Validated Maturity Review for SNPP OMPS SDR Earth View Products

Suomi NPP OMPS EV SDR Task Overview

Fred Wu, OMPS SDR Team Lead

Suomi NPP SDR Product Review
NOAA Center for Weather and Climate Prediction (NCWCP)
5830 University Research Park, College Park, Maryland
December 19, 2013

Outlines

- OMPS SDR Team
- Resolution of Issues from Provisional
- OMPS SDR Cal Val Activities Since Provisional
- OMPS SDR DR Status
- Justification for OMPS EV SDR to be Validated
- Path Forward
- Summary

OMPS SDR Team

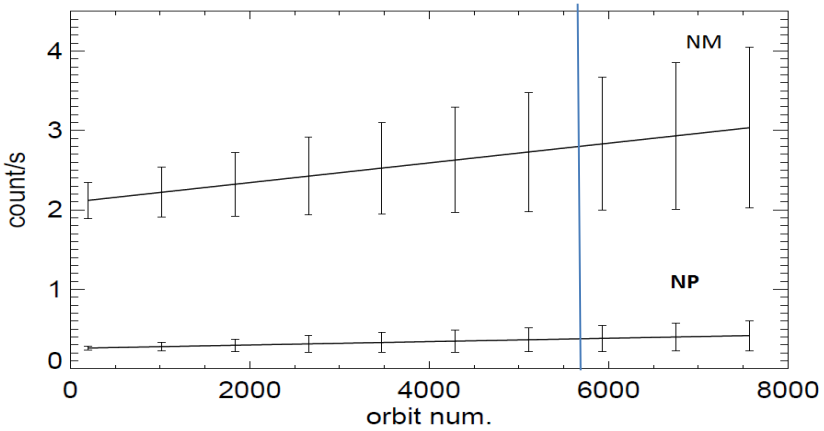
PI Name	Organization	Primary Roles
Fred Wu	NOAA/STAR	Budget and coordination; Instrument and product performance monitoring; J1 code development; TVAC data analysis; SDR algorithm.
Glen Jaross	NASA	Instrument scientist; TVAC data acquisition and analysis; SDR algorithm.
Bhaswar Sen	NGAS	G-ADA test for IDPS operations; TVAC data analysis; SDR algorithm.
Maria Caponi	Aerospace	Algorithm changes coordination; DR and issues tracking
Daniel Cumpton	Raytheon	IDPS operations

Resolution of Issues from Provisional

- Review Panel Findings (24 Oct 2012):
  - OMPS instrument performance is excellent
  - OMPS EV SDR from IDPS has not taken full advantages of that performance
  - Recommend to resolve three critical issues before OMPS EV SDR becomes Provisional:
    - Update Darks
    - Resolve Negative Smear
    - Stray Light Correction for NM
- Follow-up Actions:
  - Discussed path forward with AERB in Nov 2012.
  - Resolved issues.
  - Provisional since 1 Mar 2013 (Mx6.6).

Critical Issue #1 – Darks Update

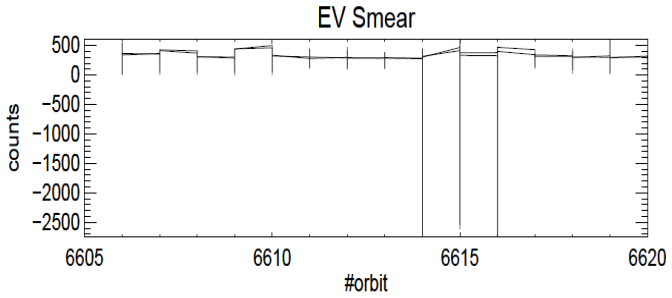
- Routine update of the dark current
  - Implemented weekly update
    - Since 21 Dec 2012 for NM and 7 Feb 2013 for NP
    - All updates have been successful, including holidays but except for the three weeks when the government was shut down
  - Work is under way to automate the process by transitioning the operation to GRAVITE

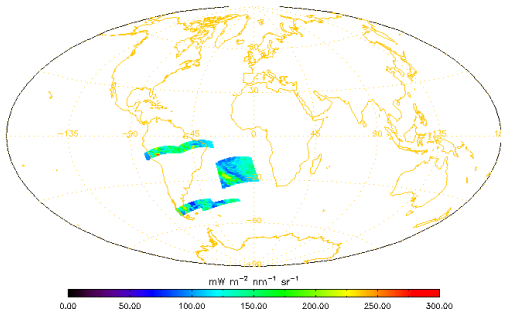


Details in Pan's presentation

Critical Issue #2 – Negative Smear

- Occasional negative smear was observed
  - Identified the root cause in Feb 2013
    - SAA DARKS was used inadvertently
    - When the predicted SAA intensity is 20% of its normal maximum.
    - Which causes negative smear.
  - Implemented the correction in May 2013
    - CCR 0952 was approved in March 2013.
    - Correction was implemented as part of Mx6.7 in May 2013.
  - Can also be caused by the fixed bias (DR7315 for NM and DR4818 for NP).
    - Rare event, minimal impact, low priority.





Critical Issue #3 – NM Stray Light

- Implement stray light correction for NM
  - Correction was recommended in Feb 2013
  - Interim correction in July as part of Mx7.0
  - Complete correction in Aug as part of Mx7.2
- Stray light correction for NP
  - Approved 6 Nov 2013
  - To be implemented in Mx8.3
- Details in Jaross presentation

OMPS Cal Val Tasks Since Provisional

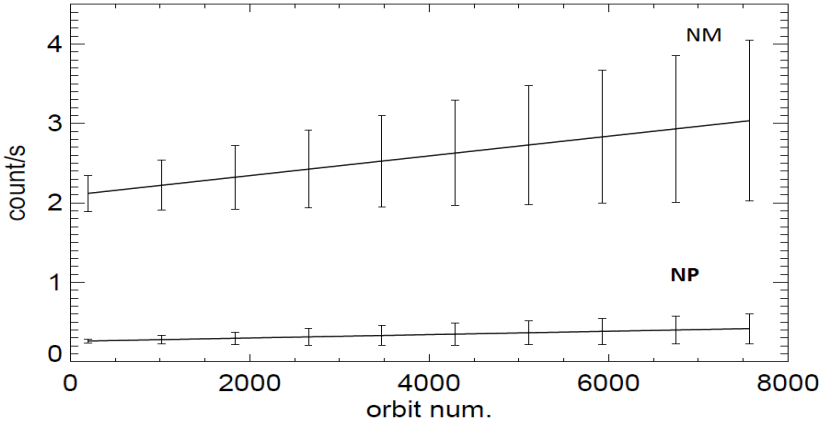
- Resolved the issues and reached Provisional
- Improved SDR algorithm and software
- Characterized and continue monitoring OMPS instrument and SDR performance
- Implemented radiometric and spectral calibration
- Documented the progress

SDR Algorithm and Software

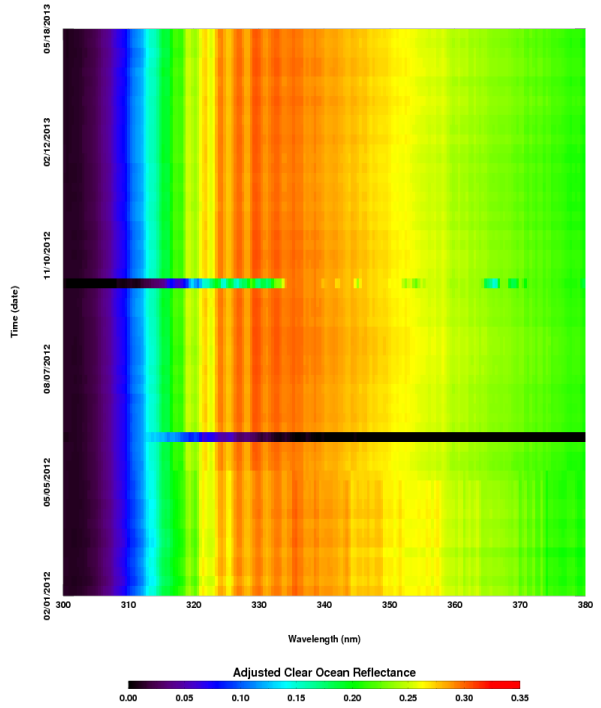
- Stray light correction for NM
  - Planned pre-launch, based on radiance
  - Post-launch, the SDR team concluded that a count-based correction is superior.
  - Modification of the code (CCR-13-0883), LUT, and ATBD was completed.
- Stray light correction for NP
  - Not planned pre-launch but recognized as necessary post-launch
  - Approved as CCR-13-1249 (to be implemented with Mx8.3).
- Details in Jaross presentation.

Instrument and SDR Performance

- Characterize and monitor OMPS nadir instrument performance – Pan presentation.



- Characterize and monitor OMPS nadir SDR performance – Wu presentation.



Radiometric and Spectral Calibration

- Improved the radiometric calibration of OMPS nadir instruments
  - Routine update of dark current
  - Inhibited the SAA dark
  - Stray light correction
- Improved the spectral calibration of OMPS nadir instruments
  - Wavelength registration – details in Flynn presentation

Documentation – Peer Reviewed

Flynn, L., and co-authors, 2013: Accepted by JGR (2013JD020467R).

Jaross, G., and co-authors, 2013: Submitted to JGR (2013JD020482R).

Pan, C.; Kowalewski, M.; Buss, R.; Flynn, L.; Wu, X; Caponi, M.; Weng, F, "Performance and Calibration of the Nadir Suomi-NPP Ozone Mapping Profiler Suite From Early-Orbit Images," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol.6, no.3, pp.1539,1551, June 2013 doi: 10.1109/JSTARS.2013.2259144.

Seftor, C., and co-authors, 2013: Submitted to JGR (2013JD020472R)

Wu, X., and co-authors, 2013: Submitted to JGR (2013JD020484R)

Documentation - Other

- Presentations in this review
  - Pan: OMPS nadir instrument performance
  - Jaross: Stray light correction
  - Flynn: Wavelength registration
  - Wu: OMPS nadir SDR evaluation
  - Long: NOAA user feedback
  - Yang: NASA user feedback
- OMPS SDR User's Guide (to be delivered)
- OMPS ATBD
- Error budget

OMPS SDR DR Status

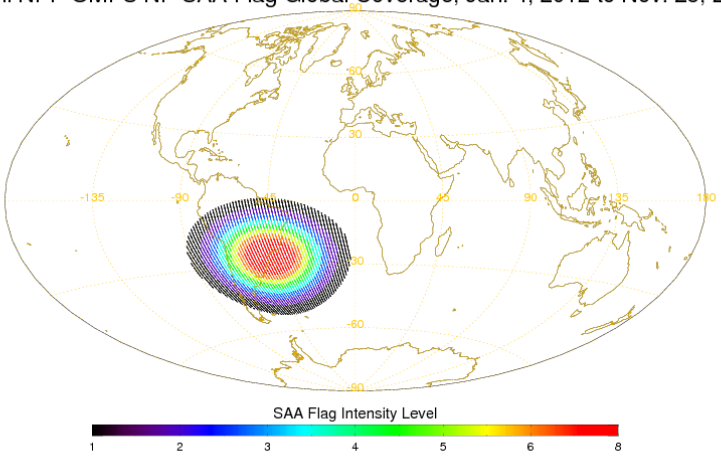
- 12 DRs remain open since Provisional:
  - All are related (one indirectly) to CAL SDR that will be closed or resolved after the CAL SDR operation is transitioned to GRAVITE.
- 122 DRs were submitted since Provisional:
  - 90 were associated with NM & NP DARKS GRN-PI update, for which CCR have been implemented.
  - 12 led to CCRs
    - Ten were approved
    - One (CCR-13-1416) to be reviewed by AERB
    - One withdrawn (version description document will be included in documentation and configuration managed).
  - 20 are in progress
    - Three are associated with J1 requirements
    - 17 are not critical for validated maturity
- Details in backup slides.

OMPS SDR Processing Status (1)

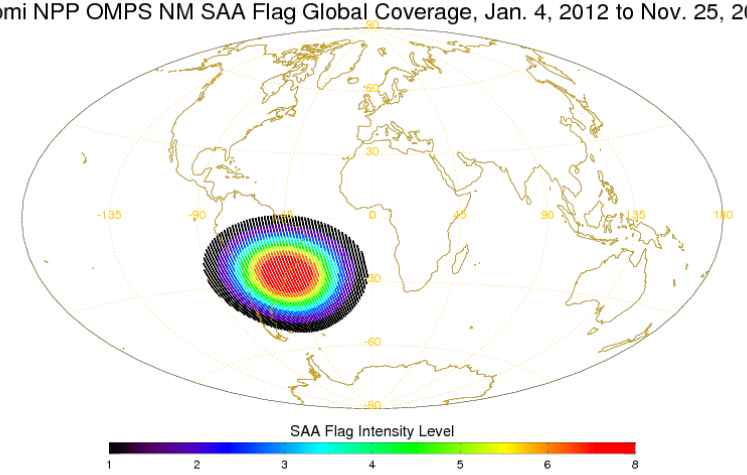
- IDPS
  - Current version Mx8.0
- ADL
  - Code updated to Mx8.1 (to be operational Feb 2014).
  - Capable of parallel processing or re-processing of SDRs.
- Quality Flag
  - SAA and SolarEclipse: Work well.
  - OutDatedCal: Need to update the CDFCB (DR7480, PCR 36737)
  - LinearCorrection: Corrected with Mx6.2.
  - QualityEarth: Obsolete.
  - SunGlint: Need investigation (not used).

SAA Flag Location and Frequency

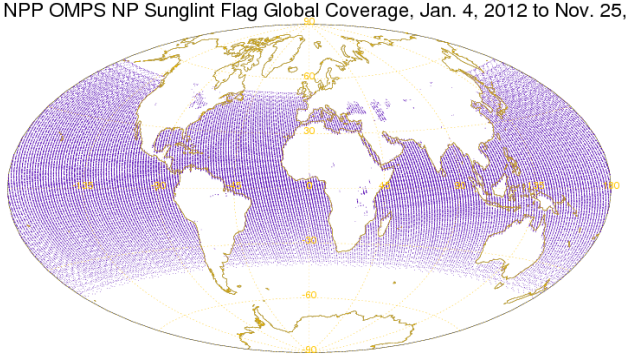
Suomi NPP OMPS NP SAA Flag Global Coverage, Jan. 4, 2012 to Nov. 25, 2013



Suomi NPP OMPS NM SAA Flag Global Coverage, Jan. 4, 2012 to Nov. 25, 2013



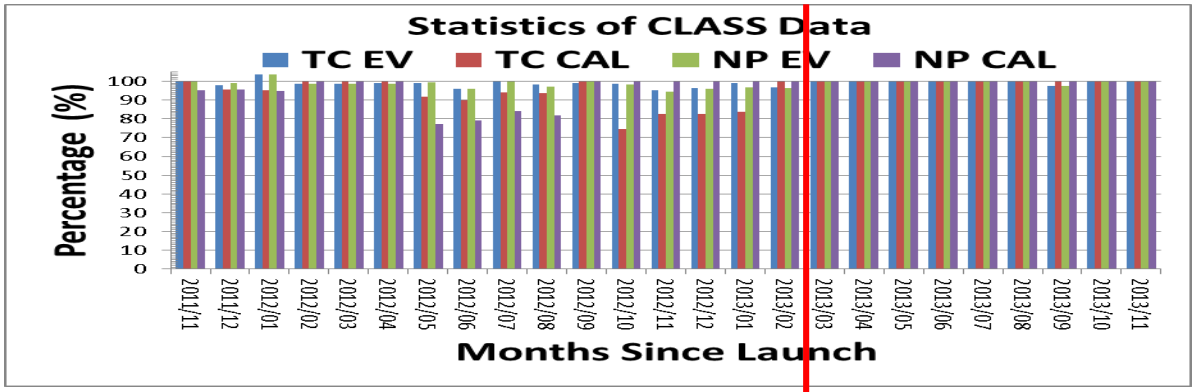
Suomi NPP OMPS NP Sunglint Flag Global Coverage, Jan. 4, 2012 to Nov. 25, 2013



NP Sun glint (NM similar)

OMPS SDR Processing Status (2)

- Data Completeness
  - One incident (Orbit 5856, 12 Dec 2012) of missing RDR:
    - 1 NM, 2 NP, and 2 LP granules of RDR were not delivered to CLASS.
    - Corresponding SDR were available.
    - Root cause: S/C diary not available at the time of RDR packaging.
    - WR was rejected because it happened only once with minor impact (not on SDR).
  - One incident of duplicate orbit:
    - 27 Jun 2013, due to a cold restart of DDS.
  - One incident due to CrIS Full Resolution test
    - 2013-03-12. Revealed the deficiency in handling swath with some packets missing. PCR34944 is being worked at low priority.



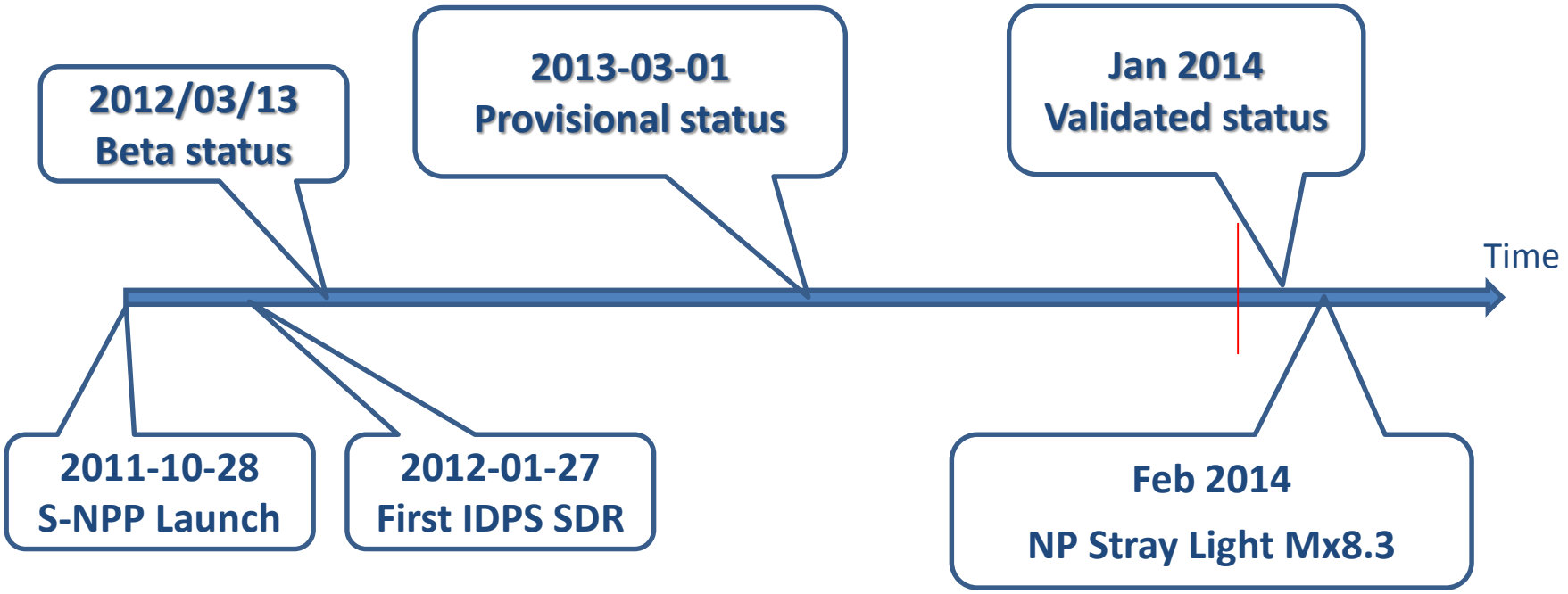
Justification for OMPS EV SDR to be Validated

- Requirements (Performance Since Provisional)
  - Instrument: **meeting specifications with adequate margins.**
  - SDR: **stable (quality and quantity)** and free of major errors.
- SDR software
  - IDPS has been producing satisfactory products.
  - Incremental improvements are planned and will continue.
- Documentation
  - 7 presentations in this meeting
  - 5 Journal papers
  - ATBD
  - SDR User's Guide (to be provided)
  - Error Budget table
- Applications:
  - **Information contents are sufficient to make positive impacts**.
  - Soft calibration is necessary, which can be applied to validated SDR.

