Performance of the Suomi-NPP OMPS Limb Profiler

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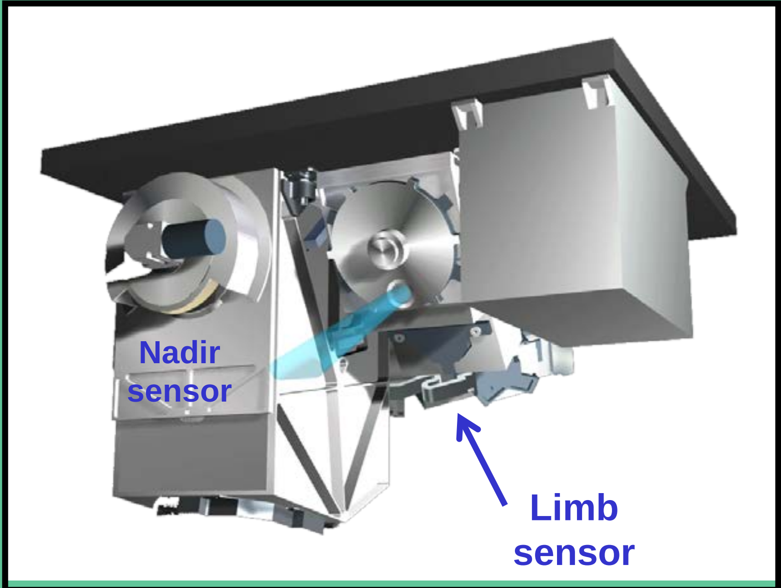
1-Universities Space Research Association and NASA GSFC

2-NASA Goddard Space Flight Center

3-Science Systems & Applications, Inc.

<u>OMPS</u>
Ozone Mapping and Profiler Suite

SNPP Launch
October 28, 2011



Courtesy of Ball Aerospace and Technology Corporation

OMPS Limb sensor

Limb Profiler

Heritage: SOLSE / LORE, OSIRIS, SCIAMACHY, GOMOS

Wavelength: 280 –1000 nm

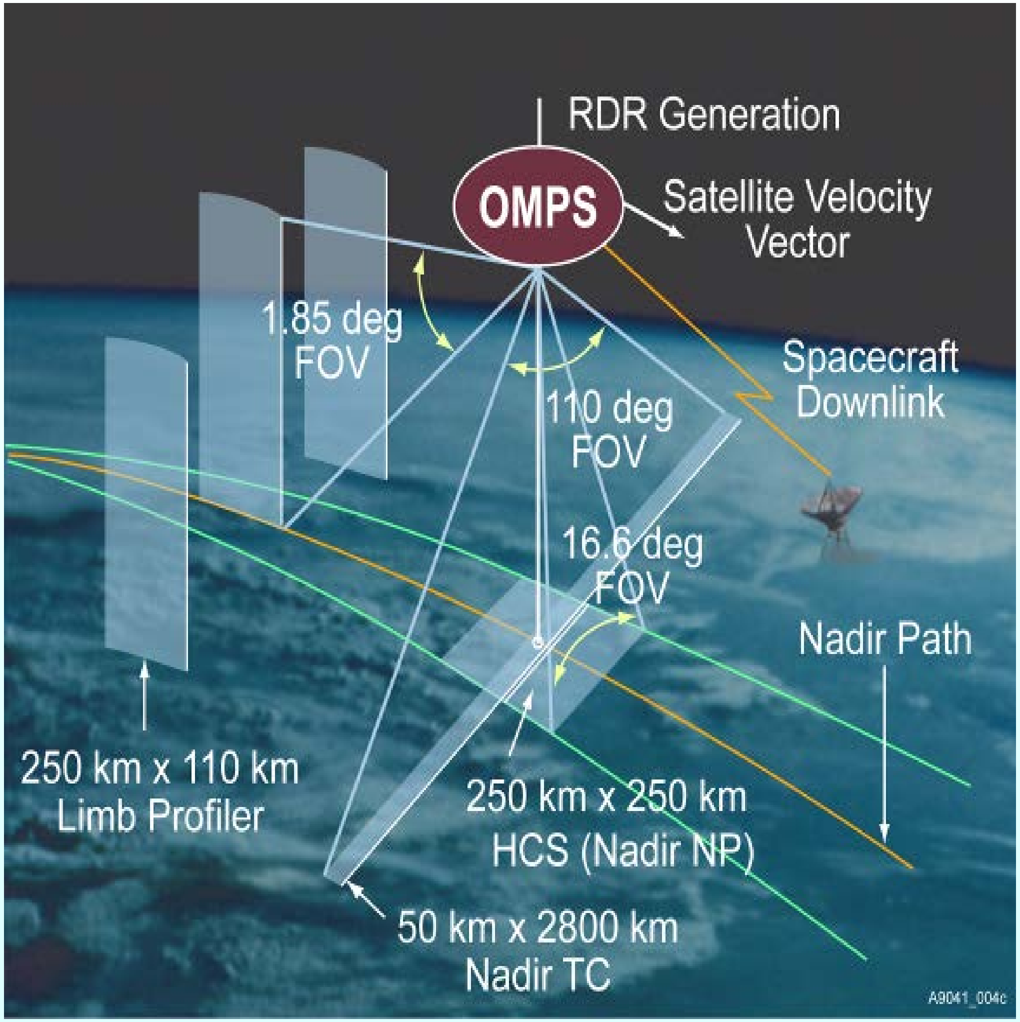
Vertical range: 105 km (5 - 80 km consistently)

Vertical Sampling: 1 km

Vertical resolution: ~2 km

Along-track sampling: 125 km

Detector: 0.25 megapixel CCD at -45 ^{0}C

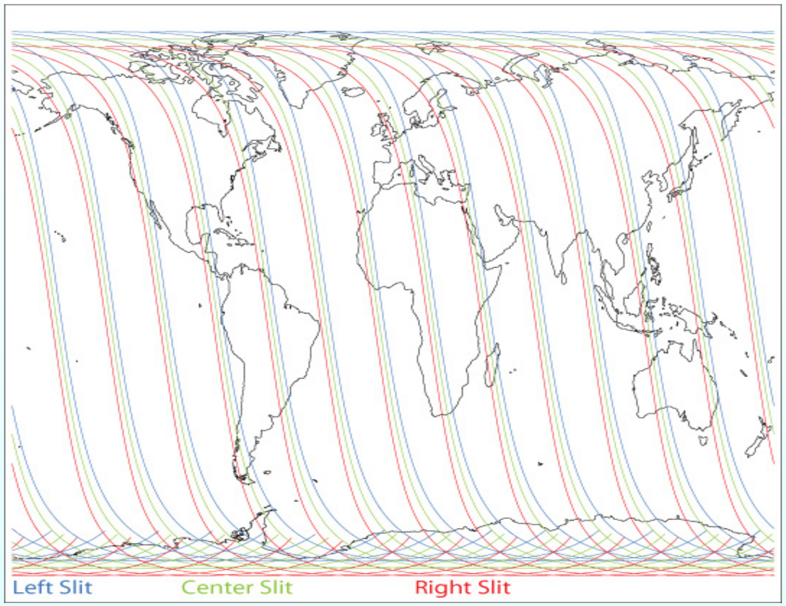


Known sensor challenges

- *Pointing*
- *Internal stray light*
- *Gain matching*

OMPS Limb data coverage

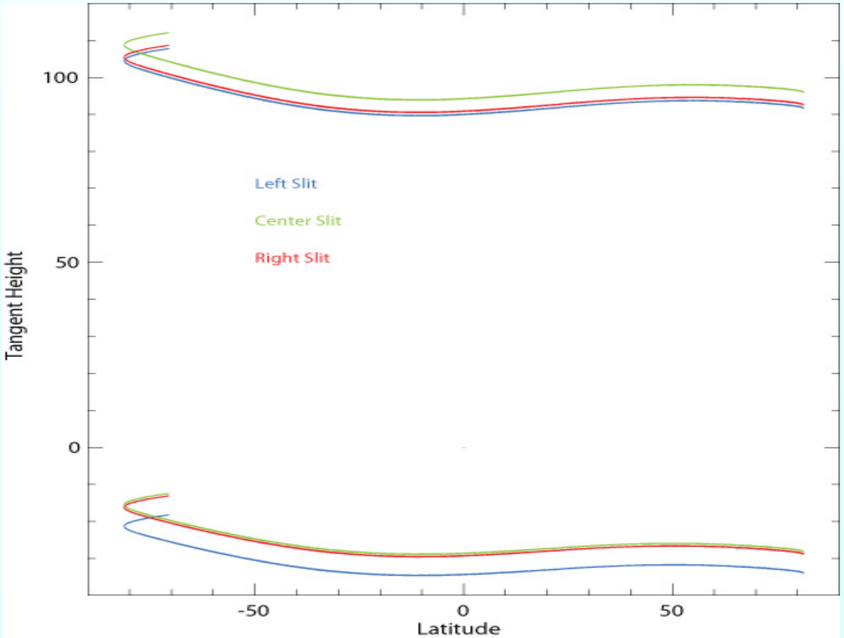
Daily Ground Track (typical)



Local Time at Ascending Node : 1335

Max. solar zenith angle: 100 deg.

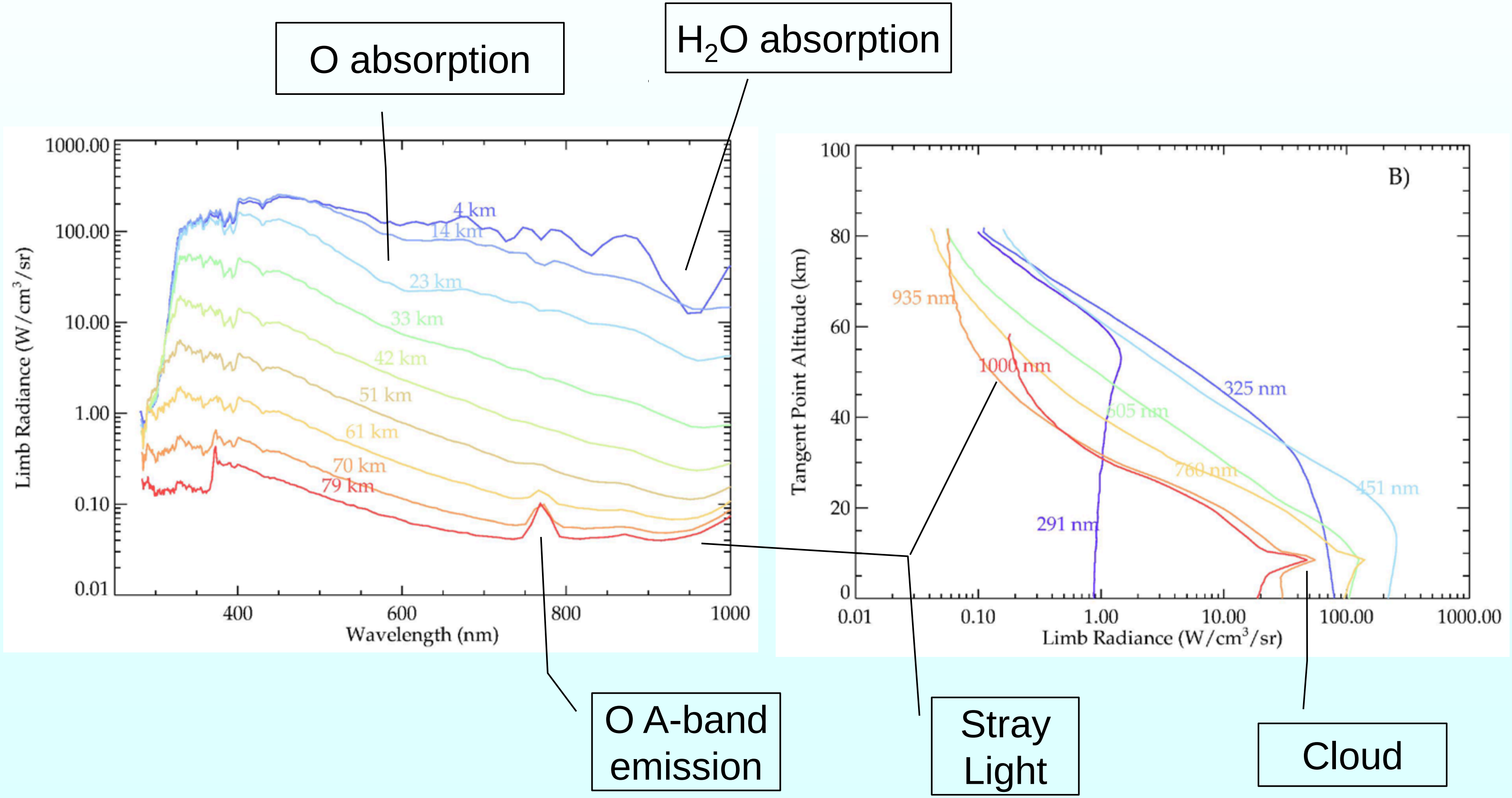
Vertical Range



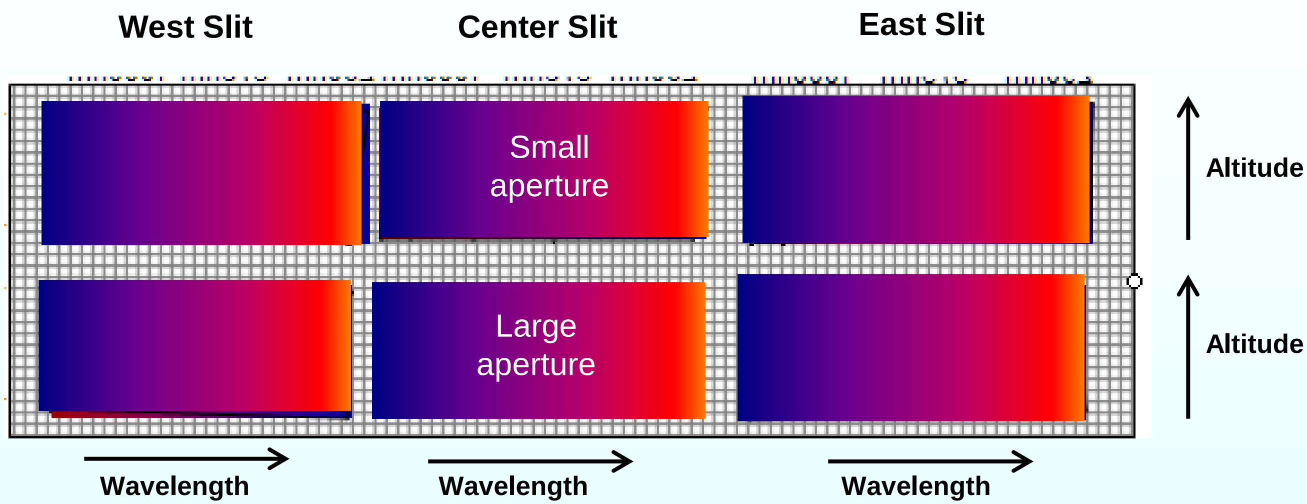
Vertical coverage governed by

- Time of year
- Geodetic pointing of satellite

Typical Radiance Profiles



6 images collected on CCD detector

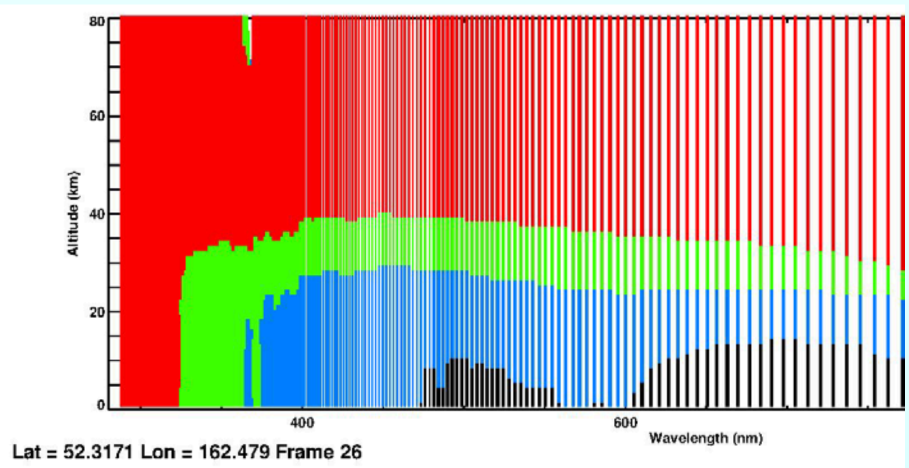


Each image collected twice:

Long = 1.25 sec

Short = 0.04 sec

Uploaded sample table control downloaded pixels



Gain 1 = 140

Gain 2 = 31

Gain 3 = 4.5

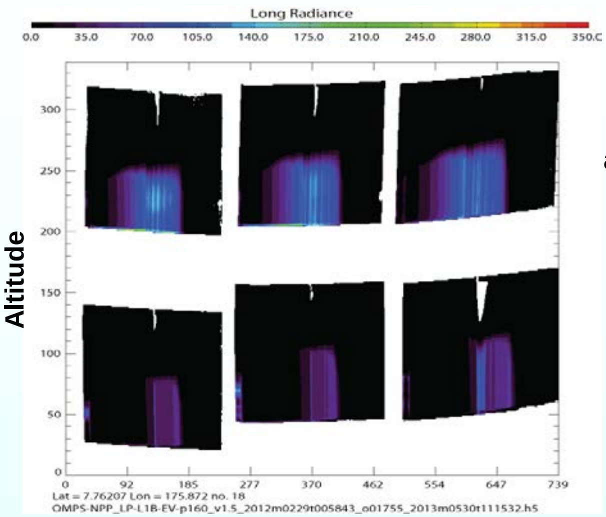
Gain 4 = 1

14-bit A/D converter

Total detector dynamic range ≈ $2 \cdot 10^6$ (need 10^4)

Radiances from different apertures never match

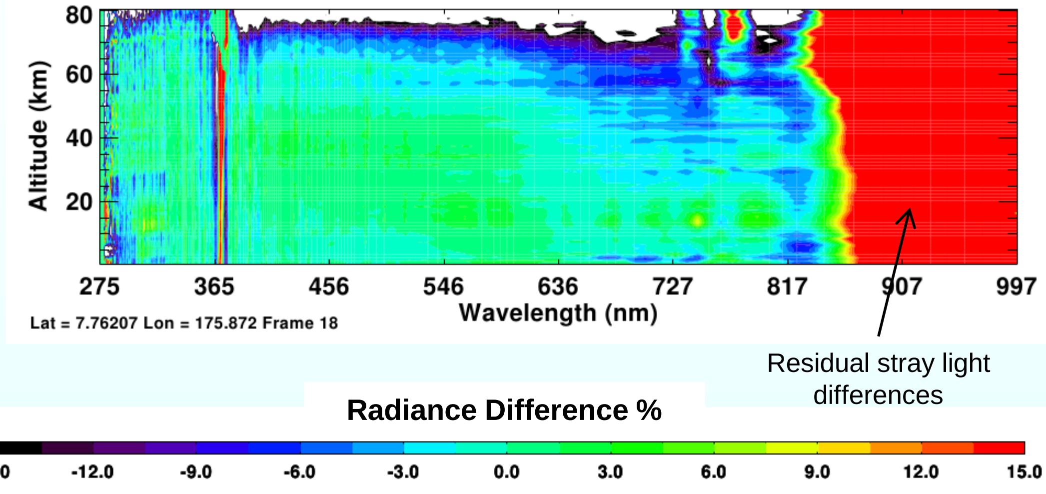
Altitude

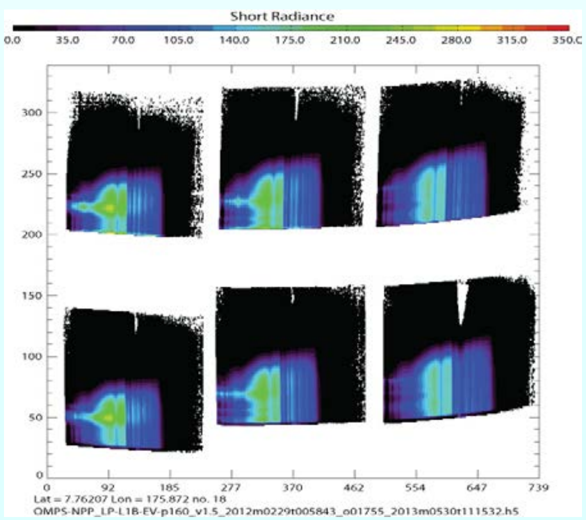


Small aperture (LG)

Large aperture (HG)

Large – Small aperture radiance difference





Small aperture (LG)

Large aperture (HG)

Wavelength

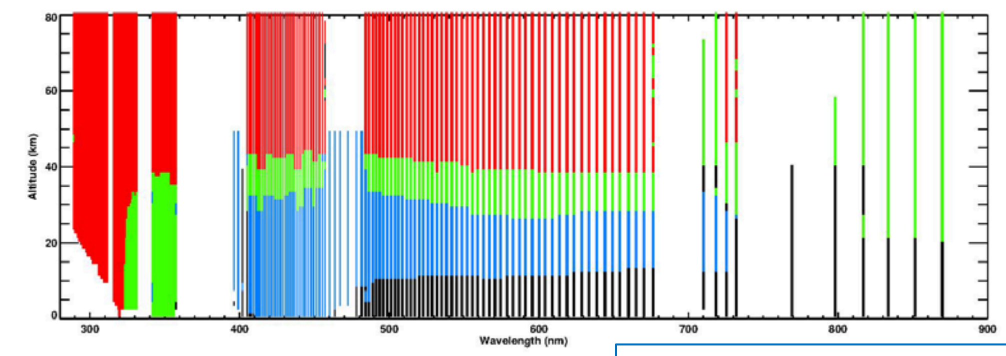
Solution:

- large aperture only for UV
- small aperture only for VIS
- small aperture only for IR

We trade mid-altitude S/N for smoother gain transitions

Sample Table and Consolidation

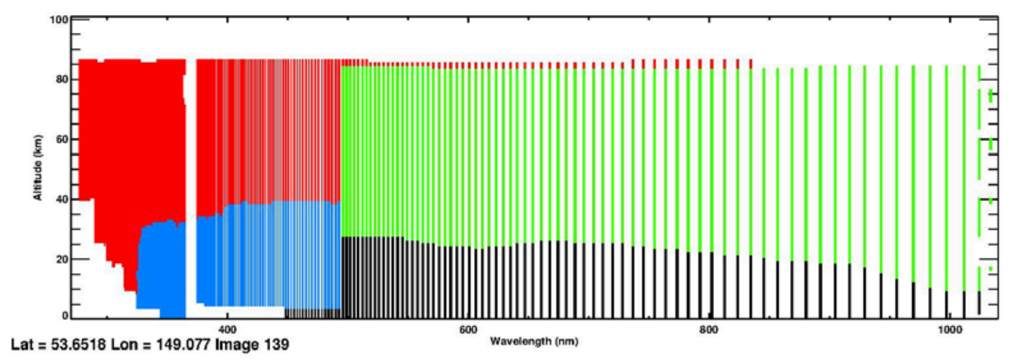
Sept. 14, 2012

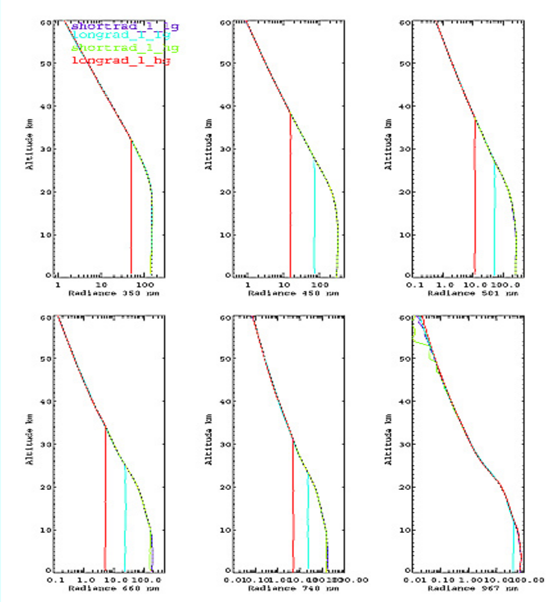


Old Sample Table
Old consolidation scheme

Radiances are gridded and consolidated using the 4 images, so as to maximize signal SNR and avoid signal saturation

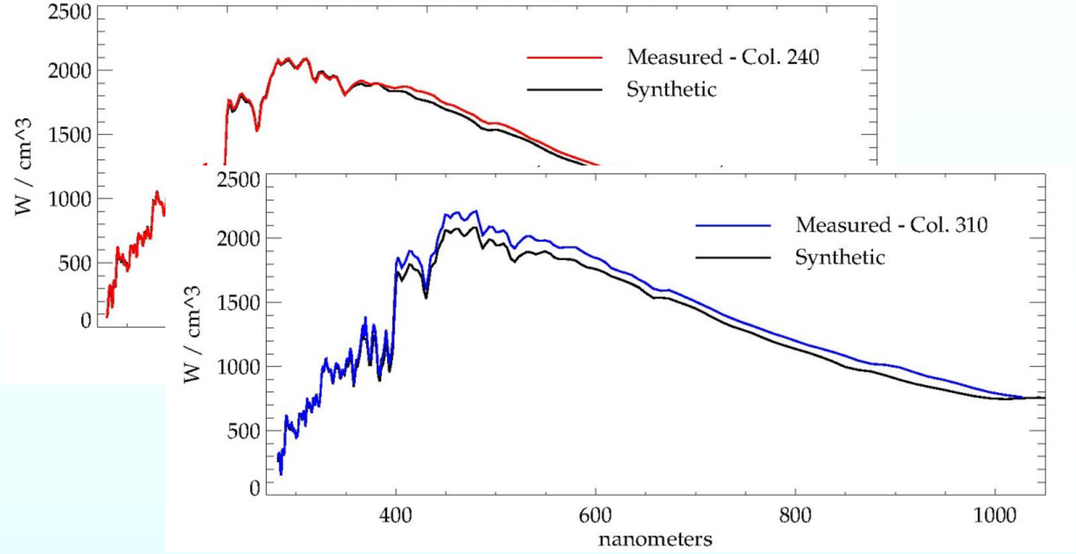
Mar. 14, 2014





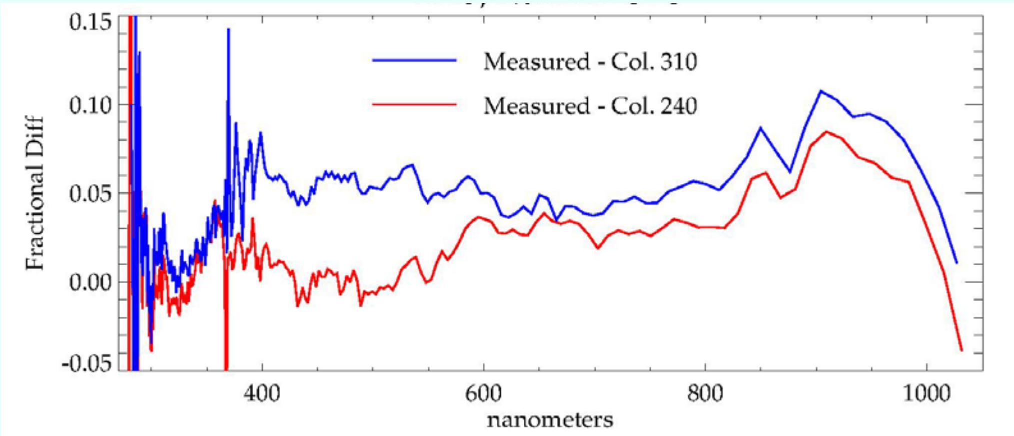
New Sample Table
Large Aperture: UV
Small Aperture: VIS/IR

Solar measurements used for spectral calibration and to monitor sensor changes



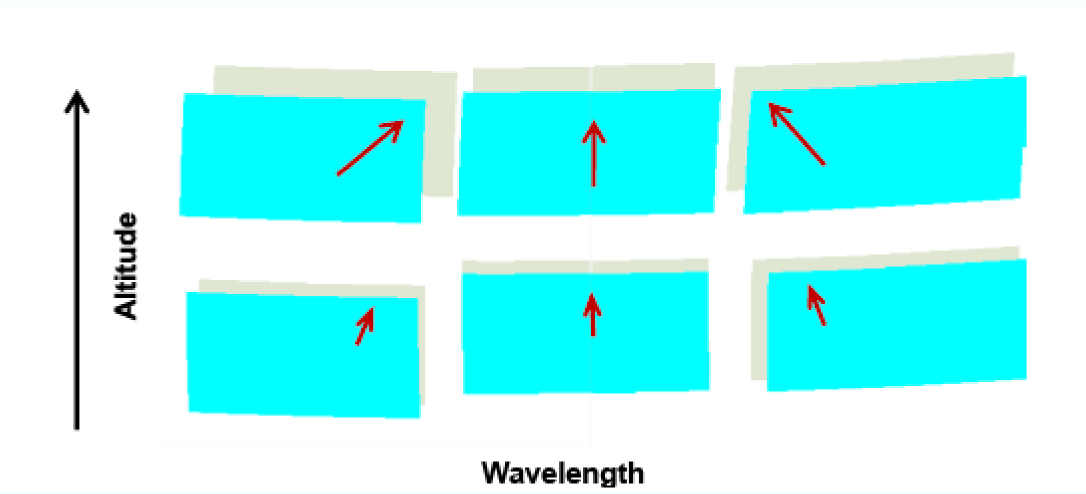
600 OMPS solar spectra
(1 for each spatial location)
are measured every week

OMPS compared to SUSIM-based spectrum

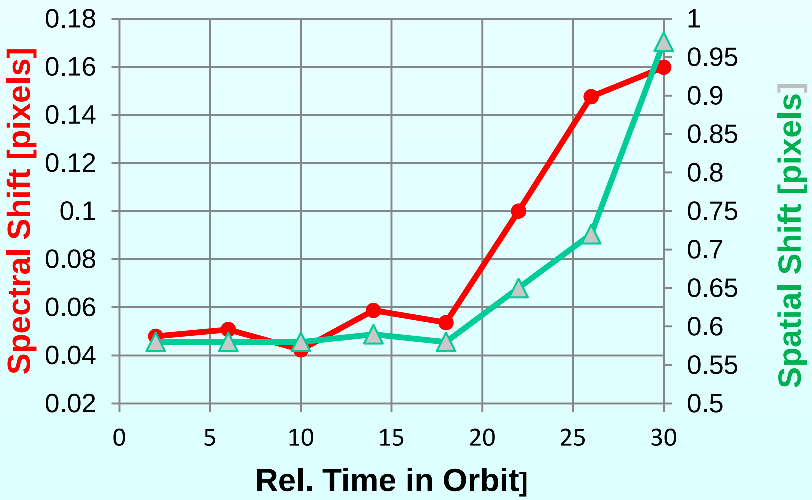


Spatial variations are indicative of radiance calibration errors at different tangent heights

Thermal sensitivity of instrument



Images shift on focal plane as sun heats the sensor. Wavelength and vertical pointing shift every orbit.



