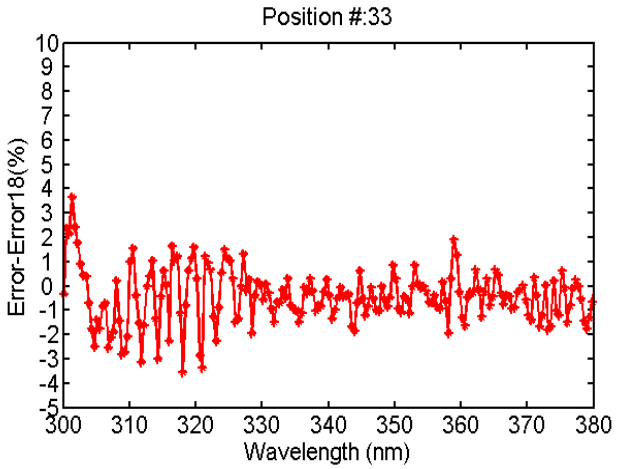


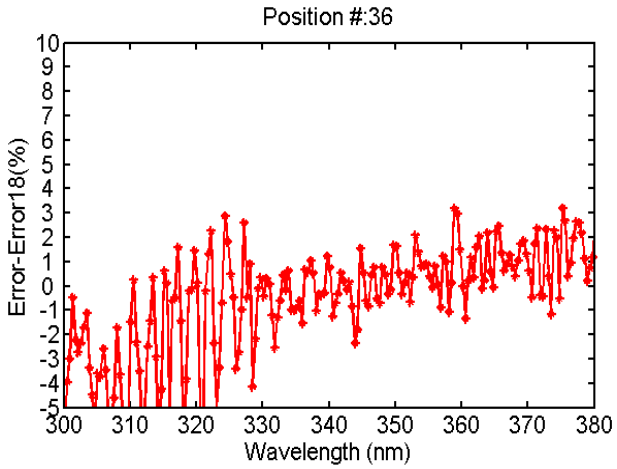
The bias in cross-track direction is generally less than 2% except at shorter wavelengths where simulations may become less accurate due to complex scattering process. The bias is also larger in side pixel locations

Observation minus Simulation at Wing Positions



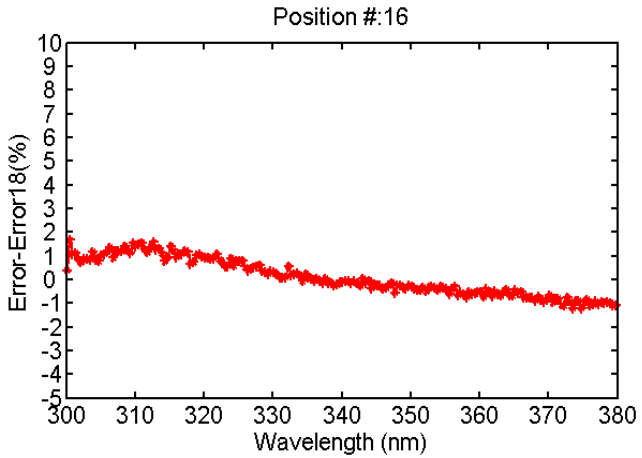


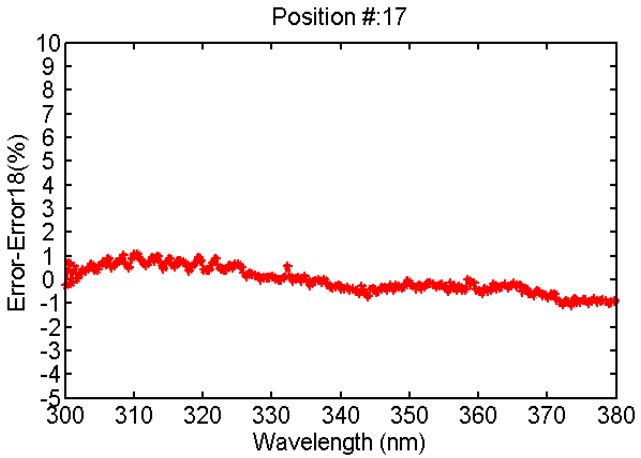


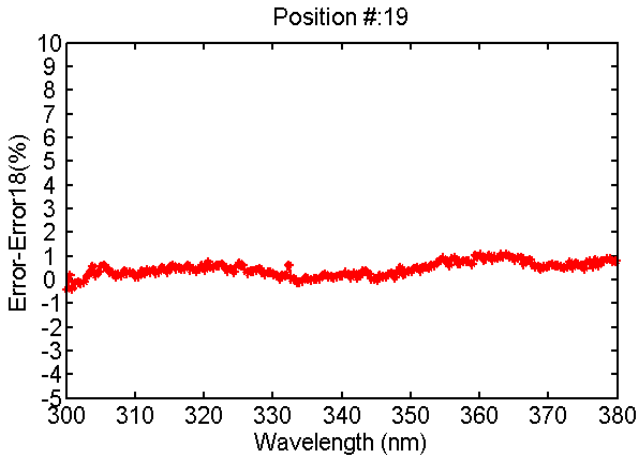


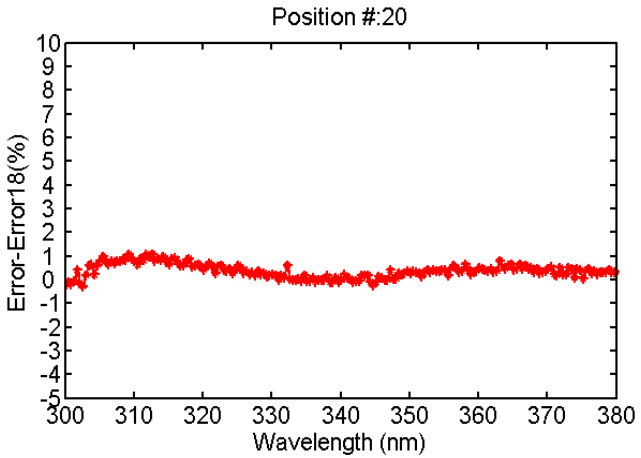
The biases at far wing positions (1-4 and 33-36) are out of specifications at wavelengths less than 320 nm. The causes can be related to complex RT processes, etc.