Instrument Performance (to be elaborated by Pan)

Parameters	Specification/Prediction Value	On-Orbit Performance
Non-linearity	< 2% full well	< 0.46%
Non-linearity Knowledge	< 0.5%	0.1%
On-orbit Wavelength Calibration	< 0.01 nm	NM: average ~ 0.01 nm RMS
Stray Light NM Out-of-Band + Out-of-Field Response	For NM ≤ 2	average ~ ± 2%
Intra-Orbit Wavelength Stability	Allocation (flow down from EDR error budget) = 0.02 nm	< 0.013 nm
SNR	1000	> 1000 from SV and EV
Inter-Orbital Thermal Wavelength Shift	Allocation (flow down from EDR error budget) = 0.02 nm	0.013 nm
CCD Read Noise	60 –e RMS	< 25 –e RMS
Detector Gain	43 (for NP) 46 (for NM)	45 (for NP) 42 (for NM)
Absolute Irradiance Calibration Accuracy	< 7%	average ~ 7% (5% for NM, 1~10% for NP)
Absolute Radiance Calibration Accuracy	< 8%	< 5%

IDPS OMPS SDR Cal Val Milestones



Path Forward

- Suomi NPP
  - Instrument and SDR performance monitoring, characterization, and improvement.
  - Support instrument cal/val (e.g., orbit adjustment, anomaly resolution)
  - Complete documentation (Users' Guide)
  - SDR software improvements
    - Stray light correction
    - Wavelength registration
  - Transition CAL SDR operation to GRAVITE.
- JPSS J1
  - Analyze TVAC data and derive LUT for J1.
  - Develop science code for J1
    - More wavelength and higher data rate for EV SDR
    - New algorithm for CAL SDR
  - Test data (high resolution data from S-NPP)

Summary

- With accomplishments achieved and efforts in progress, the OMPS nadir EV SDRs are found to have
  - Characterized for on-orbit sensor performance
  - Defined SDR product uncertainties over a range of representative conditions
  - Calibration parameters adjusted accordingly, pending soft calibration that can be applied to validated SDRs
  - Plan for later improved version
  - Strong versioning with documentation
  - Been ready for use in applications and scientific publication
- Request to declare that OMPS nadir EV SDR be Validated

BACKUP – LIST OF DR

12 DRs Open Since Provisional

DR #	Algorithm	Brief description	Status
4818	NP SDR	OMPS Fixed bias impact on smear and/or radiance	To be closed - Issue corrected
4693	TC and NP SDR	CAL SDR Strategy Study	To be closed - Resolved with transition to Gravite
4676	TC and NP EV SDR	Radiance error associated with aggregation of the two center macropixels	To be closed - Resolved with transition to Gravite
4673	TC and NP CAL SDR	Correction for different linearity slope Tup for CCD 2- Primary and redundant.	To be closed - Resolved with transition to Gravite
4672	TC and NP CAL SDR	Linearity correction update xml file basline	To be closed - Resolved with transition to Gravite
4671	TC and NP SDR and EDR	OMPS DQTT (DATA quality threshold tables) not existent for SDR and TBD for EDR	To be investigated - TBD
4627	TC and NP CAL SDR	Quantization introduced by linearity correction error	To be closed - Resolved with transition to Gravite
4615	TC and NP CAL SDR	Transient filter	To be closed - Resolved with transition to Gravite
4602	TC and NP CAL SDR	Spatial pixel mismatch	To be closed - Resolved with transition to Gravite
4318	OMPS TC, NP SDR CAL SDR	Subroutine Wave Monitor uses spectral range to bound spatial index	To be closed - Resolved with transition to Gravite
4317	TC and NP CAL SDR	Bias calculation error	To be closed - Resolved with transition to Gravite
4316	TC and NP CAL SDR	Lamp data mapping error	To be closed - Resolved with transition to Gravite

12 DRs Led to CCRs

DR #	CCR #	Description	AERB DATE	STATUS
4536	12-0625	Sample table update to include extra pixel colum	3-Oct	Implemented
4906	12-0691	RDR truncation needs correction	10-Oct	Implemented
4955	12-0736	TC EDR CTP modifications	21-Nov	Implemented
5034	13-0822	OMPS Version System Reference for OMPS GND-Pis	6-Feb	Withdrawn – Replace as document in MIS system
5000	13-0827	SDR provisional assignment	7-Mar	Implemented
5048	13-0931	TC and NP Provisional assignment	17-Apr	Implemented
7058	13-0952	SAA LUT update to inhibit SAA darks	1-May	Implemented
4907	13-0883	TC SL correction	8-May	Implemented
7266	13-1115	TC SL temporary table update	1-Jul	Implemented
7259	13-1192	Wavelength shift adjustment	28-Aug	To be implemented in 8.1
4823	13-1249	NP SL correction	6-Nov	To be implemented in 8.3
7372	13-1315	Request for S-NPP Orbital Inclination adj maneuver	6-Nov	Approved
7386	13-1416	HR Measurements in Nominal Mode	9-Dec	CCR Opened - Expected to be submitted by Dec 20

20 DRs in Progress

DR #	Algorithm	Brief description
7480	TC and NP SDR	QF error in CDFCB
7451	TC SDR	OMPS NM Wavelength Scale
7450	NP SDR	OMPS NP Wavelength Scale
7401	TC and NP SDR	Raise Character Limit of the Version Number portion of the OMPS tables Filenames
7387	TC SDR	TC Straylight LUT update
7386	TC SDR	Nominal measurements in High Resolution mode
7372	TC SDR	Maneuver for Beta angle consistency in OMPS reference diffuser measurements
7358	NP SDR	G-ADA has duplicate algorithm input configuration files for OMPS SDR binaries
7341	NP SDR	NP EV SDR pre-processor to ingest high-resolution data
7340	TC SDR	TC EV SDR pre-processor to ingest high- resolution data
7335	NP SDR	Spectrum adjustment for Solar activity variations
7315	TC SDR	OMPS Fixed bias impact on smear and/or radiance - TC SDR
7260	NP SDR	Impact of wavelength scale shift characterization for the OMPS NP SDR
7210	TC SDR and EDR	OMPS Anomaly 03/12/13-Missing Packets
7059	TC and NP EV SDR	Missing Data in SDS and CLASS
7015	TC and NP EV SDR	CDFCB suggestions for version field clarification
5034	TC and NP EV SDR	OMPS Version Reference Document
5008	NP SDR and EDR	NP SDR (and EDR) fails for Sample Table with extra pixel column
4978	TC SDR and EDR	TC EDR fails for Sample Table with extra pixel column
4927	TC and NP SDR	FT document 474-00181 and 148 need update

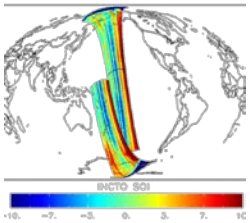
Suomi NPP OMPS EV SDR Delta Review

Fred Wu, OMPS SDR Team Lead

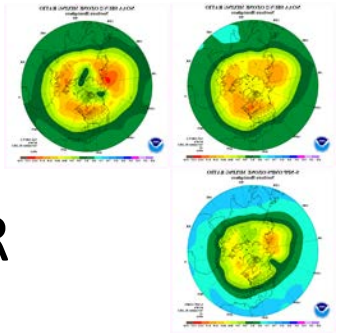
June 3, 2014

Remaining Issues from Dec 2013

- OMPS instrument performance is excellent, but has remaining issues that need to resolved in OMPS EV SDR
- Cross-track effects in NM need to be addressed.
  - SDR Team has a plan, needs to be implemented.
  - Some of these issues may be address by EDR algorithm
  - Wavelength Registration

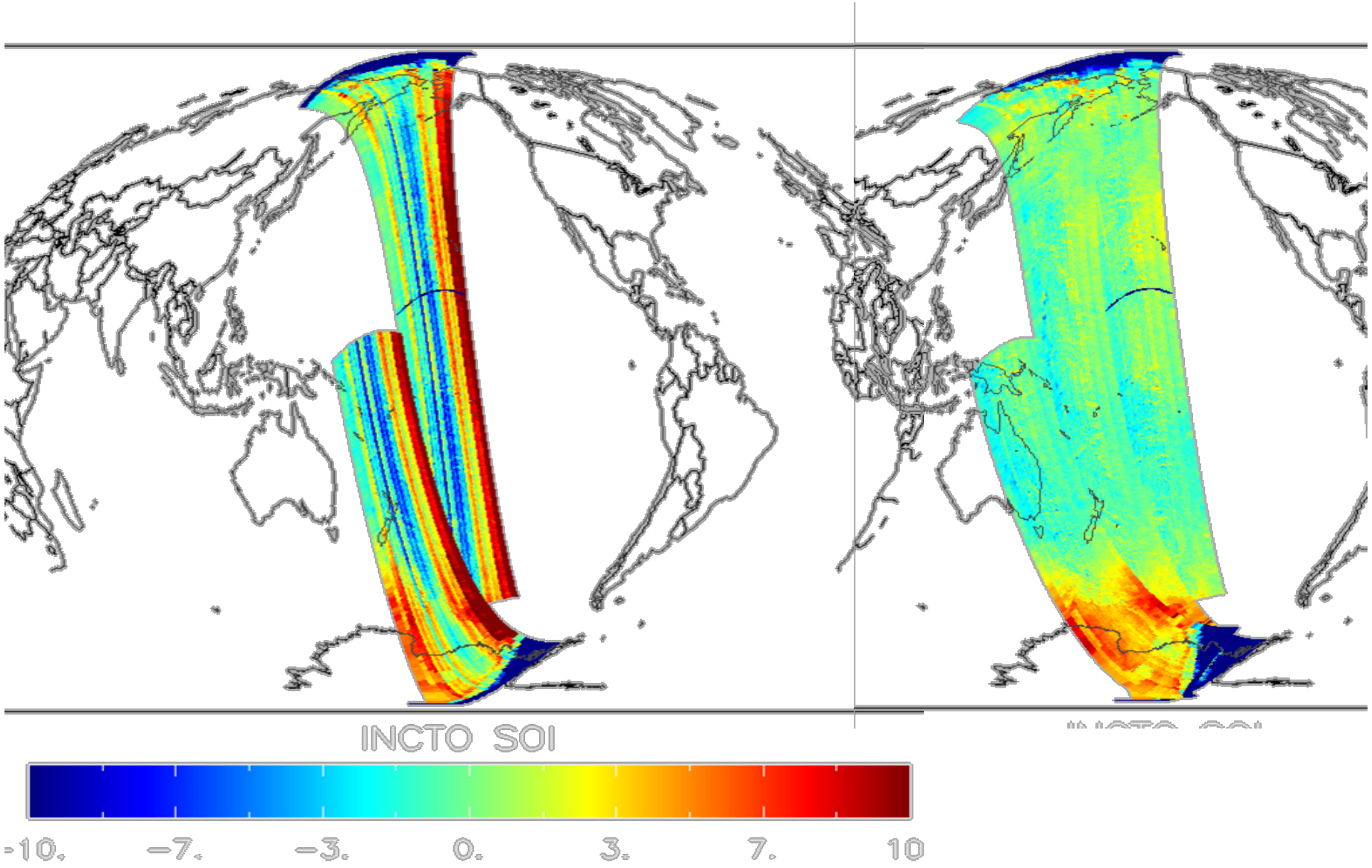


- Stray-light improvements still needed in NP SDR.
  - Stray Light Correction

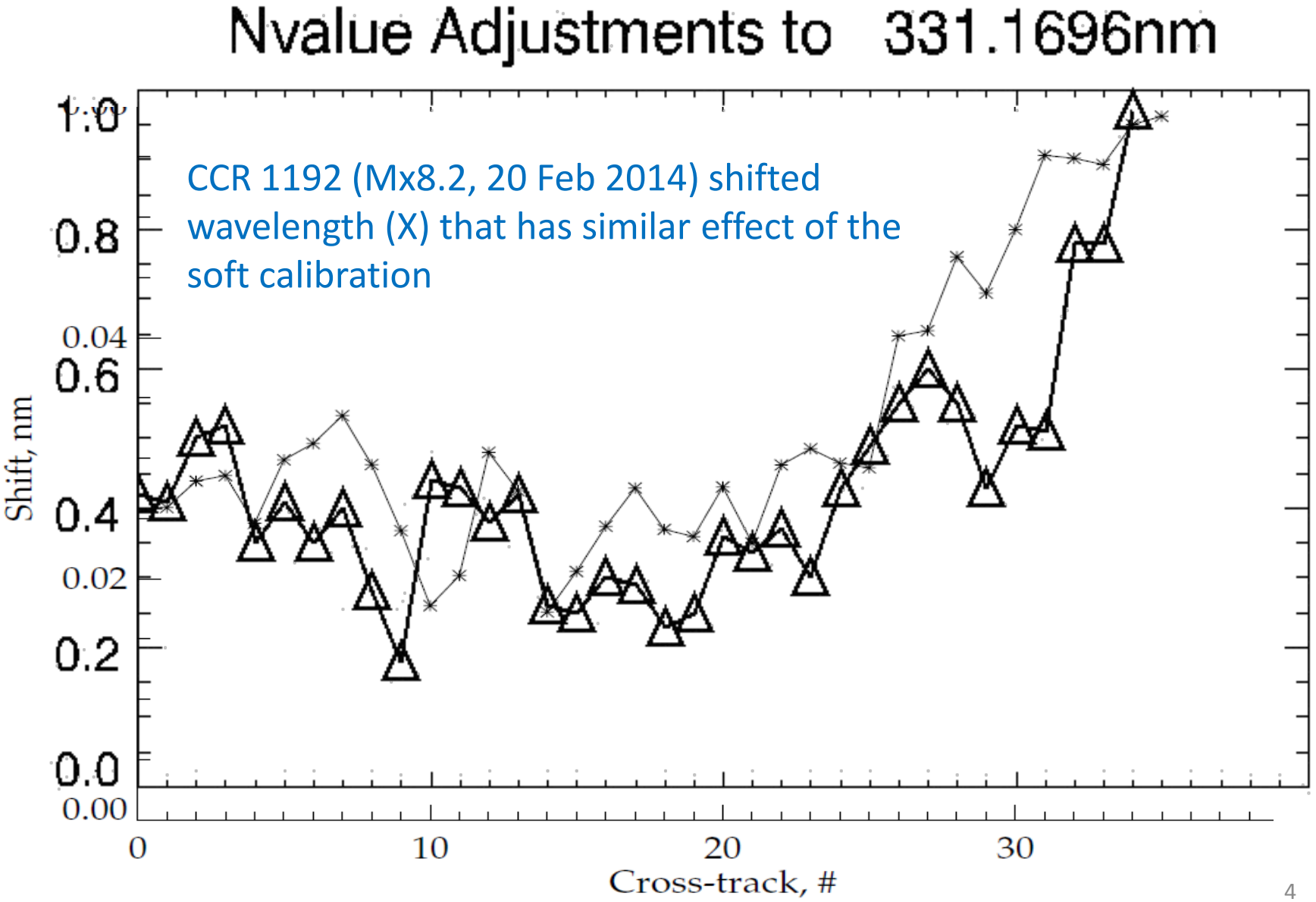


- Artificial separation between EV SDR and Cal SDR should be eliminated.
  - Cal SDR production in GRAVITE is a good solution. Why is it taking so long to implement?
  - CAL SDR Transition.

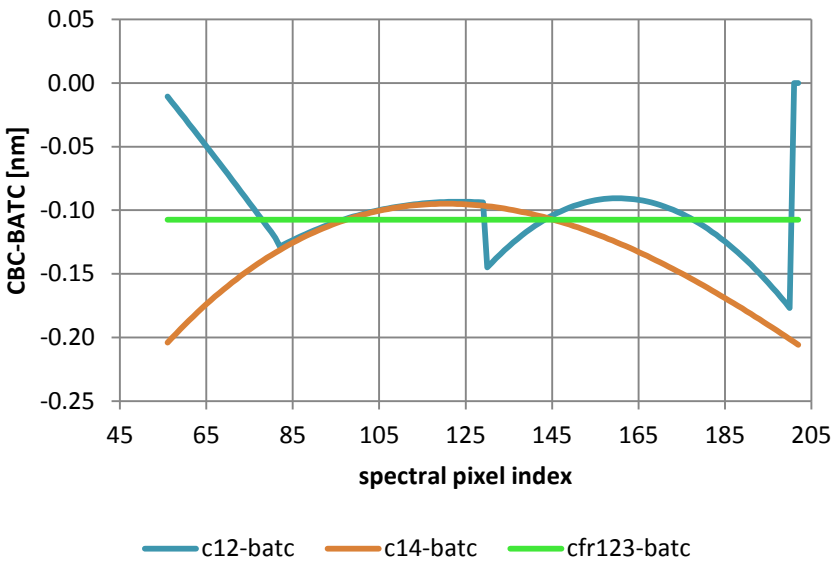
Wavelength Registration (1/3)

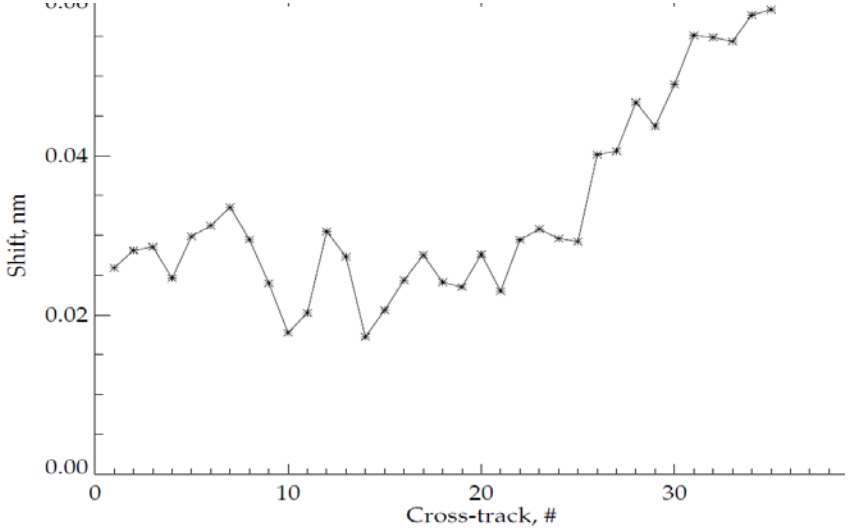


Wavelength Registration (2/3)



Wavelength Registration (3/3)