Seasonal variation in wavelengths follows the solar azimuth

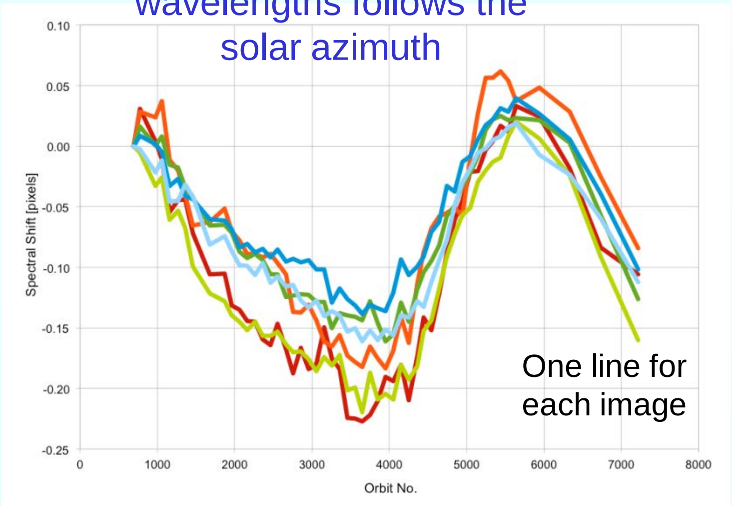
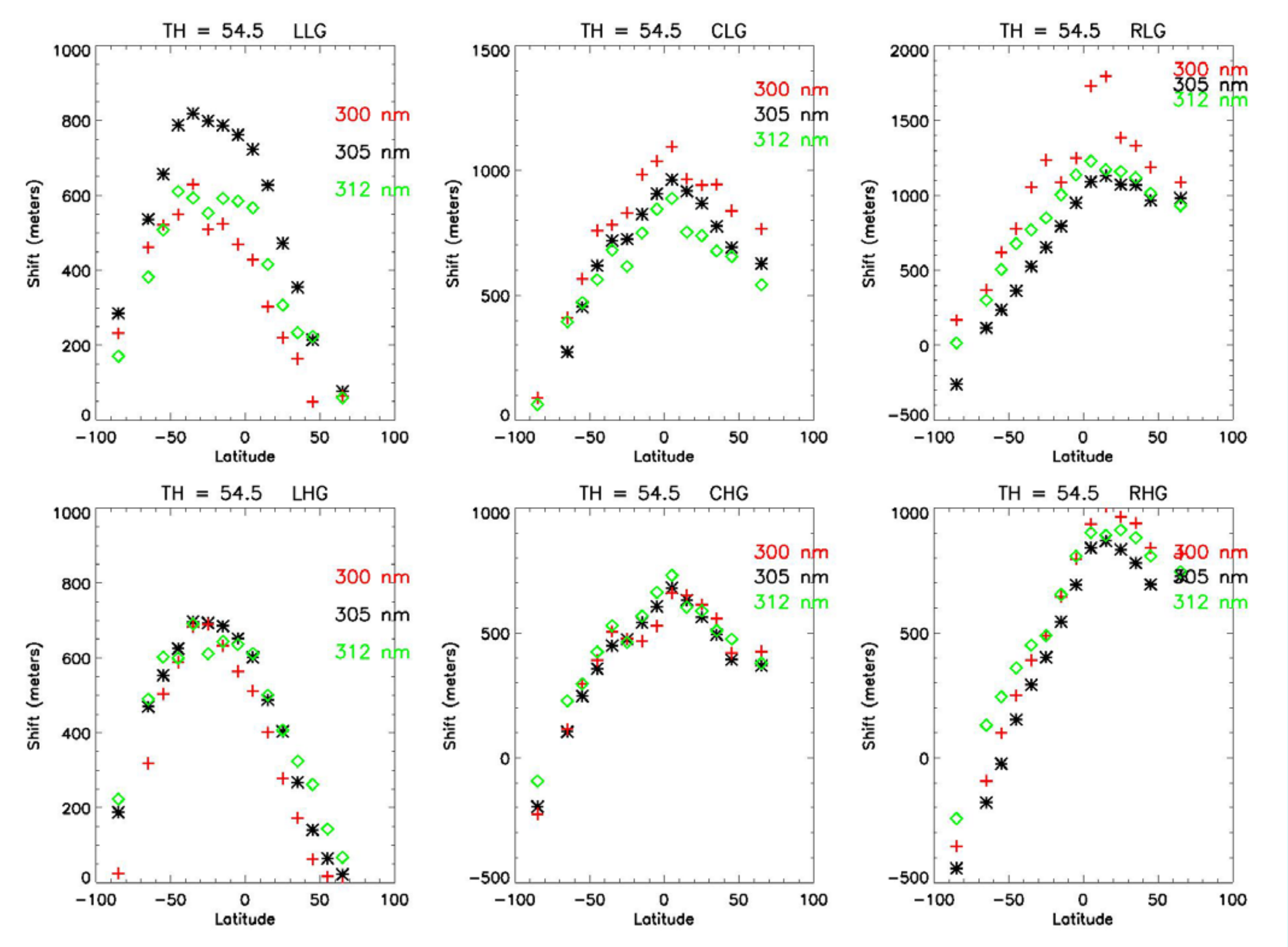


Image tangent height shift

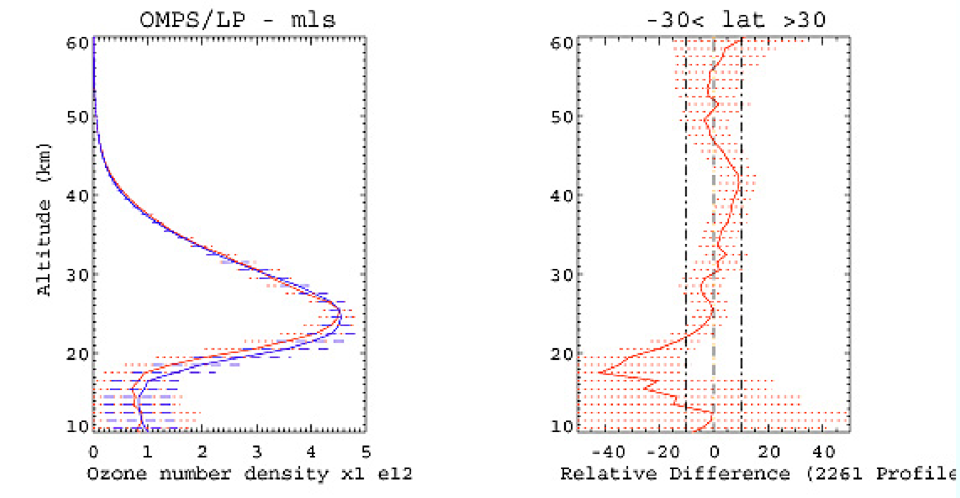


Shift is calculated by comparing to MLS-derived model calculation

Errors are relative to offsets from pre-launch pointing -

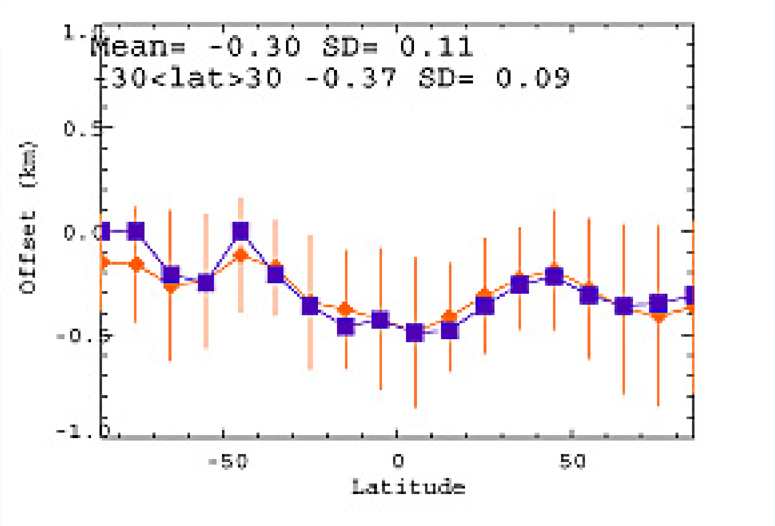
Left: 1450 m
Center: 1750 m
Right: 2600 m

Tangent height offset



Tangent Height offset is estimated through comparison with MLS ozone profile

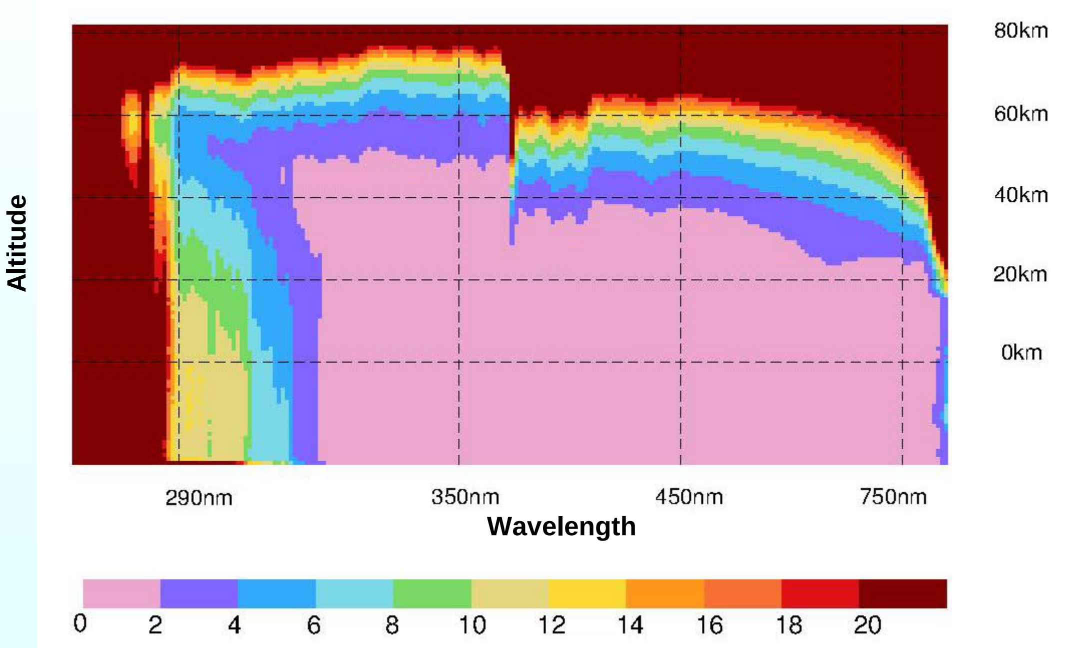
Comparison show clear TH offset signature



Using a full year data (2012), we can derive zonal mean time series of the TH offset ~0.2-0.5 km

Stray light corrections

Computed stray light as fraction of measured radiance



Percent Stray Light

Stray light corrections based on preflight instrument characterization

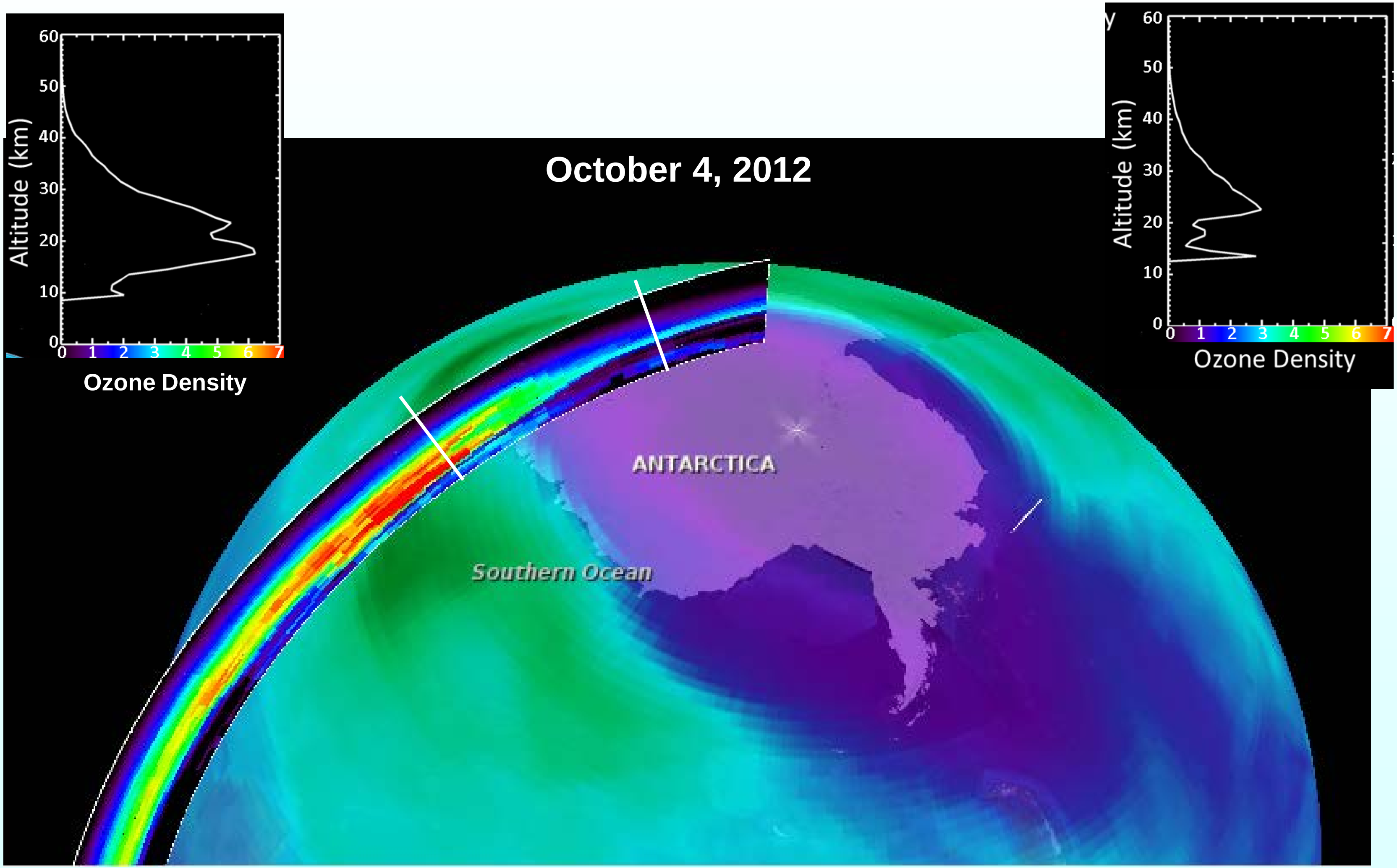
Stray light is mainly a high altitude problem

1µm has large stray light at all altitudes

Percent Stray Light at 65 km (east, center, west)

	290 nm	302 nm	310 nm	320 nm	353 nm	500 nm	602 nm	750 nm
Before Correction	9.4 10.8 13.1	10.4 11.3 15.7	8.3 8.9 12.1	7.0 7.5 11.6	5.1 5.8 10.7	18.3 20.3 34.2	23.8 26.6 45.1	34.2 36.7 49.9
After Correction	- 1.3 1.5	0.3 1.0 1.1	0.3 0.6 0.9	0.2 0.5 0.7	0.3 0.8 0.6	1.6 2.0 4.0	2.3 3.0 5.6	4.0 -5.1 6.6

OMPS Limb data available Nov. 1 at *http://ozoneaq.gsfc.nasa.gov/omps*



Extra slides

2014 STAR JPSS Science Team Annual Meeting

OMPS CONOPS

2014-May-14

T.J.Kelly & G.Jaross

S-NPP & J-1 Data Rate Comparison

SNPP: 12/32NC

- “12” is rate (in Hertz) of number of S/C bus polls for OMPS TLM
- “32” is the max number of 64-byte buffers per polling interval
- “NC” is No Compression
- Data Rate:
  - Net TLM rate:12*32*64 = 24576 Bytes/sec, or
  - 196608 bits/sec (196.6 kb/s)

J1: 10/80C

- “10” is rate (in Hertz) of number of S/C bus polls for OMPS TLM
- “80” is the max number of 64-byte buffers per polling interval
- “C” is lossless Compression
- Data Rate:
  - Net TLM rate:10*80*64 = 51200 Bytes/sec, or
  - 409600 bits/sec
- *Above is an “NC” rate*
- Compression estimate: a factor of approximately 2, so
- Effective, estimated data throughput:
  - Net TLM rate: 2 x 51 kBps
    - = 100000 Bytes/sec, or
  - 820000 bits/sec (820 kb/s)

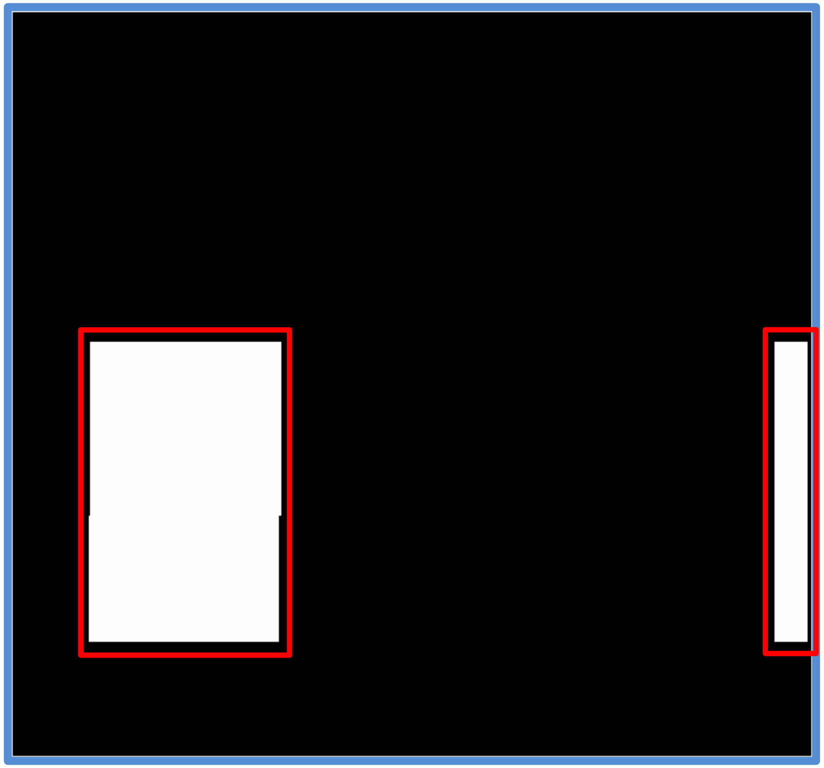
Reduced-Frame: New Capability

S-NPP: (a *first way* to run a TPG…)
- Read entire contents of CCD into memory
- Corresponds to area inside the blue frame
- Apply ST binning & Gain correction

J1: (a *second way* to run a TPG…<u>*same*</u> H/W)
- Read a select subset of pixels of CCD, shown as 2 red boxes, into memory
- Apply ST binning & Gain correction
- This is Reduced-Frame

Benefits of a Reduced-Frame:
- No time is spent reading out pixels that will only be discarded later
- Saves CCD read-out time
- Shortens along-track sampling for NM when NM and NP are read out together (every 6th frame)
- Apply mainly to Earth-View (Science Data)
- Other observations employ regular read-out

Caveats:
- Sample and Gain correction Tables must be sized for reduced-frame
- Reduced-Frame TPG is tied to ST and GT



APID will tell you whether Compressed &/or Reduced-Frame applies

On the Ground:
- Reduced-Frame looks no different in raw data
- Nothing needed in Ground SW to account for it

Interchangeability: Product Sets

- In all, BATC created 4 Data Rate/Compression packages, known as "Product Sets"
  - Not all OMPS tables are affected
  - Tables included are CBM, Image Profile, Gain, ST & TP, and a Global Config

- KEY POINT: Each Product Set works with the same version of FSW
  - A Product Set essentially configs just the necessary FSW parms

- Reason: Kind of a *Plug 'n Play* approach
  - Minimize risk in case S/C couldn't handle max data rate, etc.
  - 2 with compression, 2 without
  - Same polling rate (10 Hz)
  - Lower numbers of 64 byte buffers per S/C poll

Data Compression Testing

- Compression Studies
  - Tested several compression methods
    - COTS products
    - Included the "zlib" & "szip" packages
    - Tested on actual data from S-NPP/OMPS: EV, SCAL, LED and Darks
    - General Compression Results:
      - zlib compression of ~ 2.0X
      - szip compression of ~2.5X
  - Selected "szip", which uses extended Rice compression algorithm
- FYI: On-board CPU demand for data compression is ~3%
  - Plenty of CPU resources available
  - No problems expected to perform data compression in existing H/W
- 2x compression is conservative for EV HiRes
  - Even though results suggests 2.5X
  - Only accounts for register under-utilization (14 bits for one coadd vs. 32-bit word/pixel).
- Dark Current data achieve up to 10x compression.
- Use LEO&A to improve compression estimates
  - And improve/refine ST too
  - Enhance wavelength selection in EV ST

J1 Flight ConOps: Calibration Plans

- Solar Cals: 2 methods
  - 1-orbit and 3-orbit varieties, as with S-NPP/OMPS
    - TP and IT characteristics convey
  - Evaluate new QVD Diffuser
    - Less diffuser features than Aluminum Diffuser on S-NPP/OMPS
    - Compare performance diffs of 2 types of Solar Cals (1 vs 3-orb)
  - Desire is to utilize 3-orb solars
    - Reduces effect of Goniometry errors, incl. diffuser features
    - However … need to factor in Mech. moves over lifetime of mission
- Dark Cals with door closed
  - Performed weekly
  - Much like S-NPP/OMPS: Full-Frame (FF) images
  - Separate Image and Storage Region Darks
  - Include short-IT and medium-IT darks
- LED Cals with door closed
  - Performed every 4 weeks
  - Upgraded: FF images due to data compression
  - Collect LED Warm-up, Linearity and FF image data

J1 Flight ConOps: Special EV Plans

- Special EV data collection activities
  - Door open Dark Cals
    - Just like door closed Darks
    - Provides orbit-by-orbit updates
  - EV FF data collection for NM & NP
    - Separate orbits for each, as with S-NPP
    - ~4X increase in number of images
    - Good for straylight obs., very-fine imaging, etc.
  - PNRU obs. for NM
    - Increased wavelength range
    - over Antarctica & Greenland
    - In season: Centered on a Summer Solstice
  - EV_360
    - Essentially an extended version of EV_Hi_Res
    - NOM APIDs: Compressed & reduced-frames

J1 Flight ConOps: Science Data Plans

- EV_Hi_Res default Science Data (EV) activity
  - Timing pattern enhancements : No coadds
    - **Was** 6 coadds (of 1.25 s) for NM and 3 coadds (of 12.5 s) for NP on S-NPP/OMPS
    - **Will be**
      - NM: IT = 1.25 sec
        - » Shorter than 1.76 sec that's run on S-NPP/OMPS with CBM: EV_HiRes_O3
      - NP: IT = 7.5 sec
        - » as was tested on S-NPP/OMPS with CBM: EV_TCres_NP
    - Better along-track resolution
      - NM resolution = ~10 km "6X"
      - NP resolution = ~49 km "5X"
  - Wavelength range enhancements:
    - J1 NM available wavelength range increased
      - 298 to 423 nm
      - Marginal sensitivity from 392 to 413 nm
    - J1 NP wavelength range unchanged
      - 252.0 nm to 305.87 nm

J1 Flight ConOps: Science Data Plans

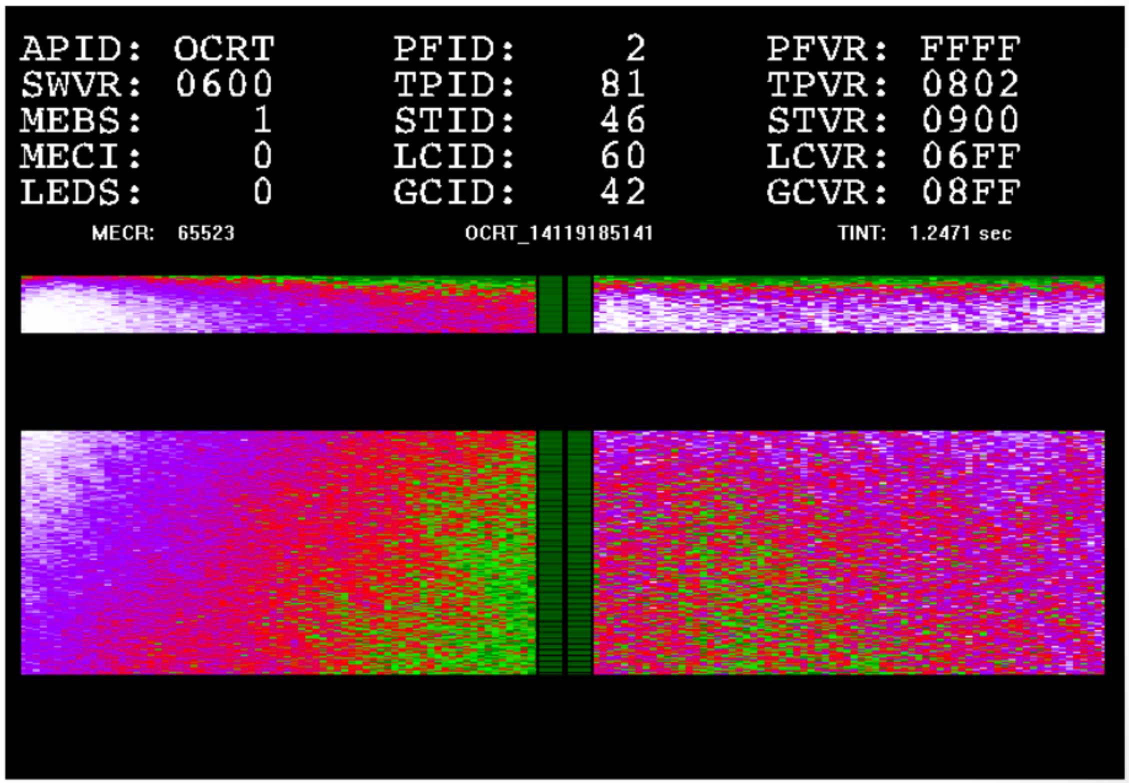
- EV_Hi_Res (continued)
  - Sample Table enhancements: Finer Binning
    - For NM: How best to distribute?
    - Option 1: BATC delivered an NM ST with BF=5
      - 210 spectral pixels (170 + 40)
      - The 170: Spectral range covers PRD wavelengths from 307.6 to 378.2 nm
      - Extra 40: 407.0 to 423.4 nm
    - Option 2: May reduce to BF=4 with 170 wavelengths
      - Done on S-NPP: Early version of ST for EV_HiResO3
    - Option 3: May use variable binning
      - Done on S-NPP: EV_HiResO3 run on Saturdays
      - Reduces off-nadir swell
      - If select BF=4:3:2, can collect 80 to 100 wavelengths
    - For NP: BATC-delivered ST
      - 5X spatial resolution
      - Has been tested on S-NPP: EV_Tcres_NP & nomEV_Tcres_NP
      - 150 spectral pixels (as mentioned on prior slide)
  - FOVs of BATC delivered J1 EV STs:
    - NM: approximately **13** km wide x **10** km along-track at nadir "4X x 6X"
    - NP: approximately **50** km wide x **55** km along –track "5X x 5X"

J1 Flight ConOps: Routine Data Collection

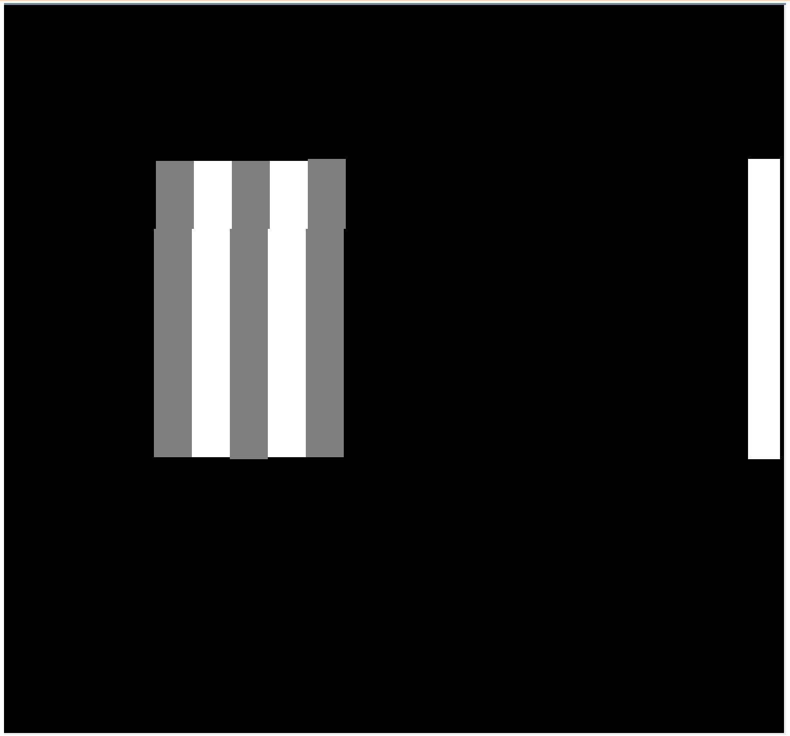
- EV_Hi_RES is default activity
- Solar Working Cal every other week
- LED Cal every 4th week
- Dark Cals
  - Door closed once a week
  - Door open is default nightside activity
- Solar Ref Cal approx'ly semi-annually
  - Maintain constant Solar Azimuth/β Angles as S-NPP

J1 Routine Science Data: BATC NM Test ST

Sample/Bin TC “Hi-Res” EV



J1 Routine Science Data: NP Test ST



- J1 NP Test EV ST
  - 5X spatial resolution

Planned NPP Improvements

- Load J1 FSW6.0 on S-NPP
  - After all … same hardware!
  - LP inactive during test
  - Concurrent with Block2.0 changes
  - Must wait due to changes in OMPS header
  - Incremental Approach: Operate under a 12/32NC ConOps
    - Duplicate existing S-NPP config
    - Need new product set (can't re-use J1)
  - Next Increment: 12/32C ConOps
    - Supports Reduced-Frames
    - Expect performance to be similar to J1's *10/80NC* ConOps
      - OMPS-to-S/C data rate is a "32" and not an "80"
      - Lessen ST loads if necessary, i.e, adjust wavelength range
    - Science Data Options:
      - EV_LOW_RES CBM (same as currently on S-NPP)
      - EV_MED_RES: Enhanced resolution
        - » NM: 2X cross-track and 3X along-track (25 km x 16 km Nadir FOV, resp)
        - » NP: 5X5
- Table changes needed:
  - FSW, Global_Config, Mech_Options, Fault, CBM, CSM, ProfileID, Gain, ST, TPGs
  - Need a day to get all uploaded
- BATC would outline and test all transition steps in advance
- Provide data for ground system use

Back-Up Slides

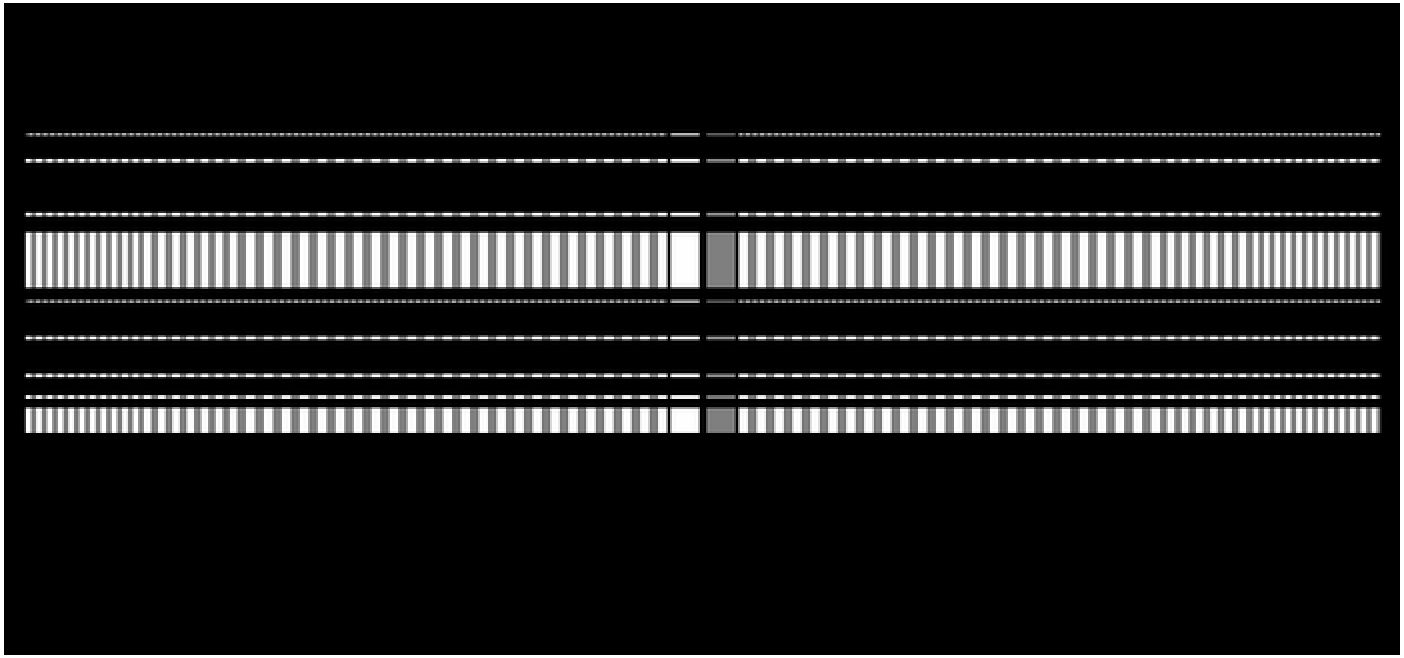
OMPS H/W on S-NPP & J-1

- The addition of both Data Compression and Reduced-Frame is built into the Flight Software (FSW)
- Hardware for S-NPP and J1 are identical
  - Except for omission of LP
  - Better "same-ness" between S-NPP and J2 !
- Upshot: Data Compression and Reduced-Frame could work for S-NPP too
  - Not impossible to test on S-NPP

Facts & Info

- OJ1 is capable of producing at a 40X rate greater than the OMPS 1553 bandwidth allocation.