Observation minus Simulation near Center



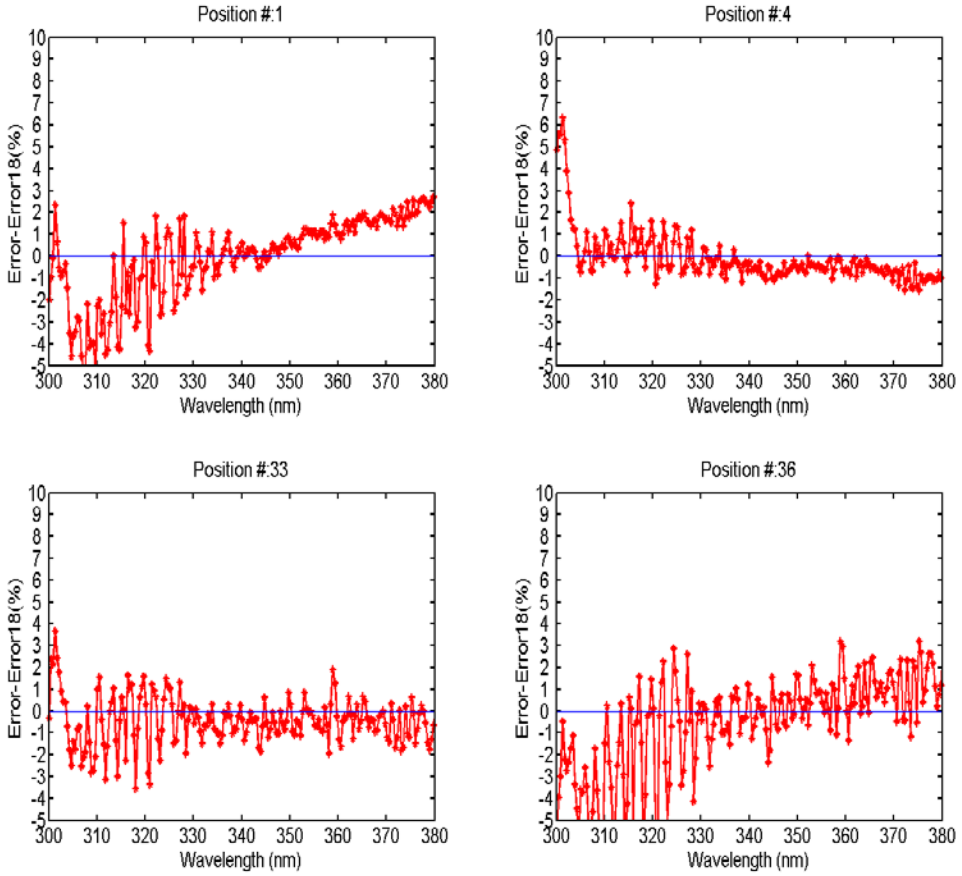


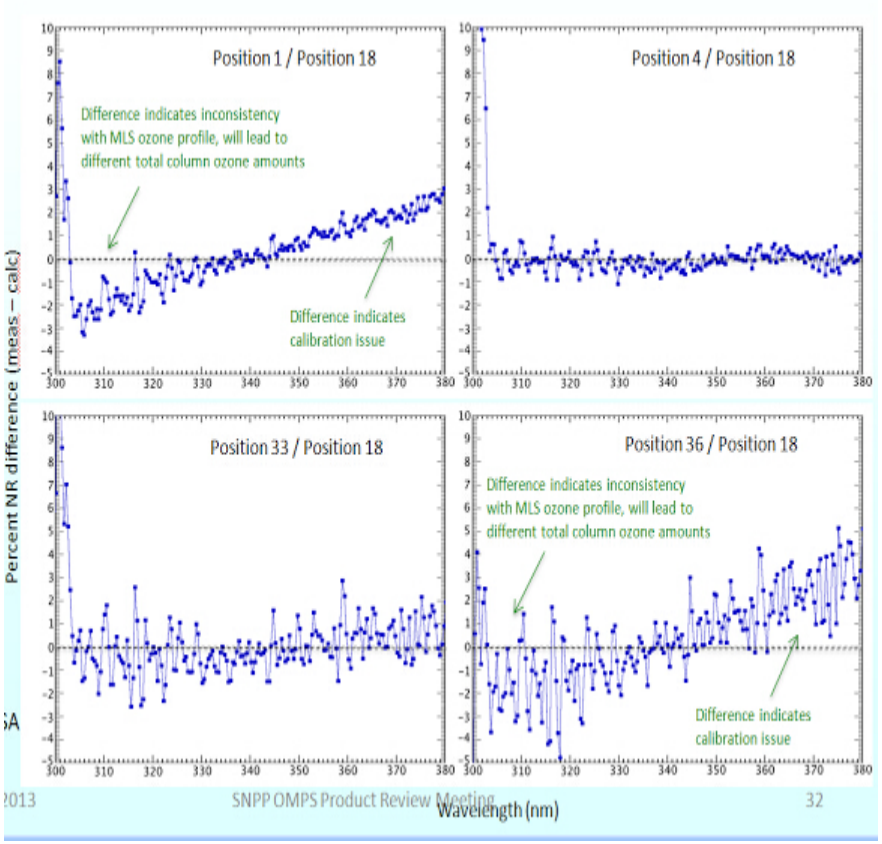




The biases near center all meet specifications at all wavelengths

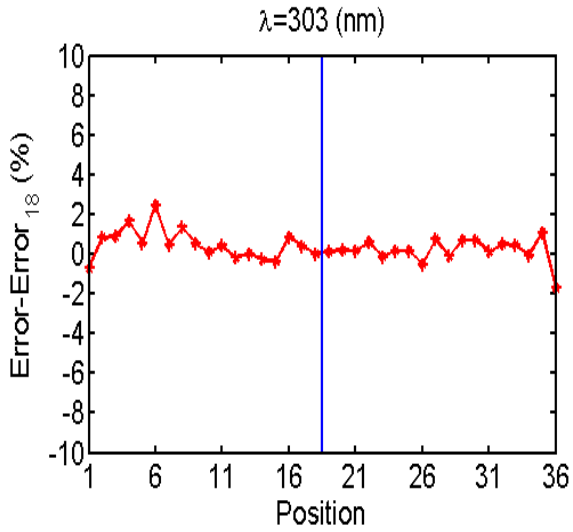
Observation minus Simulation (NOAA vs. NASA)

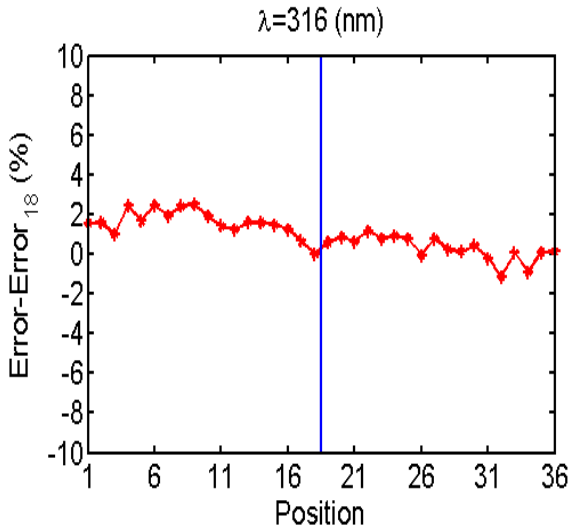


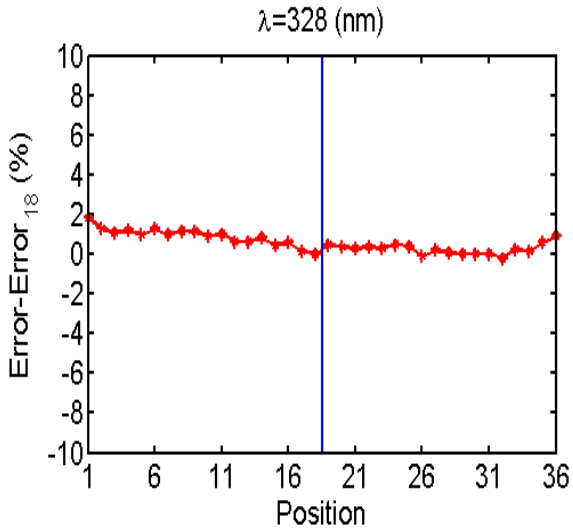


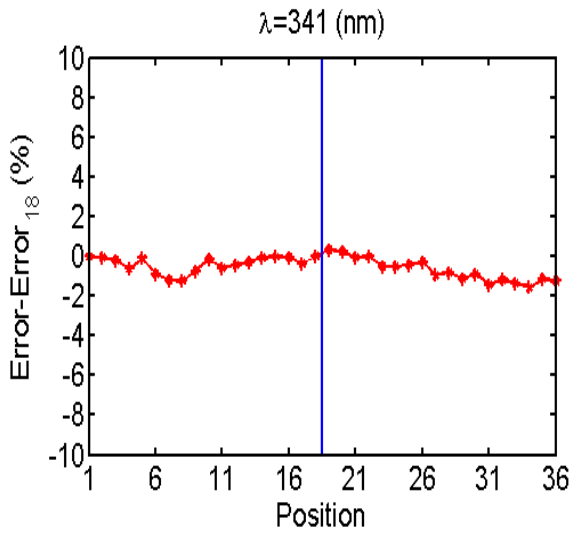
The bias characteristics simulated from NOAA (left red curves) and NASA (left blue curves) are consistent in cross-track direction and wavelength domain.