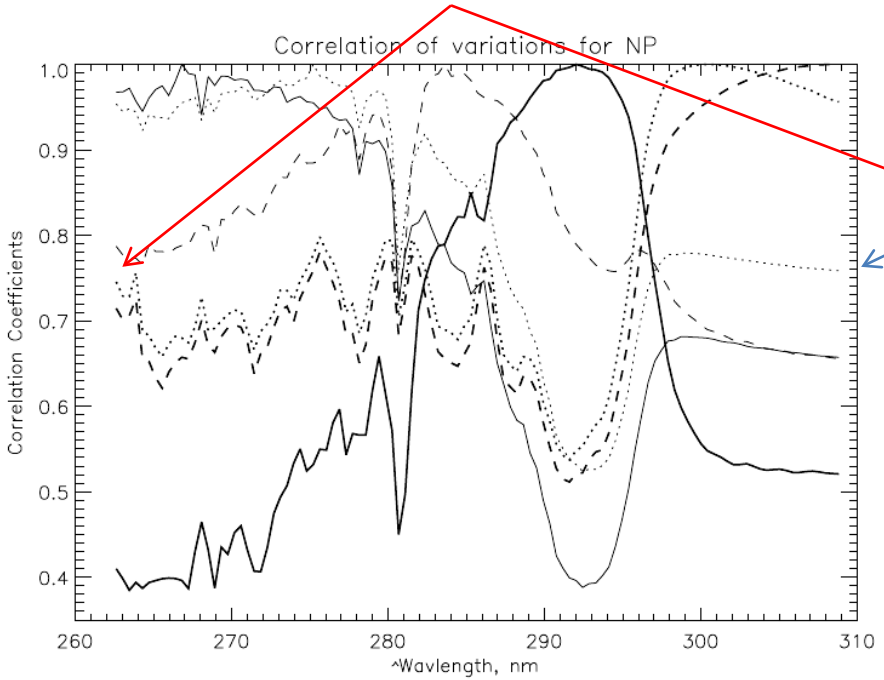




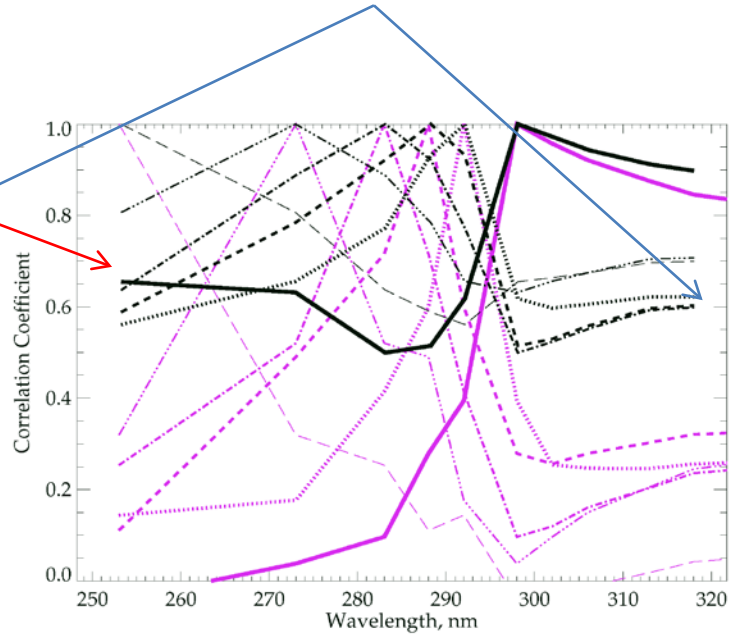
DR 7654 & 7655 will update a LUT for NP (left) and NM (right) to minimize the required shift.

Stray Light Correction - NP

298 nm: 0.75 to 0.65 (goal is <0.3)



273 nm: 0.75 to 0.60 (goal is <0.3)



Before (left), After (right), and Goal (purple)

CCR 1249 (Mx8.3, 18 Mar 2014) corrected part of the NP stray light.

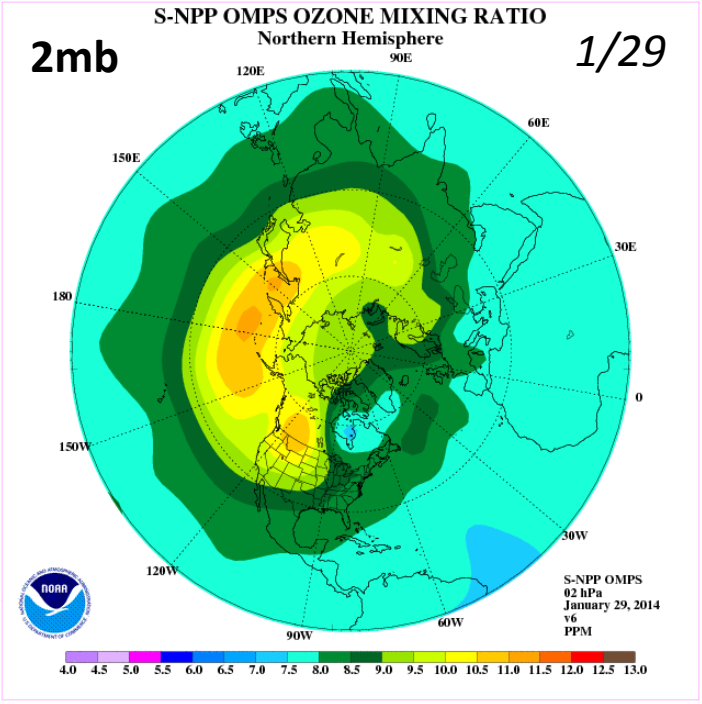
Further improvement is being investigated (DR 7623).

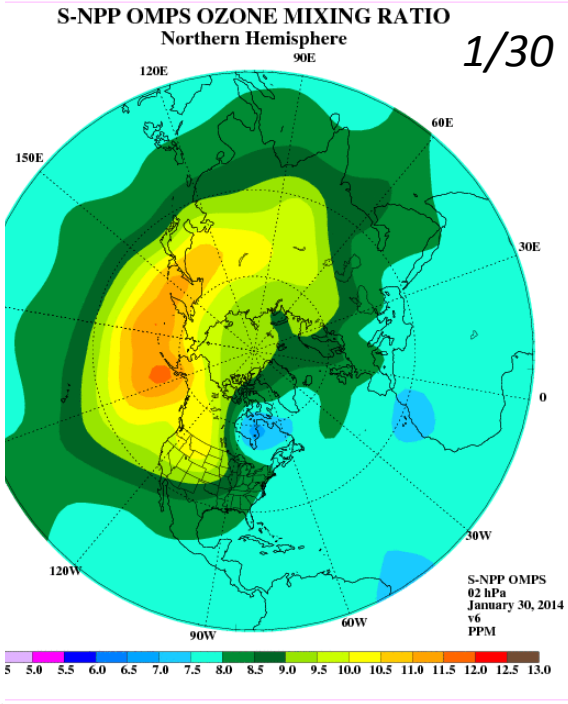
Improvements in O3MR due to addition of 252nm channel

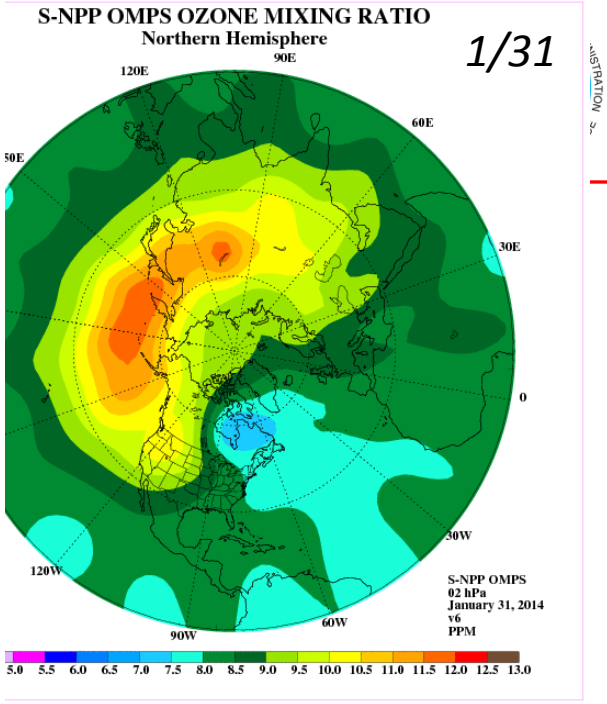
- Most noticeable improvements at 2 and 3 hPa.
- The OMPS v6 o3mr at 2mb now looks very similar to the N19 SBUV/2 2mb analysis.
- Further improvement with OMPS NP stray light correction.

- **note that 2/01 is the same as 1/31 since there is no new obs for 2/01.*

2mb


S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
1/29
120E
90E
60E
150E
30E
180
0
150W
30W
120W
90W
60W
S-NPP OMPS
02 hPa
January 29, 2014
v6
PPM
4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0


S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
1/30
120E
90E
60E
150E
30E
0
30W
120W
90W
60W
S-NPP OMPS
02 hPa
January 30, 2014
v6
PPM
5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0


S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
1/31
120E
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02 hPa
January 31, 2014
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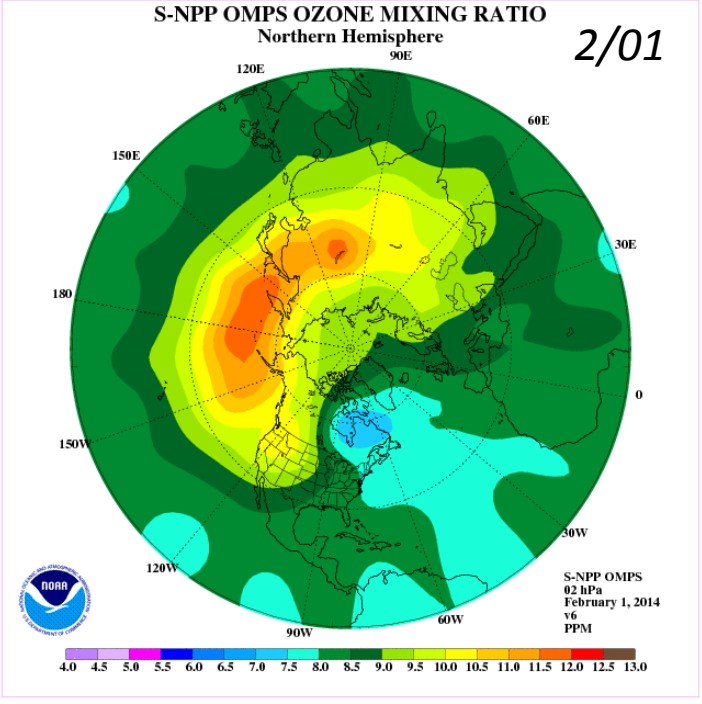
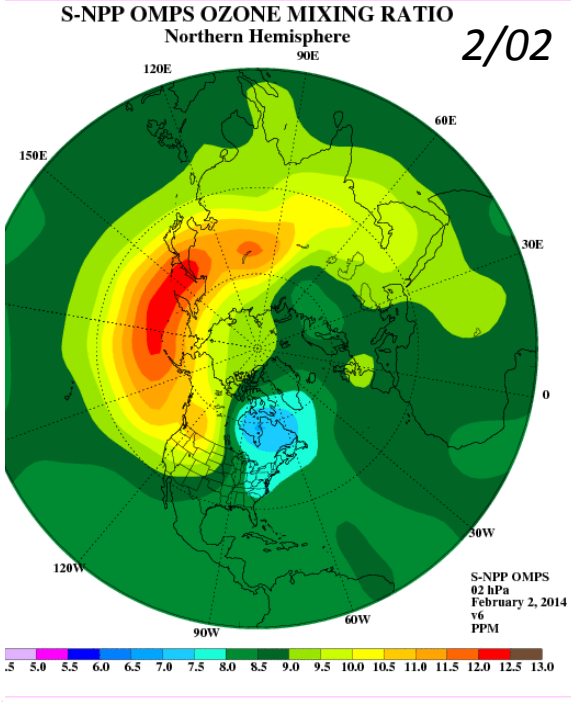
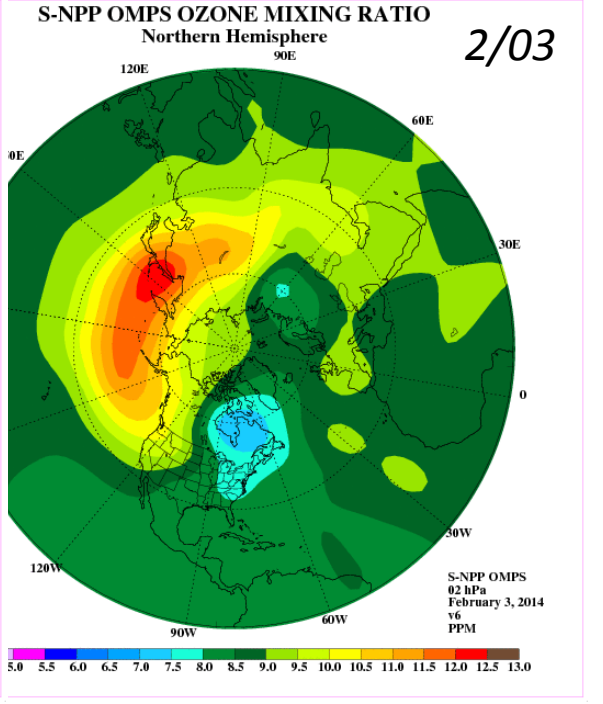
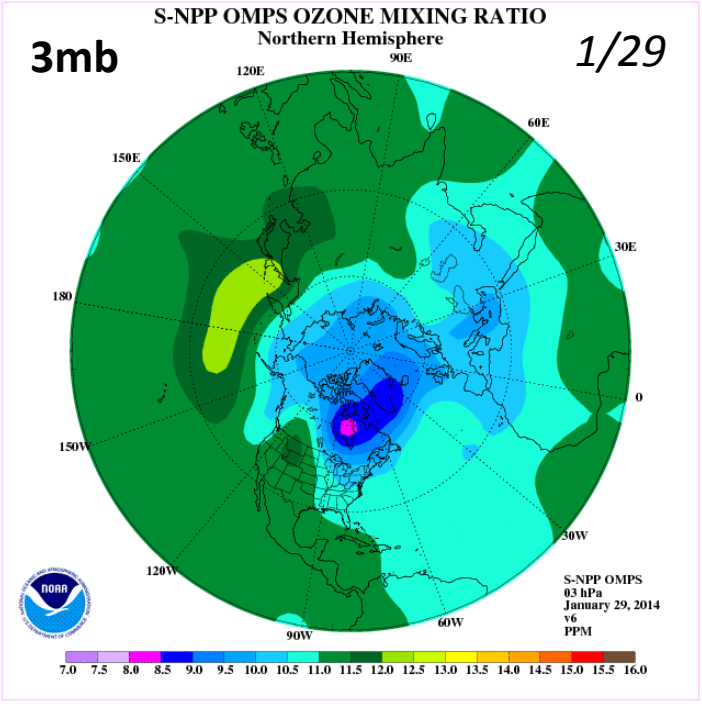
5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0

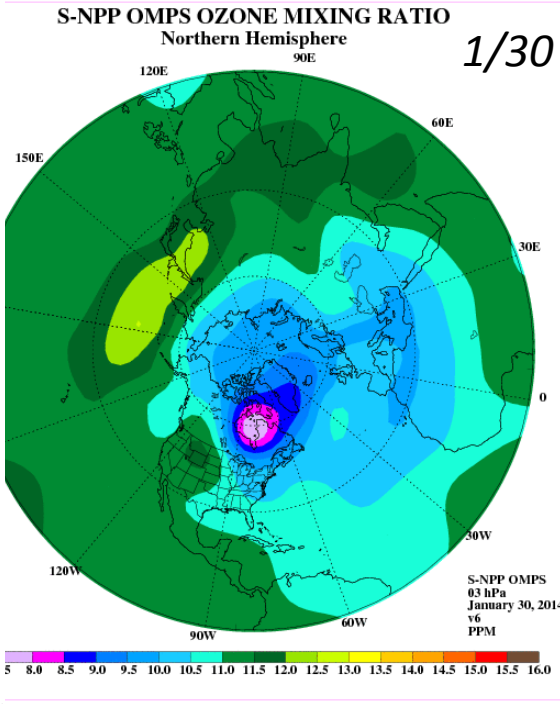

S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
2/01
120E
90E
60E
150E
30E
180
0
150W
30W
120W
90W
60W
S-NPP OMPS
02 hPa
February 1, 2014
v6
PPM
4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0

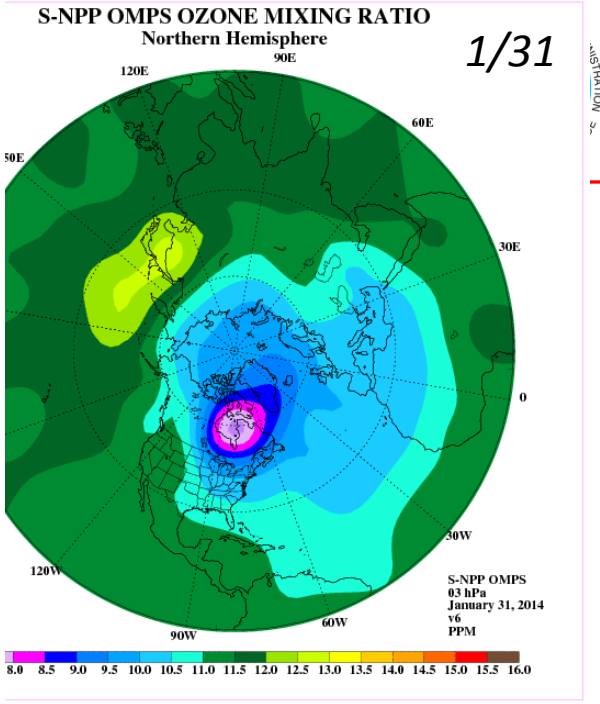

S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
2/02
120E
90E
60E
150E
30E
0
30W
120W
90W
60W
S-NPP OMPS
02 hPa
February 2, 2014
v6
PPM
5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0

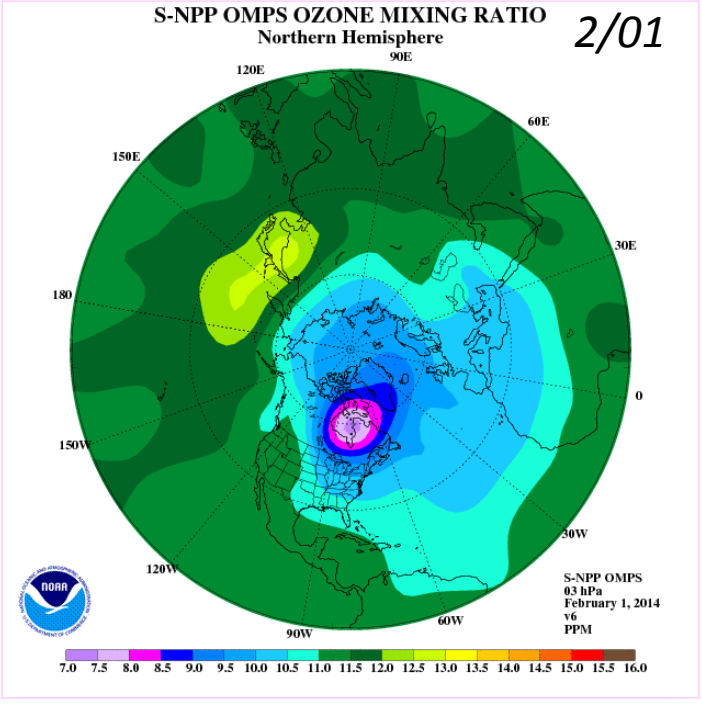

S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
2/03
120E
90E
60E
30E
0
30W
120W
90W
60W
S-NPP OMPS
02 hPa
February 3, 2014
v6
PPM
5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0