S-NPP/OMPS EV_HiRes_O3 ST



- Not J1 High-Res EV ST, but …
    - Similar spatial resolution (horizontal)
    - S-NPP case has reduced wavelength coverage (data rate limit)

GODDARD SPACE FLIGHT CENTER

Status and improvements of J1 OMPS pre-launch calibration

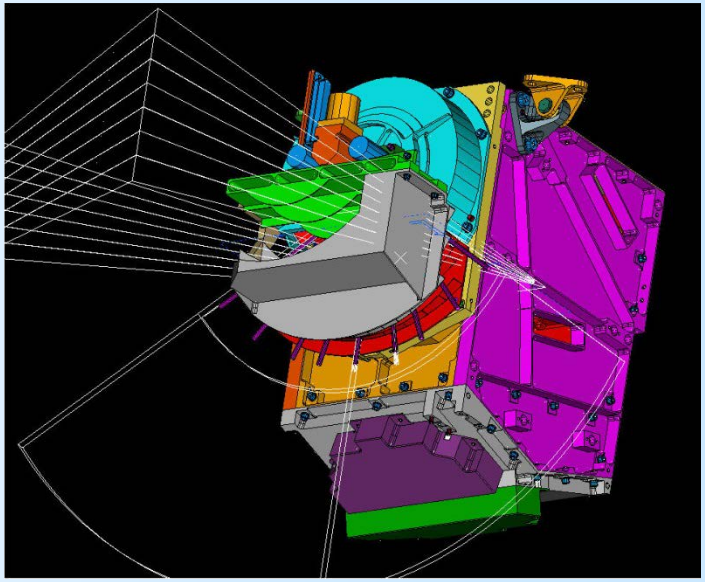
Matt Kowalewski, USRA

14 May 2014

Outline

- Instrument design changes
  - Wavelength coverage
  - QVD
- Calibration test phase summary
- Calibration issues
  - Diffuser stability
  - G/I and R recalibration summary
- Summary

JPSS OMPS instrument design changes



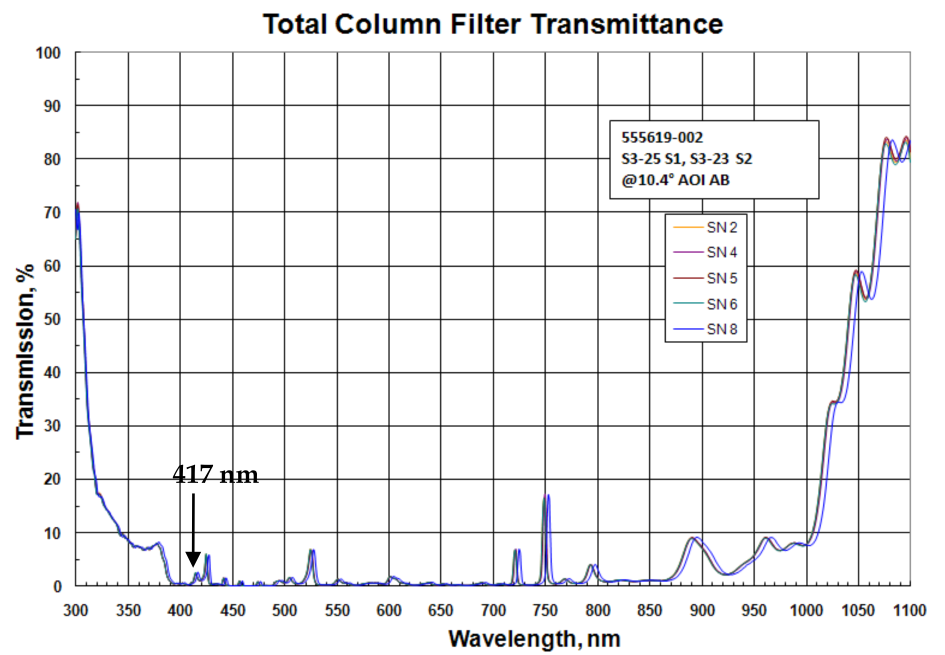
- No Limb sensor
- J1 Nadir instrument overview
  - 110deg FOV
  - Nadir Profiler: 250-310nm
  - Total Column: 305-380, 417nm*
  - Enhanced spatial resolution with new timing patterns*
    - Nadir Profiler: 250km to TBD
    - TC Mapper: 50km to 15km
  - 2 quasi-volume diffusers*
  - TC slit redesigned to reduce "puckering"*
  - Optical mounts redesigned to improve boresight stability*

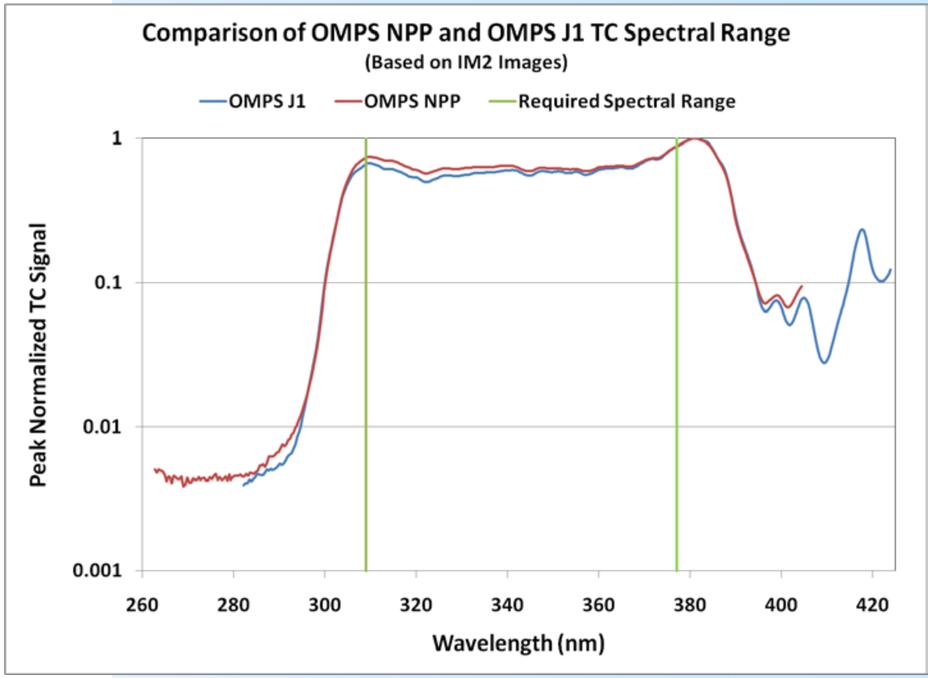
*Differences wrt NPP OMPS

J1 OMPS TC wavelength coverage

GODDARD SPACE FLIGHT CENTER

- **J1 Total Column (TC) modified optical alignment permits wavelengths up to ~420nm to be measured.**