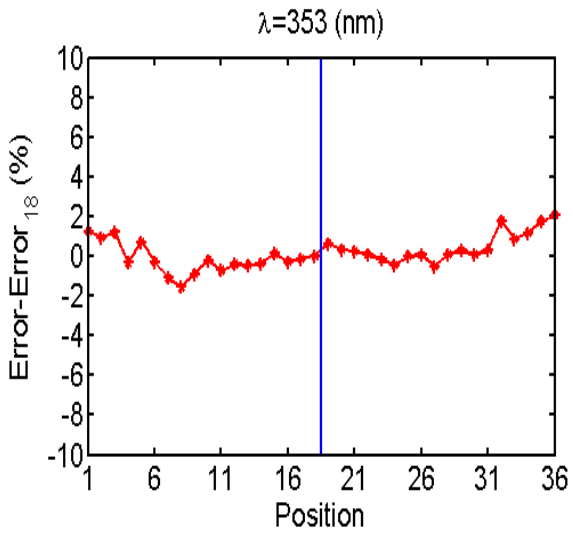
Error vs. Scan Position

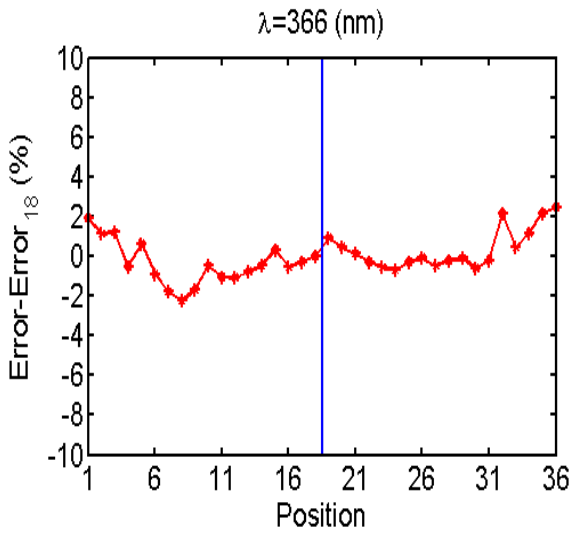






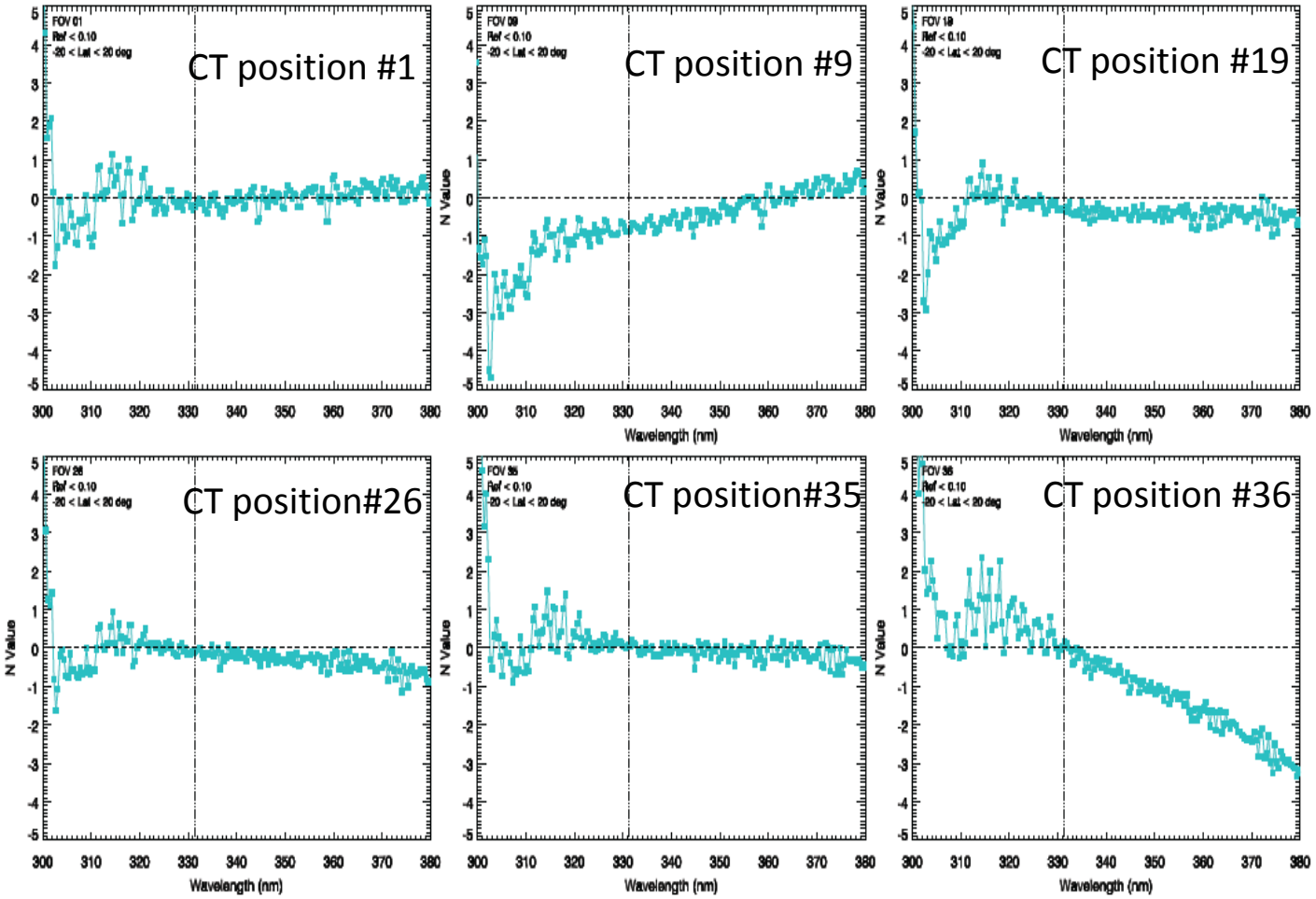






Cross-Track Difference for Earth View N-Value or Radiance

Wavelength-dependent Cross-Track Normalized Radiance Error Meets Requirement



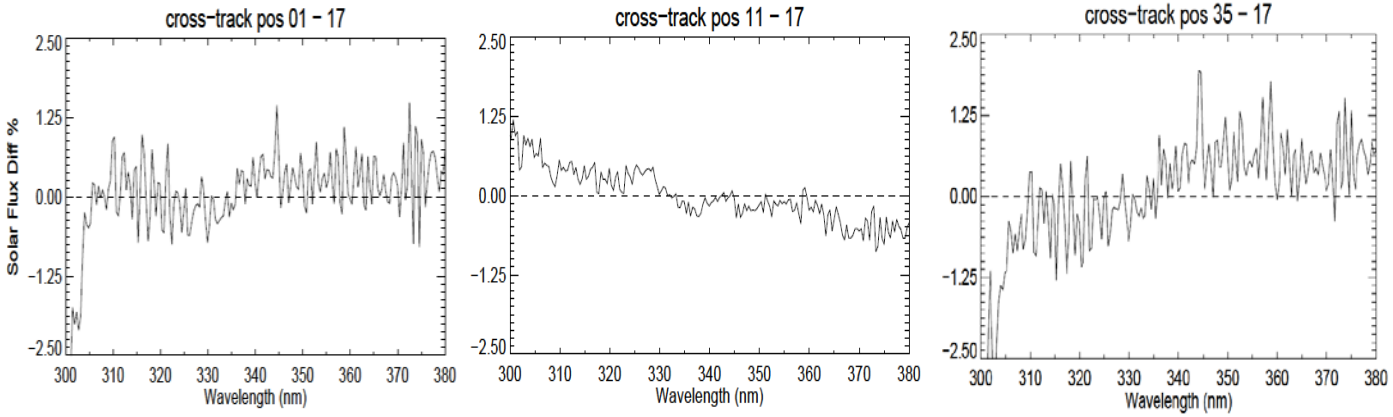
- Normalized radiance error is percent difference between OMPS and MLS via. TOMRAD
- Figures shows the errors for 6 different cross-track (CT) positions
- Errors were minimized < 2% for most of the channels.
- Except ion is CT#36 on wavelength > 360 nm. Soft calibration are being implemented to eliminate this residual error.

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

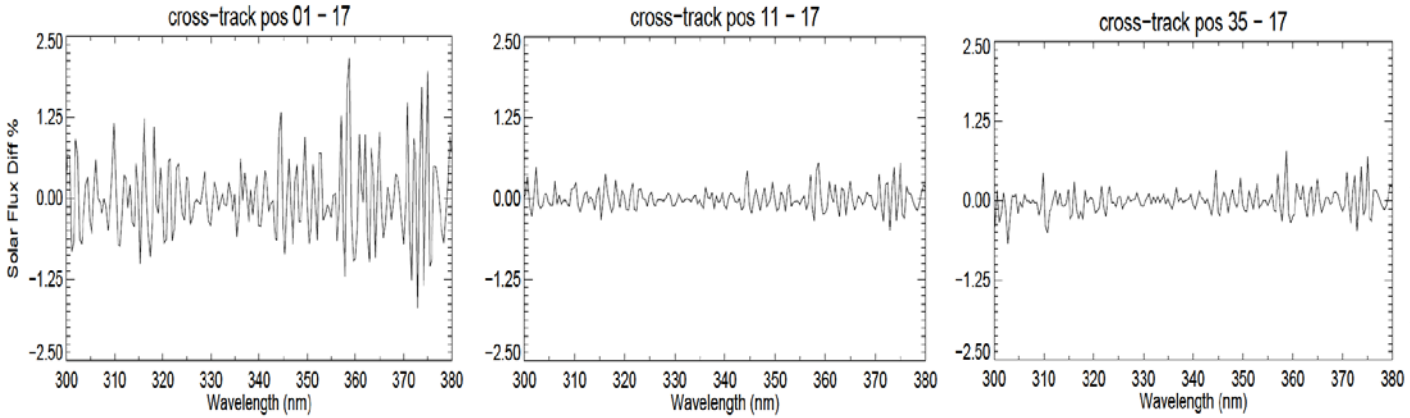
Solar Irradiance (Flux) Cross-Track Difference for NM

Wavelength Dependent Cross-Track Solar Irradiance Error Was Eliminated

Previous wavelength LUT cause errors in cross-track position.