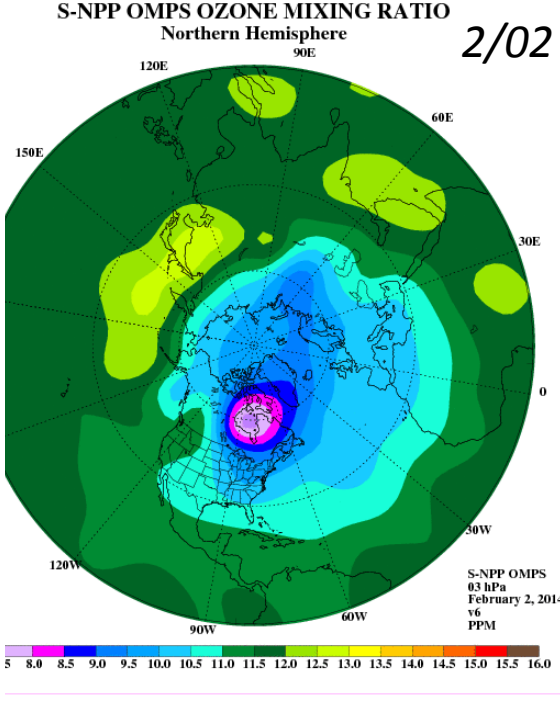
3mb

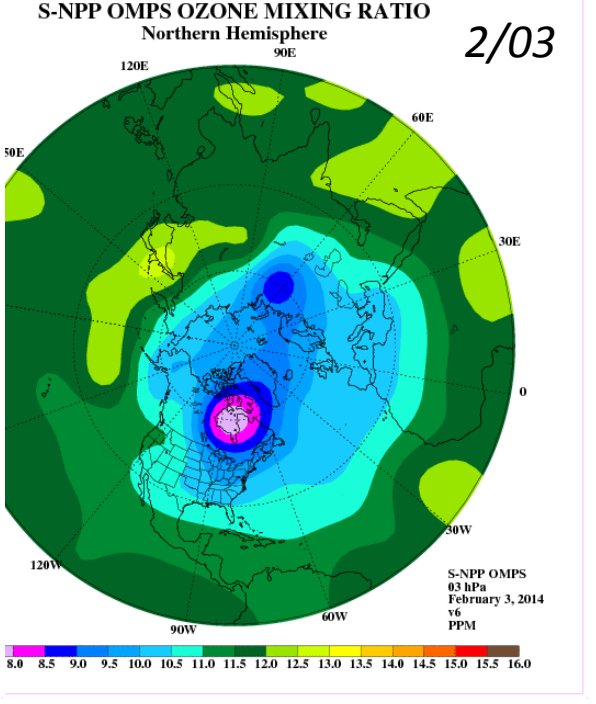

S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
1/29
90E
120E
60E
150E
30E
180
0
150W
30W
120W
60W
90W
S-NPP OMPS
03 hPa
January 29, 2014
v6
PPM
7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0


S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
1/30
90E
120E
60E
150E
30E
0
30W
120W
60W
90W
S-NPP OMPS
03 hPa
January 30, 2014
v6
PPM
5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0

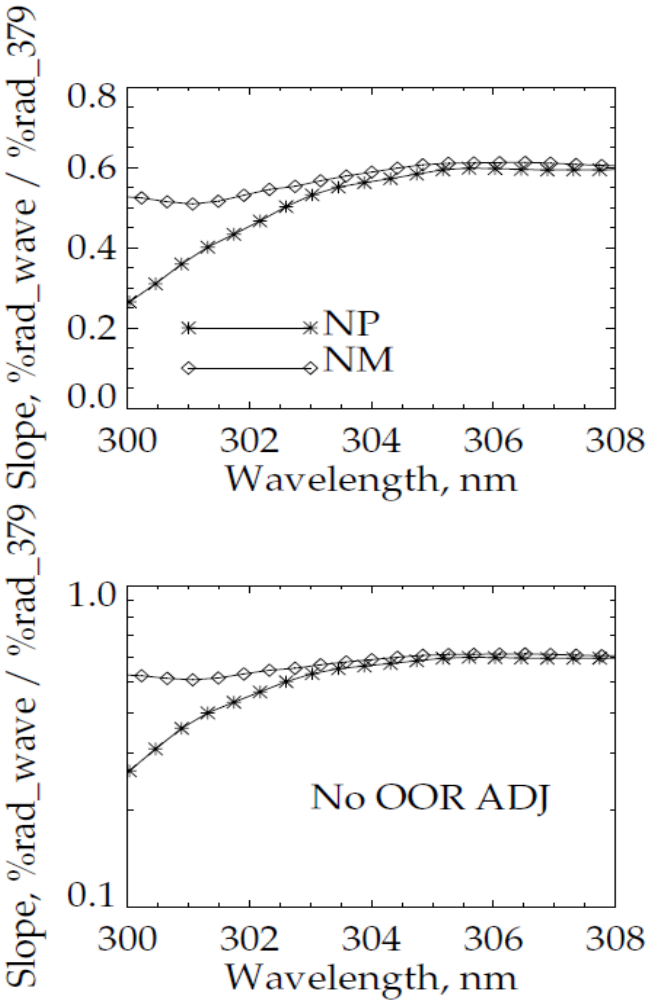

S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
1/31
90E
120E
60E
50E
30E
0
30W
120W
60W
90W
S-NPP OMPS
03 hPa
January 31, 2014
v6
PPM
8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0

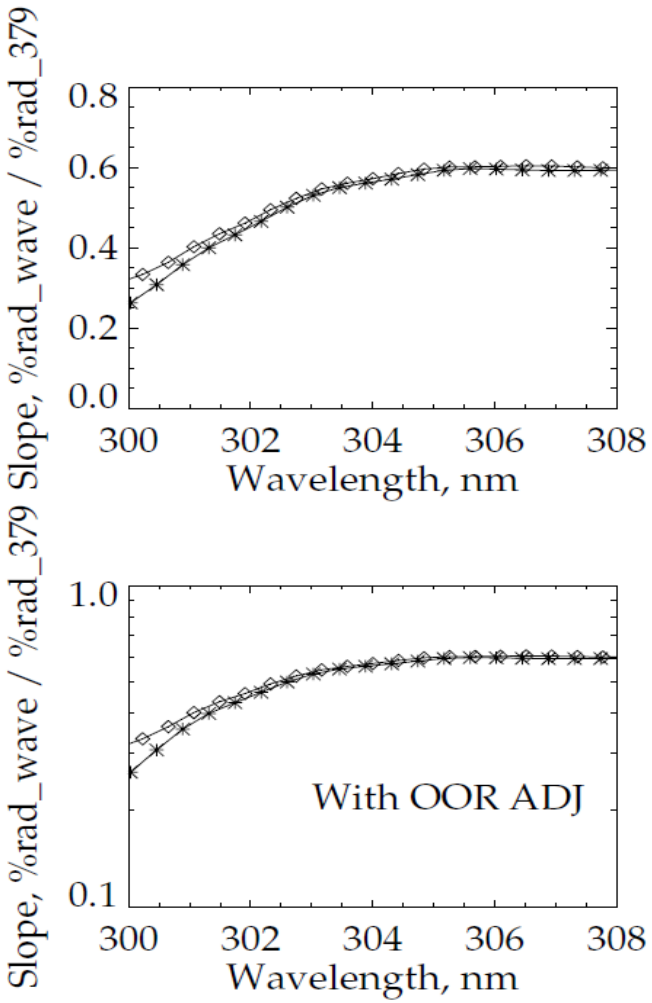

S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
2/01
90E
120E
60E
150E
30E
180
0
150W
30W
120W
60W
90W
S-NPP OMPS
03 hPa
February 1, 2014
v6
PPM
7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0


S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
2/02
90E
120E
60E
150E
30E
0
30W
120W
60W
90W
S-NPP OMPS
03 hPa
February 2, 2014
v6
PPM
5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0


S-NPP OMPS OZONE MIXING RATIO
Northern Hemisphere
2/03
90E
120E
60E
50E
30E
0
30W
120W
60W
90W
S-NPP OMPS
03 hPa
February 3, 2014
v6
PPM
8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0

Stray Light Correction - NM





CAL SDR Transition

GRAVITE OMPS SDR Cal Integration Design Review

April 17, 2014

Pat Purcell,
JPSS DPES SEI& T Manager

Documentation

- ATBD – updated.
- Users' Manual – optional
- Error Budget – updated

Other Improvements

- DR 7315 (Revise bias correction to remove negative smear in NM) – CCR 1672- LUT update, out of cycle implementation expected by first week of July
- DR 4818 (Revise bias correction to remove negative smear in NP) - CCR 1777 – LUT update, out of cycle implementation expected by first week of July
- DR 7630 (Revise the incorrect use of 94 as spatial bin size in NP bias calculation) - CCR 1798 – under regressing testing. Expected AERB approval on June 4, 2014 and implementation in 8.6
- DR 7014 (Modification of CDFCB dark fields)- Work under PCR – Expected implementation for 8.5
- DR 7253 (Field modifications in the CDFCB for OMPS NP dark orbit and id information) - Work under PCR – Expected implementation for 8.5
- DR 7613 (Obsolete QF for NM) - CCR 1766 – approved May 28
- DR 7614 (Obsolete QR for NP) - CCR 1767- approved May 28

Path Forward

- Suomi NPP
  - Instrument and SDR performance monitoring, characterization, and improvement.
  - Support instrument cal/val (e.g., orbit adjustment, anomaly resolution)
  - Complete documentation (Users' Guide)
  - SDR software improvements
    - Stray light correction
    - Wavelength registration
  - Transition CAL SDR operation to GRAVITE.
- JPSS J1
  - Analyze TVAC data and derive LUT for J1.
  - Develop science code for J1
    - More wavelength and higher data rate for EV SDR
    - New algorithm for CAL SDR
  - Test data (high resolution data from S-NPP)

Summary

- With additional accomplishments since December 2013, the OMPS nadir EV SDRs are found to have
  - Characterized for on-orbit sensor performance
  - Defined SDR product uncertainties over a range of representative conditions
  - Adjusted calibration parameters accordingly, pending soft calibration that can be applied to validated SDRs
  - Plan for later improved version
  - Strong versioning with documentation
  - Been ready for use in applications and scientific publication
- Request to declare that OMPS nadir EV SDR be Validated

Delta Review for SNPP OMPS SDR Earth View Products

Fuzhong Weng

OMPS SDR Team

NOAA/NESDIS/STAR

August 17, 2015

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

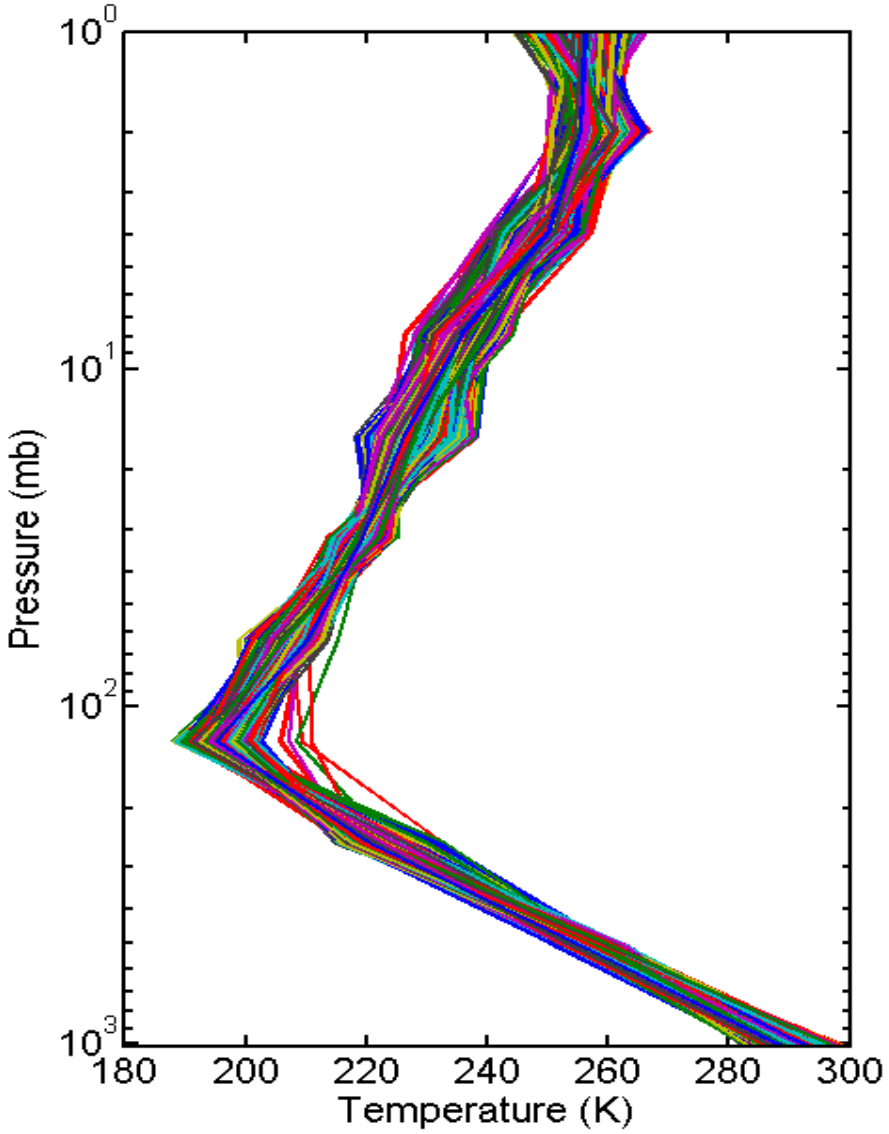
Building on-Orbit Truth for Estimating OMPS Earth View SDR Accuracy

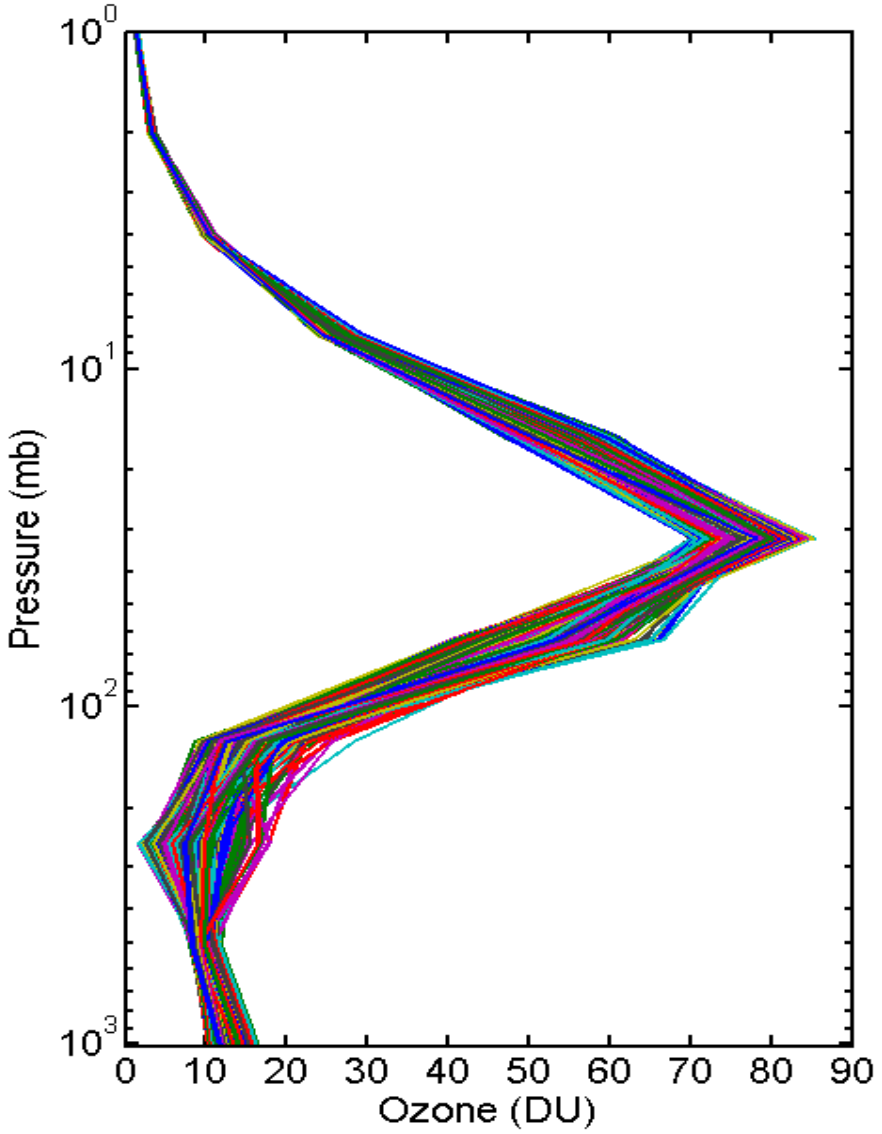
- Develop the “truth” simulated from the forward radiative transfer model at OMPS EV location (Macropixel)
- Radiative transfer model must include comprehensive scattering and absorption processes at UV regions
- Accurate understanding of atmospheric and surface status at OMPS EV location.
- The difference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

OMPS EV Radiative Transfer Simulations

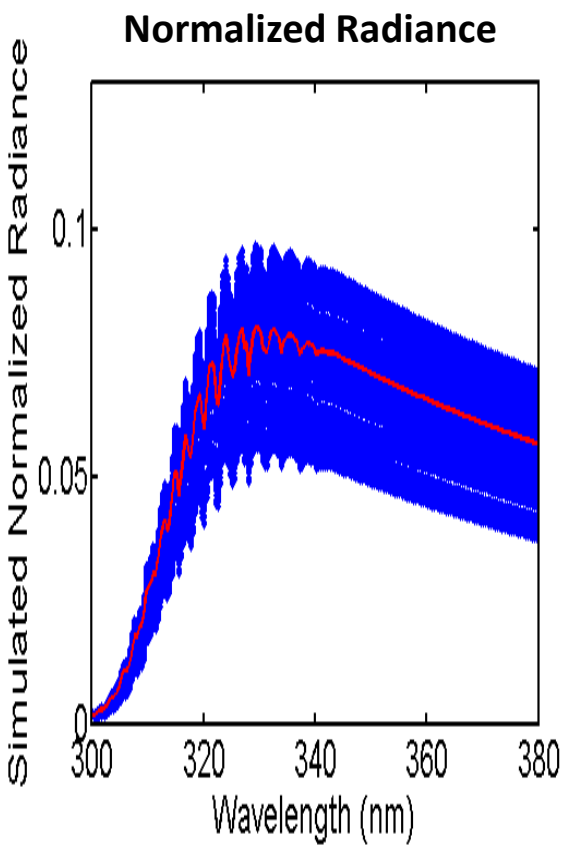
- TOMRAD-2.24: TOMS (Total Ozone Mapping Spectrometer) Radiative Transfer Model
  - Rayleigh scattering atmosphere with ozone and other gaseous absorption
  - Spherical correction for the incident team
  - Molecular anisotropy and Raman scattering
- Inputs to TOMRAD
  - Wavelength, solar and satellite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