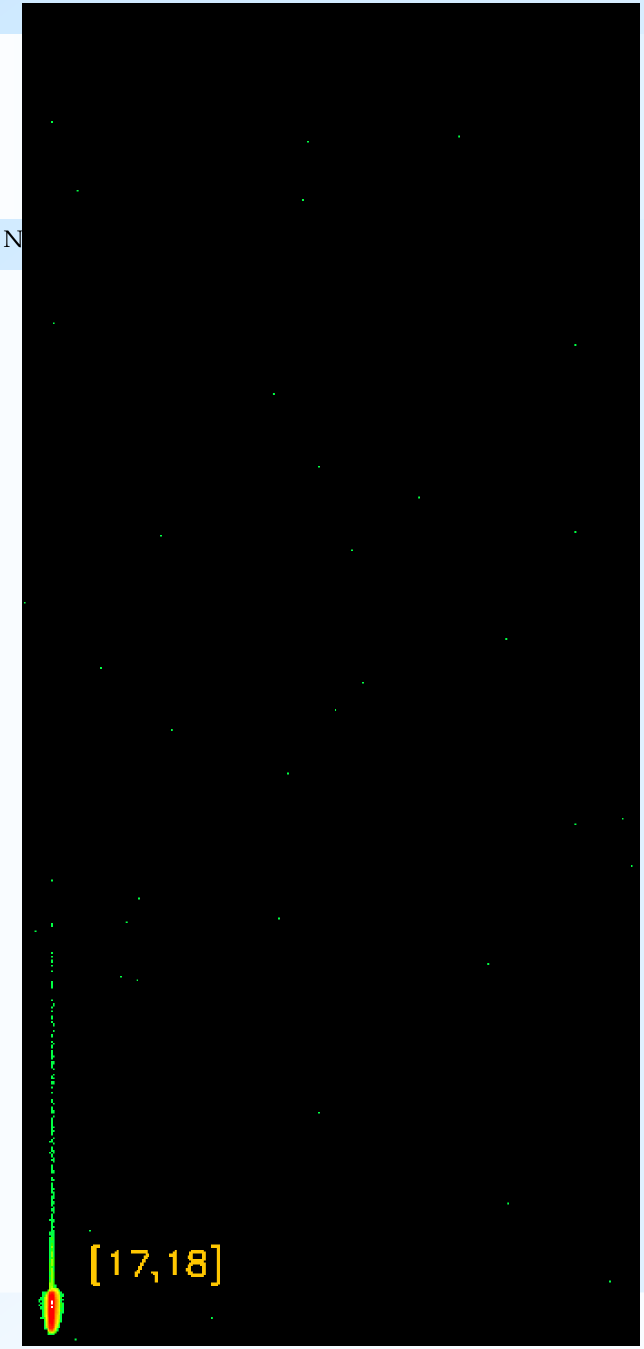


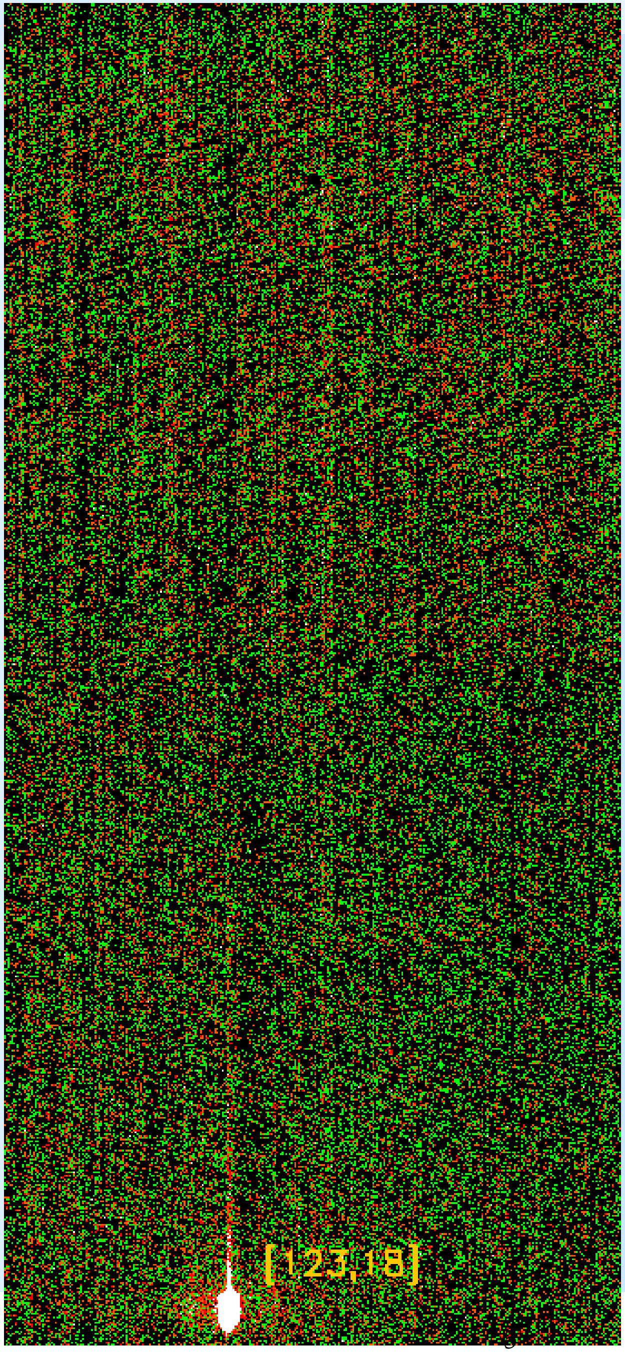
GODDARD SPACE FLIGHT CEN

OGTC
Az: -54deg

Left: 417nm

Right:372nm



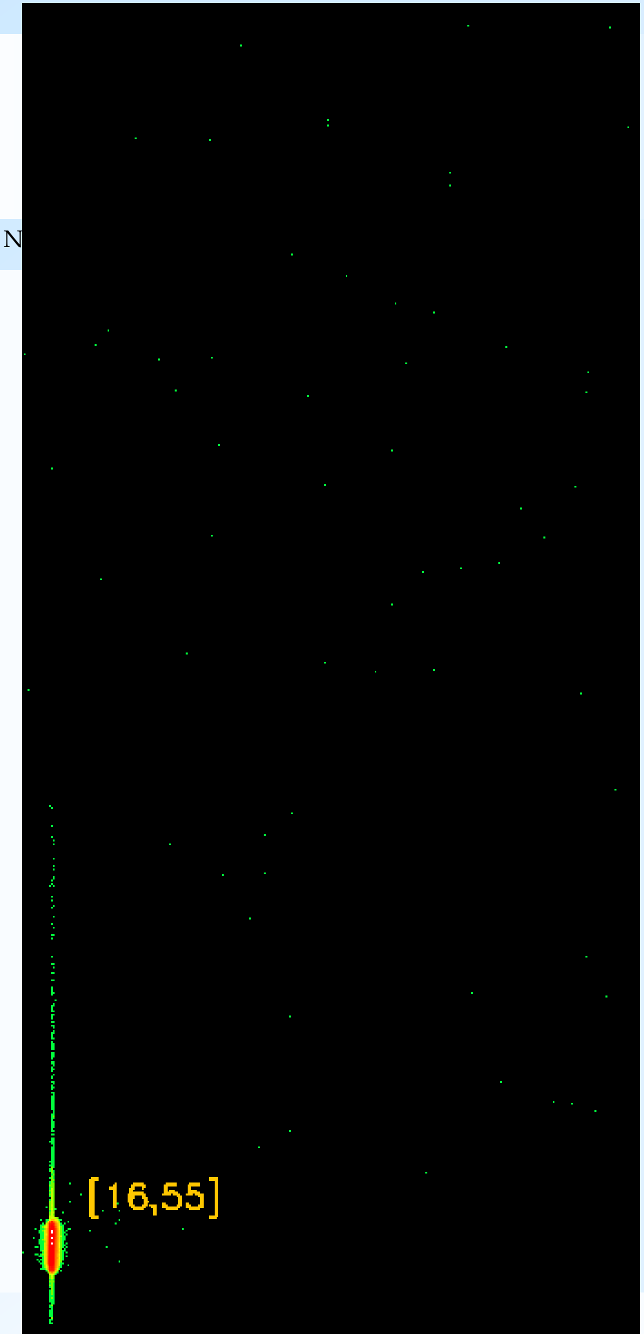


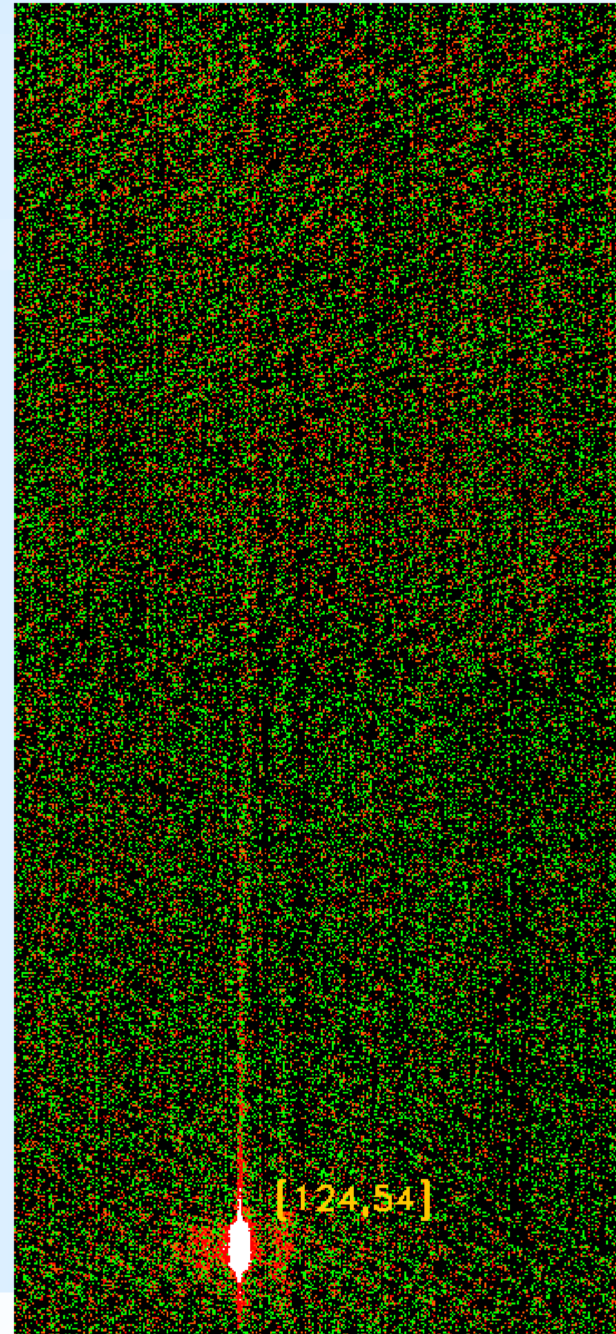
GODDARD SPACE FLIGHT CEN

OGTC
Az: -48deg

Left: 417nm

Right:372nm



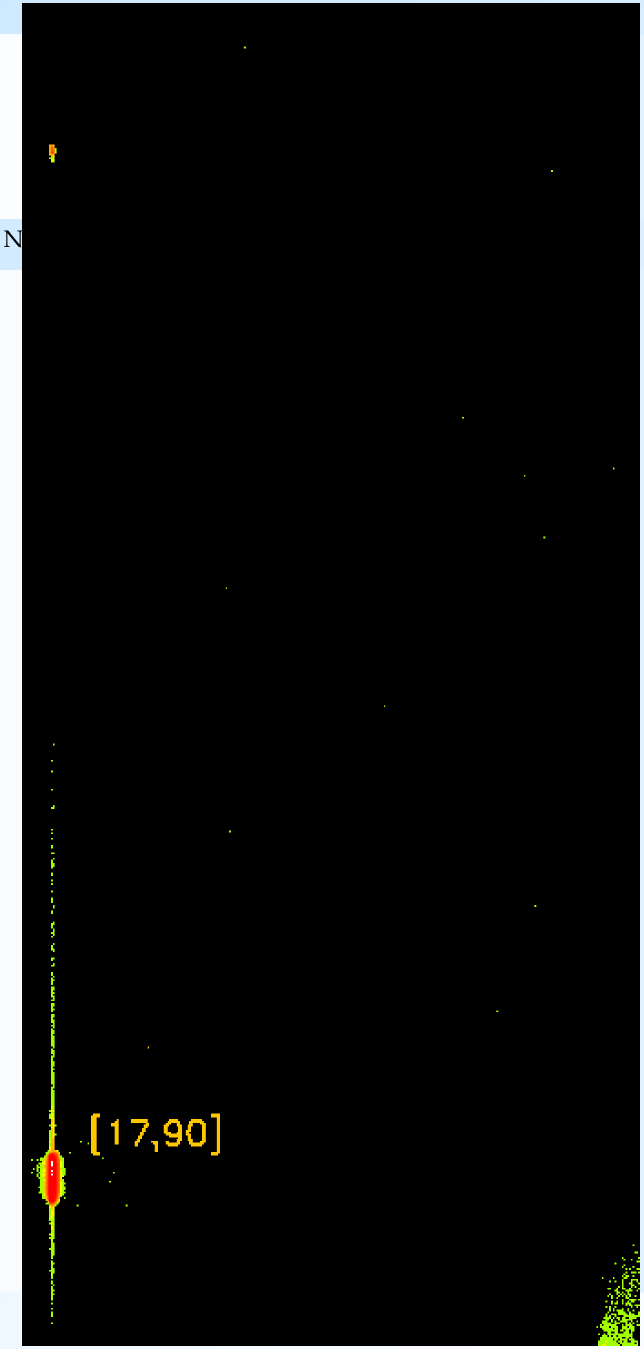


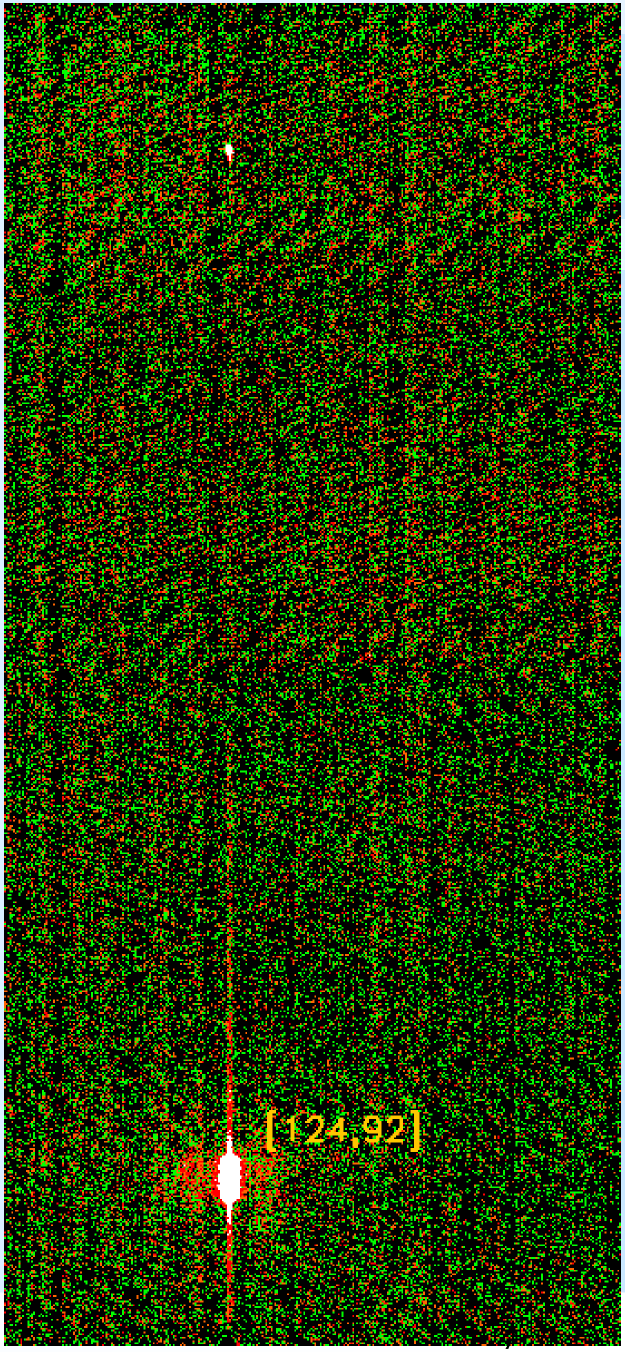
GODDARD SPACE FLIGHT CEN

OGTC
Az: -43deg

Left: 417nm

Right:372nm



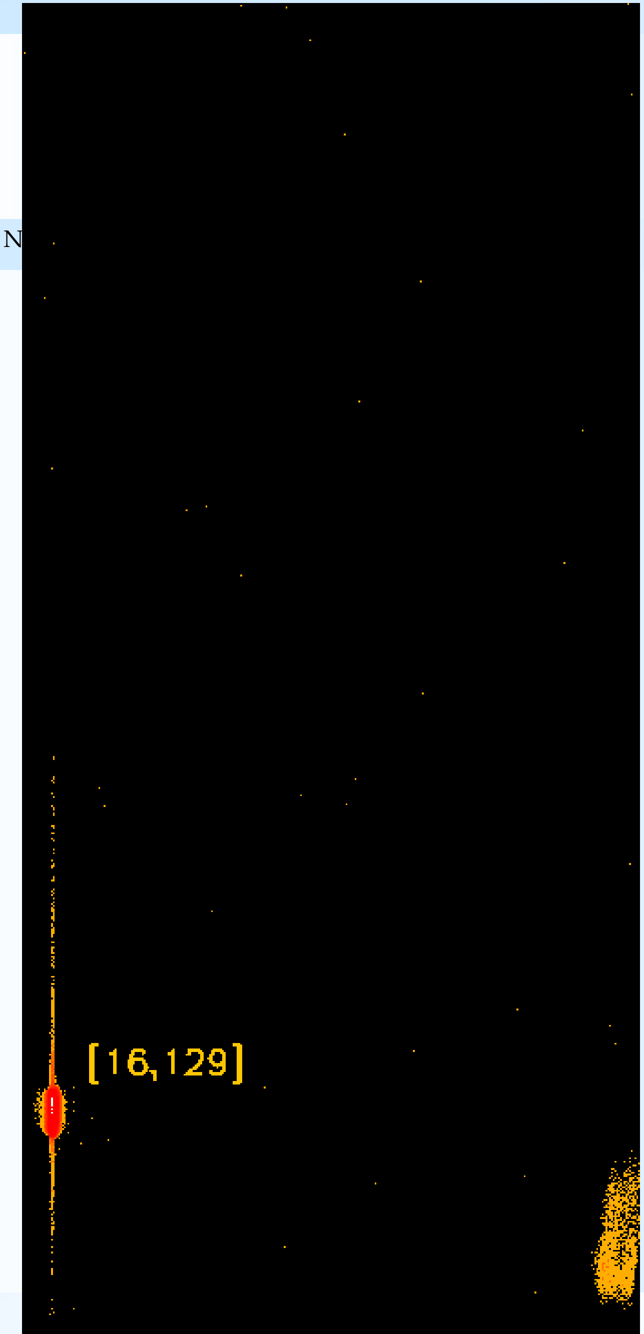


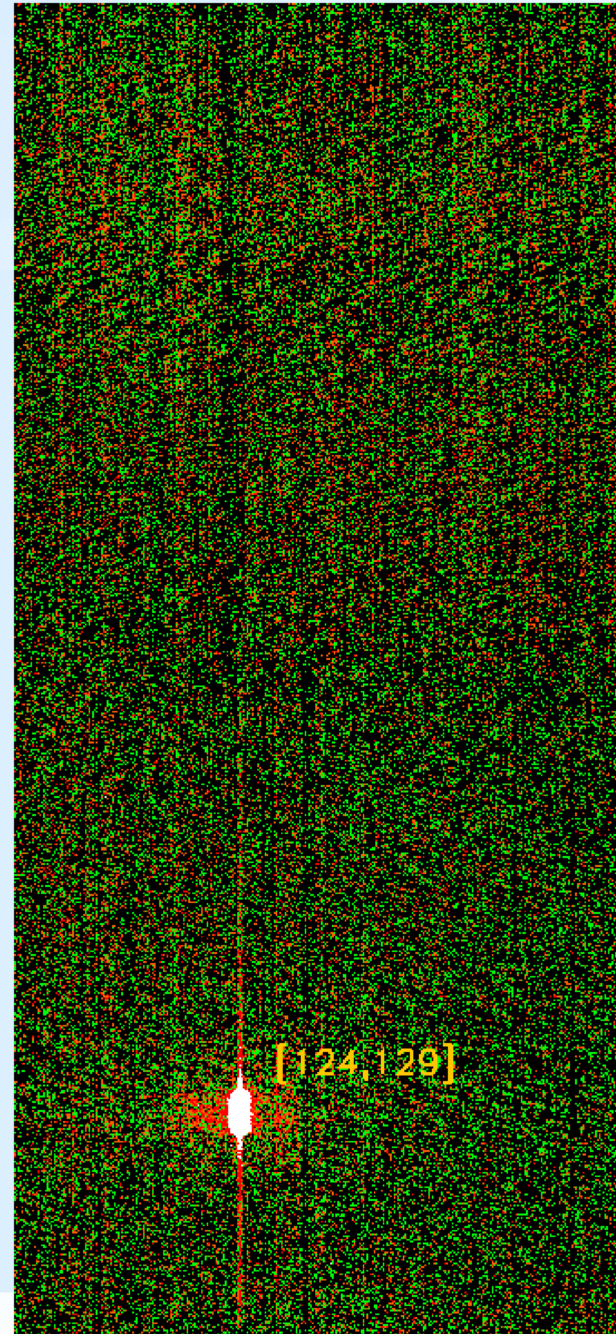
GODDARD SPACE FLIGHT CEN

OGTC
Az: -37deg

Left: 417nm

Right:372nm



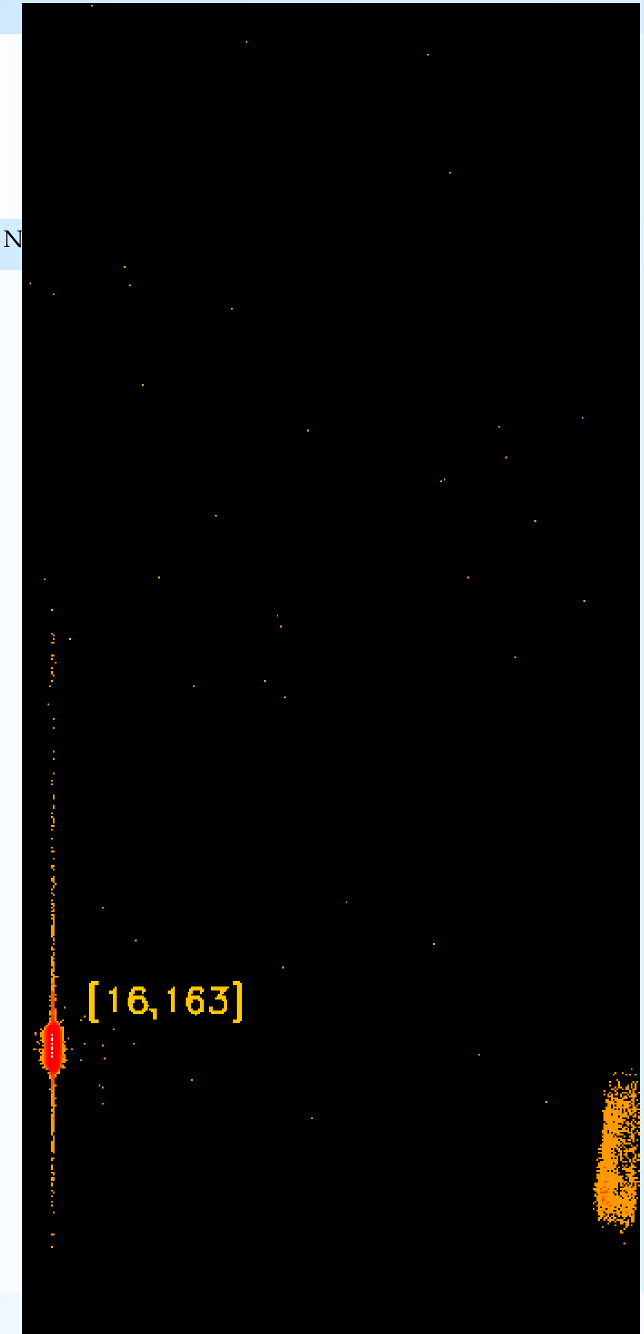


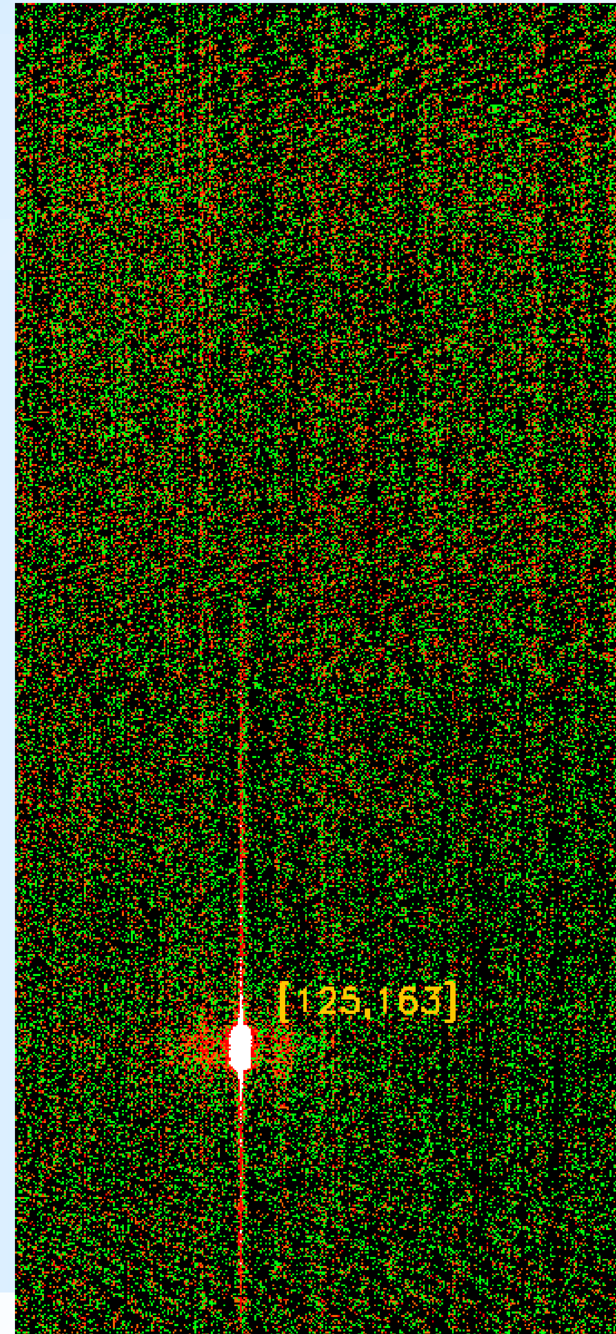
GODDARD SPACE FLIGHT CEN

OGTC
Az: -32deg

Left: 417nm

Right:372nm



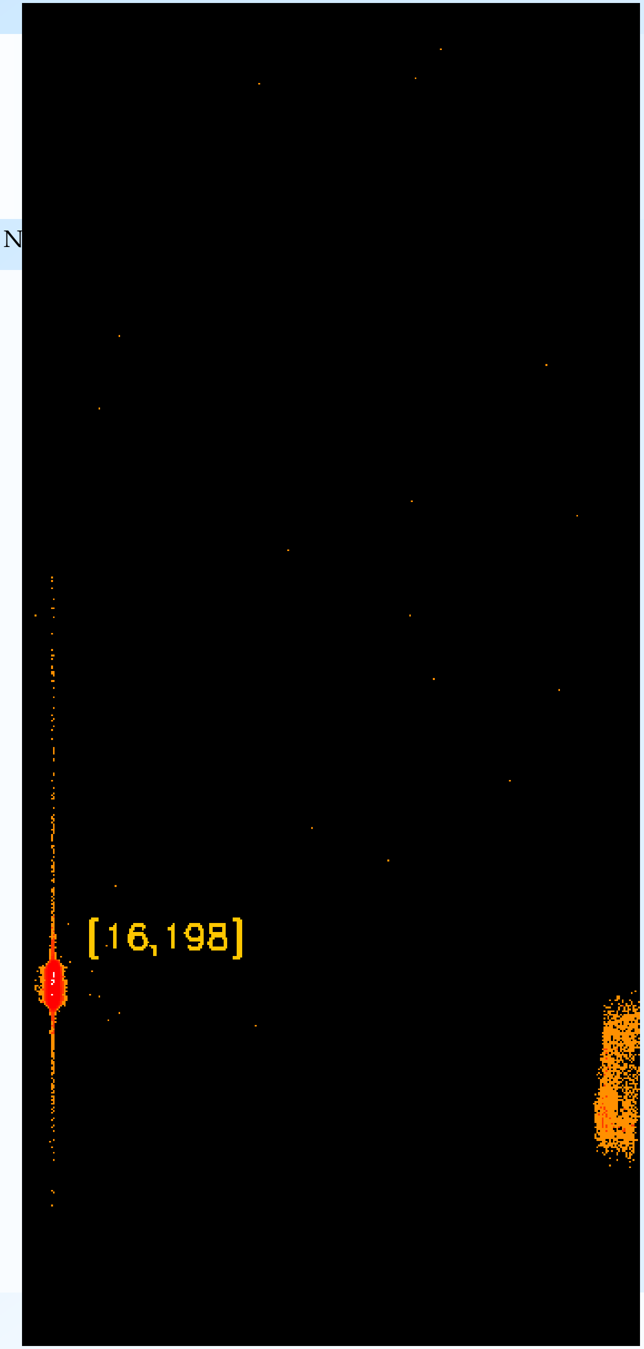


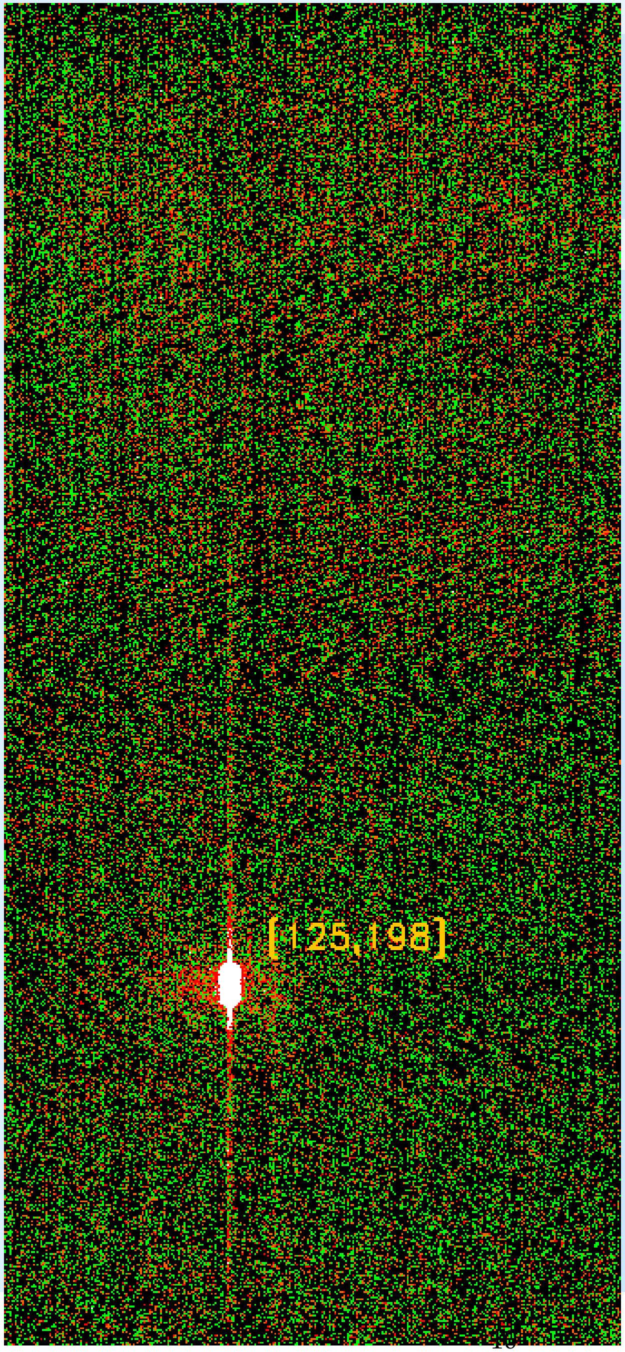
GODDARD SPACE FLIGHT CEN

OGTC
Az: -27deg

Left: 417nm

Right:372nm



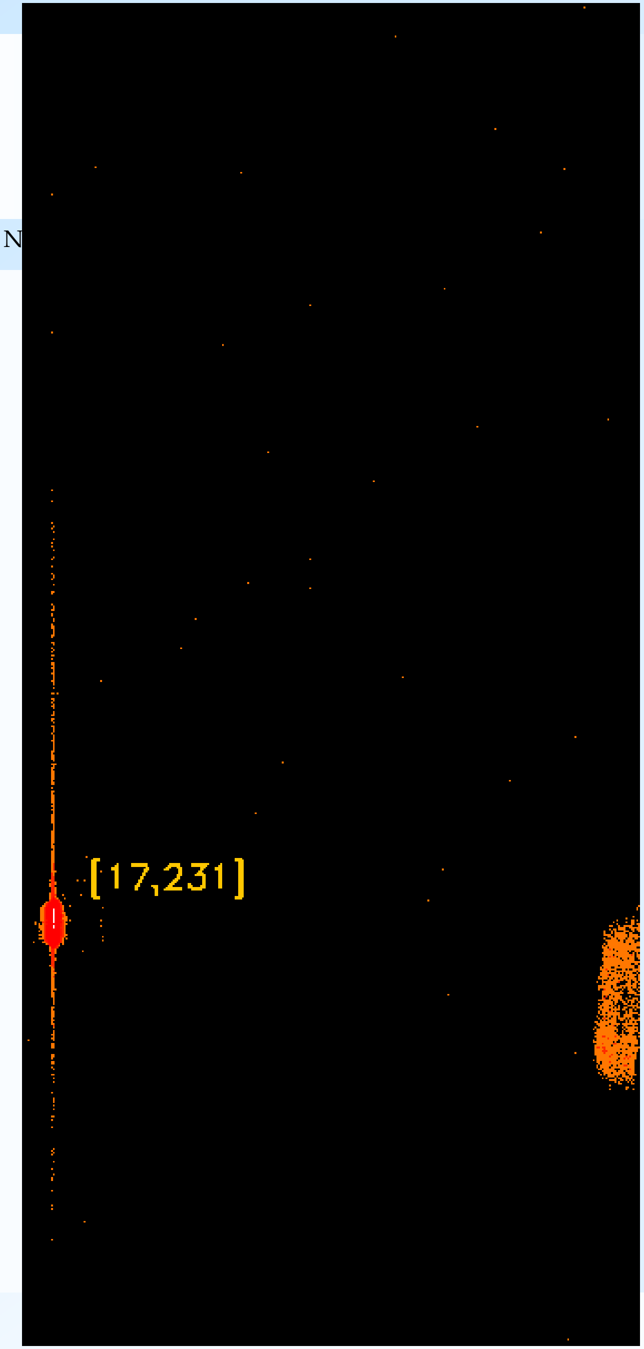


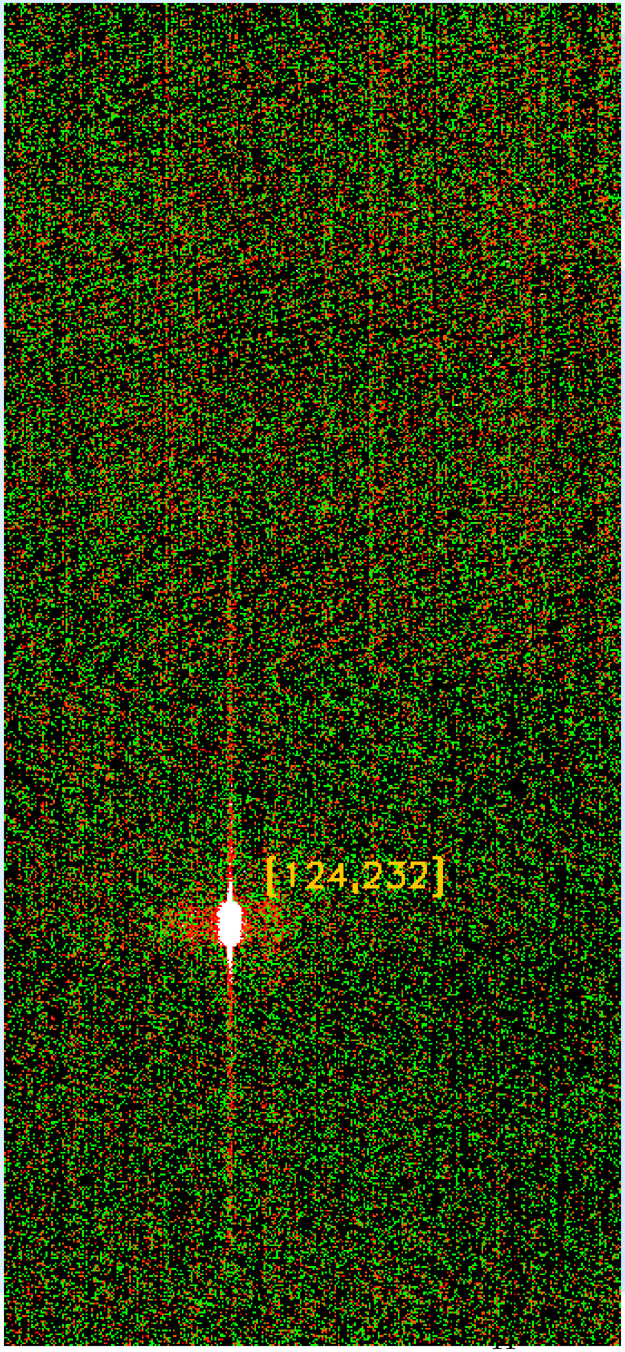
GODDARD SPACE FLIGHT CEN

OGTC
Az: -21deg

Left: 417nm

Right:372nm

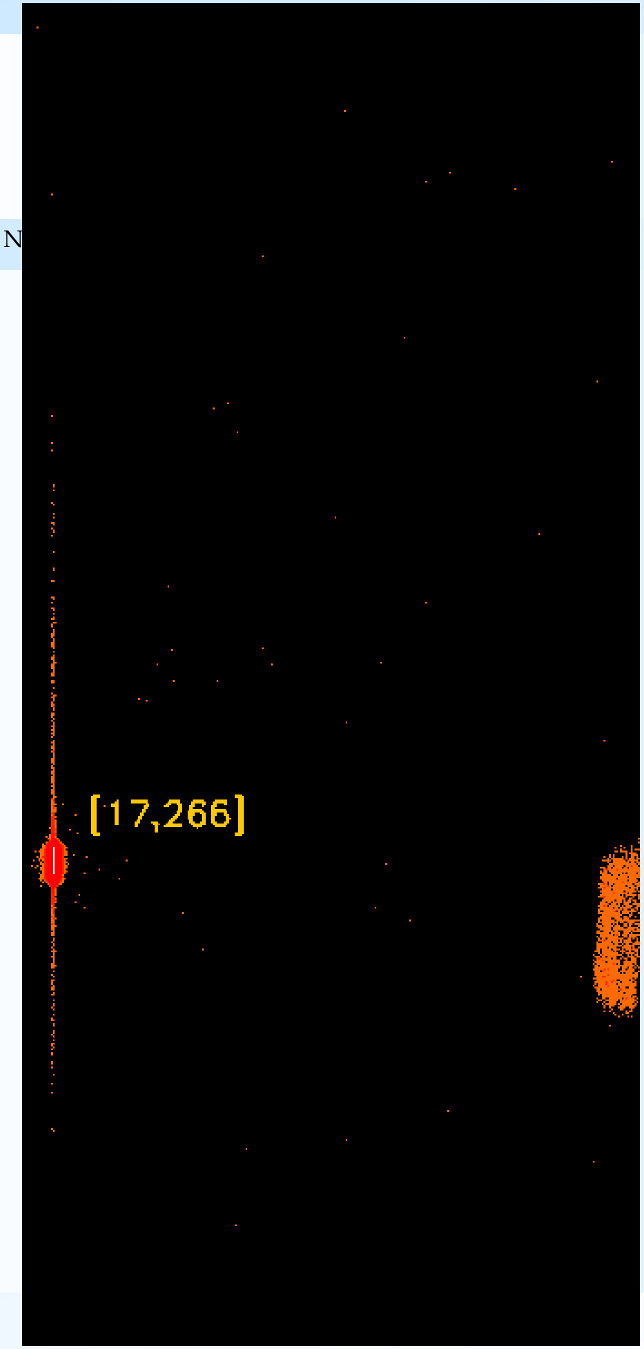


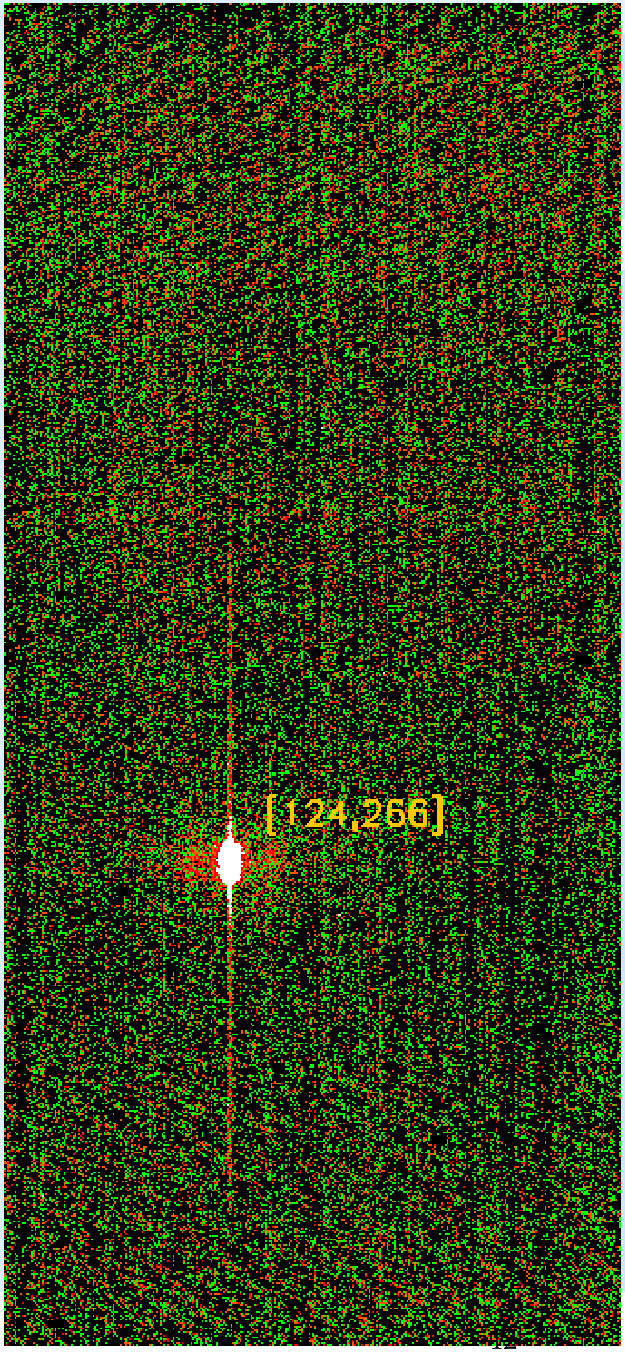


OGTC
Az: -16deg

Left: 417nm

Right:372nm



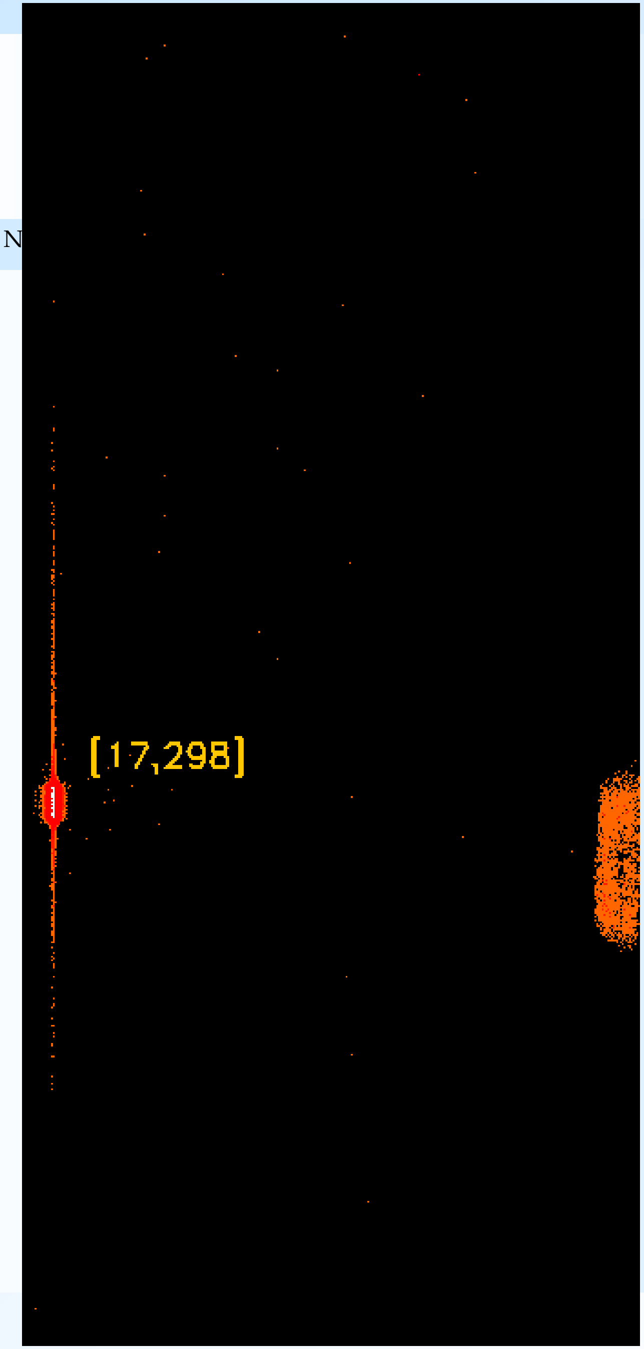


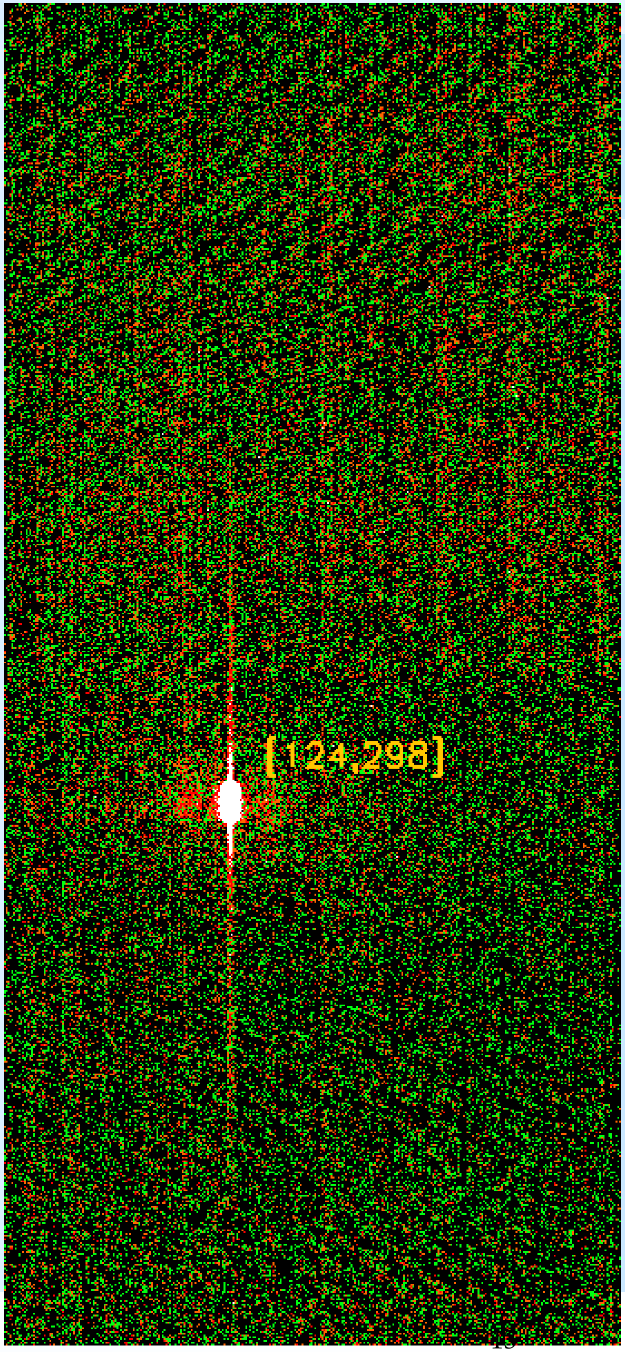
GODDARD SPACE FLIGHT CEN

OGTC
Az: -10deg

Left: 417nm

Right:372nm



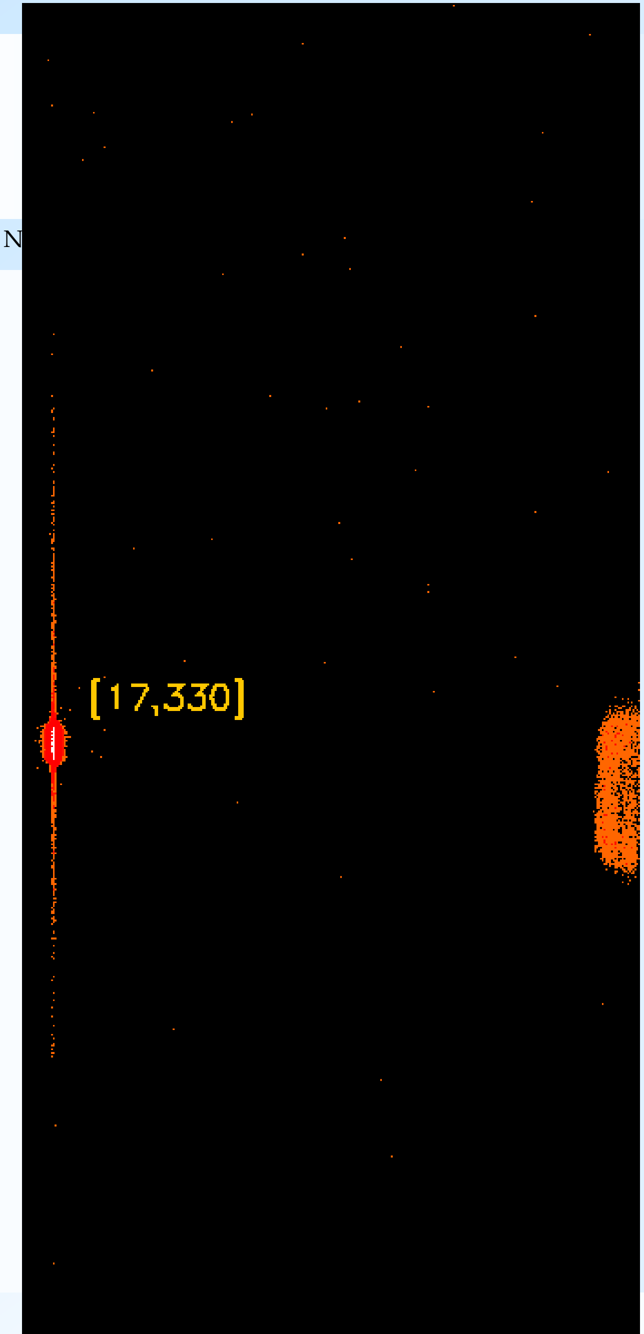


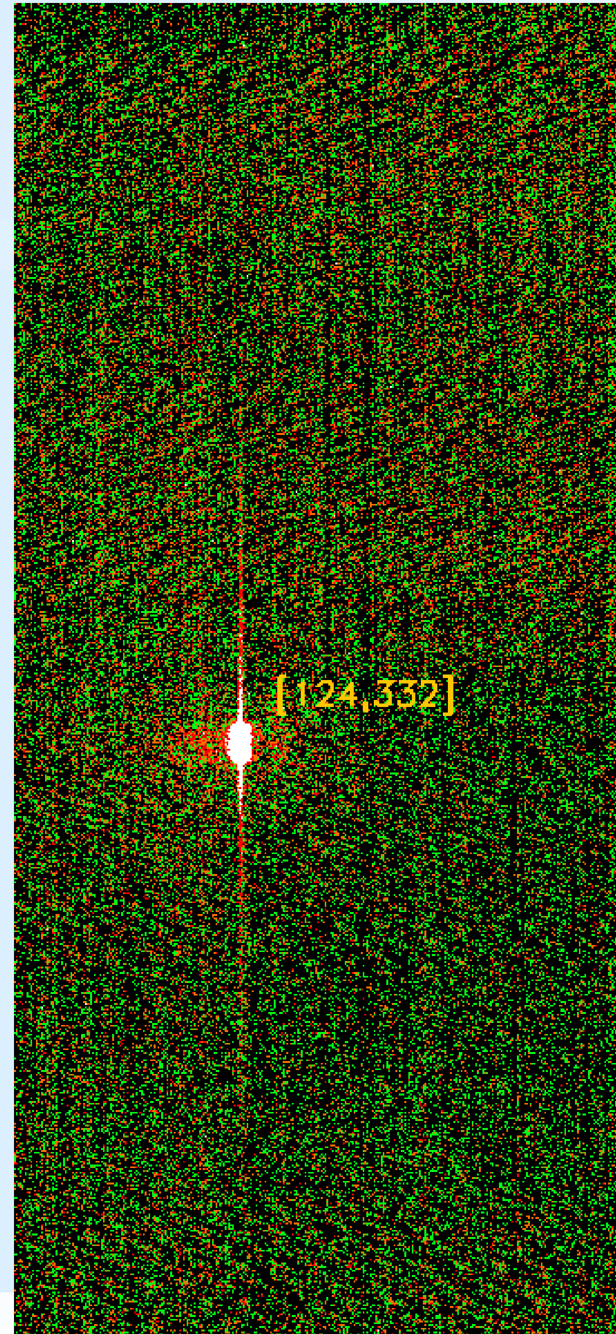
GODDARD SPACE FLIGHT CEN

OGTC
Az: -5deg

Left: 417nm

Right:372nm

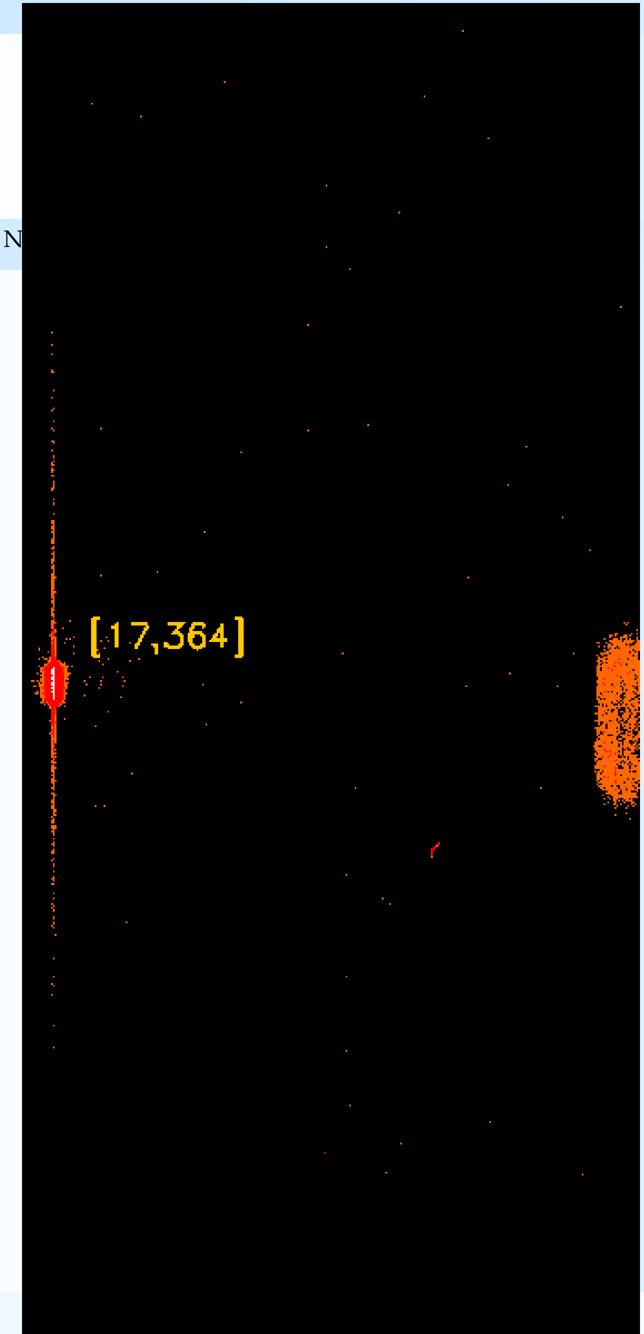


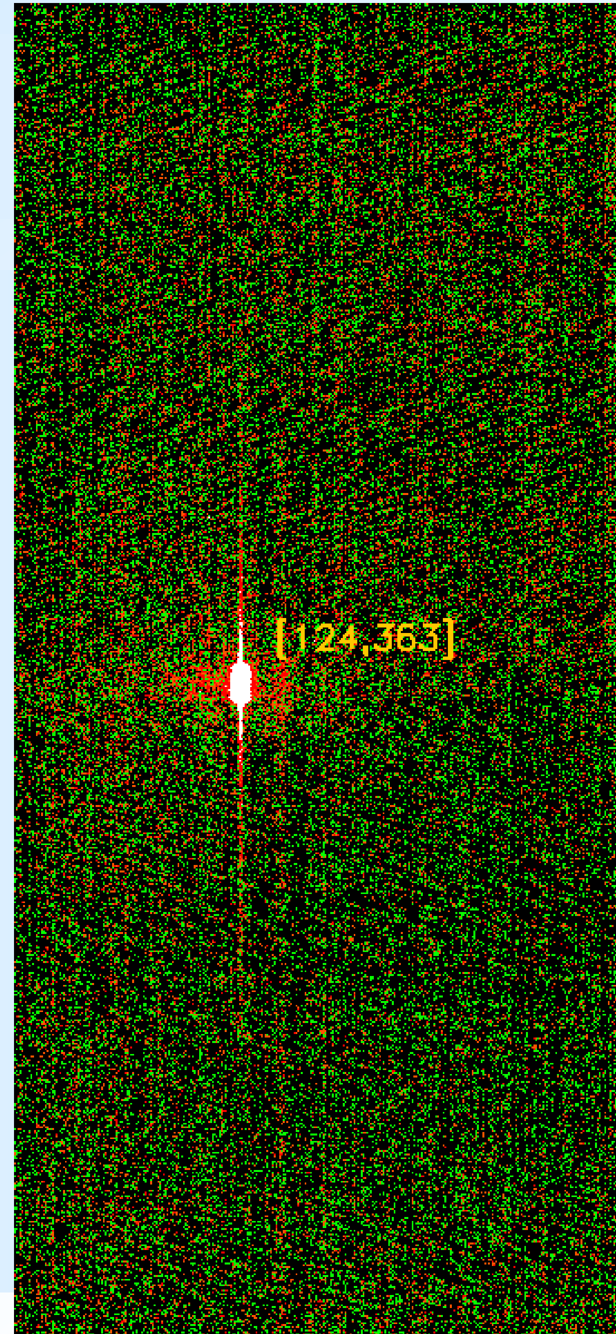


OGTC
Az: 0deg

Left: 417nm

Right:372nm



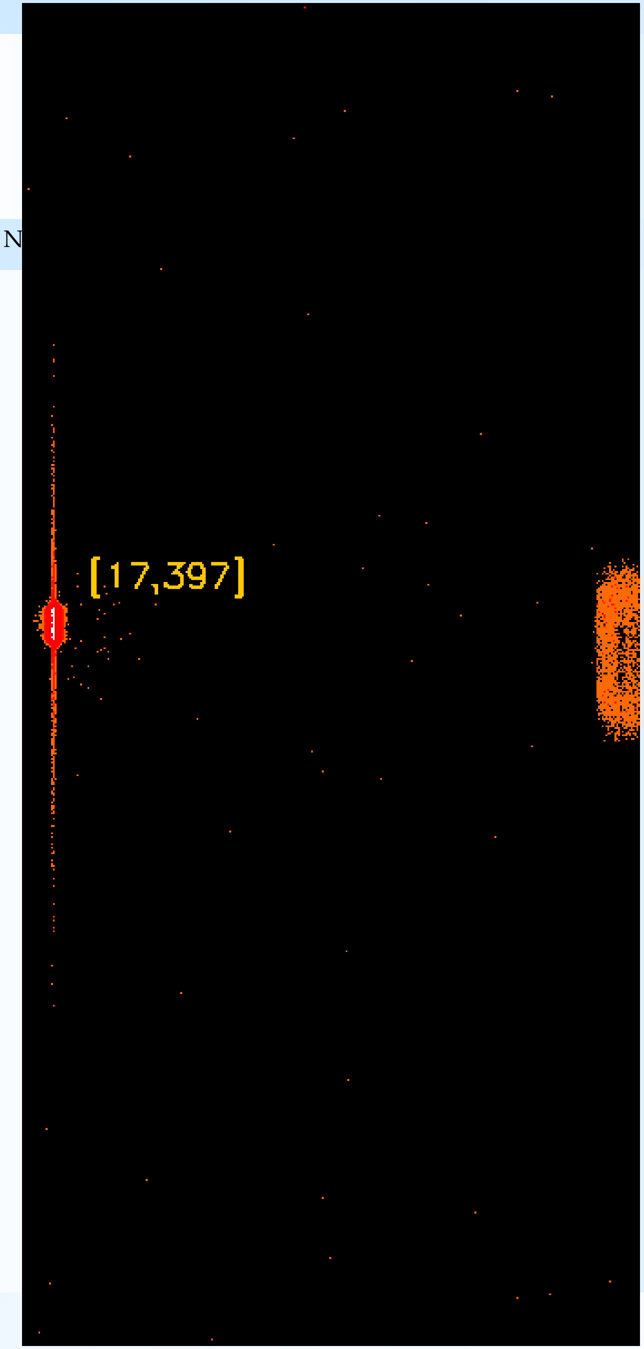


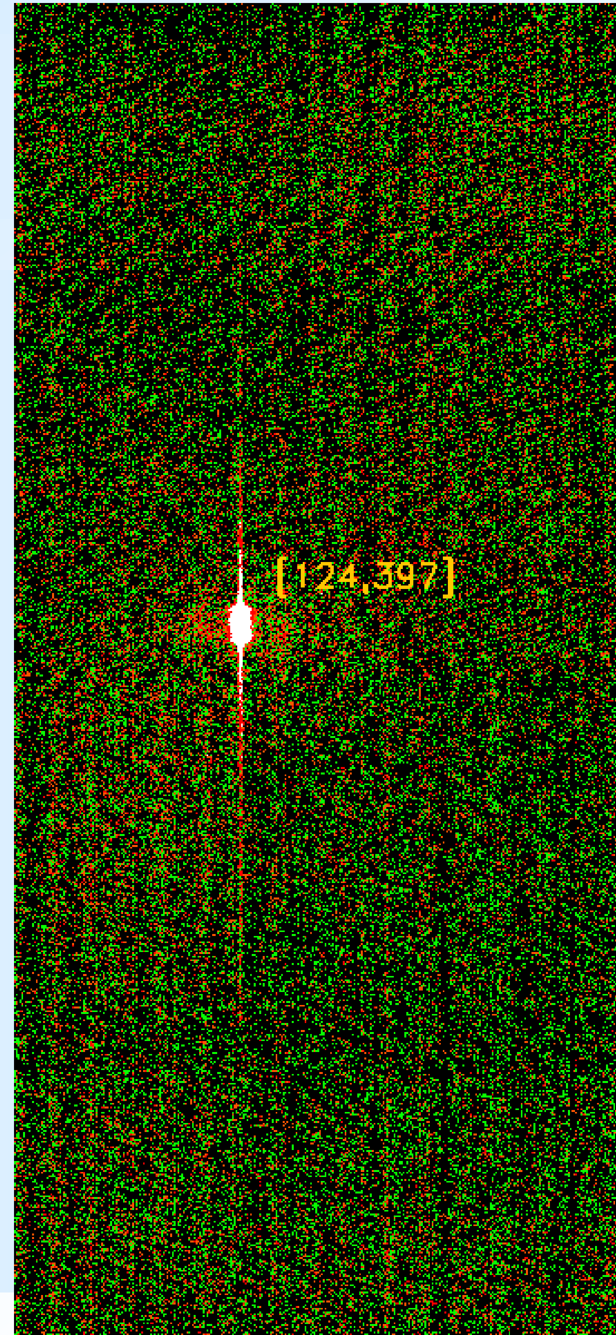
GODDARD SPACE FLIGHT CEN

OGTC
Az: +5deg

Left: 417nm

Right:372nm

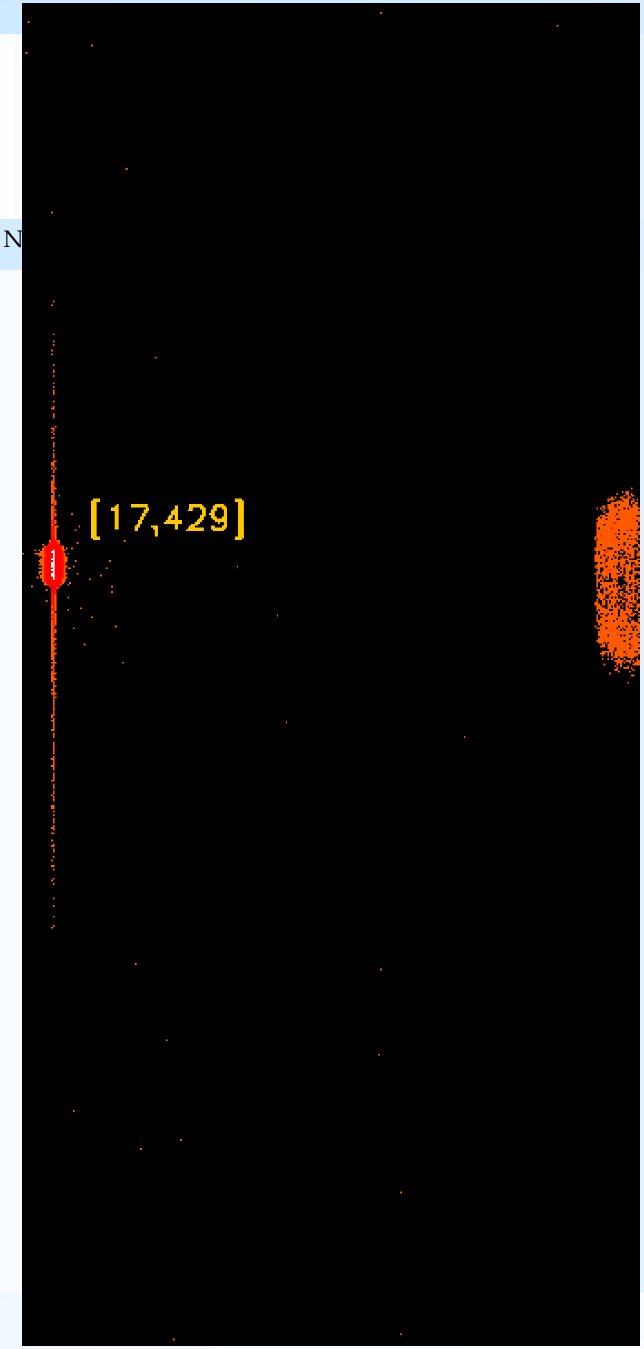


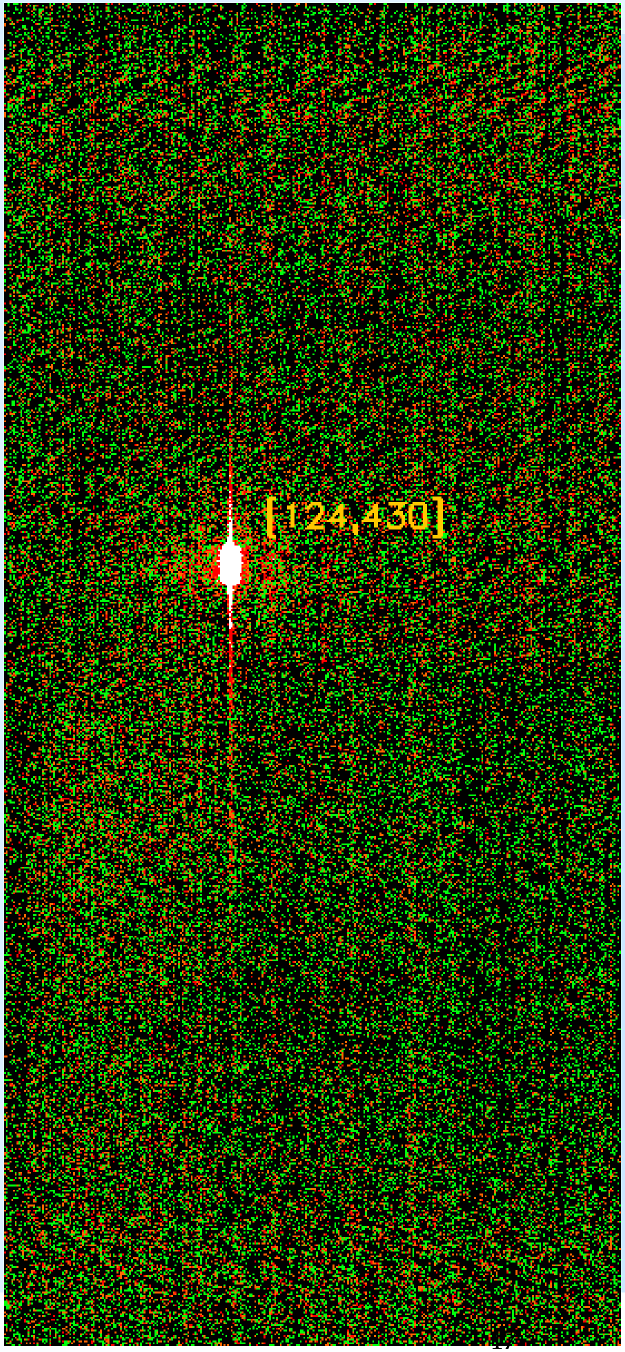


OGTC
Az: +10deg

Left: 417nm

Right:372nm



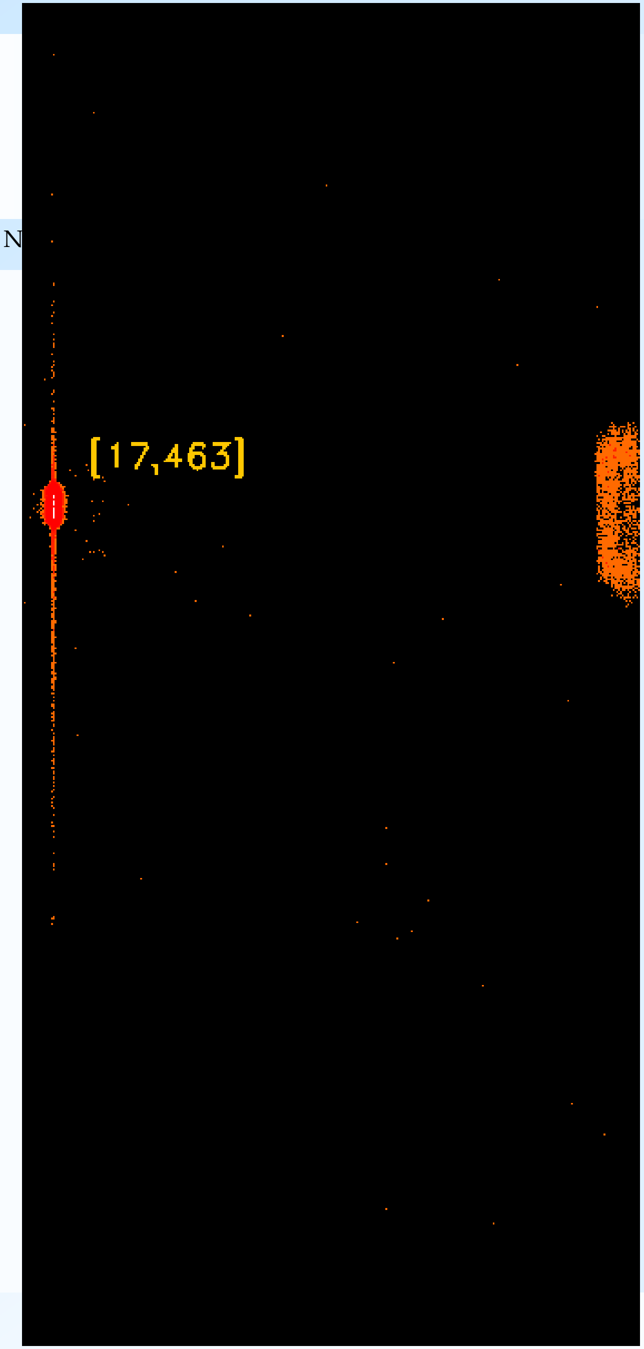


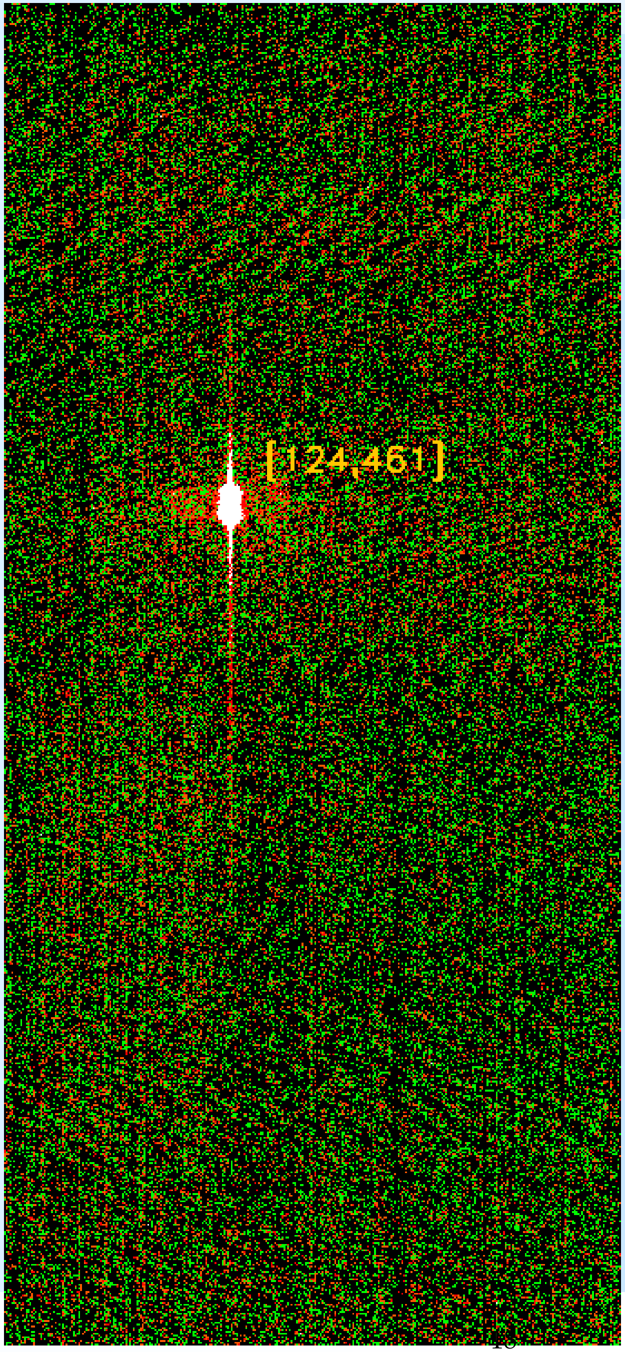
GODDARD SPACE FLIGHT CEN

OGTC
Az: +16deg

Left: 417nm

Right:372nm

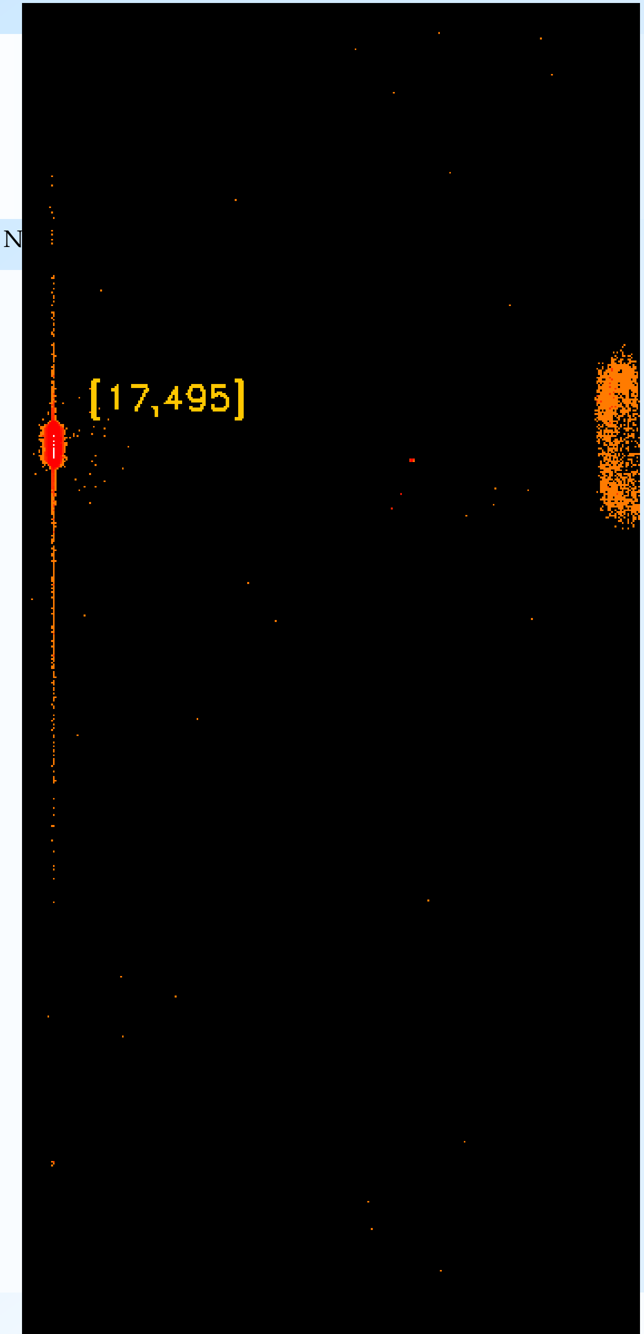


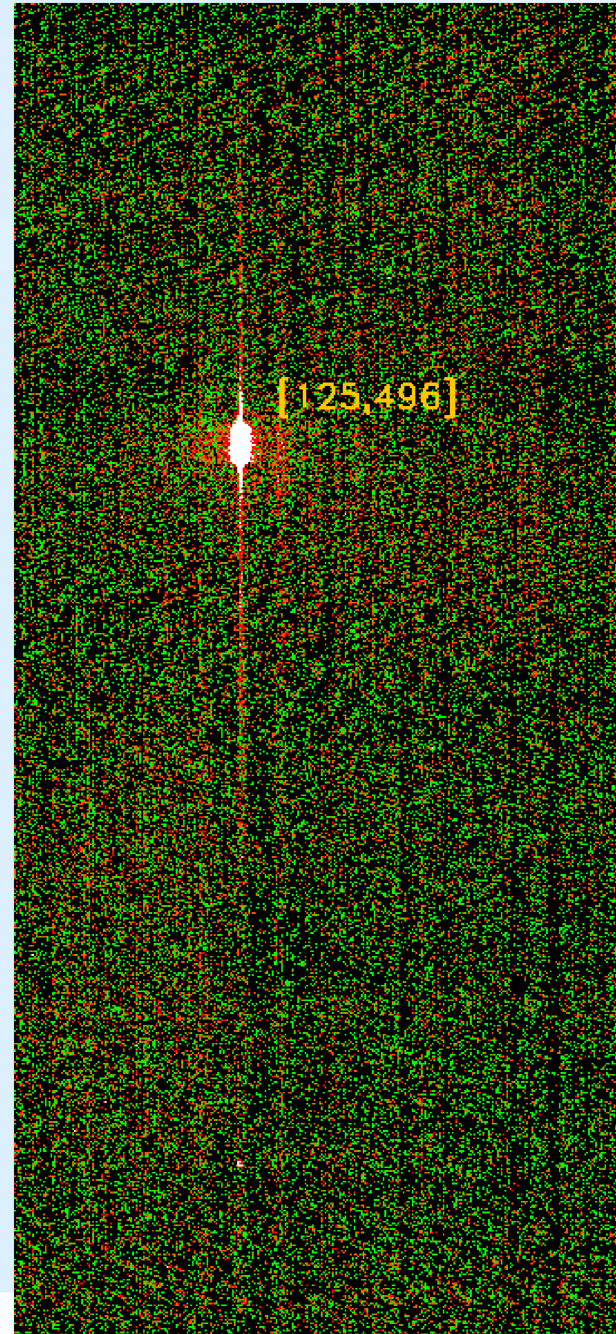


OGTC
Az: +21deg

Left: 417nm

Right:372nm



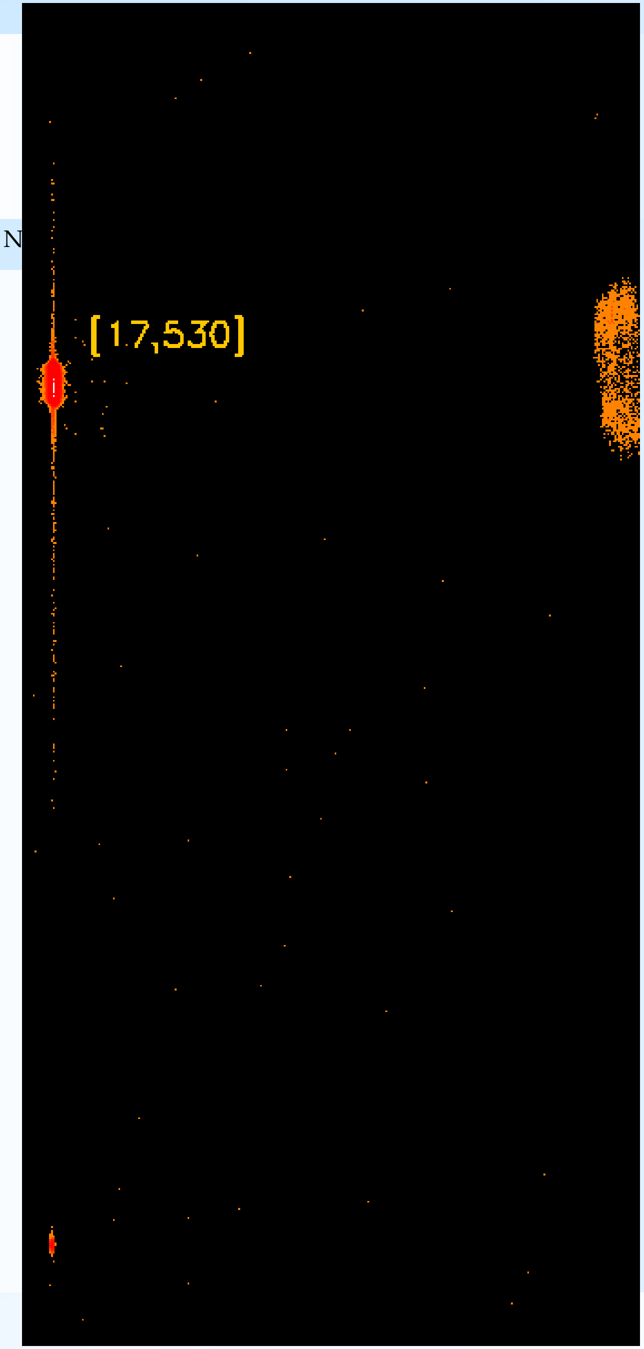


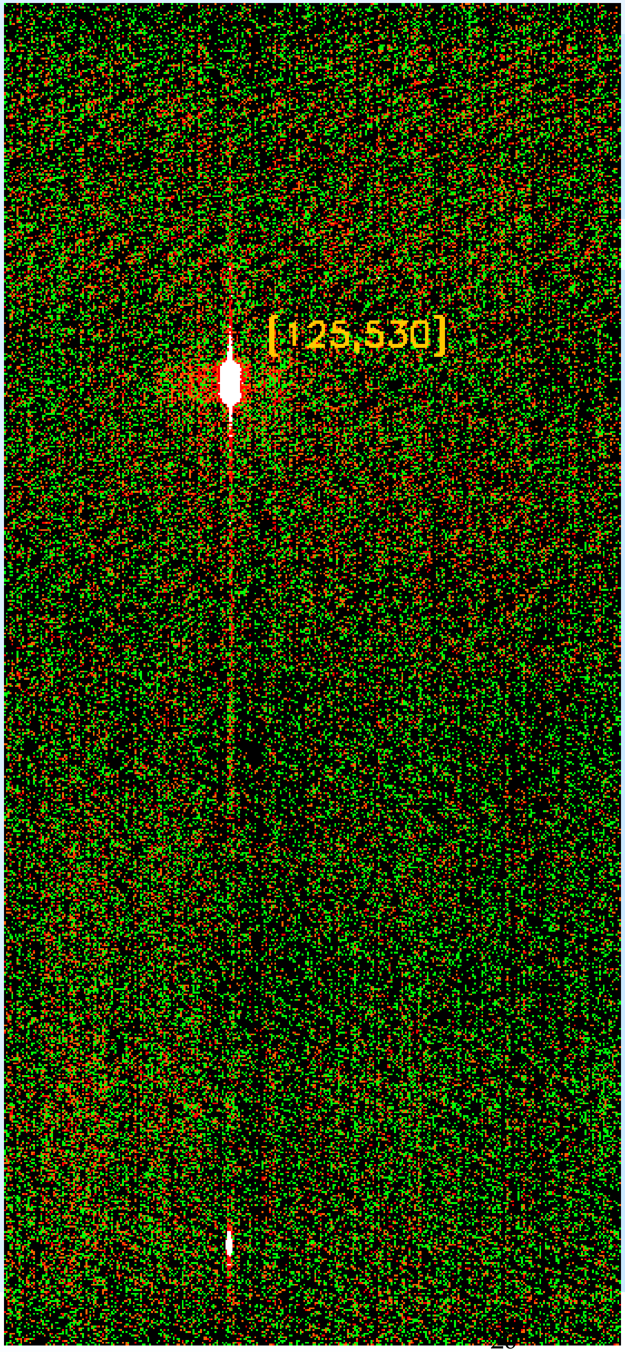
GODDARD SPACE FLIGHT CEN