Updated wavelength LUT eliminates 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

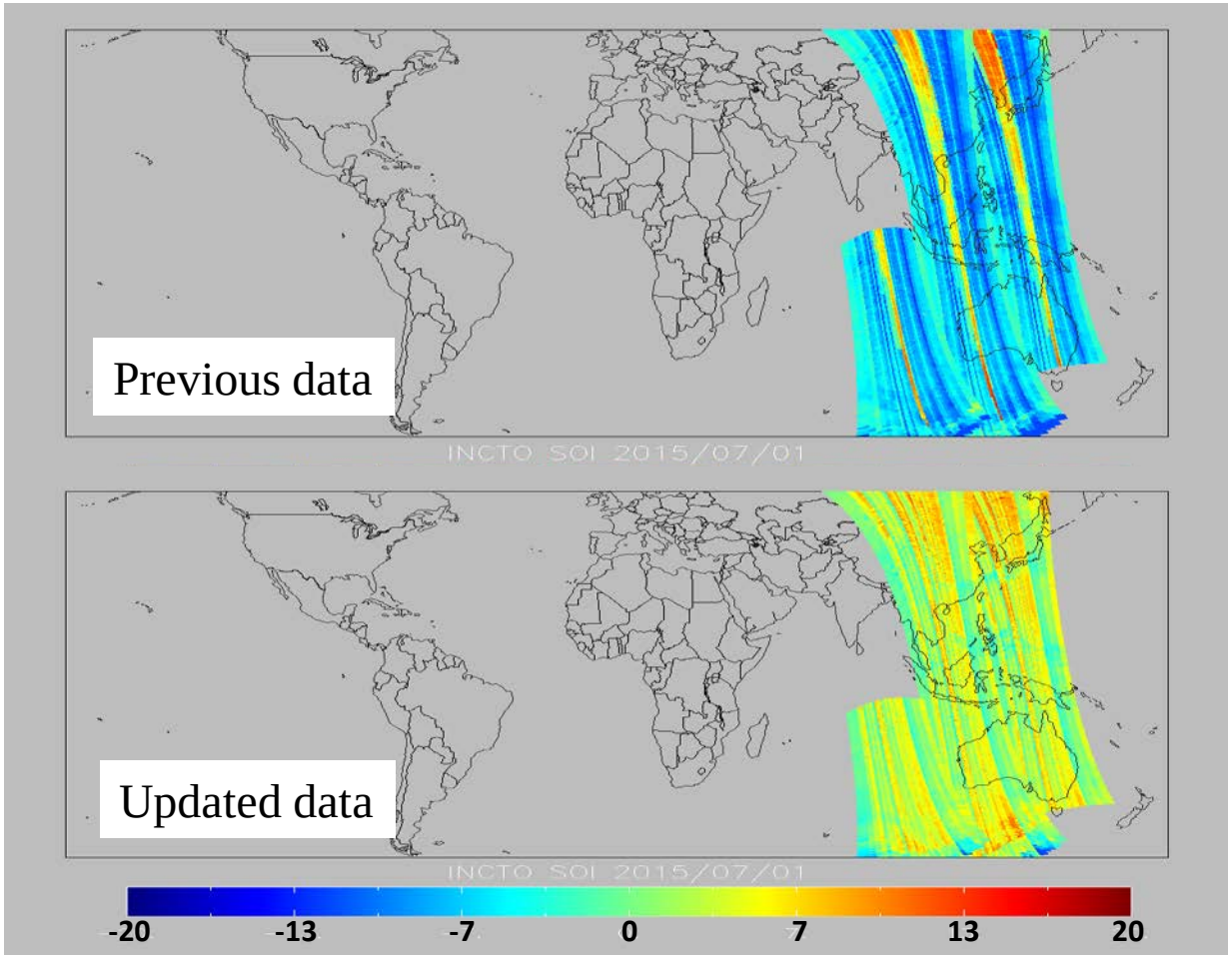
- Updated wavelength and solar flux LUTs have eliminated cross-track irradiance error .

- Up to 2.5 -3.0 % improvement has been achieved

Solar irradiance error in cross-track direction is eliminated.

Reduced Cross-Track Dependence in OMPS NM Derived EDR (SO2)

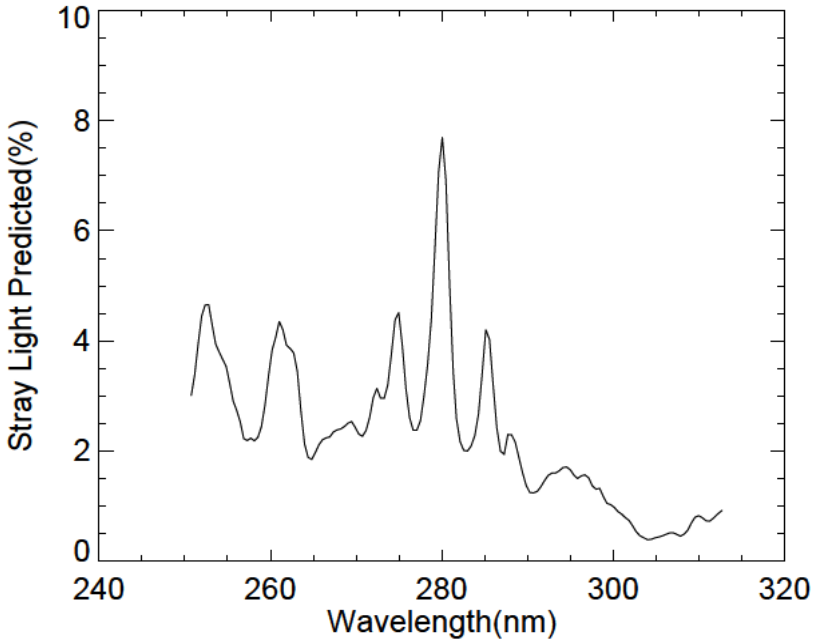
SO2 Index Comparison before and after Wavelength Update



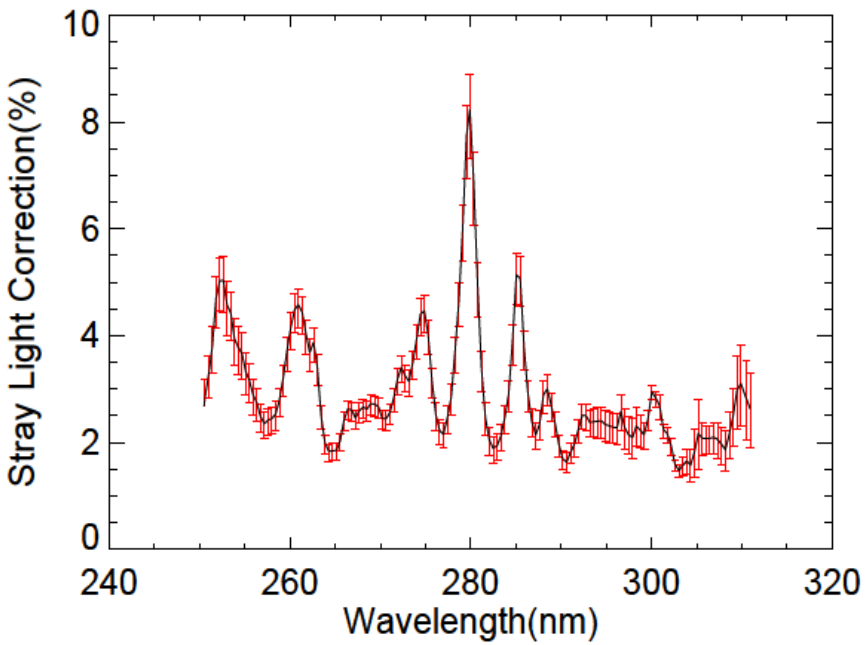
- SO2 index cross-track variation was minimized from -15 ~ 13 to 6~7.
- Residual error are caused by EDR V7 TOZ algorithm, that inappropriately exaggerates the impact of wavelength variation.
- The residual error can be corrected by EDR V8 algorithm with an appropriate n-value adjustment.
- Data comes from OMPS NM EDR products INCTO SO2 2015/07/01

Improved OMPS NP Stray-Light Correction (1/2)

Prelaunch predicted SL contamination



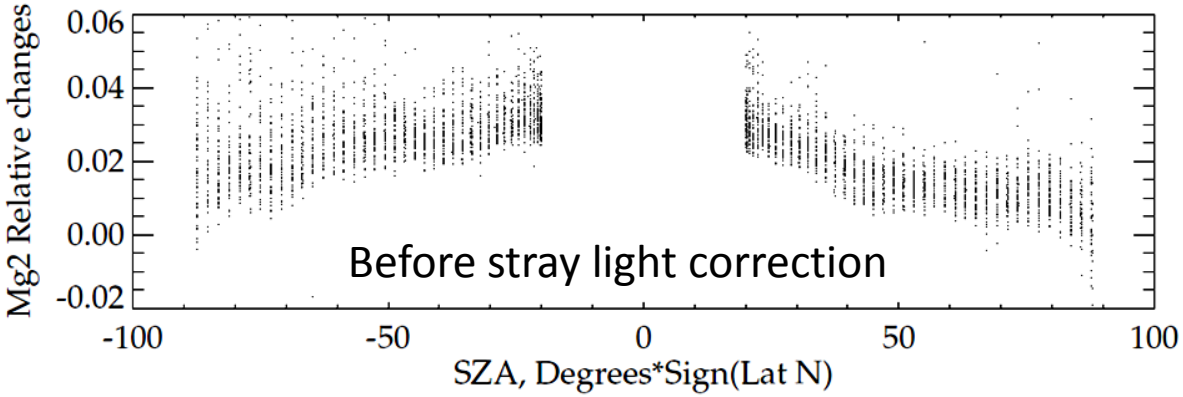
Orbital 19048 corrected SL contamination