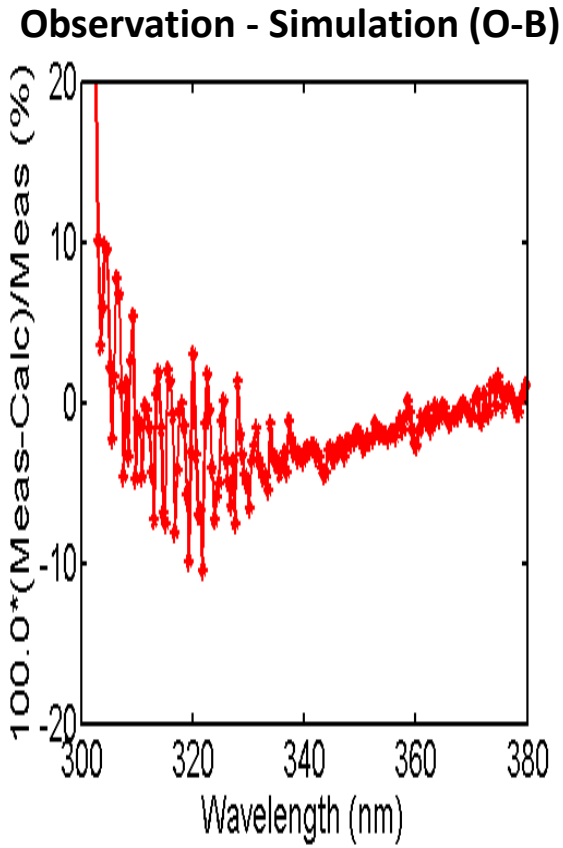
Co-located OMPS/MLS Temperature and Ozone Profiles

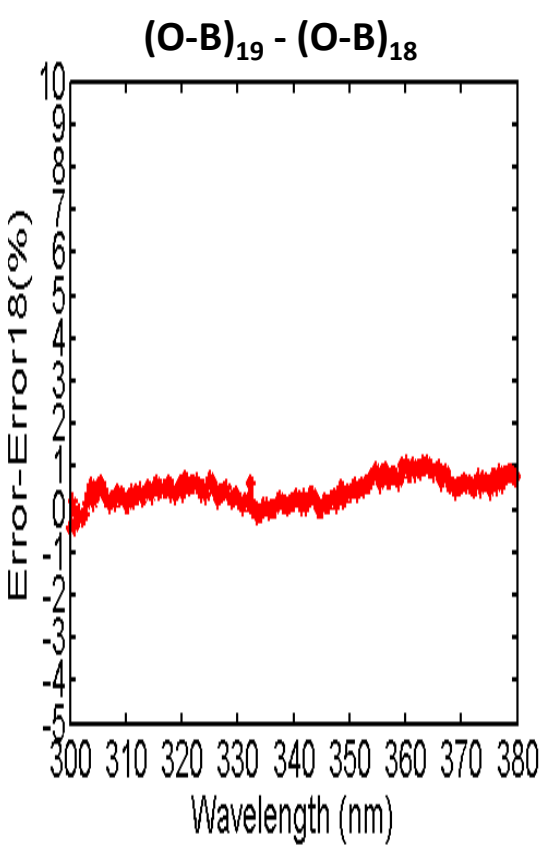




Simulated Normalized Radiance at OMPS Macropixel Position 19

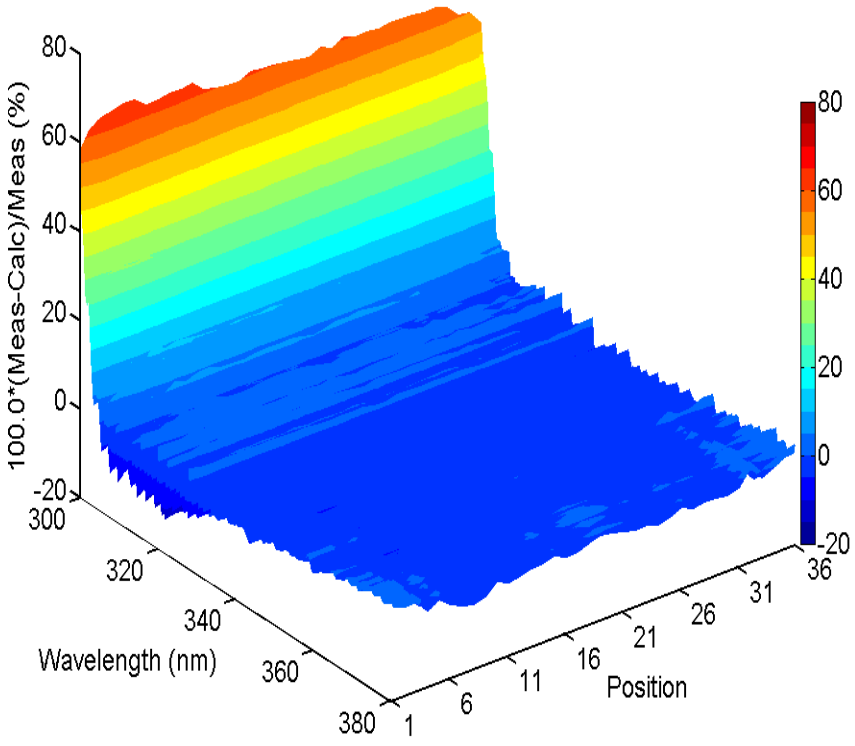




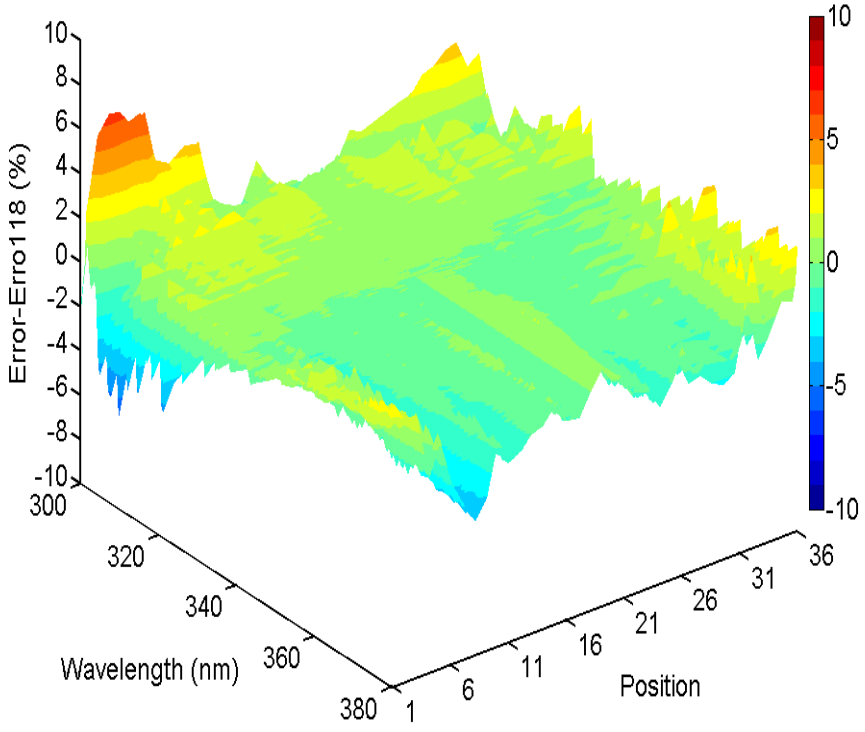


Observation minus Simulation (O-B)

Relative Error

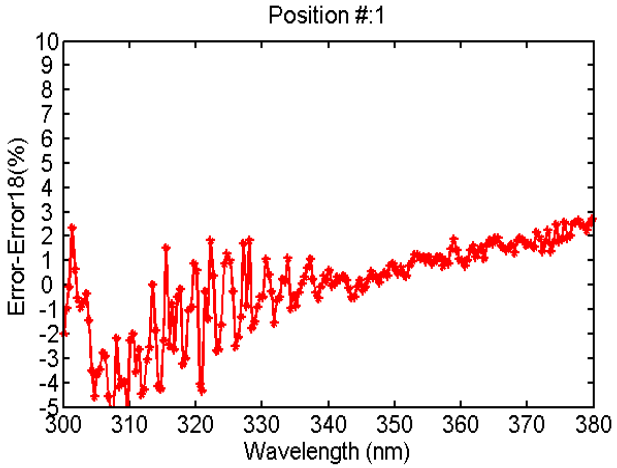


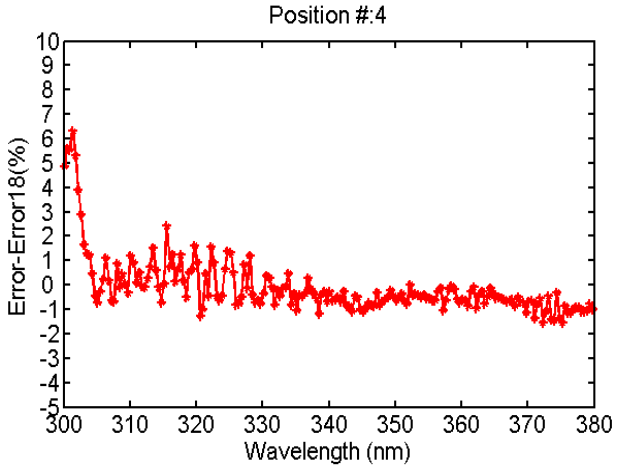
Relative error wrt to Position 18 (nadir)

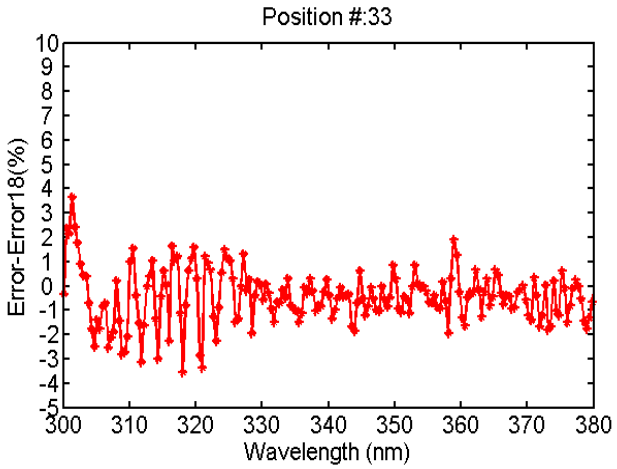


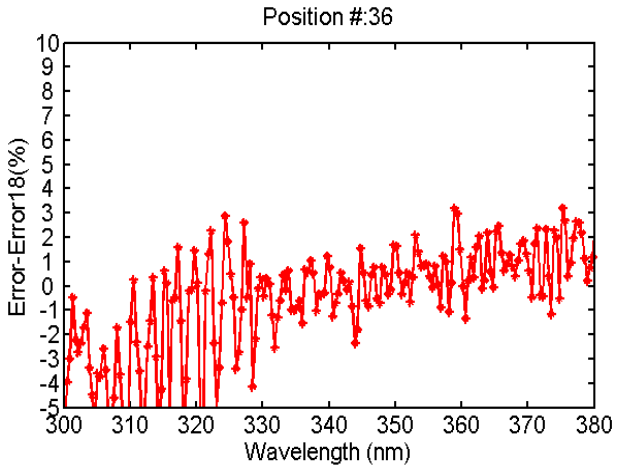
The bias in cross-track direction is generally less than 2% except at shorter wavelengths where simulations may become less accurate due to complex scattering process. The bias is also larger in side pixel locations

Observation minus Simulation at Wing Positions



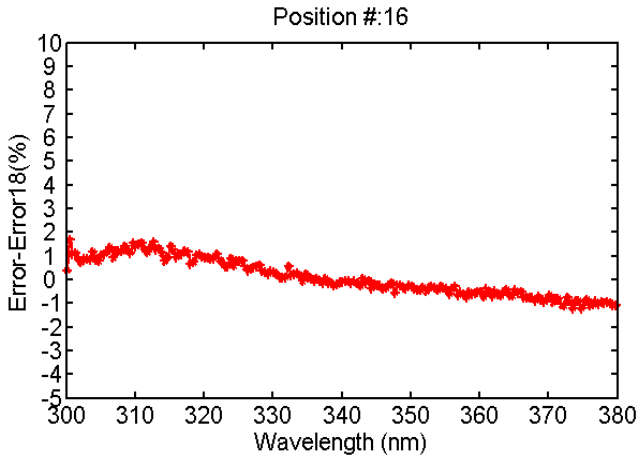


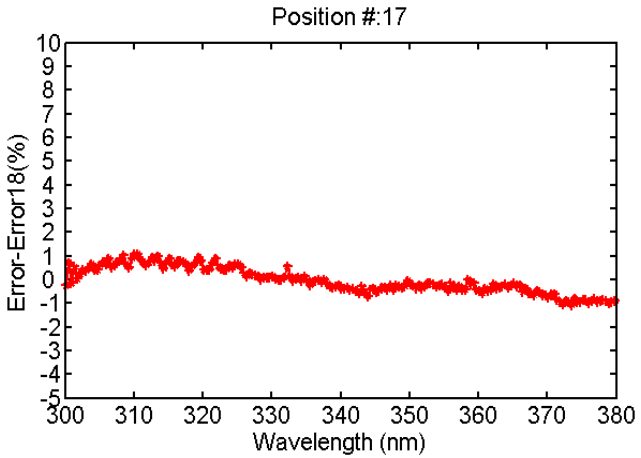


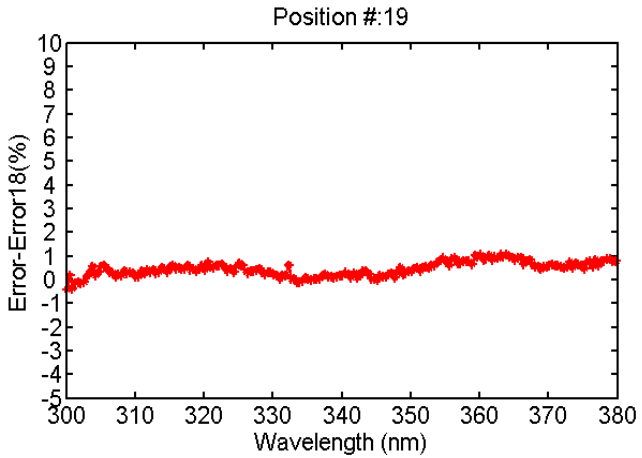


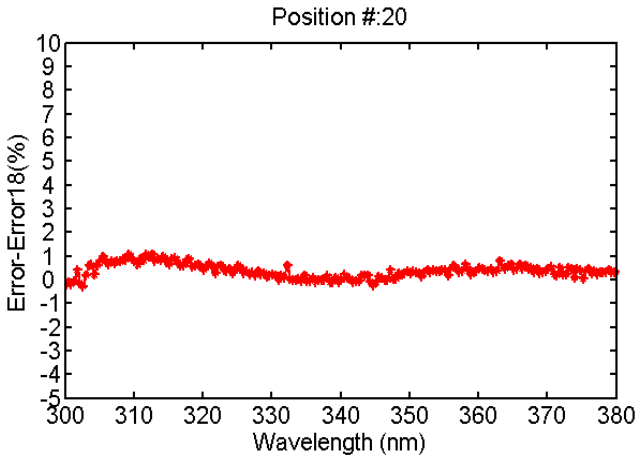
The biases at far wing positions (1-4 and 33-36) are out of specifications at wavelengths less than 320 nm. The causes can be related to complex RT processes, etc.

Observation minus Simulation near Center



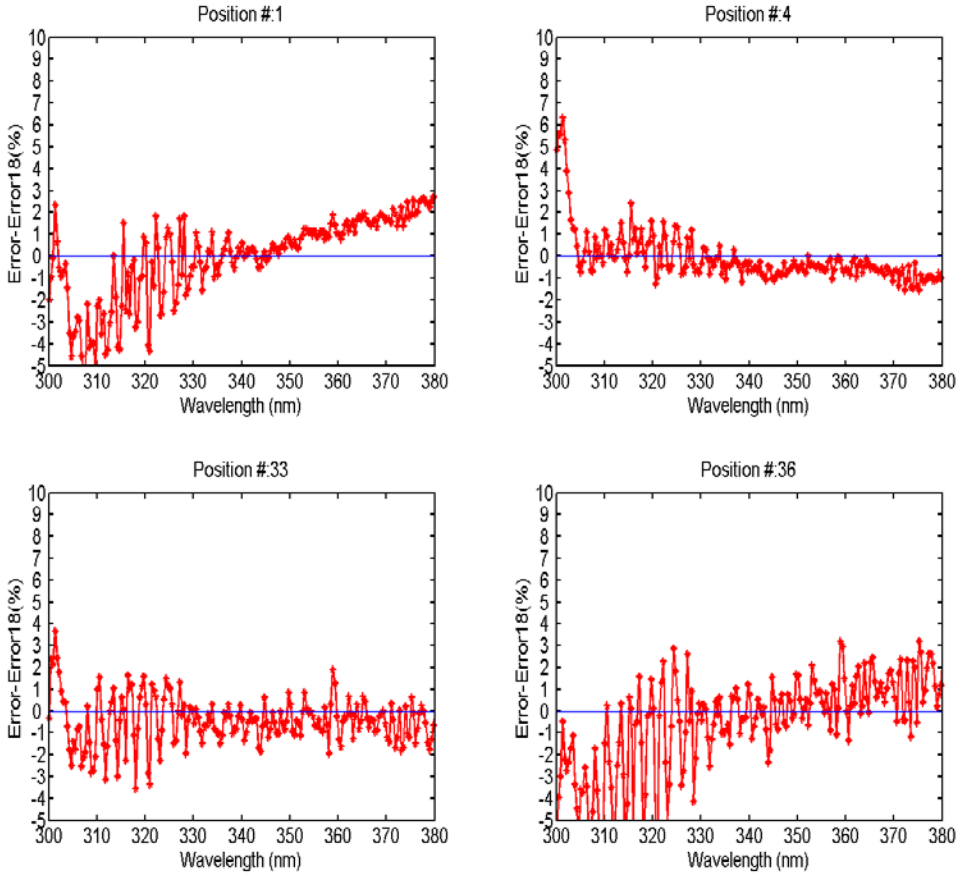


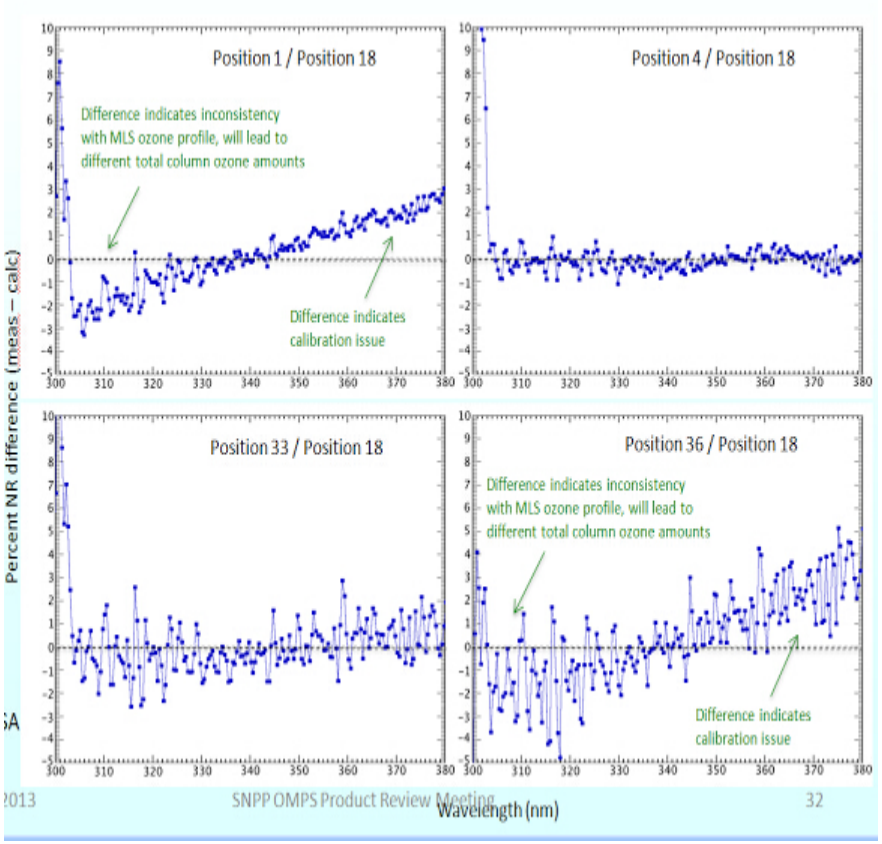




The biases near center all meet specifications at all wavelengths

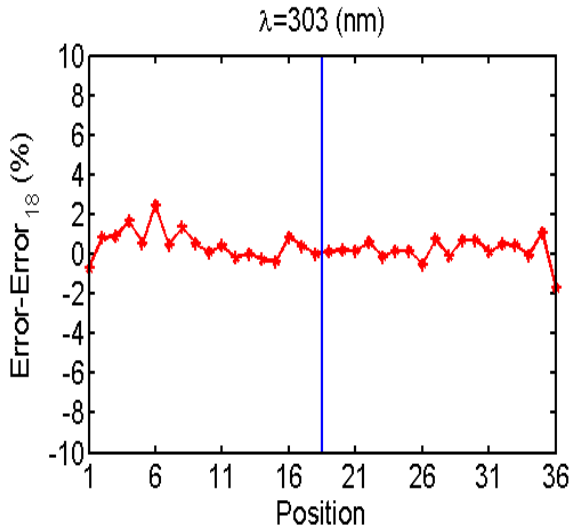
Observation minus Simulation (NOAA vs. NASA)