OGTC
Az: +27deg

Left: 417nm

Right:372nm



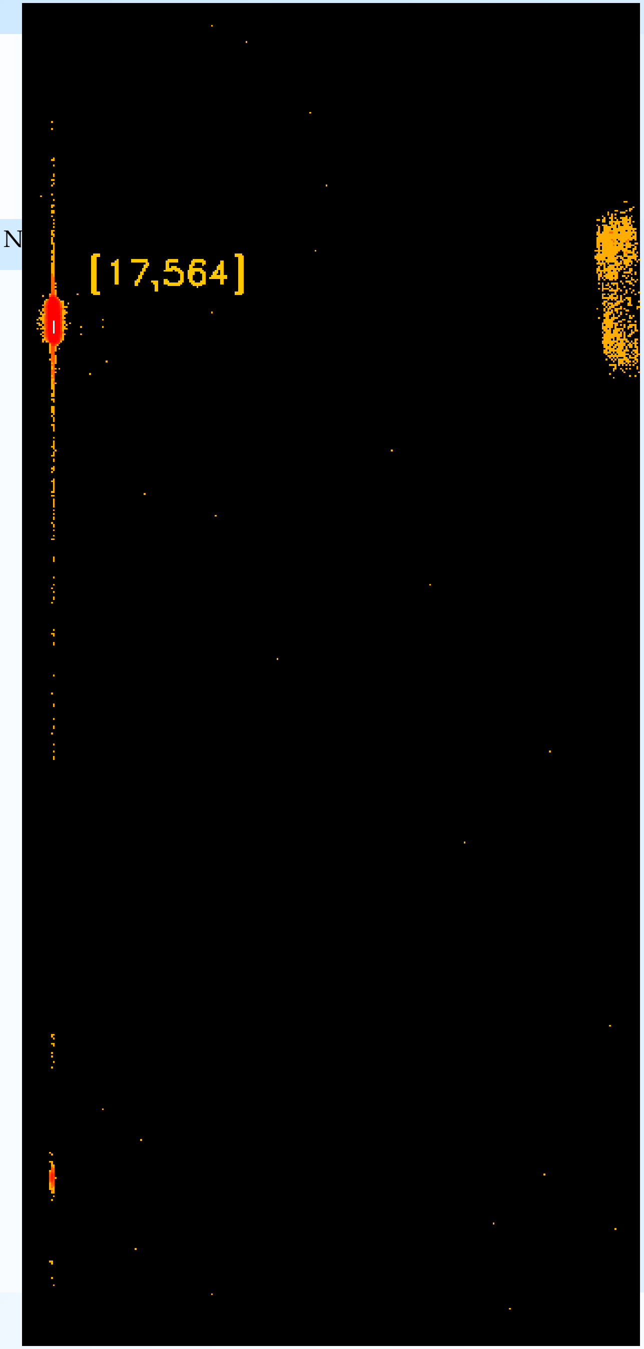


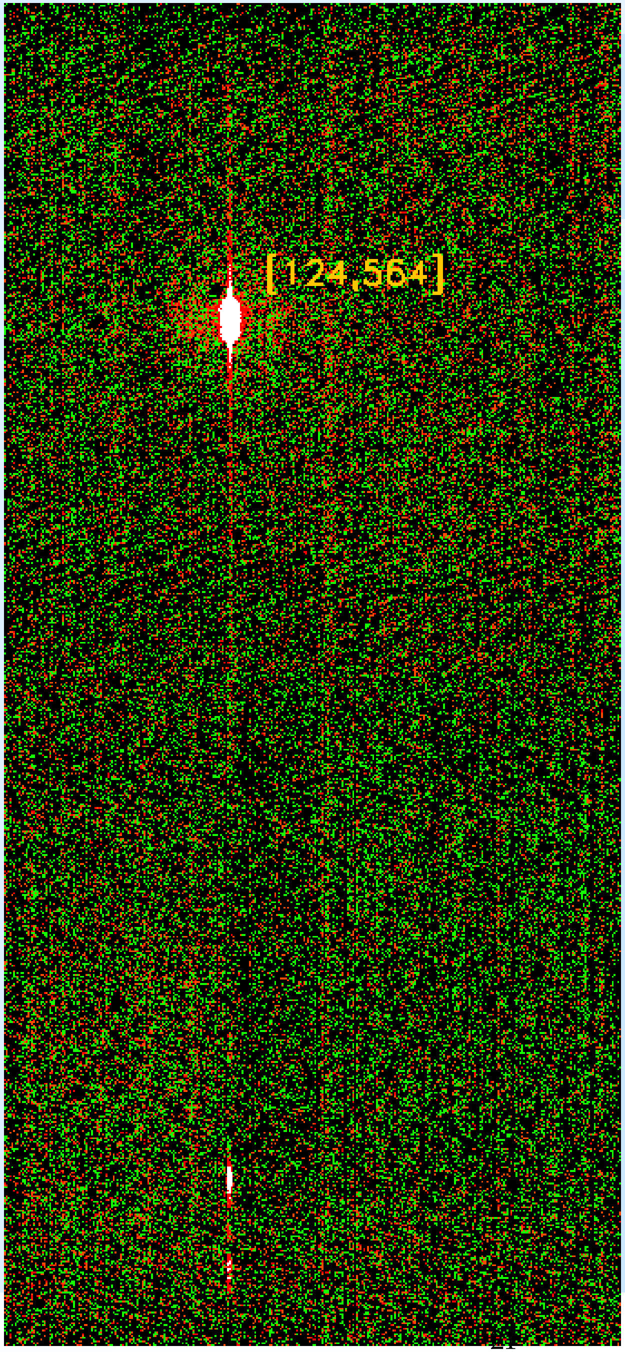
GODDARD SPACE FLIGHT CEN

OGTC
Az: +32deg

Left: 417nm

Right:372nm



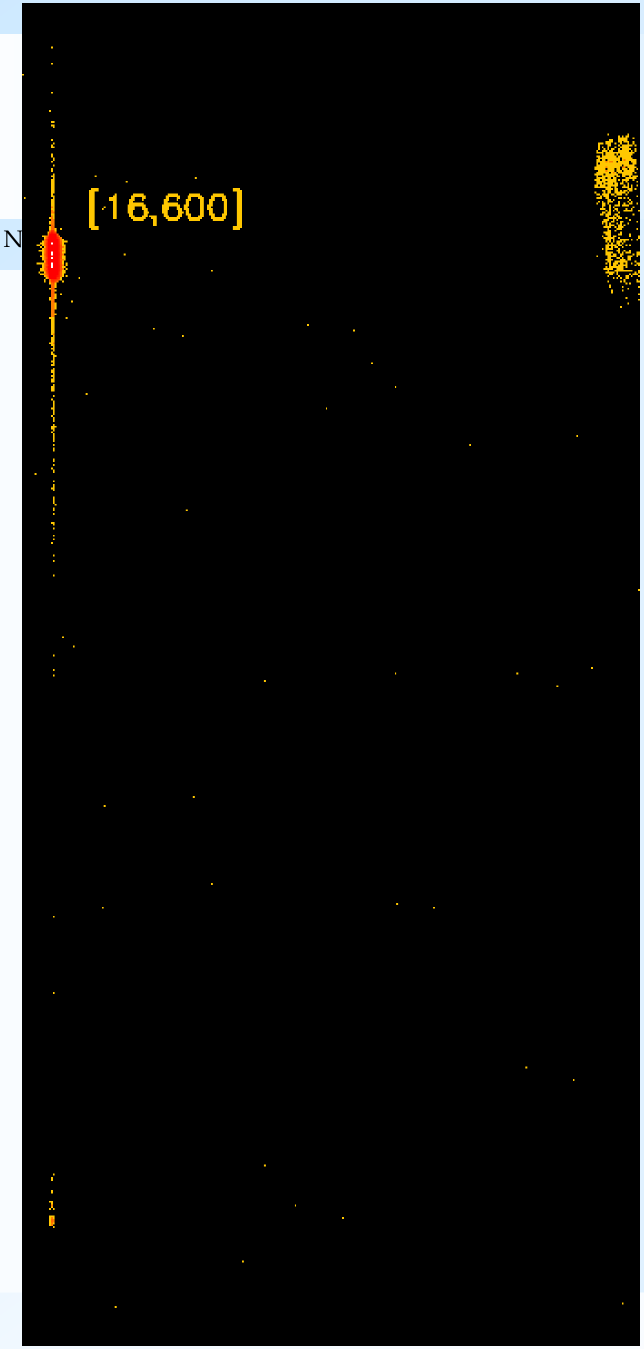


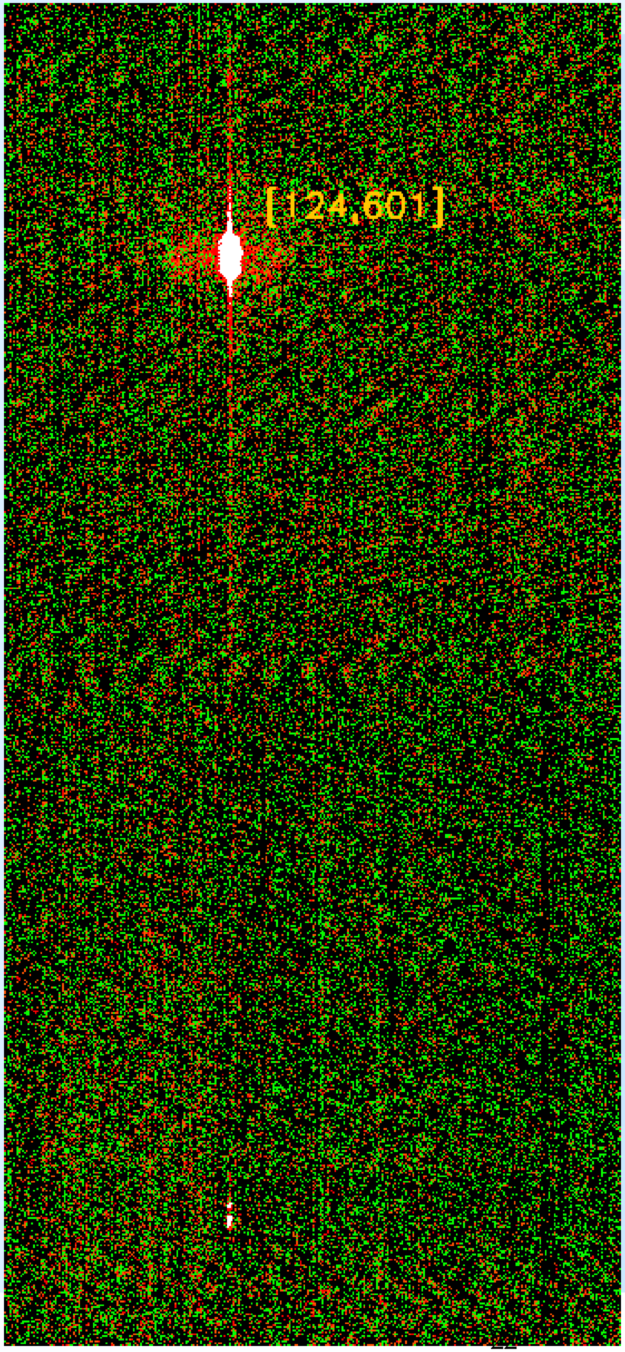
GODDARD SPACE FLIGHT CEN

OGTC
Az: +37deg

Left: 417nm

Right:372nm

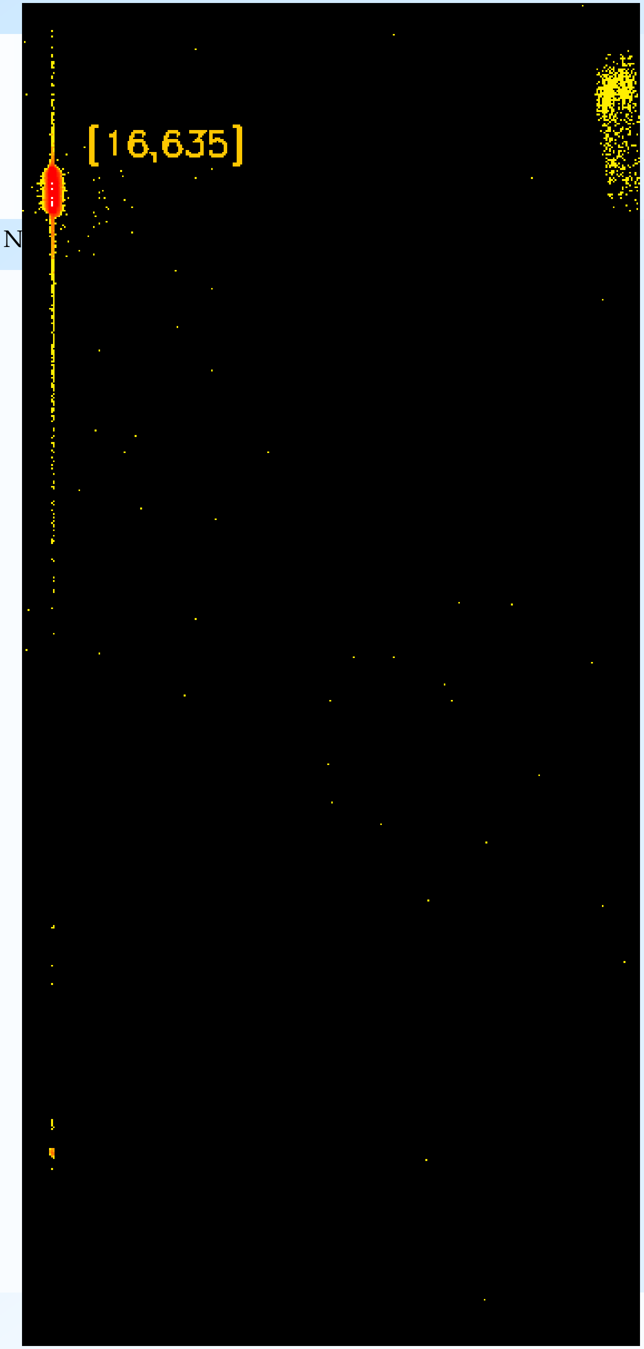


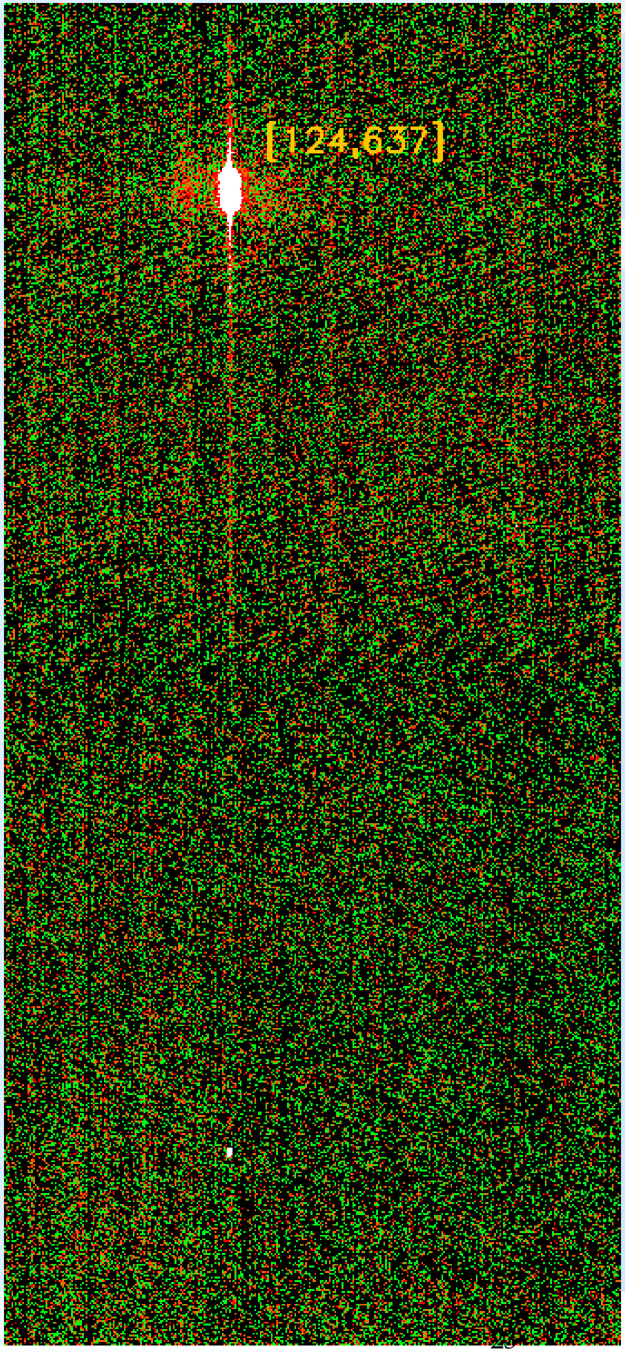


OGTC
Az: +43deg

Left: 417nm

Right:372nm



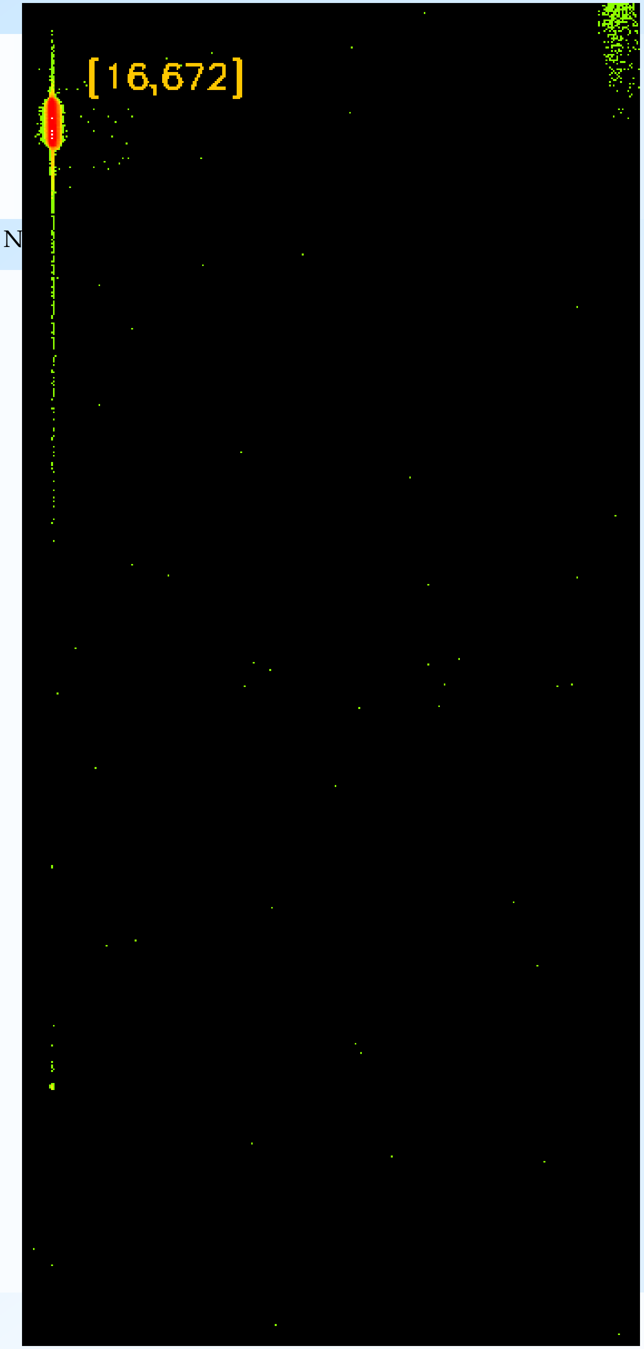


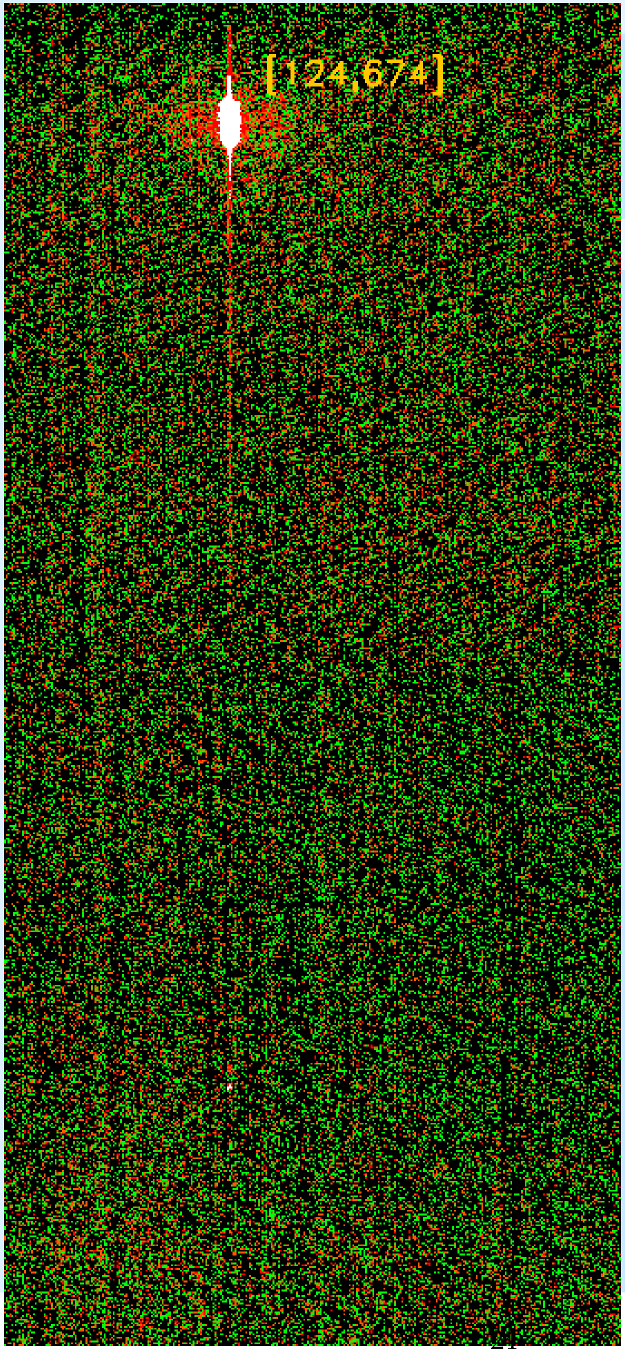
GODDARD SPACE FLIGHT CEN

OGTC
Az: +48deg

Left: 417nm

Right:372nm



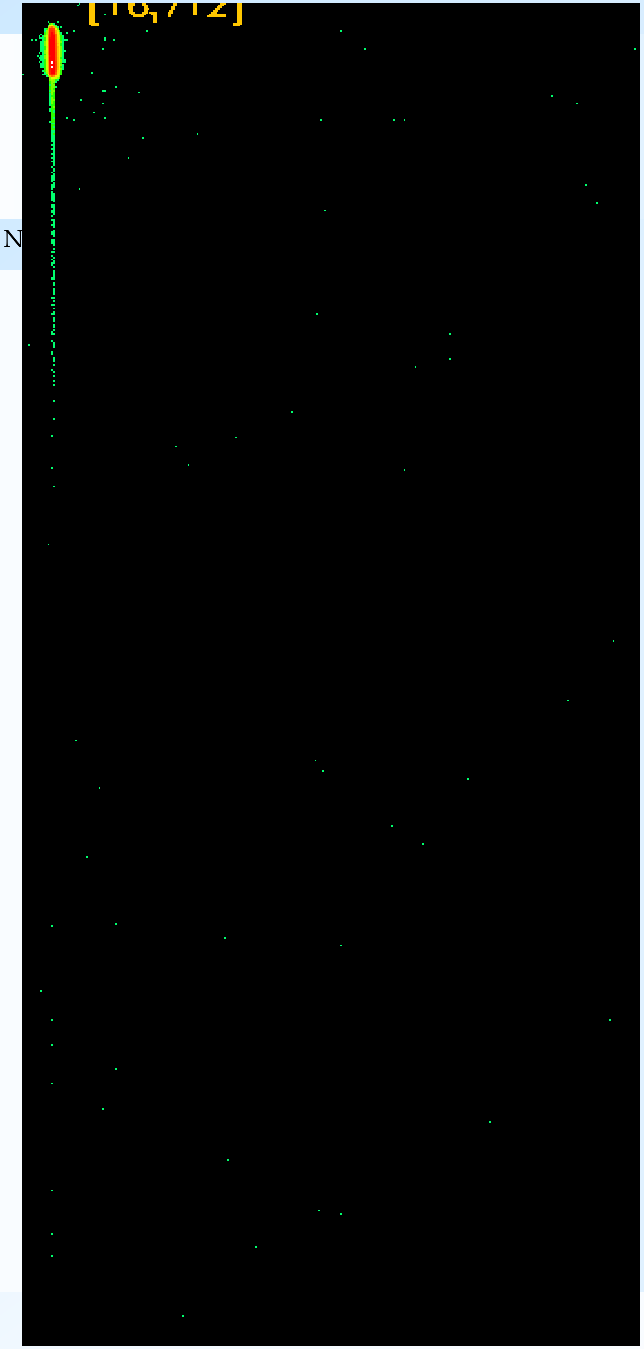


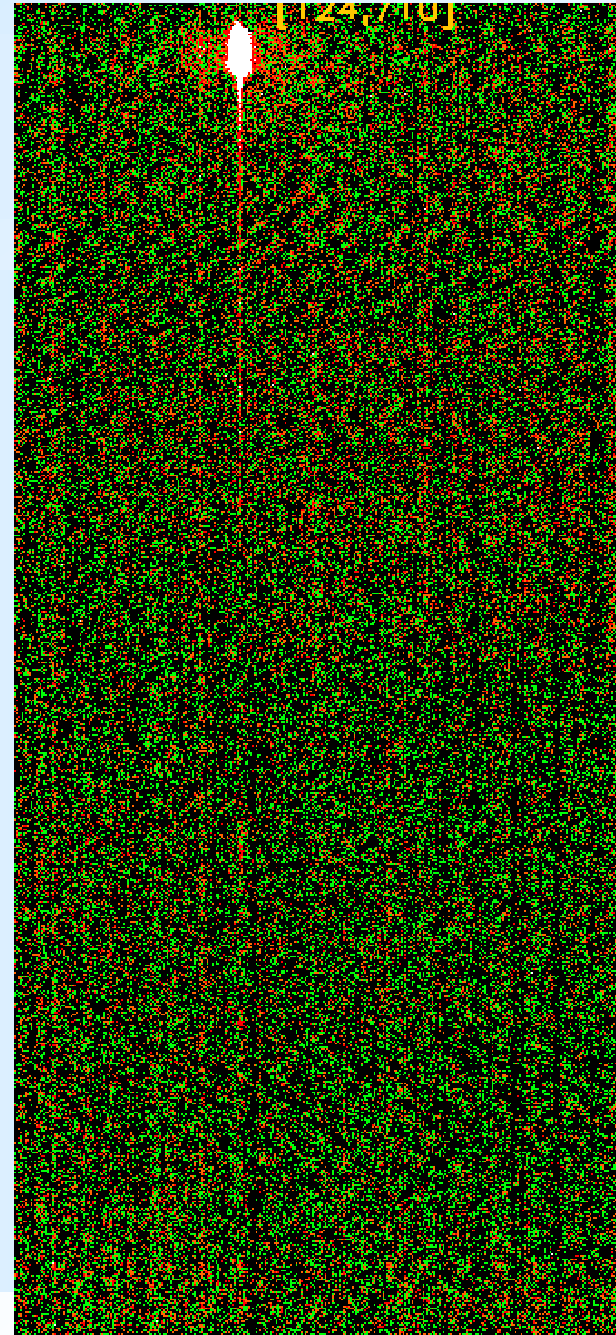
GODDARD SPACE FLIGHT CEN

OGTC
Az: +54deg

Left: 417nm

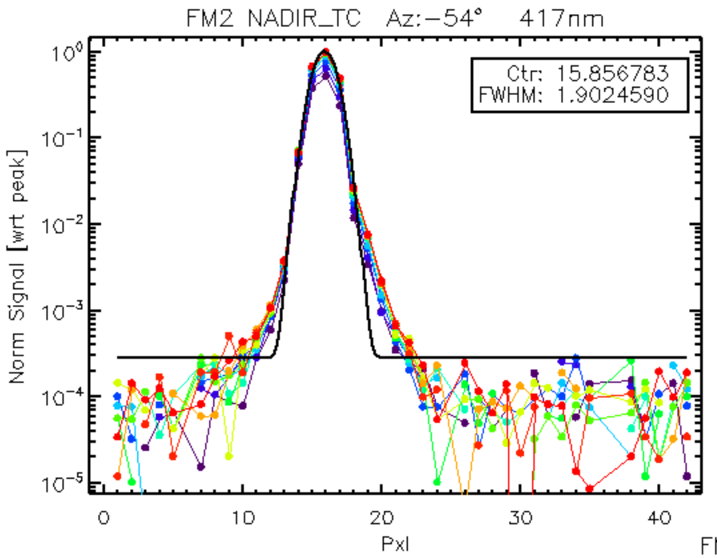
Right:372nm

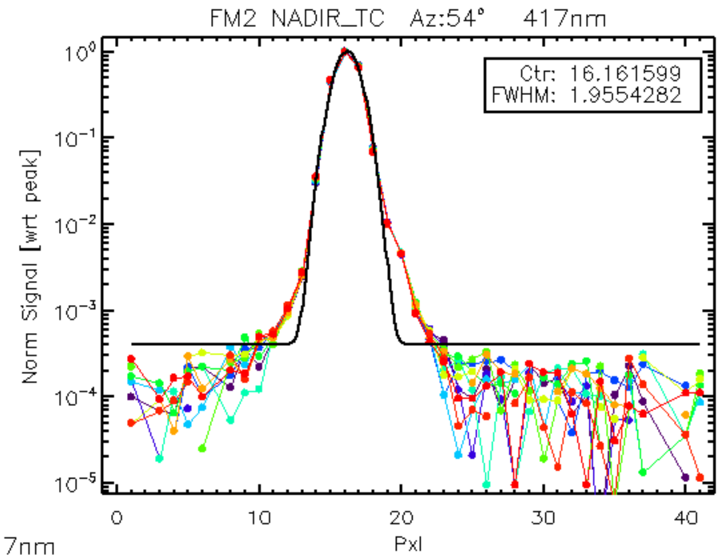


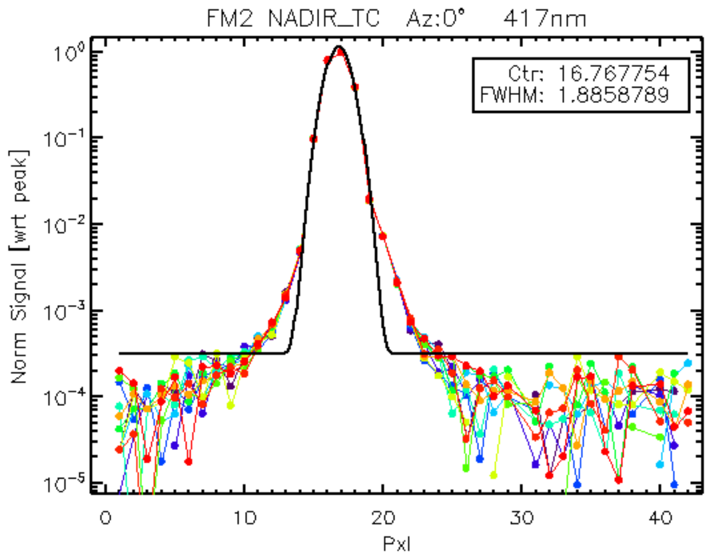


417nm Line Fits

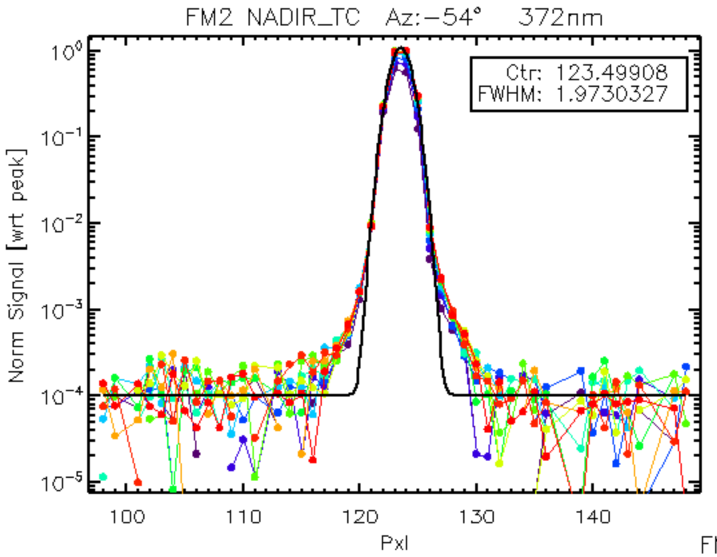
GODDARD SPACE FLIGHT CENTER

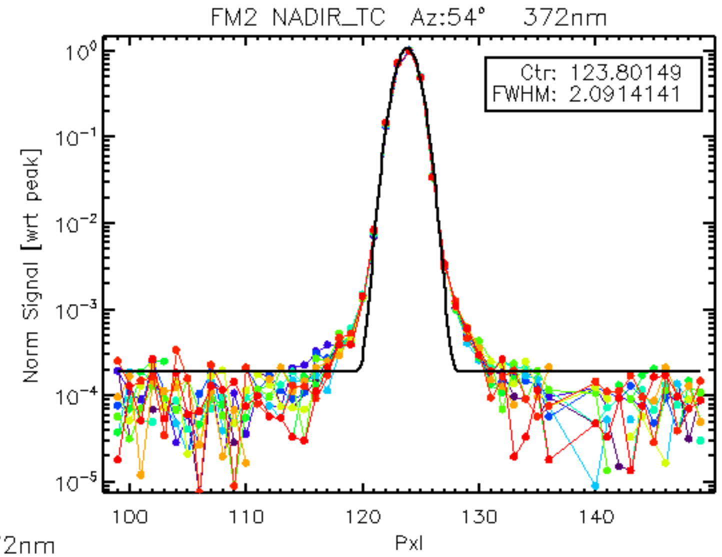


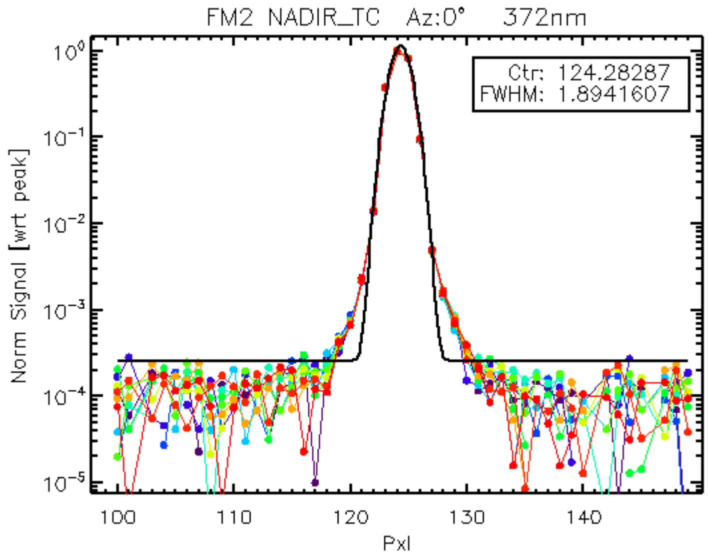




372nm Line Fits



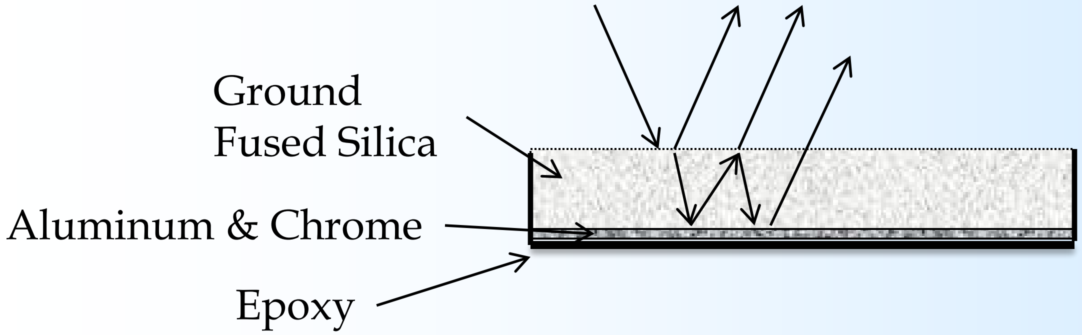




J1 OMPS QVD

- **NPP OMPS utilized ground aluminum diffusers.**
- **New diffuser (QVD) design implemented in order to minimize spectral features in solar calibrations.**
  - **Reduces wavelength dependent albedo calibration uncertainty.**
  - **Reduces time required for ground characterization.**

- **Design**

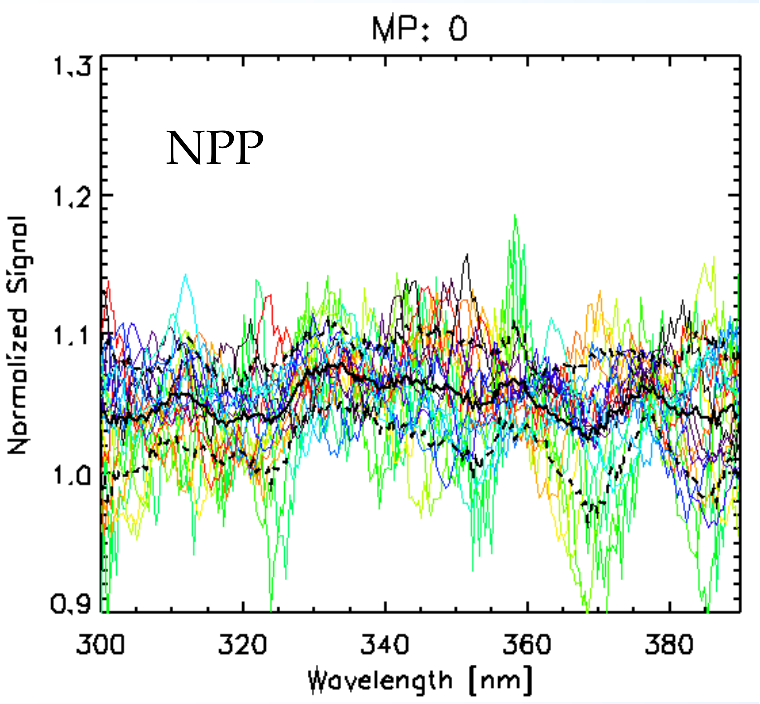


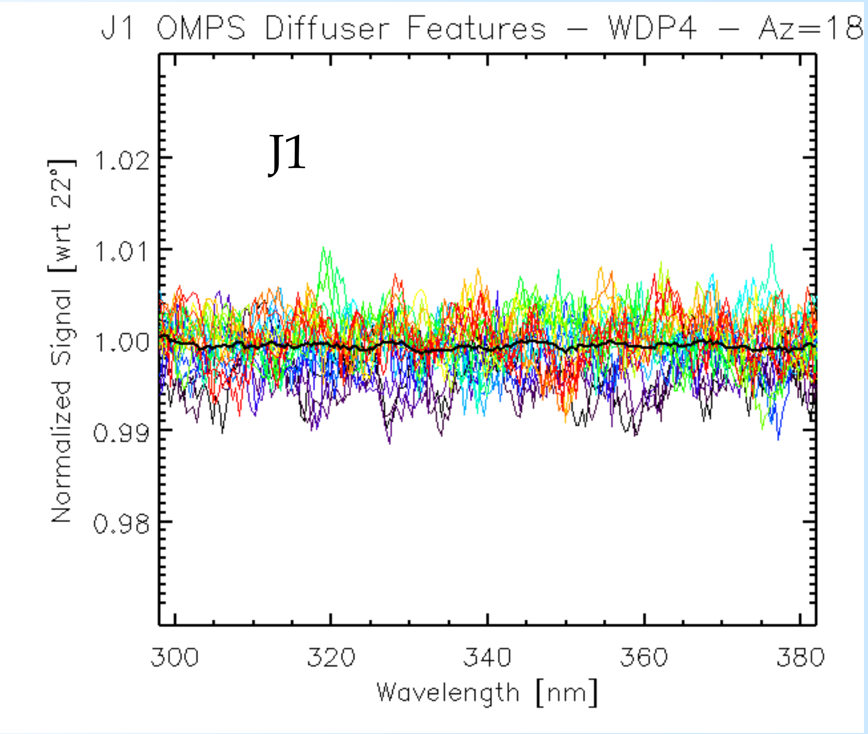
c/o BATC

Flight 1 Diffusers/Wipers

J1 OMPS QVD – Diffuser Features

GODDARD SPACE FLIGHT CENTER





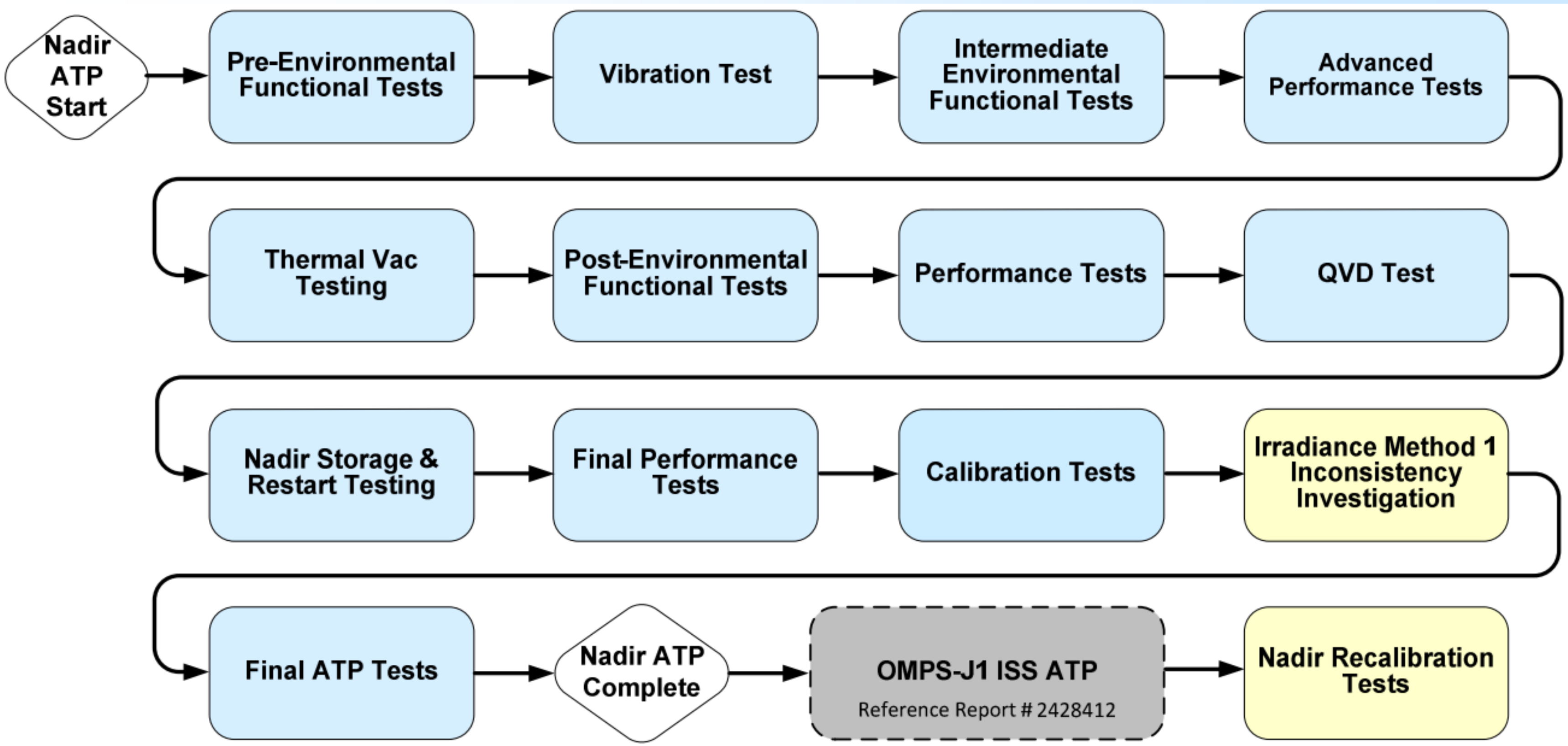
- Diffuser features significantly reduced in J1 QVD.
- Colored lines are individual rows.
- Solid black is the macro-pixel average.

Outline

- Instrument design changes
  - Wavelength coverage
  - QVD
- **Calibration test phase summary**
- Calibration issues
  - Diffuser stability
  - G/I and R recalibration summary
- Summary

Calibration test phase summary

GODDARD SPACE FLIGHT CENTER



reference: IN0092-TST2-054

Calibration test phase highlights

- No significant changes to performance requirements.
- QVD
  - Smaller goniometry step size: was 0.5deg; is 1deg