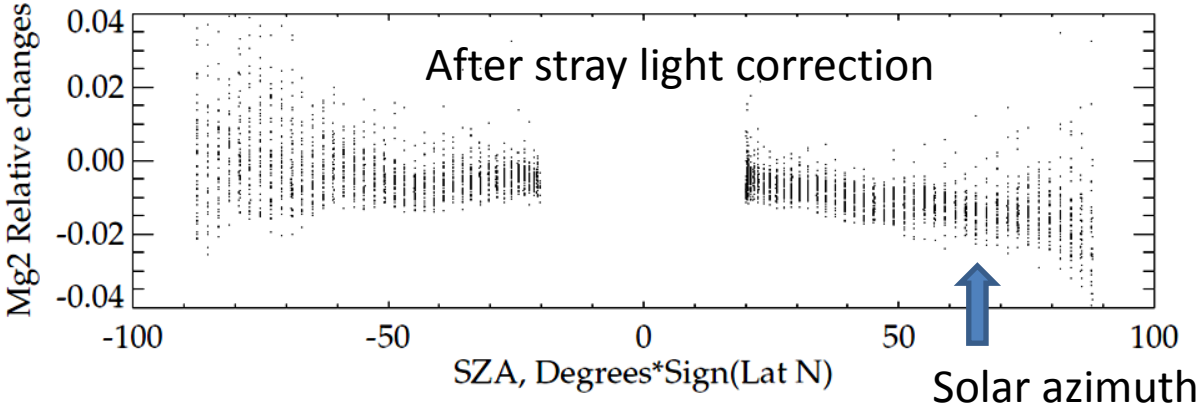


Example of orbital stray light correction vs. prelaunch predicted value shows that the orbital stray light correction is adequate across all the wavelengths

Improved OMPS NP Stray-Light Correction (2/2)

Earth-view Mg II Index for March 2014





Change in EV Mg II index reflects stray light correction.

Mg II index varied with SZA before the NP stray light correction. Stray light contamination caused up to -1. ~ 5.% errors in EV radiance

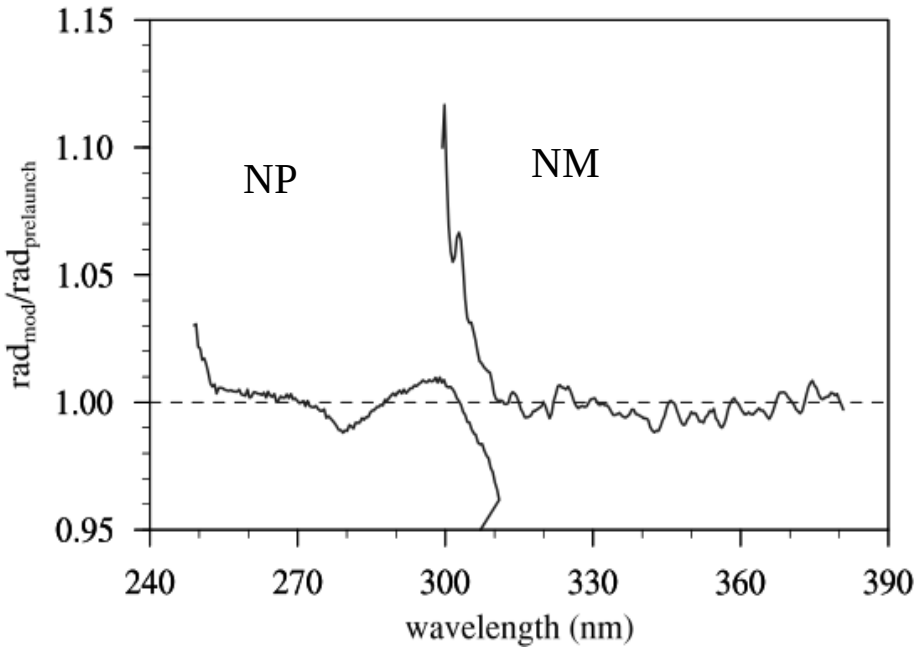
The errors are within ±2% for the most of the channels after stray light correction was applied.

Solar azimuth angle dependent correction residual is caused primarily by the ring effect.

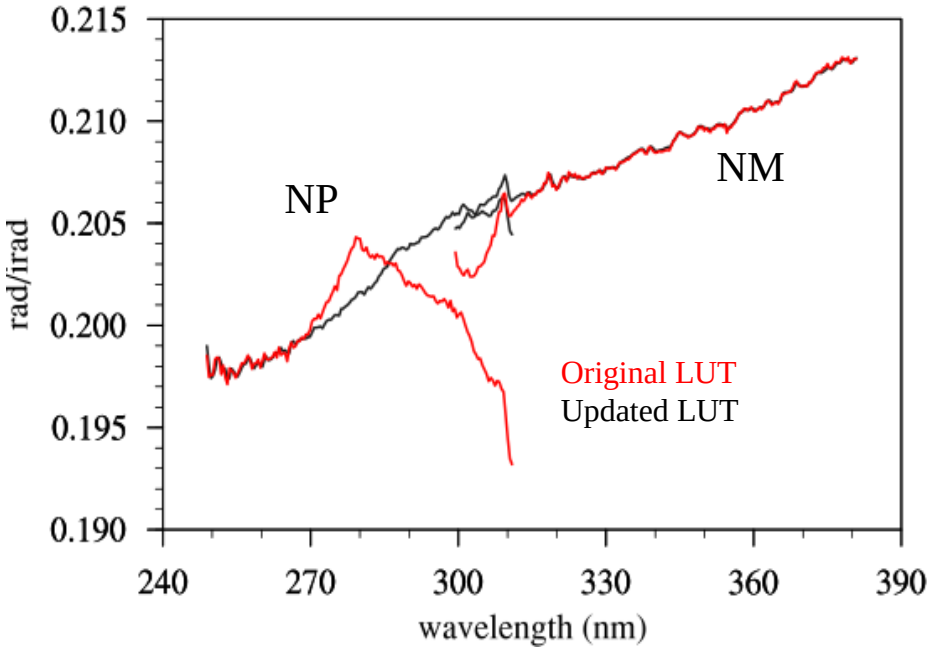
Additional Improvement in Radiometric Calibration (1/2)

- 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.