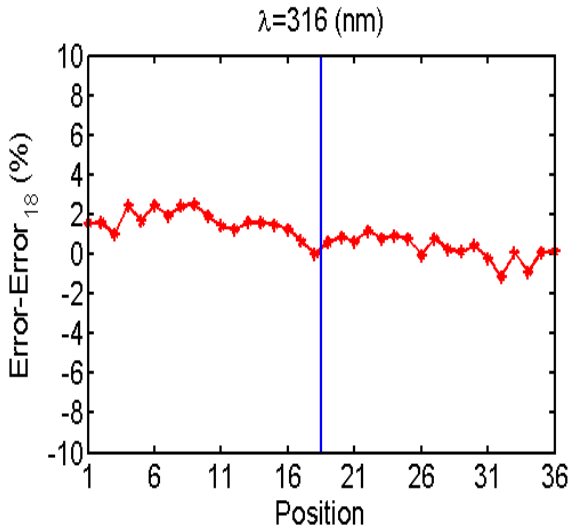


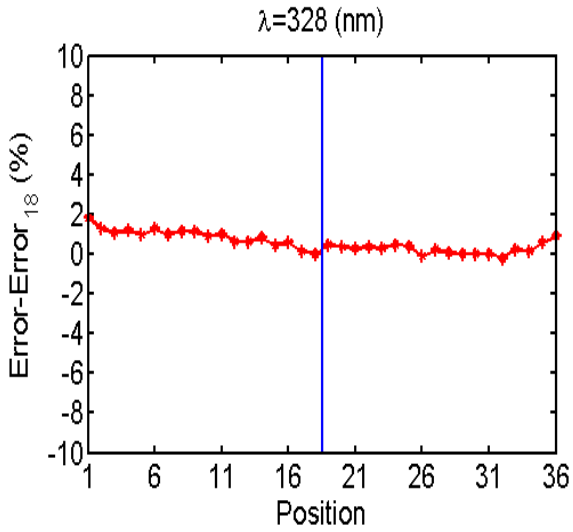


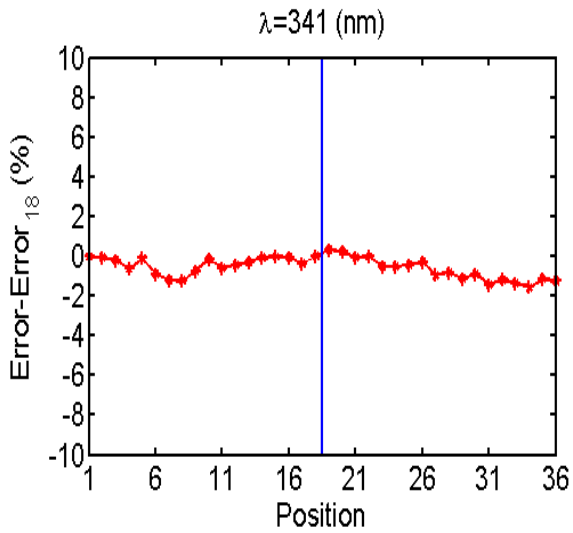
The bias characteristics simulated from NOAA (left red curves) and NASA (left blue curves) are consistent in cross-track direction and wavelength domain.

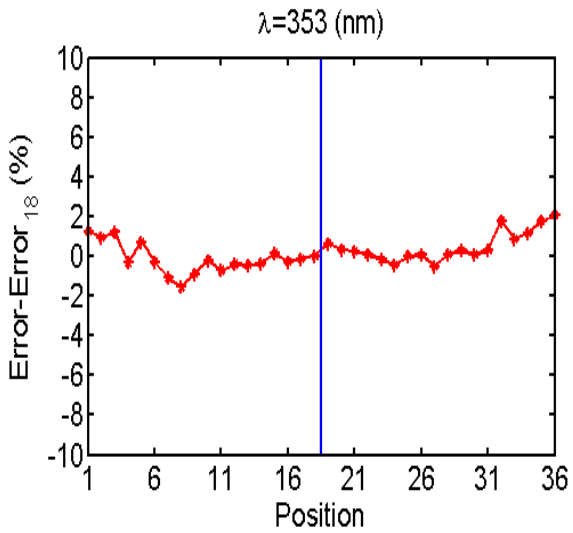
Error vs. Scan Position

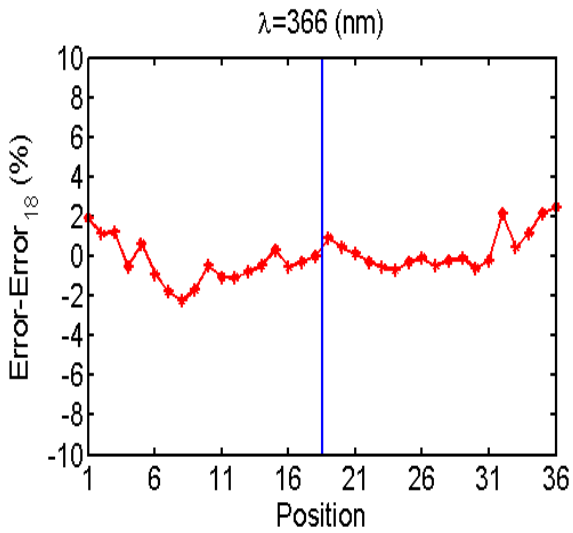






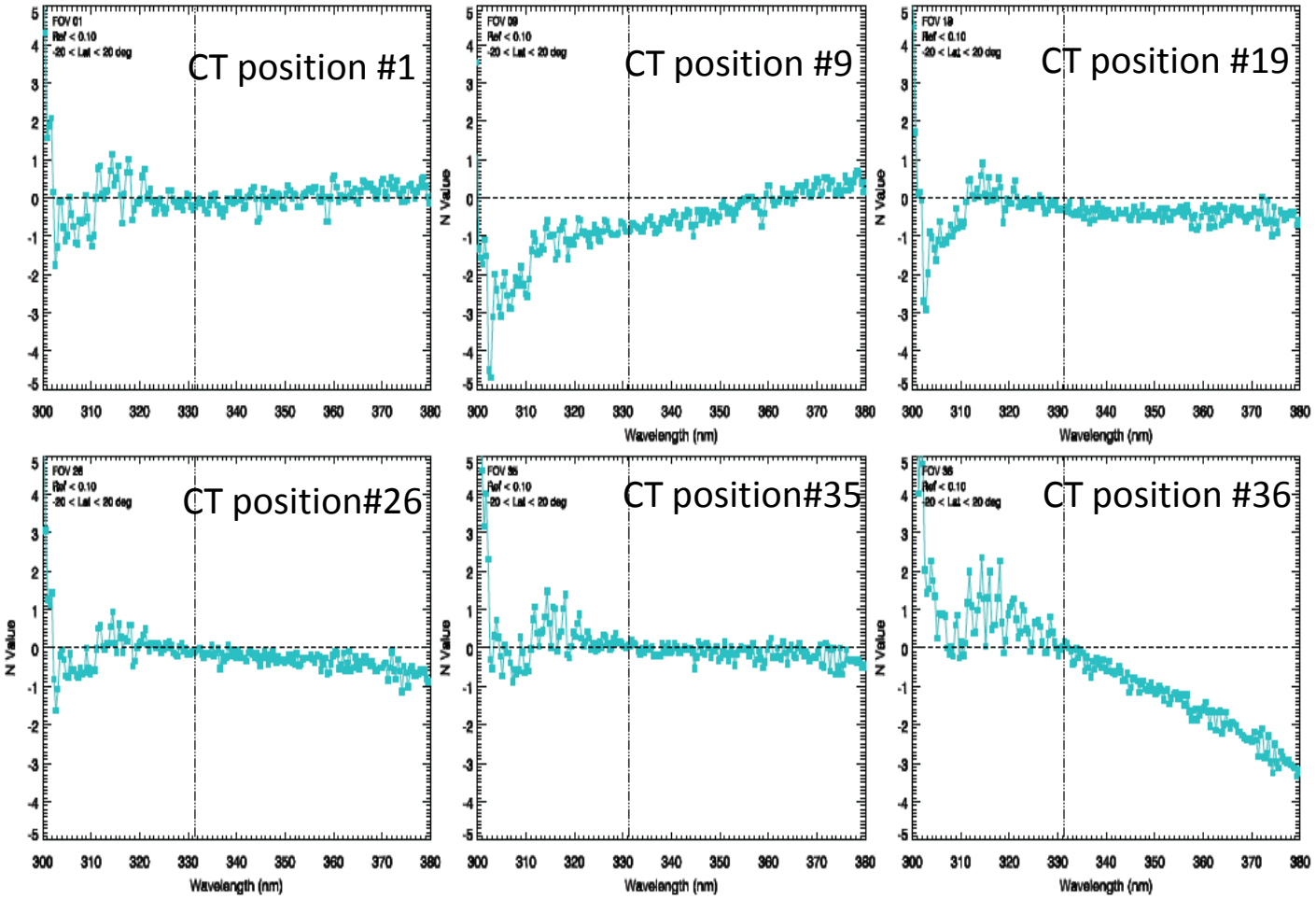






Cross-Track Difference for Earth View N-Value or Radiance

Wavelength-dependent Cross-Track Normalized Radiance Error Meets Requirement



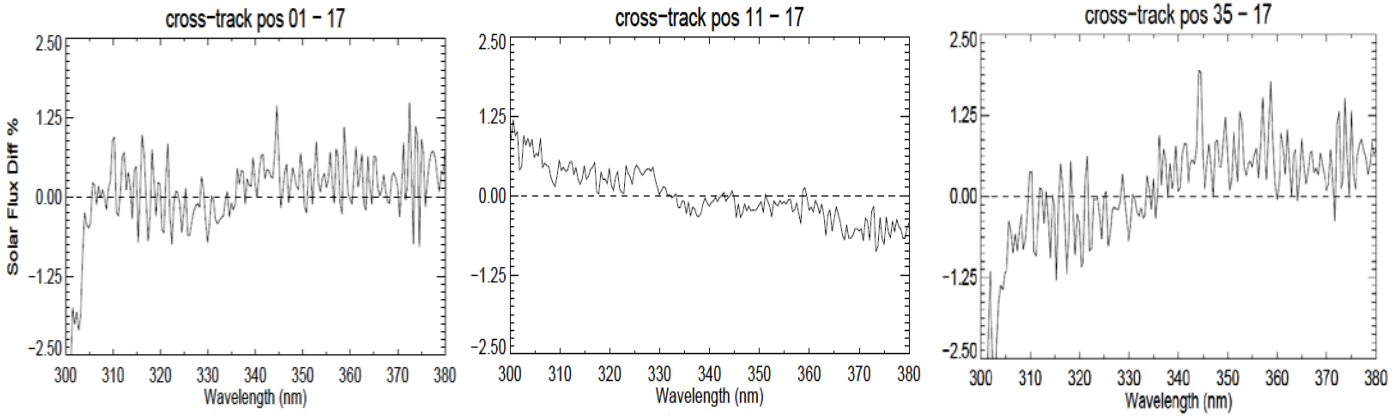
- Normalized radiance error is percent difference between OMPS and MLS via. TOMRAD
- Figures shows the errors for 6 different cross-track (CT) positions
- Errors were minimized < 2% for most of the channels.
- Except ion is CT#36 on wavelength > 360 nm. Soft calibration are being implemented to eliminate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

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

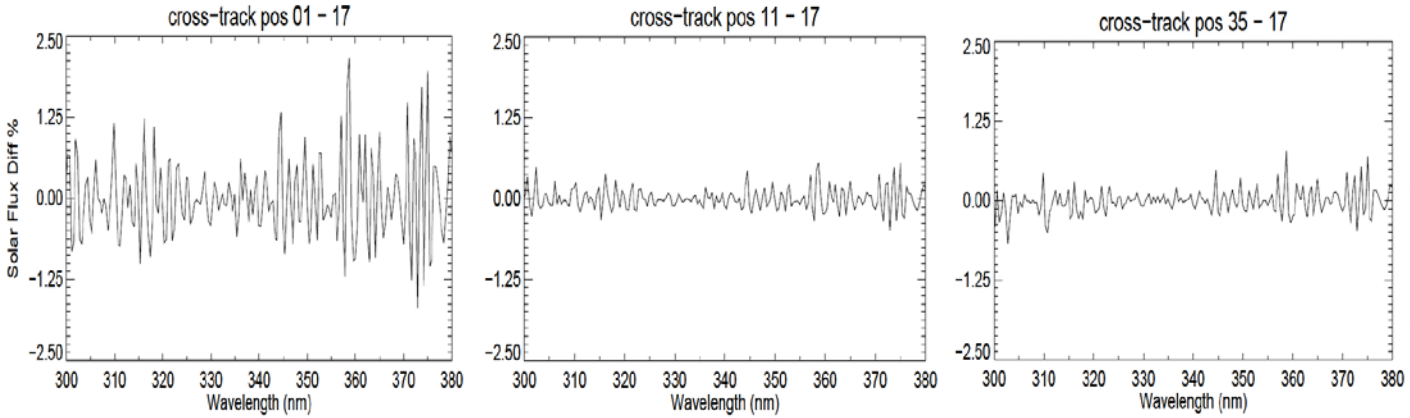
Solar Irradiance (Flux) Cross-Track Difference for NM

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

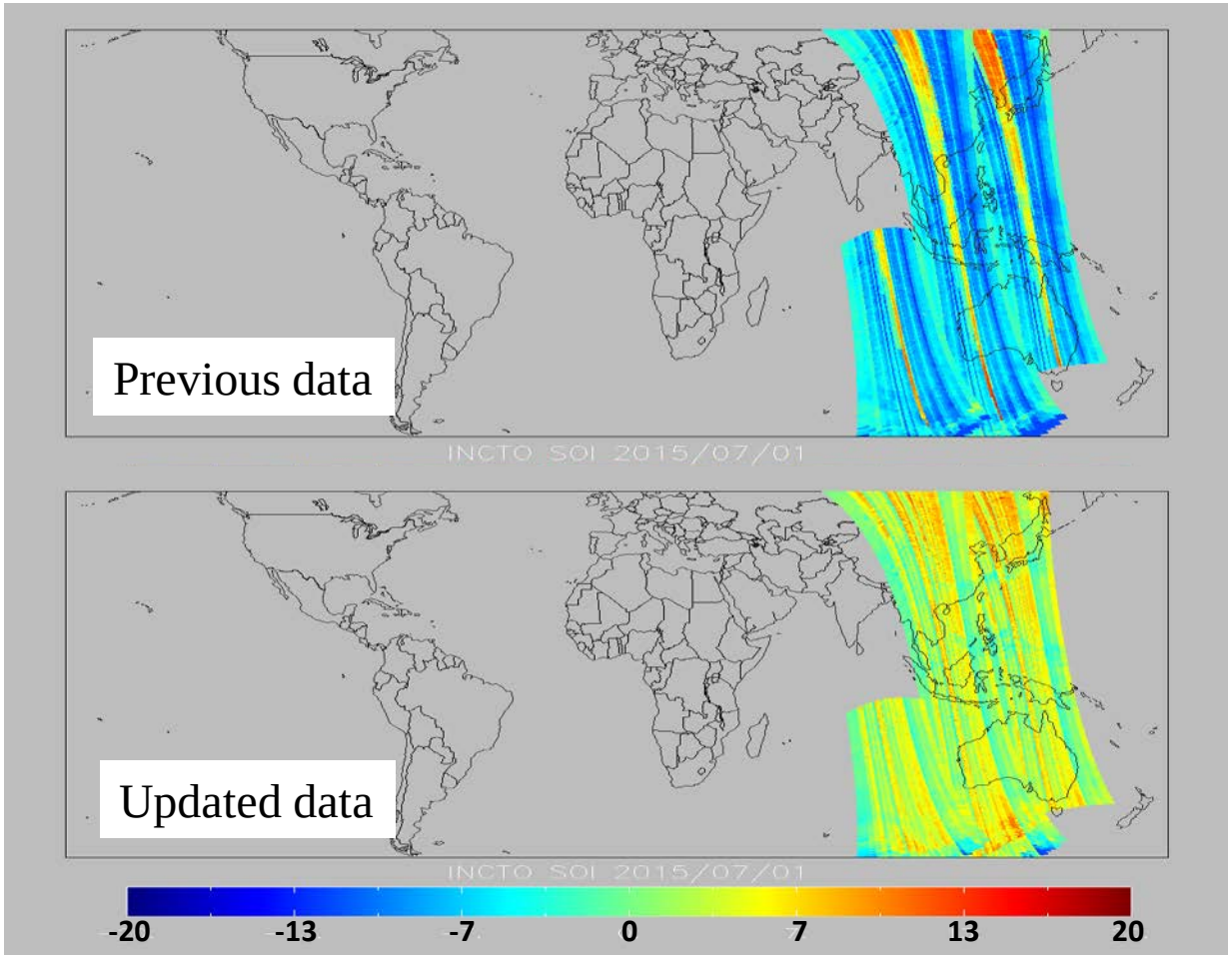
- Updated wavelength and solar flux LUTs have eliminated cross-track irradiance error .