  - Reflectivity changes and conditioning necessitated goniometry, irradiance, and radiance calibration checks after ISS TVAC.
- Wavelength coverage
  - Band pass measurements at 417nm
  - Stray light PSF measurements at 417nm (TBC)
- Air to vacuum albedo check
  - Verify instrument albedo calibration consistent in air and vacuum conditions.
  - Performed during ISS TVAC testing.

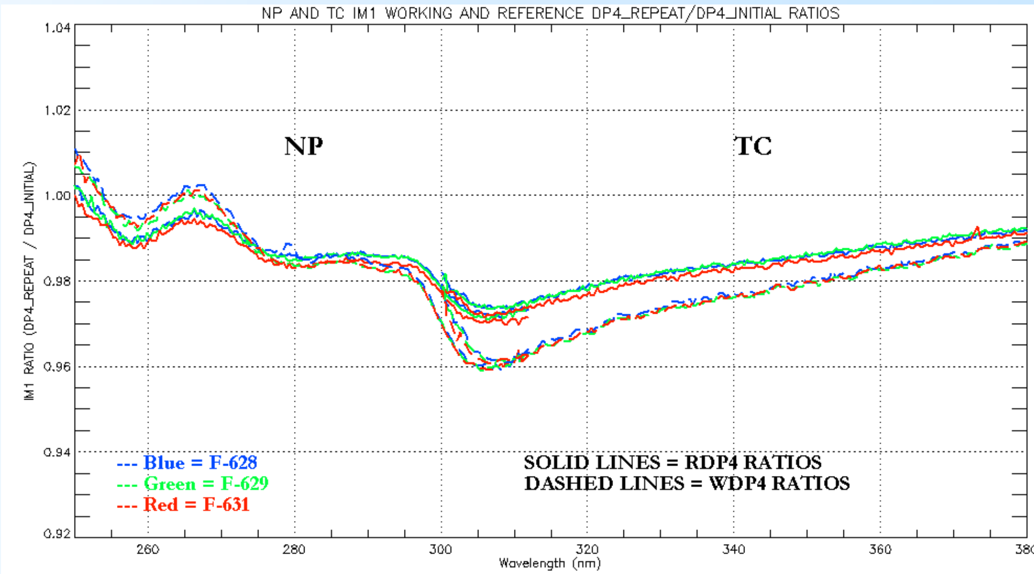
Outline

- Instrument design changes
  - Wavelength coverage
  - QVD
- Calibration test phase summary
- **Calibration issues**
  - **Diffuser stability**
  - **G/I and R recalibration summary**
- Summary

J1 OMPS QVD

GODDARD SPACE FLIGHT CENTER

- QVDs experienced optical degradation over course of ground testing.
  - Failure Review Board found that epoxy exposure to UV light caused change in its optical characteristics.
  - Aluminum coating on back side of diffuser did not fully cover roughened back surface, thus allowing UV light to interact with epoxy.



c/o BATC

- BATC performed "conditioning" of diffusers in order to stabilize reflectivity.
- Verification tests performed after conditioning.
  - Goniometry and absolute irradiance calibration
  - Absolute radiance calibration

J1 OMPS QVD – Verification Tests

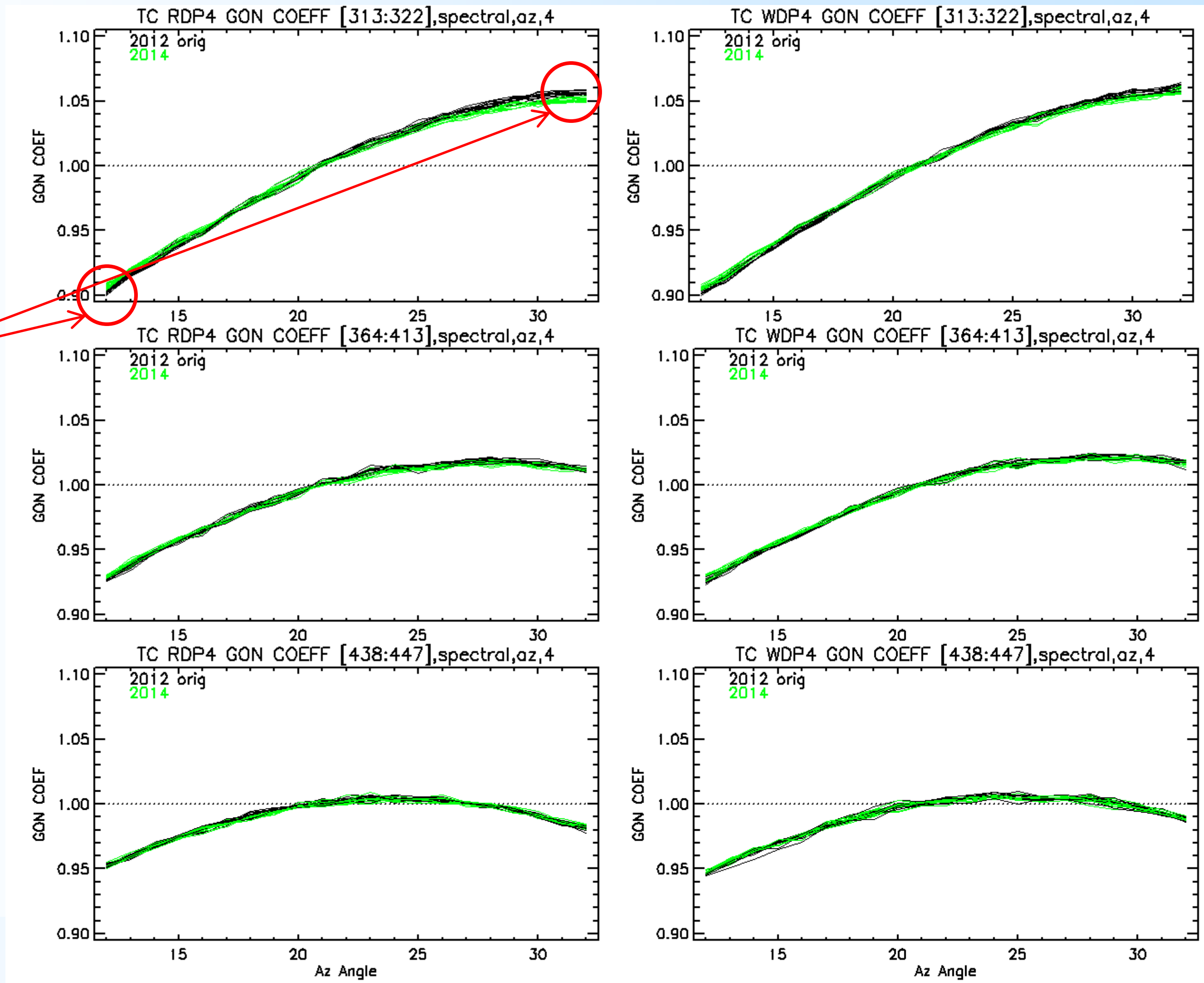
- Irradiance and Goniometry
  - Repeated goniometry at 3 diffuser positions to verify that QVD characterization from 2012 still valid.
    - 2012 and 2014 goniometry matched to within about 0.5% for repeated diffuser positions.
    - Correction methodology developed using 2014 data.
  - Repeated absolute irradiance calibration at all positions for most accurate albedo calibration.

- Radiance Check and ReTest
  - Subset of radiance calibration performed to verify 2012 characterization still valid.
  - Differences ~2% seen, prompting repeat of full radiance calibration.

J1 OMPS QVD – TC Goniometry Comparison

GODDARD SPACE FLIGHT CENTER

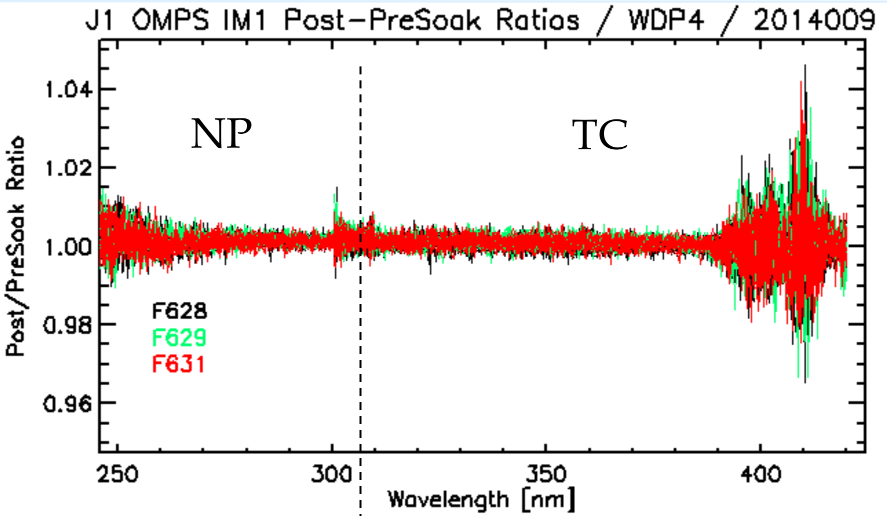
- Plots at right compare azimuthal dependence of Total Column flight diffuser goniometry before (black) and after (green) “conditioning”.
- Differences are relatively small (~0.25%).
- Effect of this error would be to cause season dependence in derived ozone.

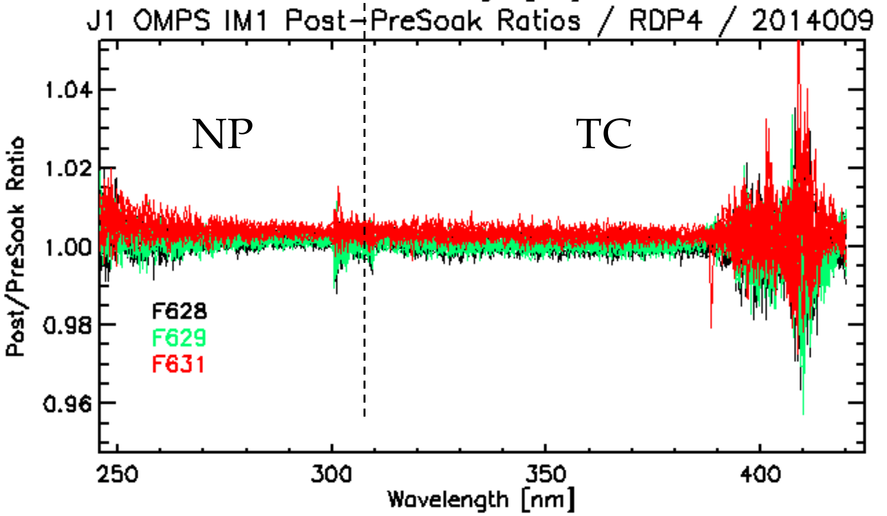


J1 OMPS QVD Stability

- Final UV soak of both flight diffusers performed to ensure stability.