Ratio Radiance before/after Updates



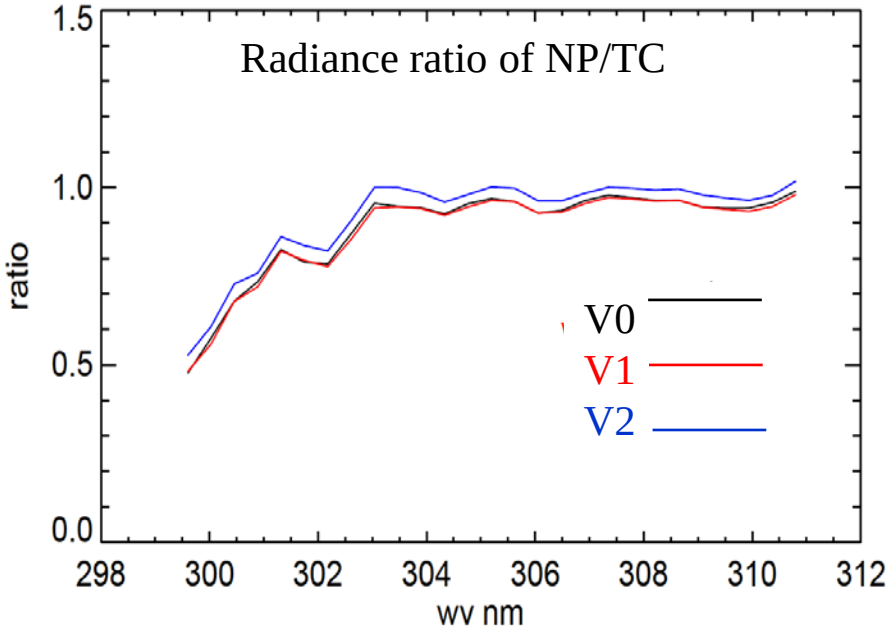
Normalized Radiance: rad/irad

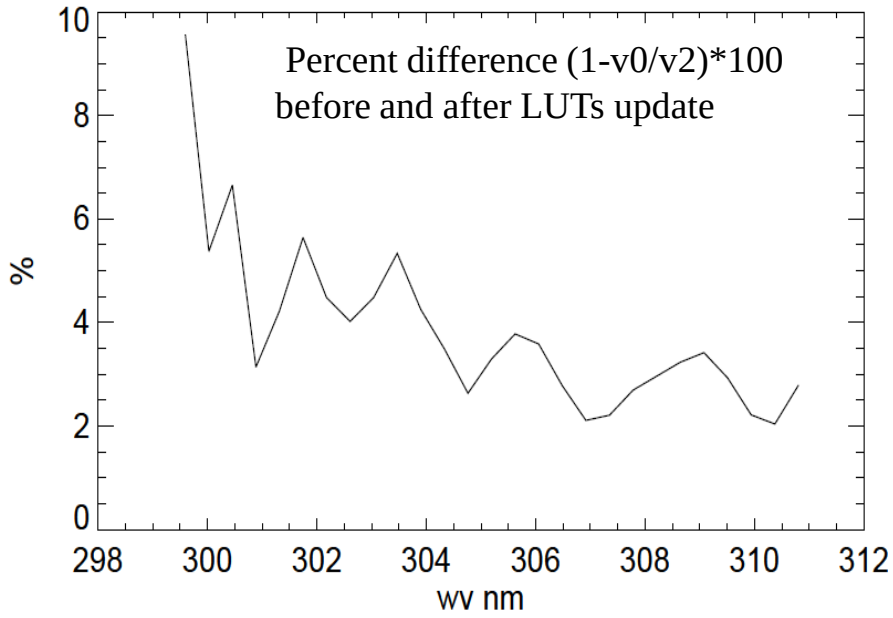


Updated radiance coefficient LUTs improve normalized radiance consistency up to ~10% between NP and NM in 300-310 nm.

Additional Improvement in Radiometric Calibration (2/2)

Improvement in the Spectral Range of 300 - 310 nm

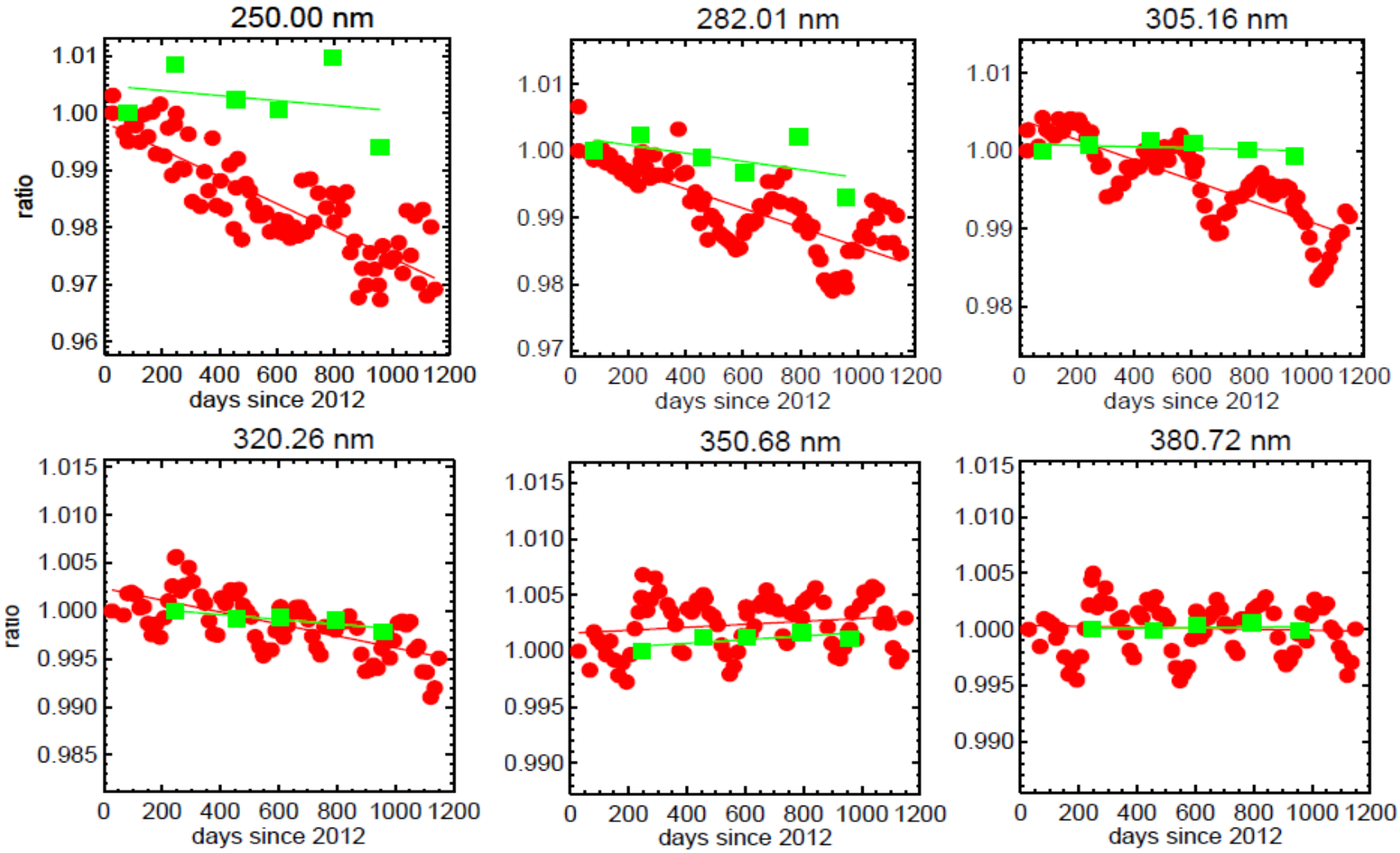




- The improvement was validated via SDR products from both NP and NM.
- EV Radiance from NP and NM are collocated spatially and spectrally
- 1174 granules (globe coverage) were used for validation
- Radiance is computed via old LUTs (V0), updated wavelength & day one solar (V1) and updated wavelength,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

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

Monitoring OMPS Solar Diffuser Degradation

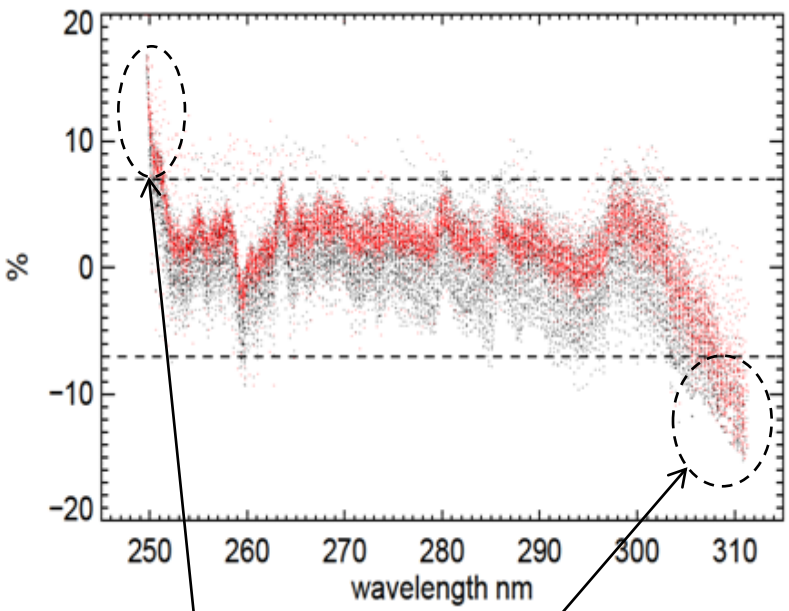


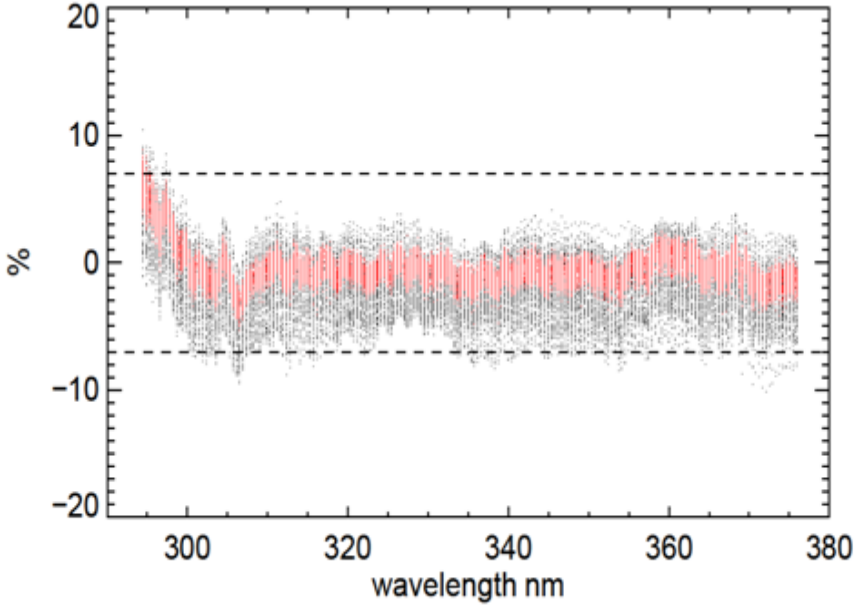
Sensor optical degradation < 1.0 %.