- 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)

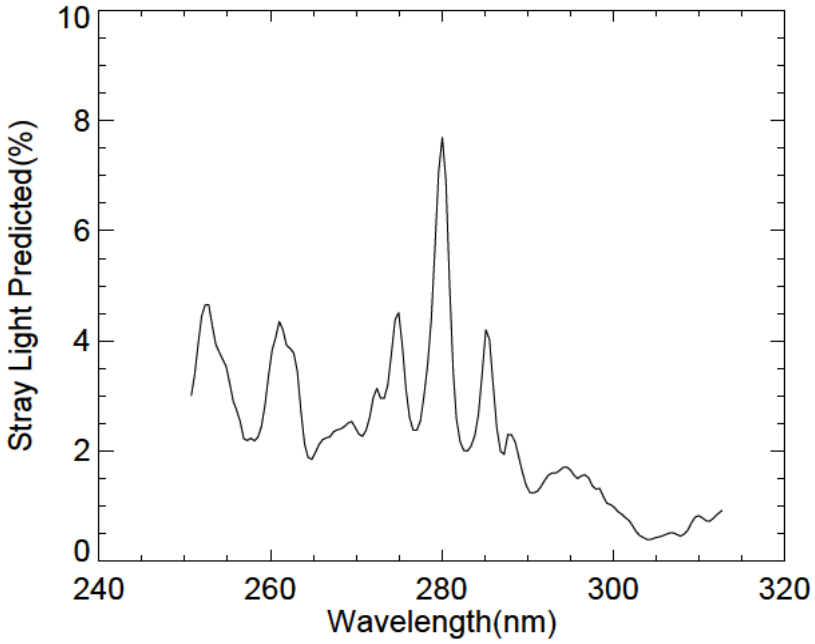
SO2 Index Comparison before and after Wavelength Update



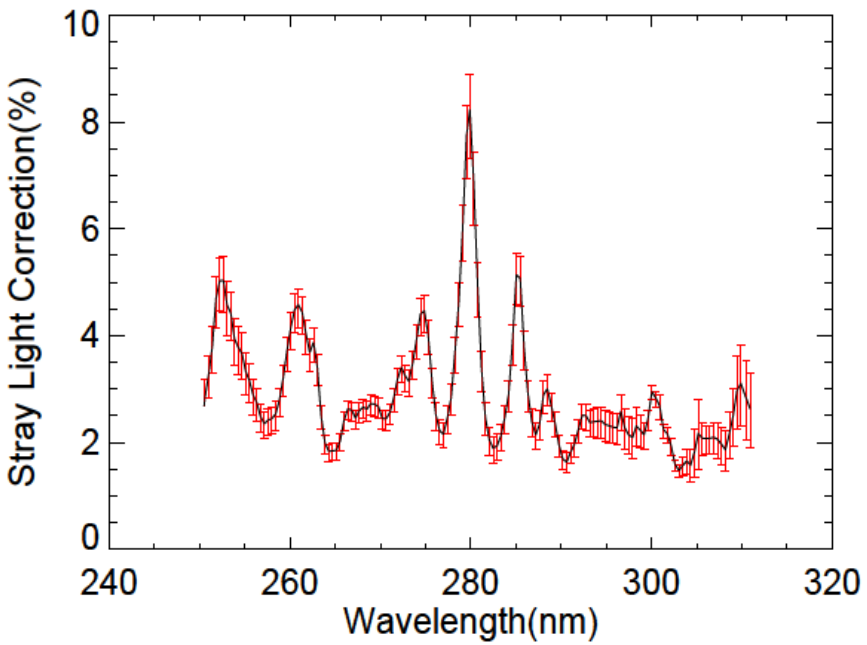
- SO2 index cross-track variation was minimized from -15 ~ 13 to 6~7.
- Residual error are caused by EDR V7 TOZ algorithm, that inappropriately exaggerates the impact of wavelength variation.
- The residual error can be corrected by EDR V8 algorithm with an appropriate n-value adjustment.
- Data comes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

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

Prelaunch predicted SL contamination



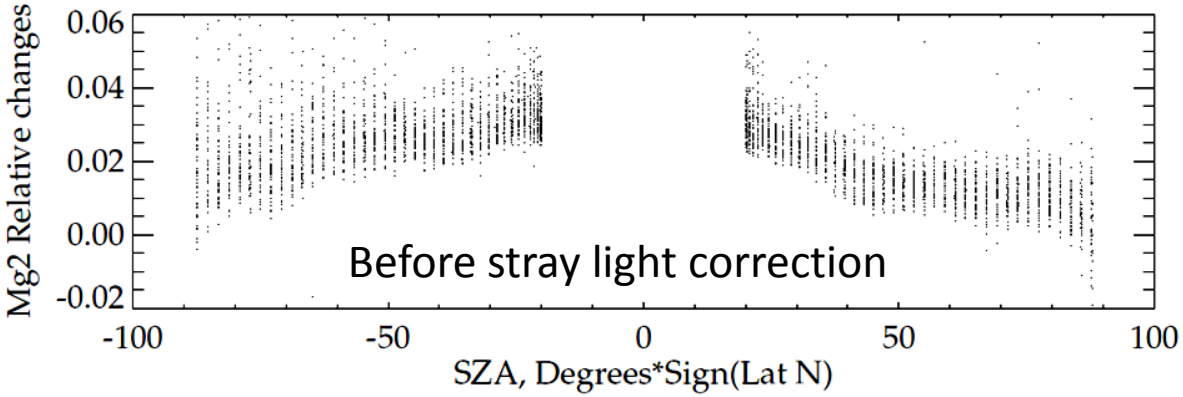
Orbital 19048 corrected SL contamination

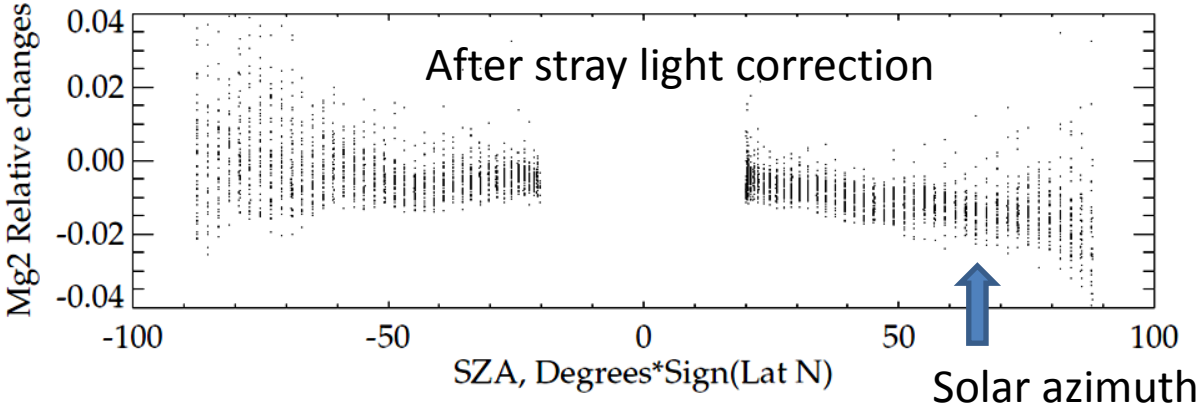


Example of orbital stray light correction vs. prelaunch predicted value shows that the orbital stray light correction is adequate across all the wavelengths

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

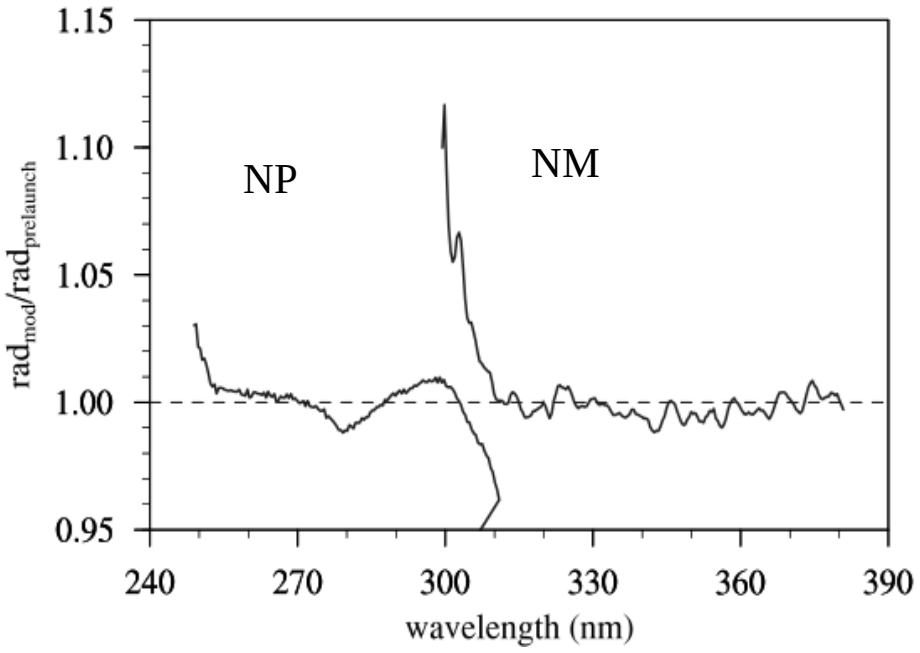
The errors are within ±2% for the most of the channels after stray light correction was applied.

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

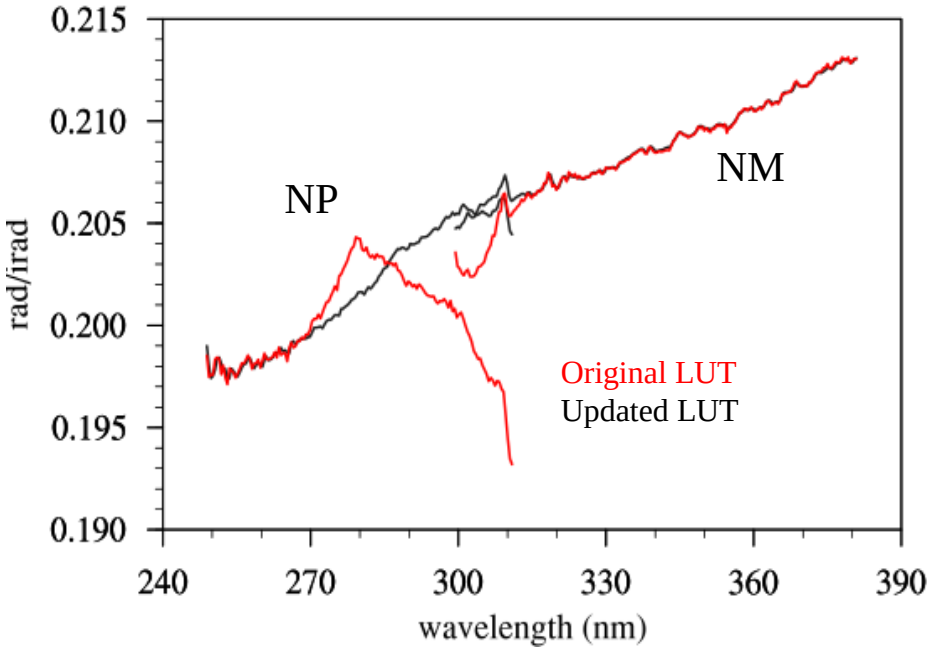
Additional Improvement in Radiometric Calibration (1/2)

- 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



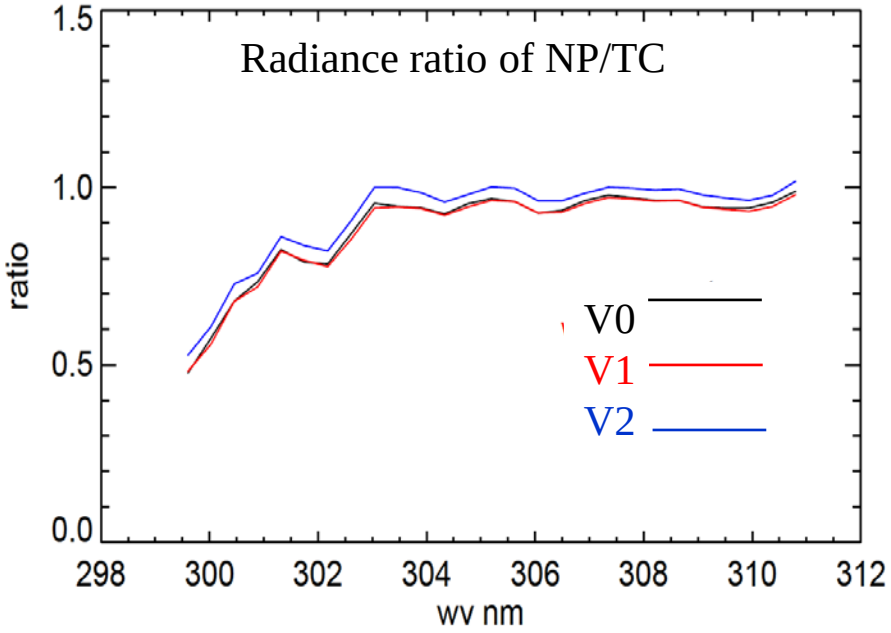
Normalized Radiance: rad/irad

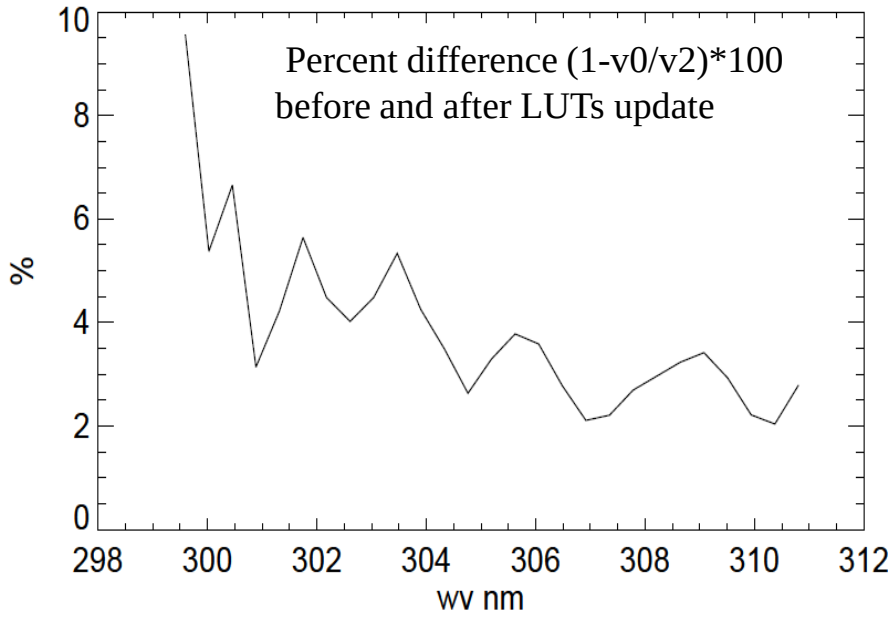


Updated radiance coefficient LUTs improve normalized radiance consistency up to ~10% between NP and NM in 300-310 nm.

Additional Improvement in Radiometric Calibration (2/2)

Improvement in the Spectral Range of 300 - 310 nm

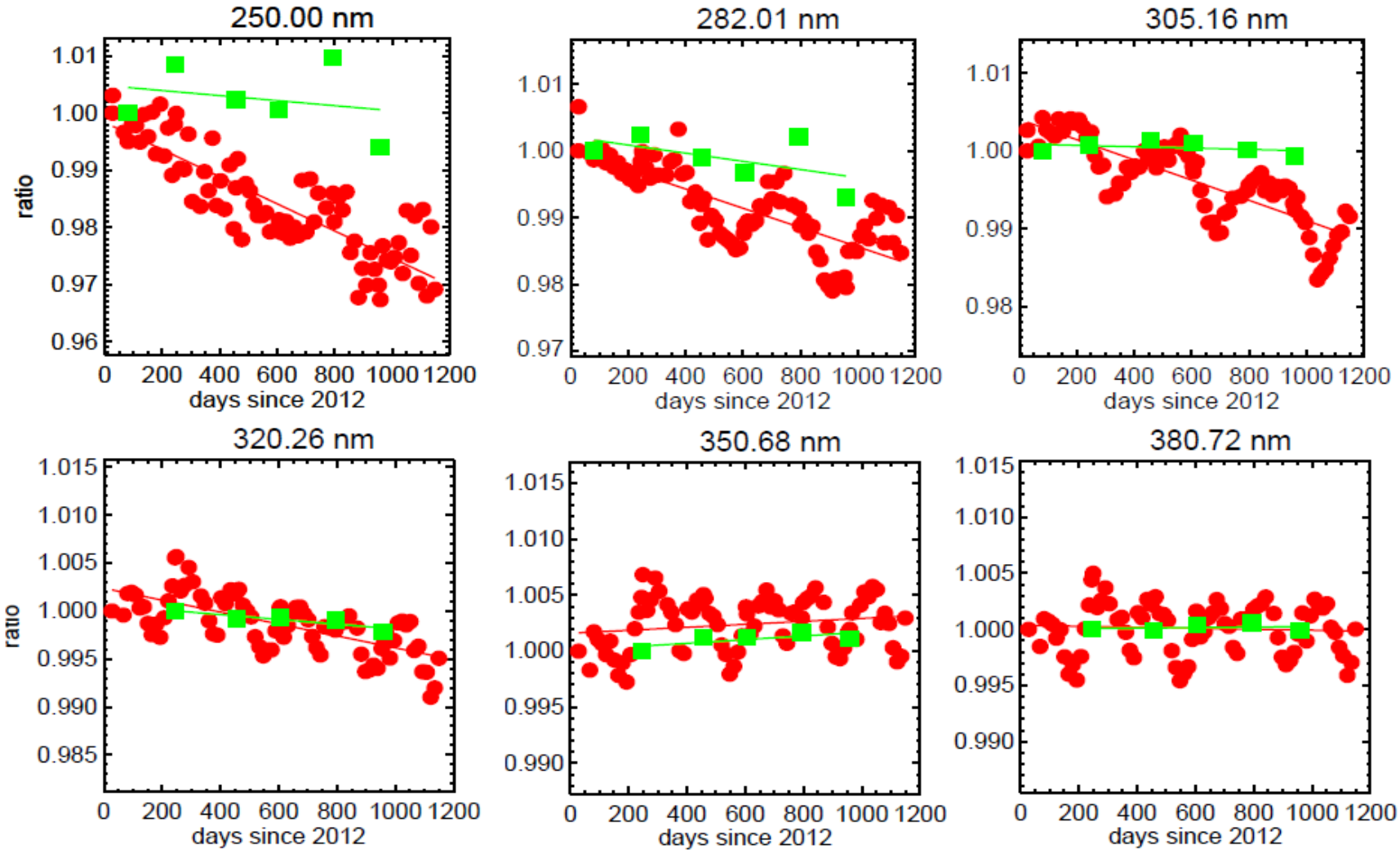




- The improvement was validated via SDR products from both NP and NM.
- EV Radiance from NP and NM are collocated spatially and spectrally
- 1174 granules (globe coverage) were used for validation
- Radiance is computed via old LUTs (V0), updated wavelength & day one solar (V1) and updated wavelength,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

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

Monitoring OMPS Solar Diffuser Degradation

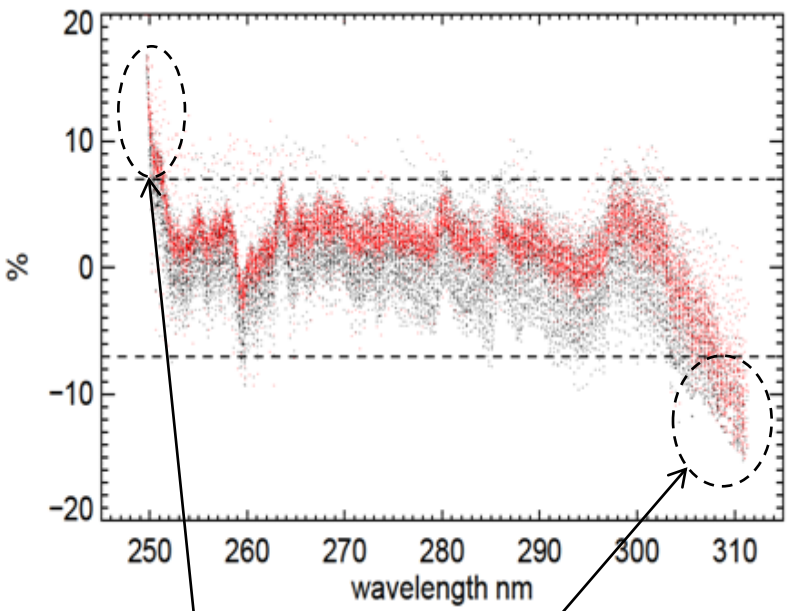


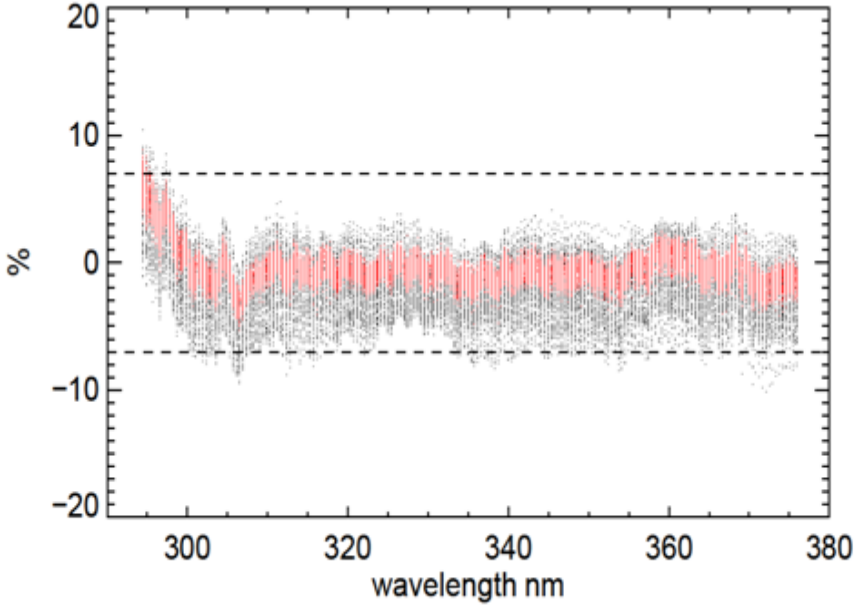
Sensor optical degradation < 1.0 %.