- Plots at right show comparison between pre- and post-soak absolute irradiance calibration measurements.
  - Multiple light sources used (colors).
  - Time separation between measurements approximately 8 hours xenon arc exposure.
- Results demonstrate stability in both diffusers to within measurement uncertainty (~0.75).

Conclusion: J1 OMPS calibration stability and accuracy meets science requirements.





Outline

- Instrument design changes
  - Wavelength coverage
  - QVD
- Calibration test phase summary
- Calibration issues
  - Diffuser stability
  - G/I and R recalibration summary
- Summary

Summary

- **QVD implementation yields improvements in the albedo uncertainty budget.**

	Radiance		Irradiance		Albedo – Wvl Independent		Albedo – Wvl Dependent	
	NP	TC	NP	TC	NP	TC	NP	TC
NPP Goniometry	0	0	0.38	0.41	0.38	0.41	0.15	0.36
J1 Goniometry	0	0	0.21	0.21	0.21	0.21	0.1	0.11
NPP OMPS	3.383	3.067	3.499	3.194	1.653	1.717	0.426	0.497
J1 OMPS (Est)	2.36	1.81	2.57	2.04	1.62	1.71	0.29	0.31
Requirement	8	8	7	7	2	2	0.5	0.5

- **Extended wavelength coverage potentially enhances science return and no significant stray light effects.**
- **No major differences in Acceptance Test Program.**

J1 SCDB Analysis, Conversion to LUT, and Testing

Bhaswar Sen, Jian Zeng

May 14, 2014

Outline

- Sensor Characterization Databases
- Algorithm Lookup Tables
- Plan Forward and Schedule

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

Sensor Characterization Databases

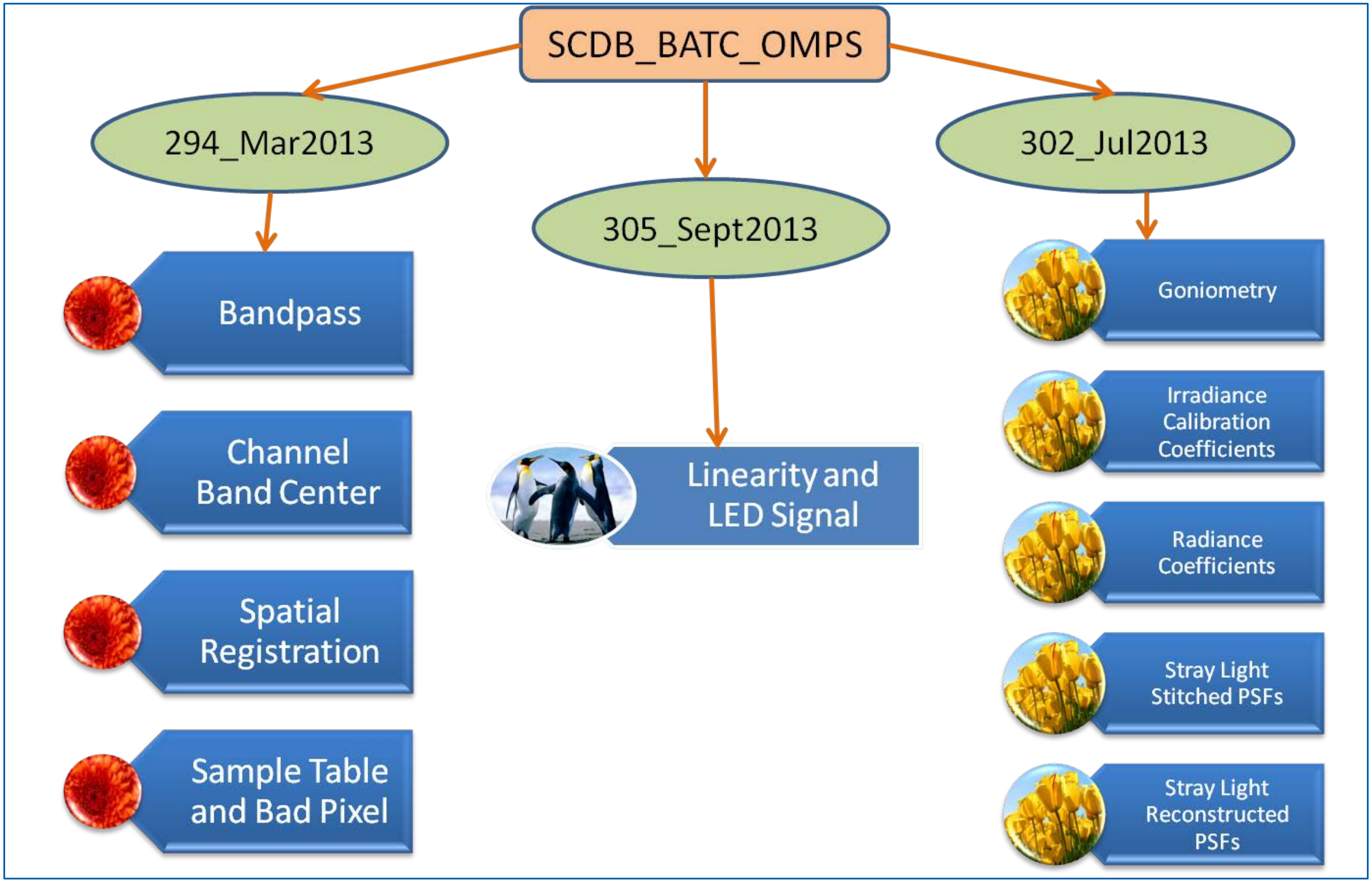
Sensor Characterization Databases

- Sensor characterization databases (SCDB) provide the best estimate of OMPS sensor characteristics based on ground-based measurements
  - Measurement: Sample Table (STB), Timing Pattern (TGP)
    - TPG are based on On-Orbit Operators Manual (OOOM)
  - Spectrometric: Channel Band Center (CBC), Band Pass (BPS)
  - Radiometric: Radiance Coefficients (RAD), Irradiance Coefficient (IRD), Stray Light (SLT)
  - Geolocation: Spatial Registration (SRG)
- SCDB evaluation includes
  - Review of accompanying DADD for product requirements , product generation algorithm, test and verification procedures
  - Review of product metadata and database structure in HDF file
  - Inspection of product database dimensions and values
    - Values, Range, Fill, Offsets, Flags