OMPS Solar Irradiance Errors Measured from Solar Diffusers

Errors from work diffuser measurements

Errors from Reference diffuser measurements

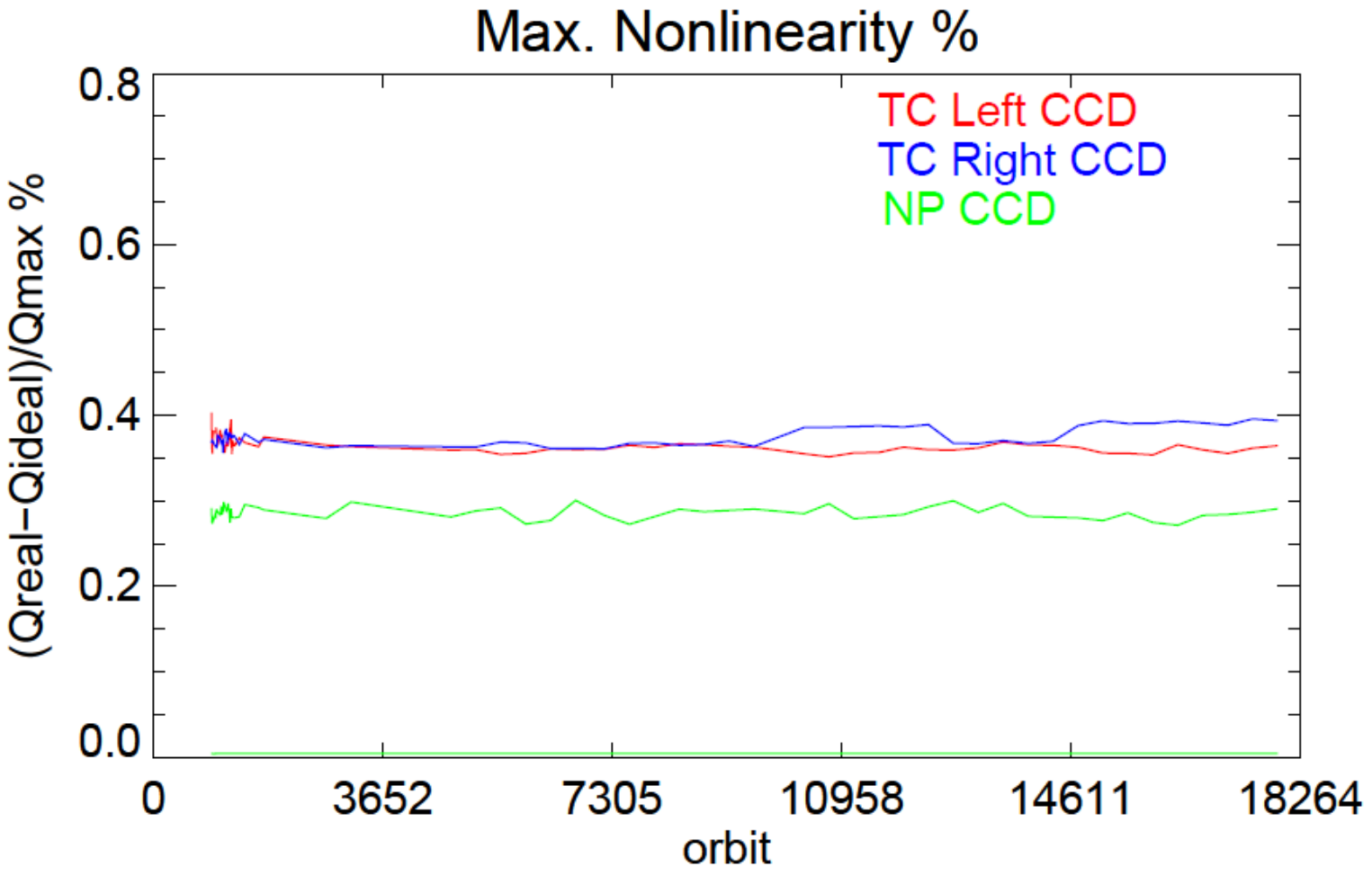




Channels with large noise

Irradiance error meets the requirement of 7% for most of the channels.

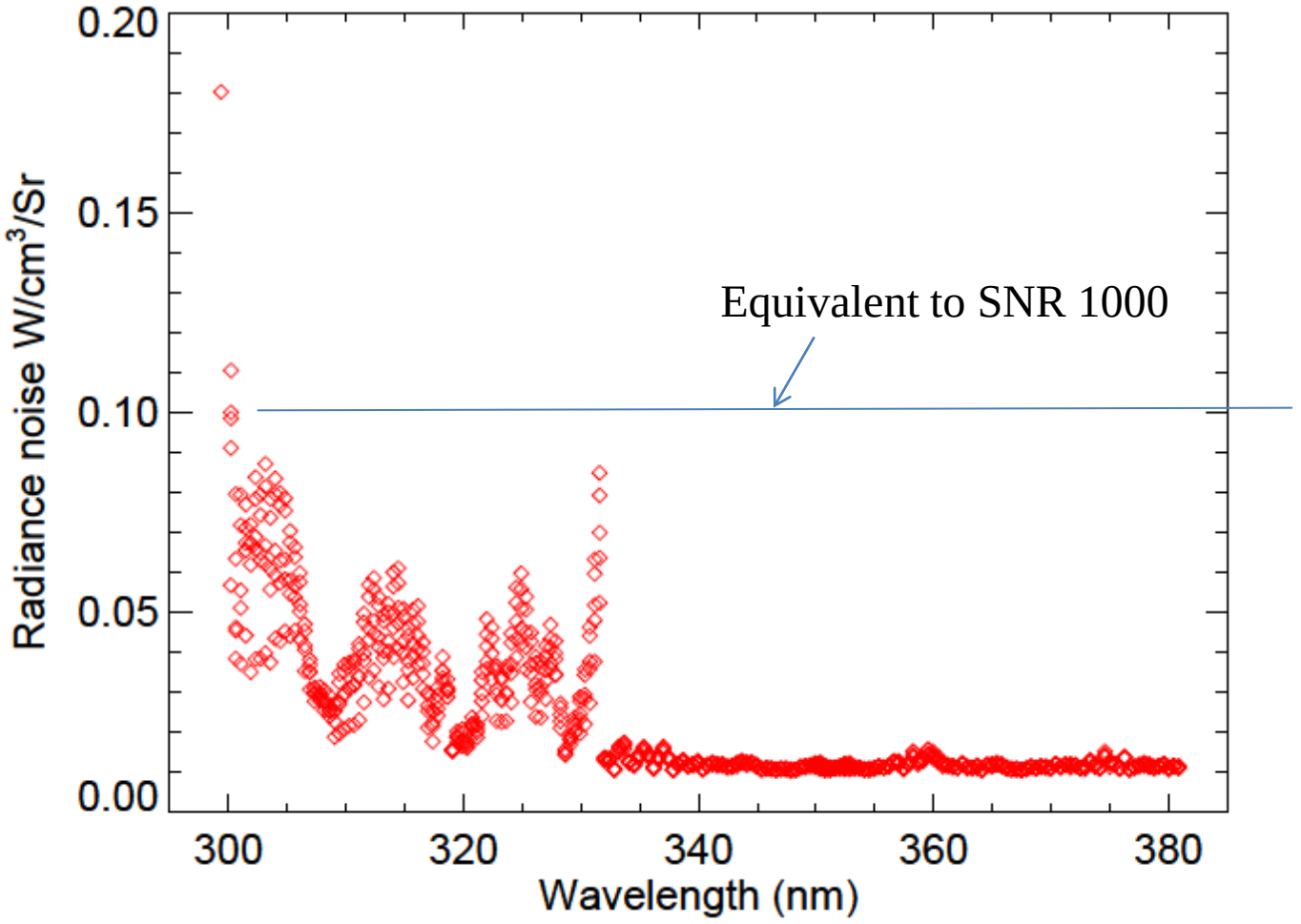
OMPS System Nonlinearity



System nonlinearity meets the requirement of 2%.