OMPS Solar Irradiance Errors Measured from Solar Diffusers

Errors from work diffuser measurements

Errors from Reference diffuser measurements

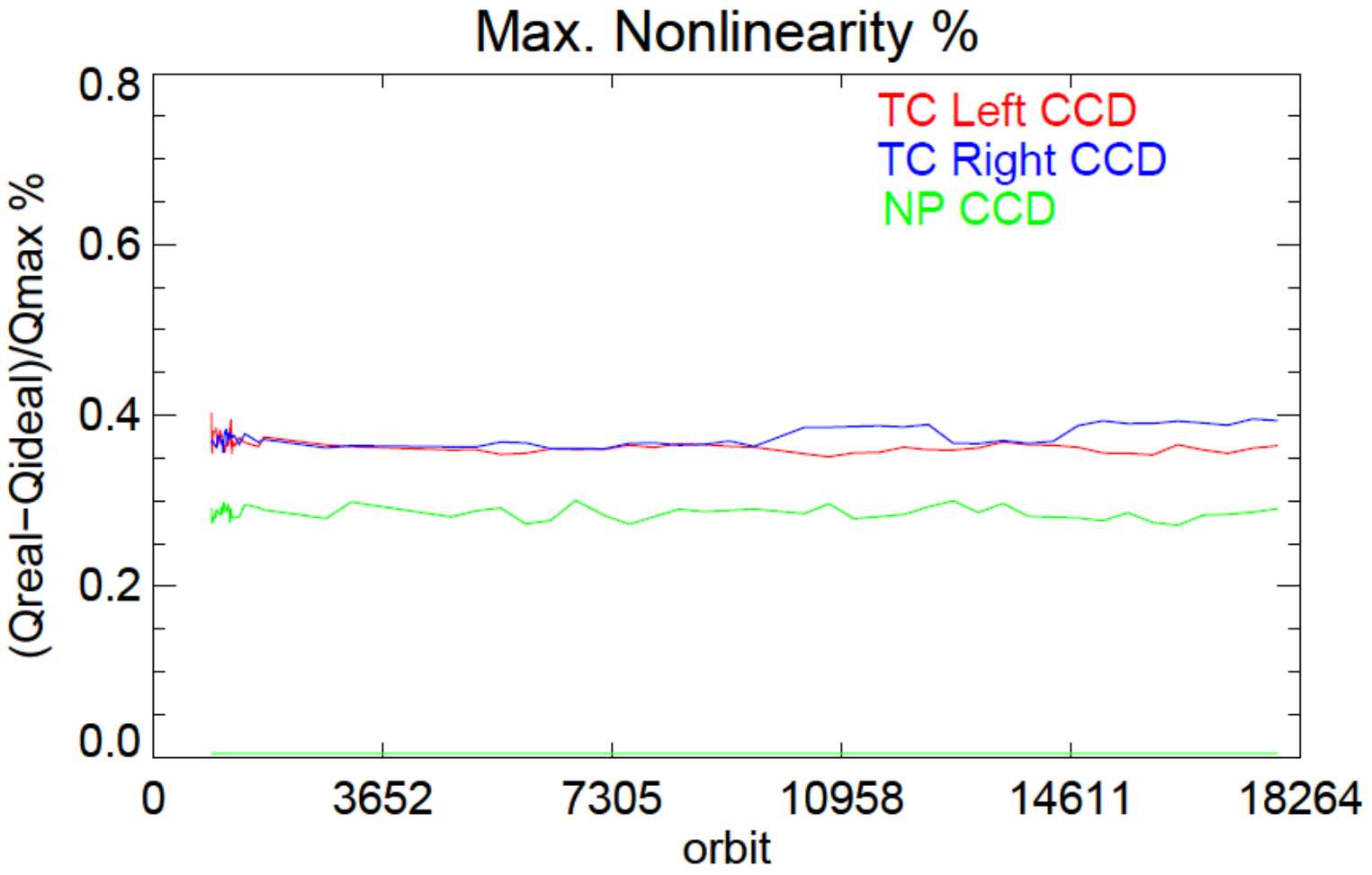




Channels with large noise

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

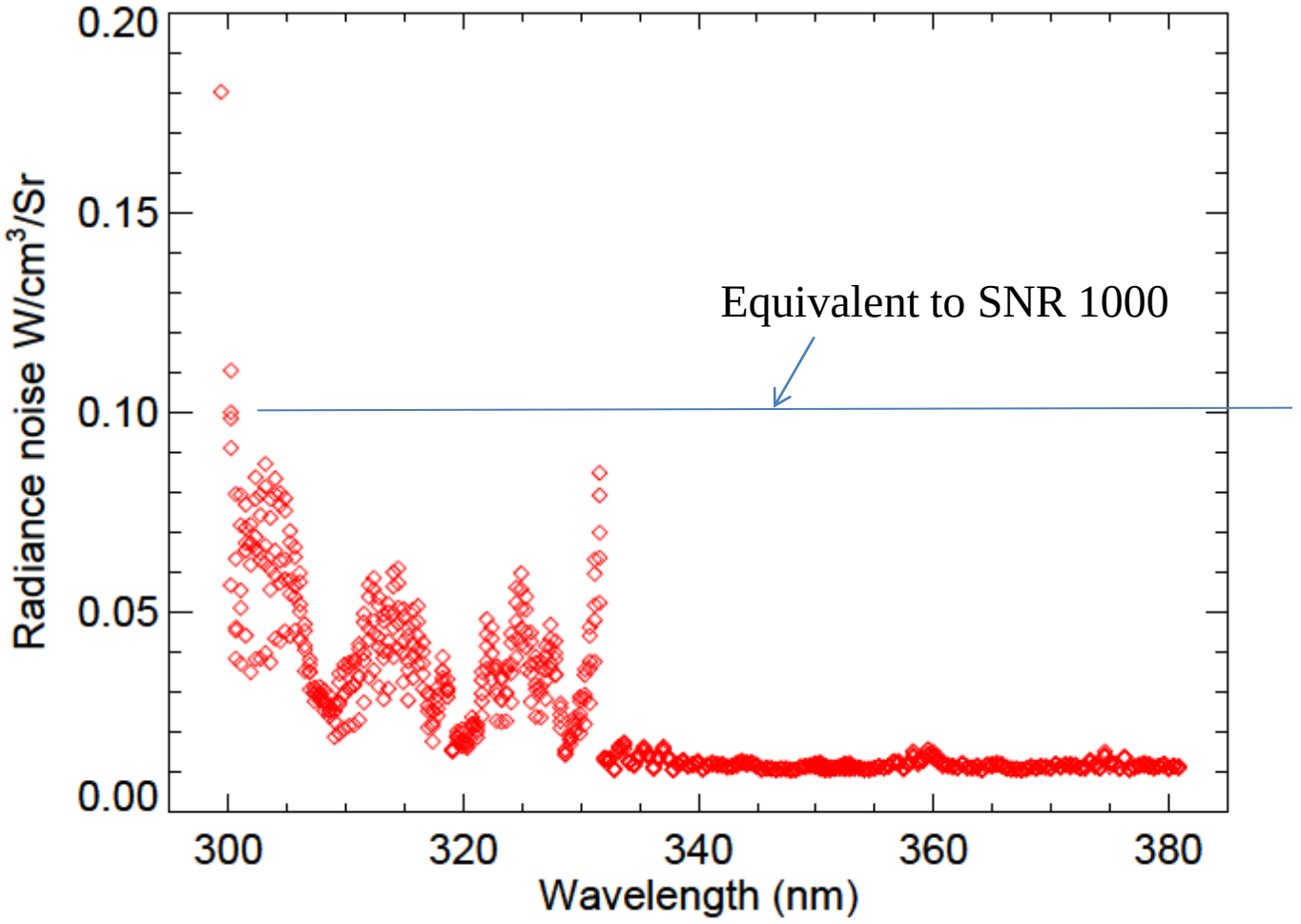
OMPS System Nonlinearity



System nonlinearity meets the requirement of 2%.

Sensor Signal to Noise Ratio from EV data

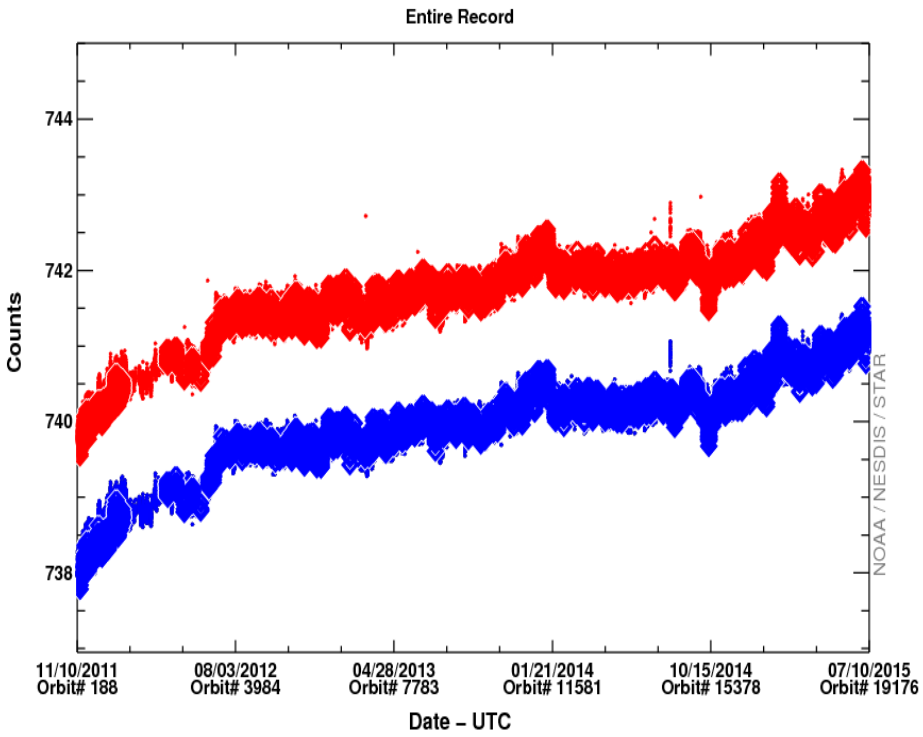
Data collected from 1178 EV granules on July 1, 2015



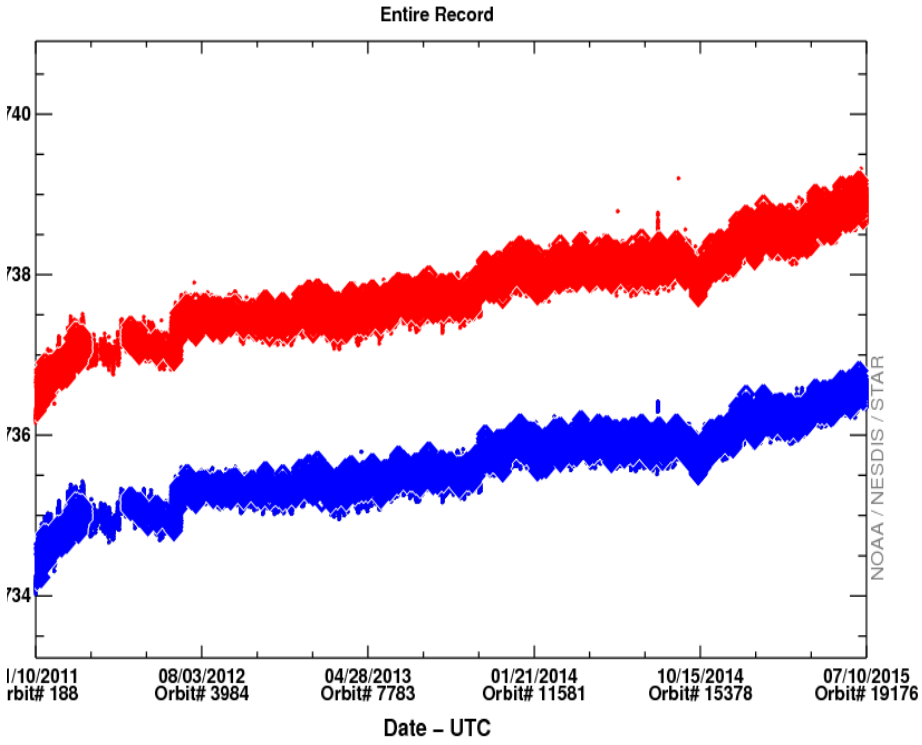
Sensor signal to noise ratio from EV data meets the requirement of 1000.

OMPS Solar Diffuser Count Drafts

NP

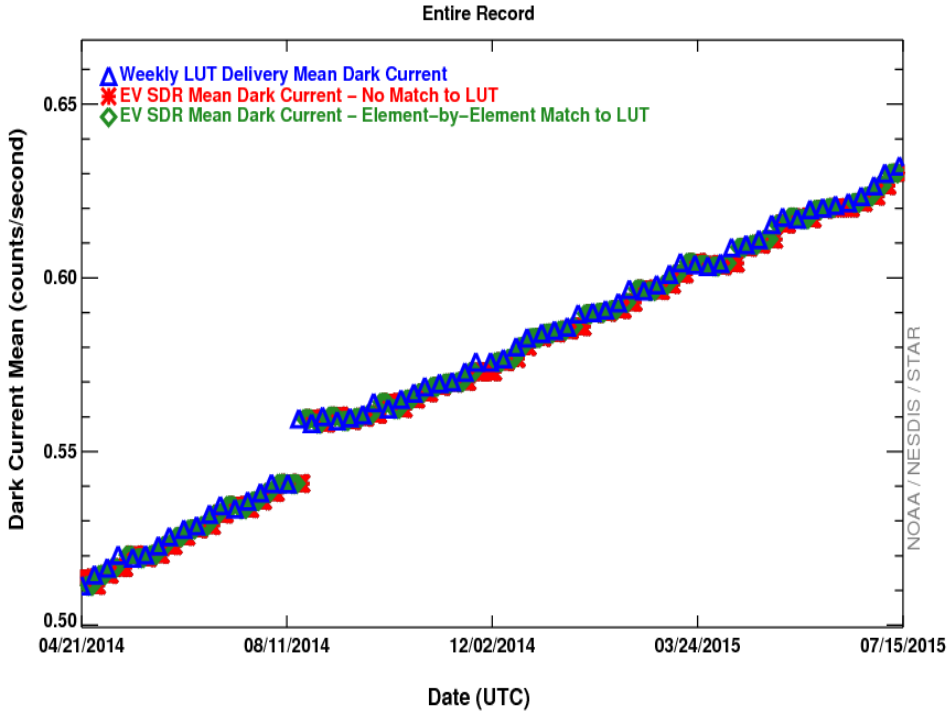


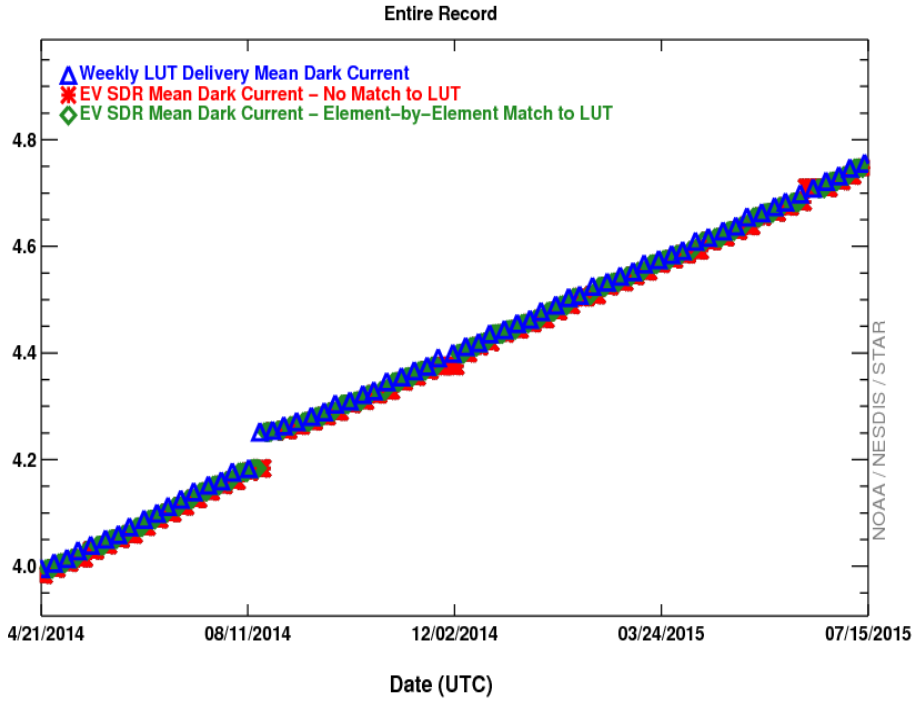
NM Left CCD



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.