Sensor Signal to Noise Ratio from EV data

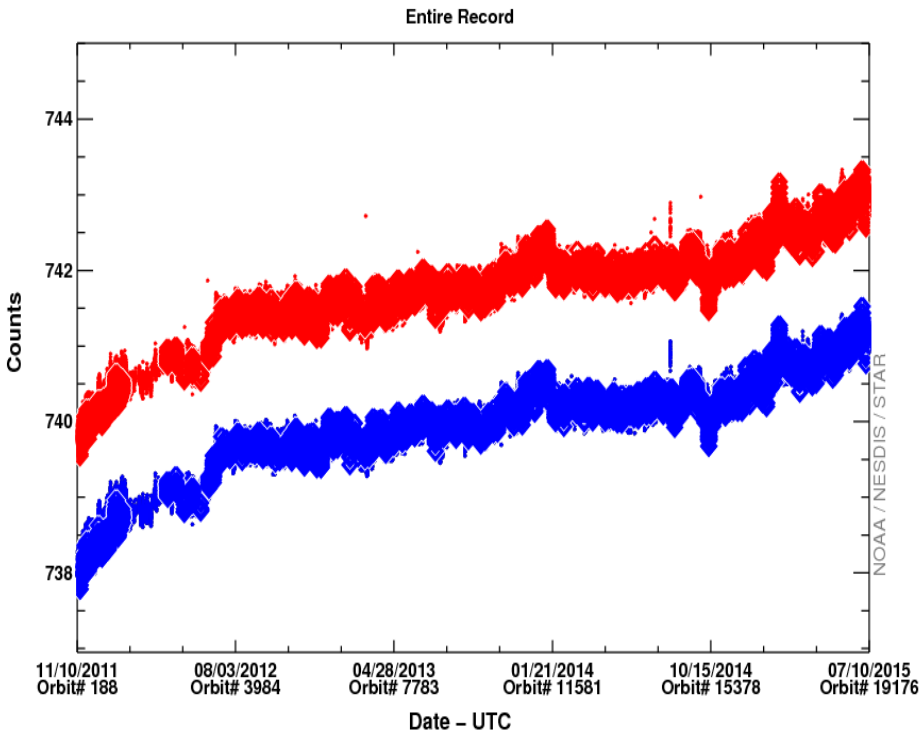
Data collected from 1178 EV granules on July 1, 2015



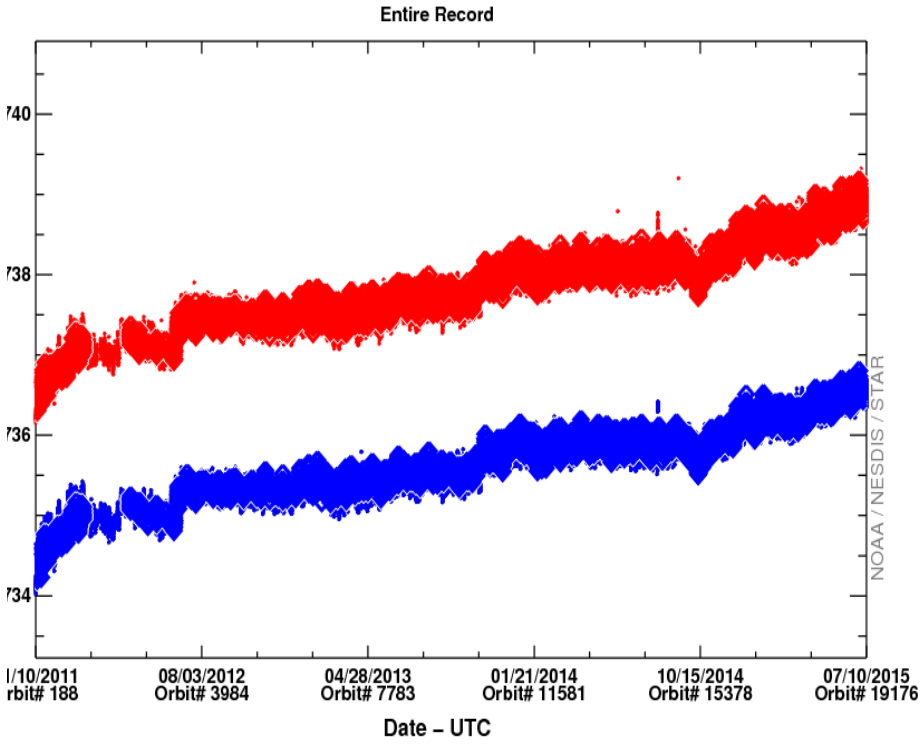
Sensor signal to noise ratio from EV data meets the requirement of 1000.

OMPS Solar Diffuser Count Drafts

NP

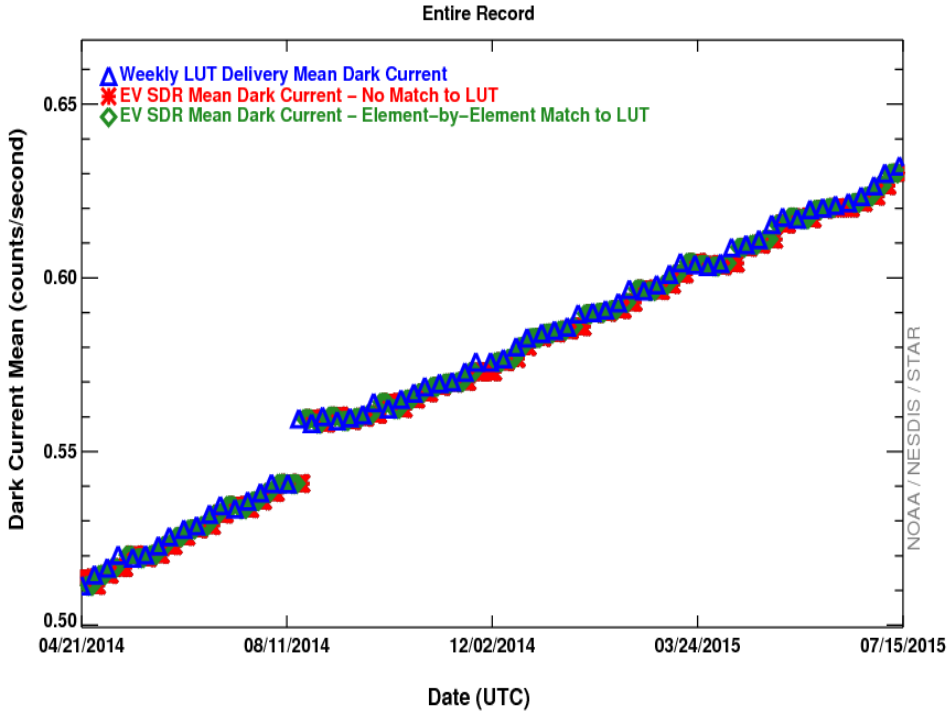


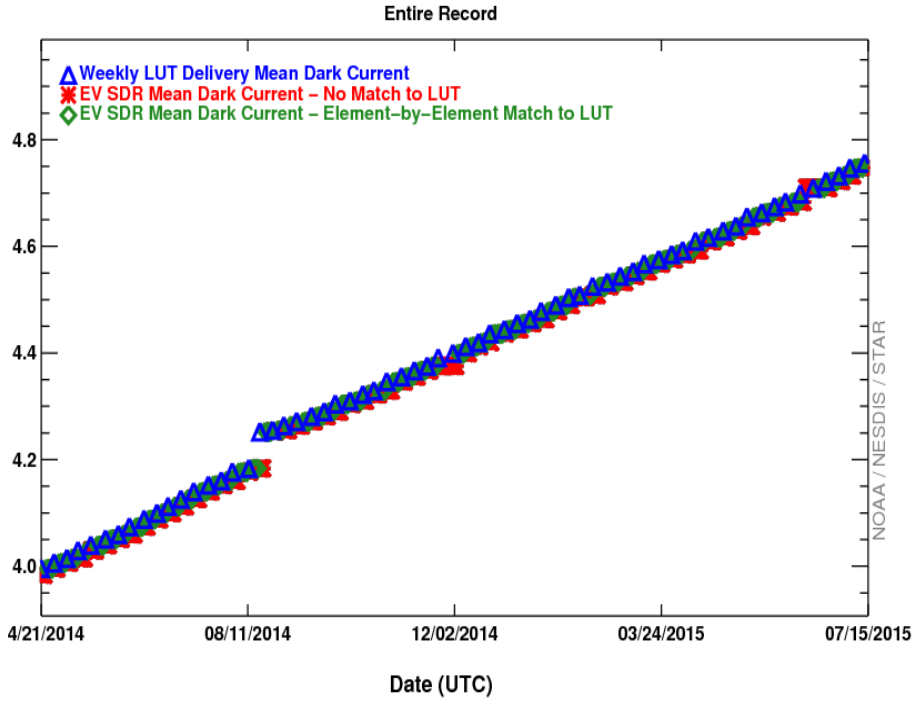
NM Left CCD



Bias drifts are small for both sensors. Sometime, unexpected bias drifts are observed, but do not have negative impact on the SDRs since the magnitudes in general are small.

OMPS Dark Current Trend





Dark data shows a bump-up trend after the spacecraft maneuver.

- NM slowly returns to the original trend and the change rate is slowing down
- NP has a static offset of $8.1e^{-3}$ count/sec in mean dark and parallel with the original trend.

Dark increases as expected. Dark changes have no significant impact on SDRs.