Sensor Characterization Databases

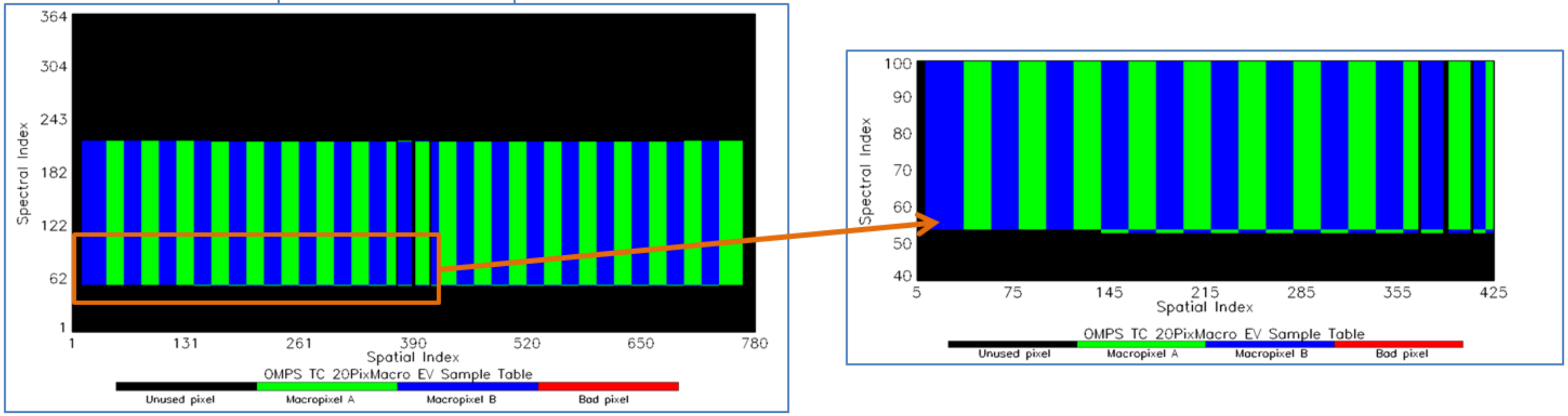
- SCDB evaluation includes (continued)
  - Analysis of product database
    - Execute a sample of BATC test procedures
    - Visualization of product database
    - Conversion to product database to SDR algorithm LUT
    - Verification of SDR algorithm LUT

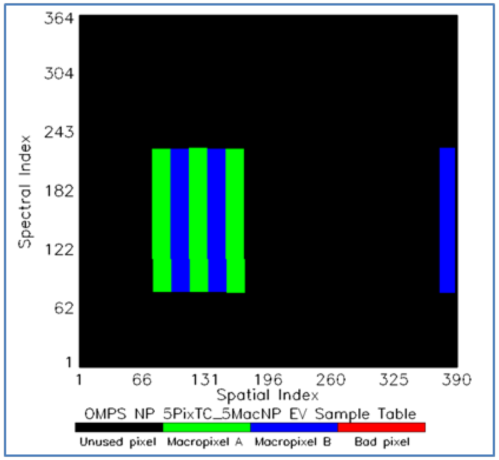
Summary of Database Content



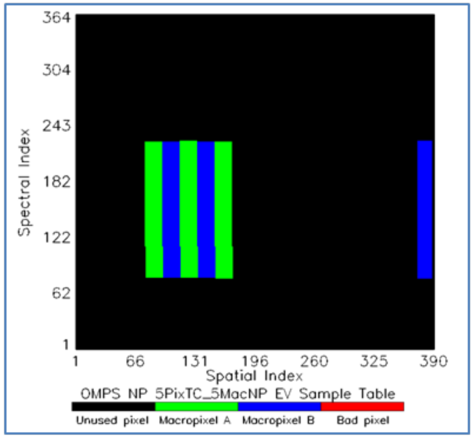
Flight-like Earth View Sample Table (NM and NP)

NM 20-pixel



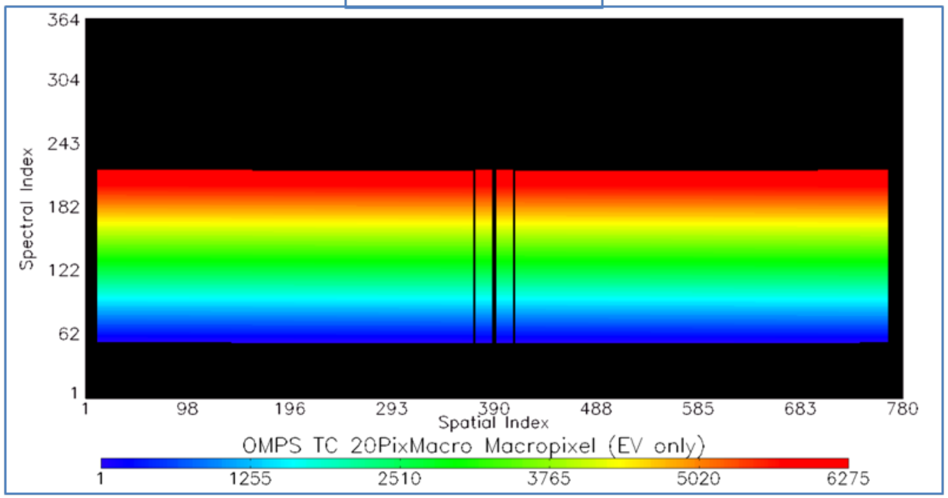


NP

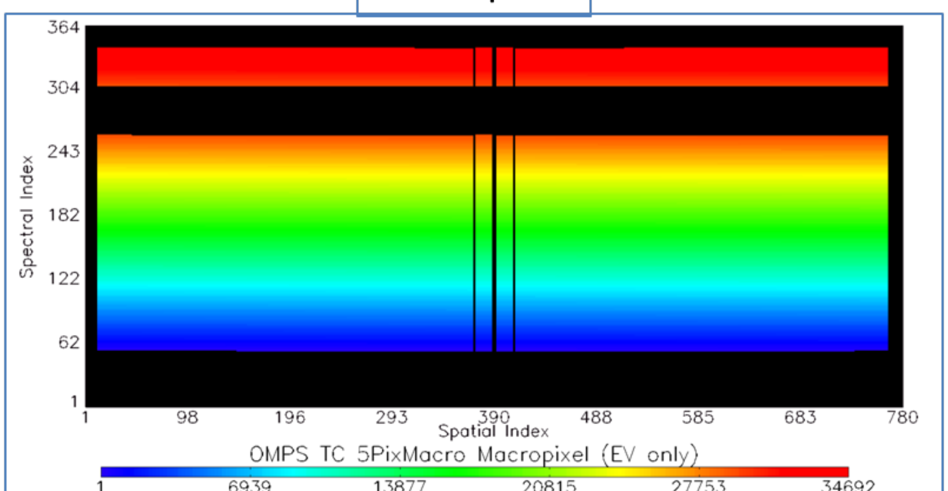


Earth View Macropixel Table

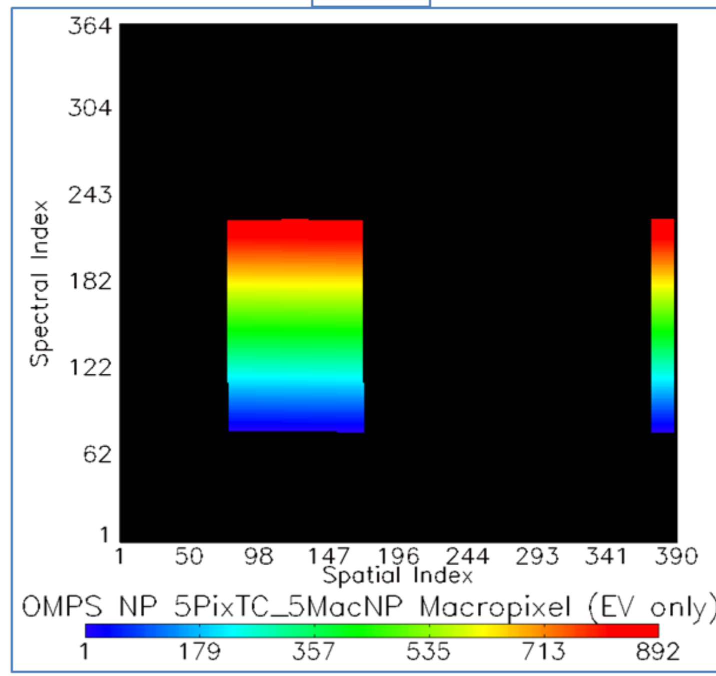
NM 20-pixel



NM 5-pixel



NP



- NM 20-pixel macropix #: 1-6275
- NM 5-pixel macropix #: 1-34692
- NP macropix #: 1-892

Two sets of Band-pass Functions at Channel Centers: On-orbit Temp (Top) and Ambient Temp. (Bottom)

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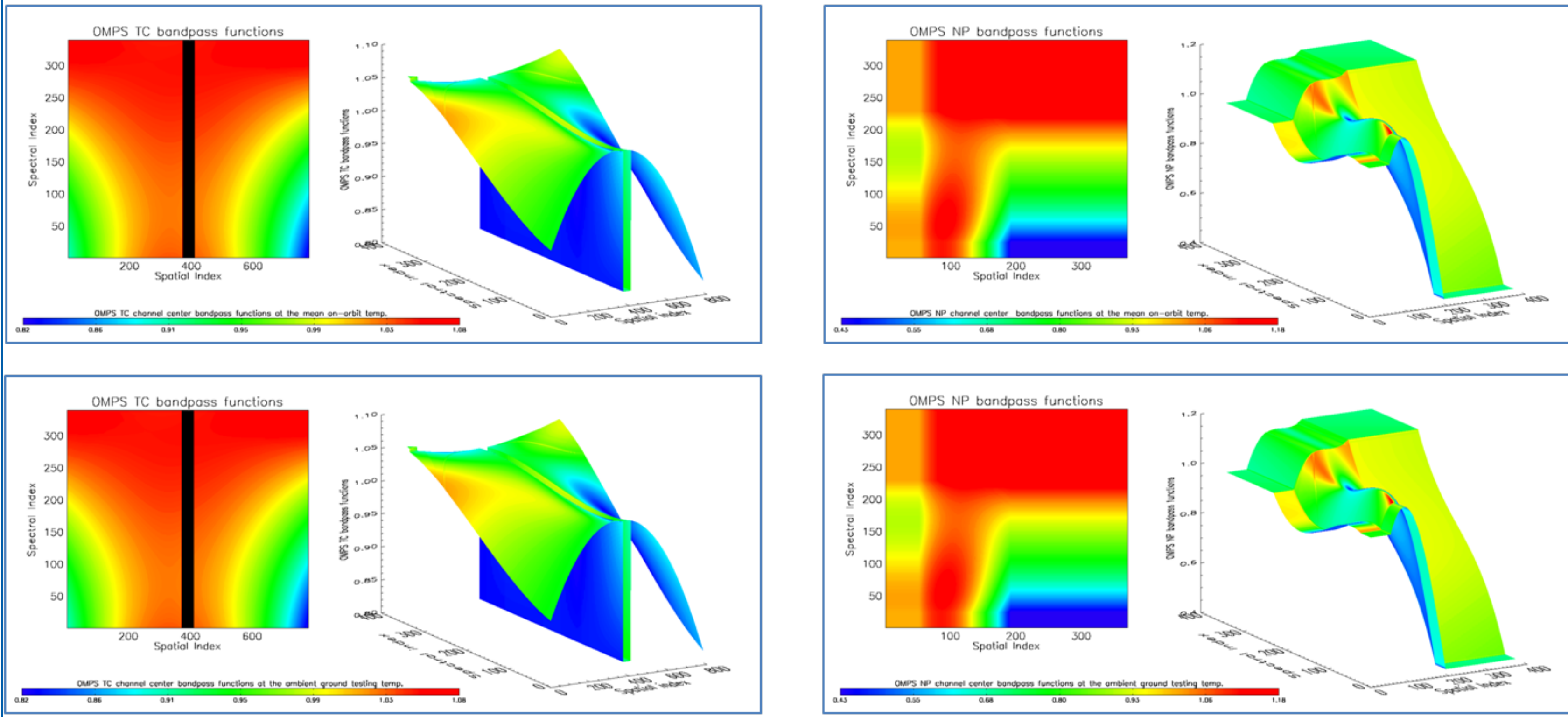
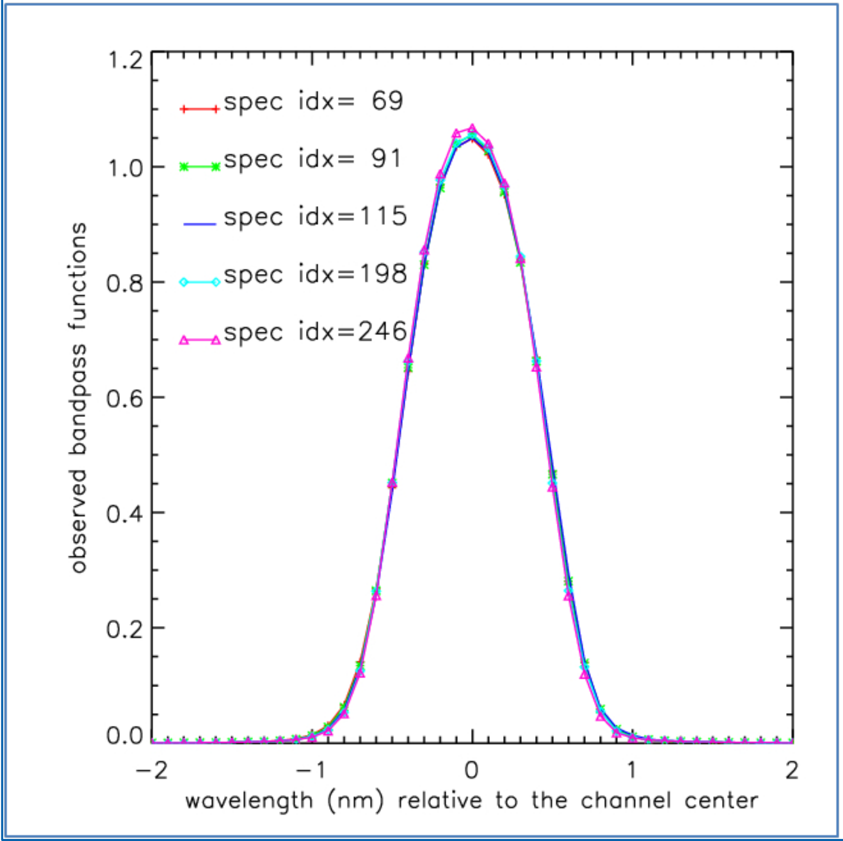
NM NP



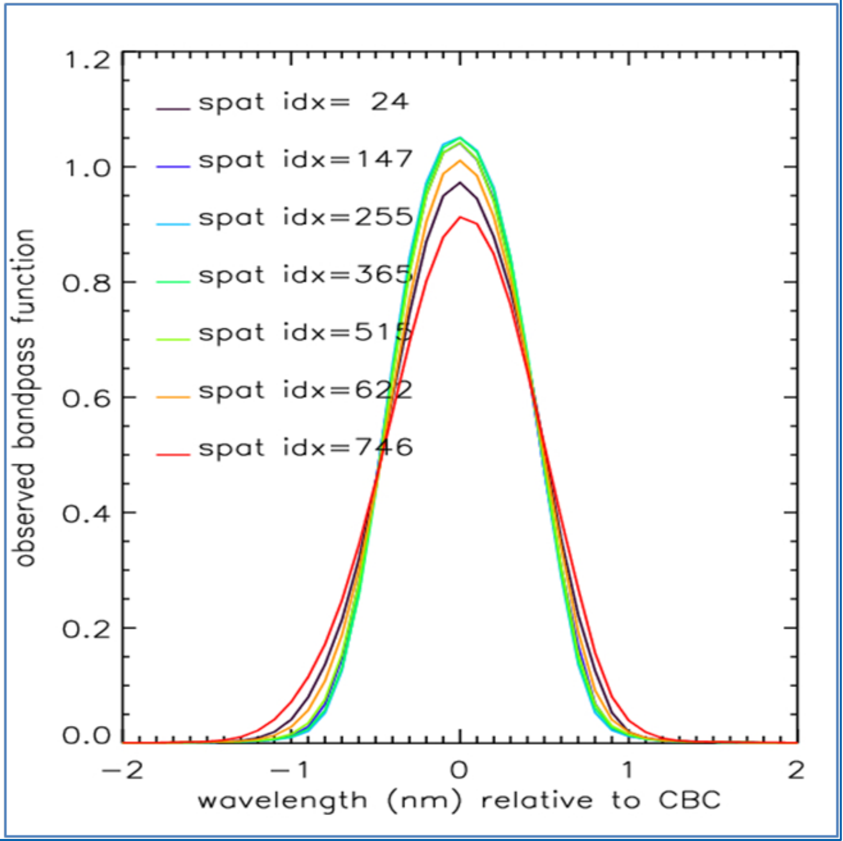
J1 OMPS BPS is temperature independent!

Band-pass Functions Spatial and Spectral Variations

Spectral Variation at Spatial #365



Spatial Variation at Spectral #115



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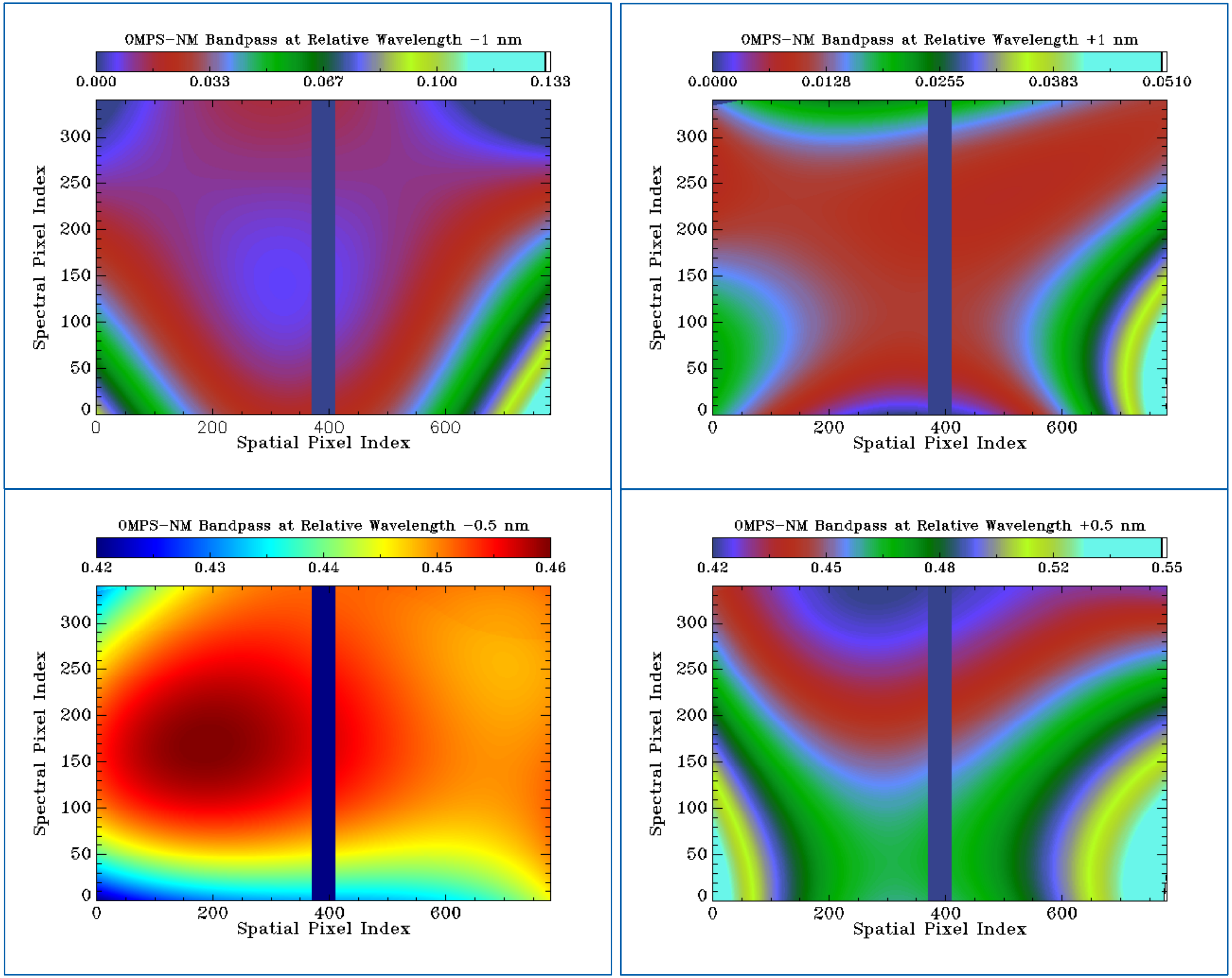
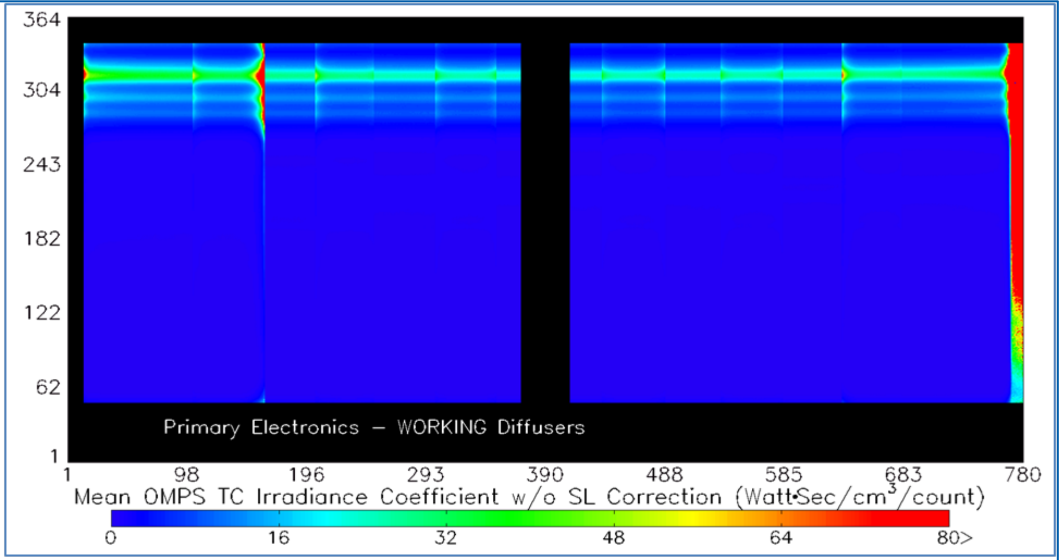
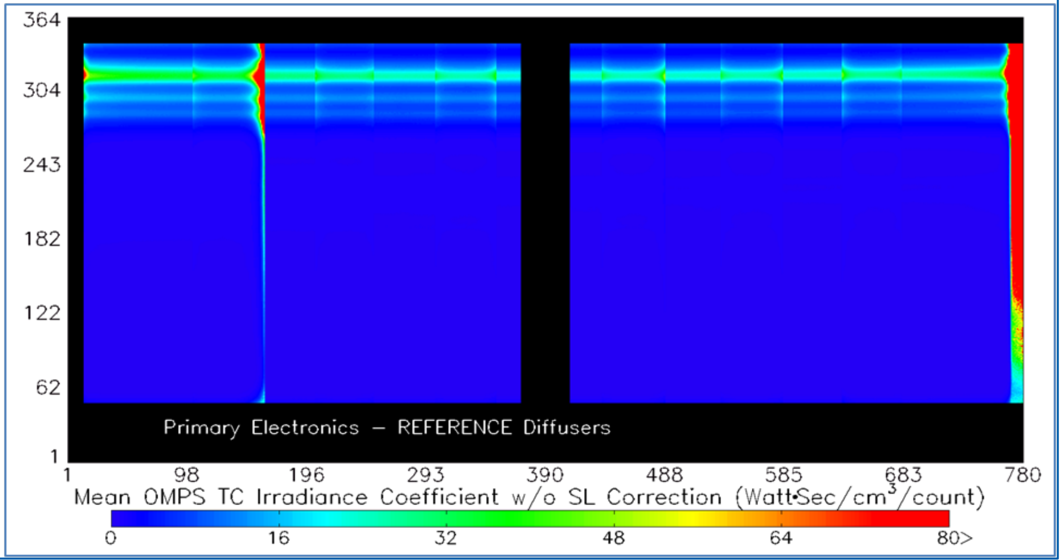
OMPS-NM Ground Band-Pass J1 SCDB



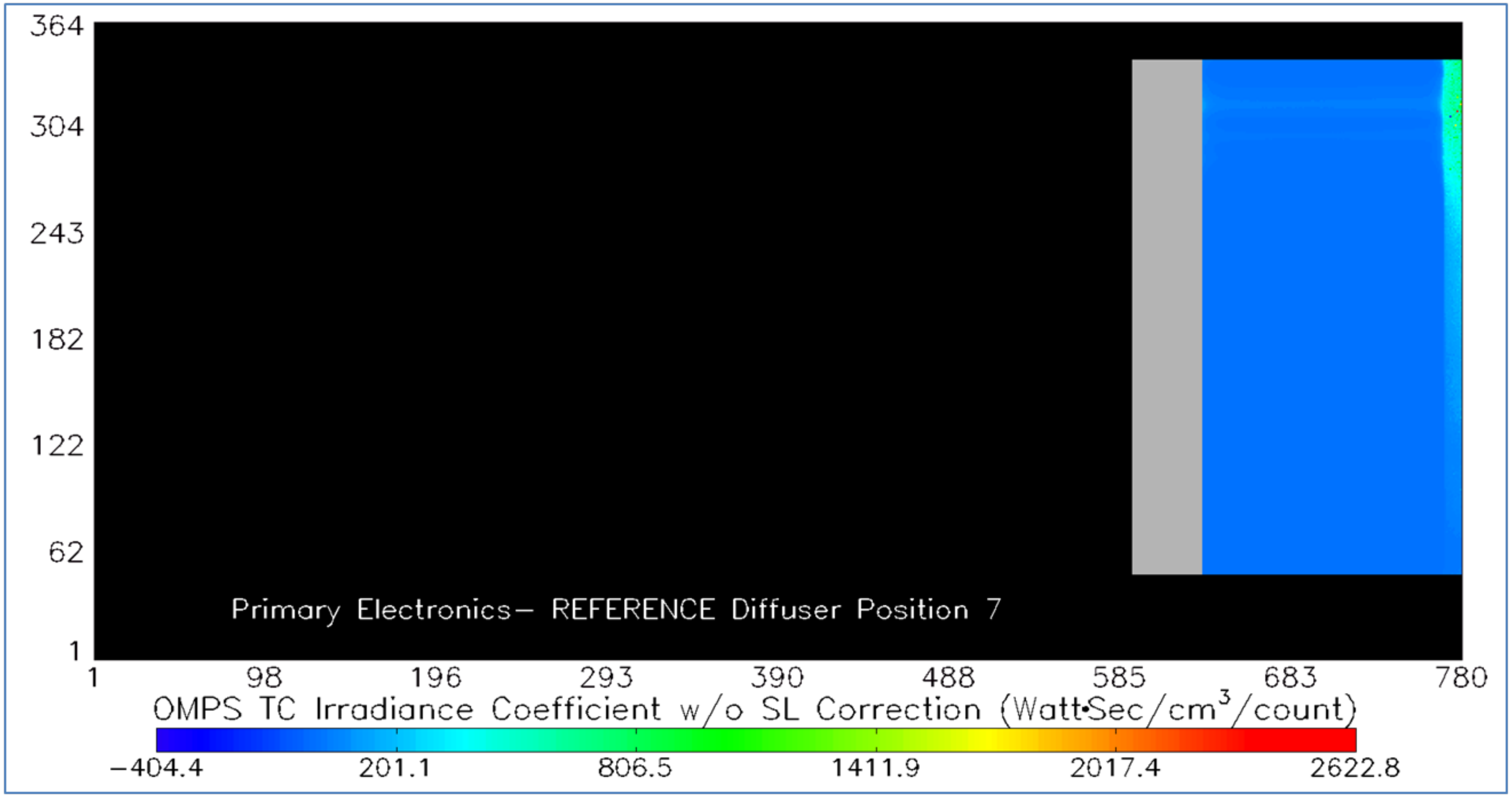
NM Irradiance Calibration Coefficient

1. Combined coefficients of seven diffusers.
2. Overlapped regions show the mean values.





NM Irradiance Calibration Coefficient of the Reference Position 7 Diffuser

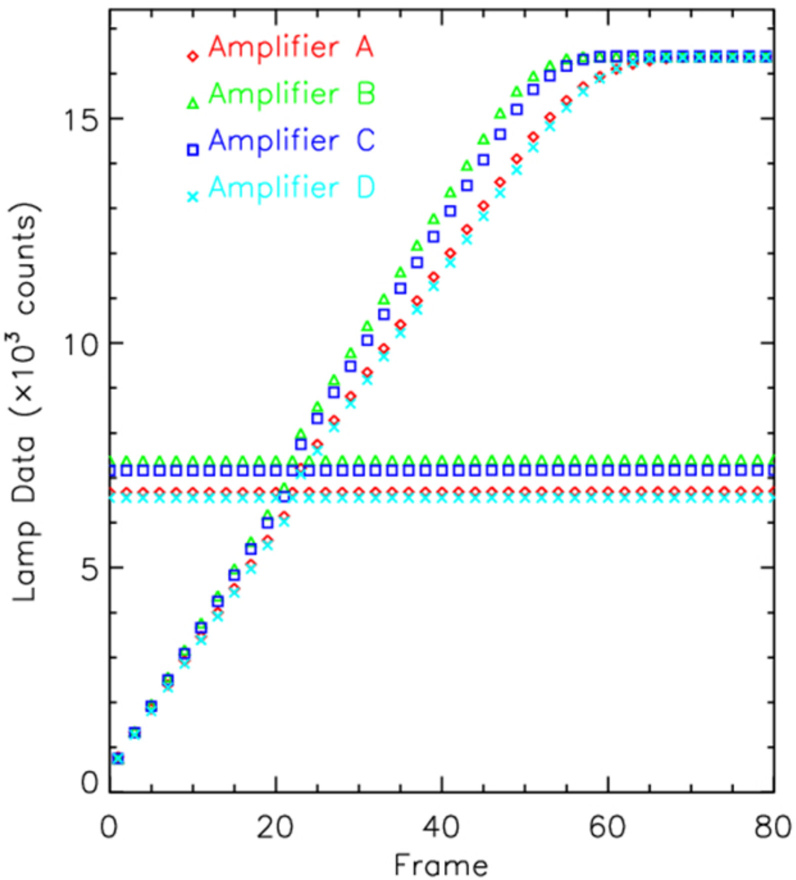


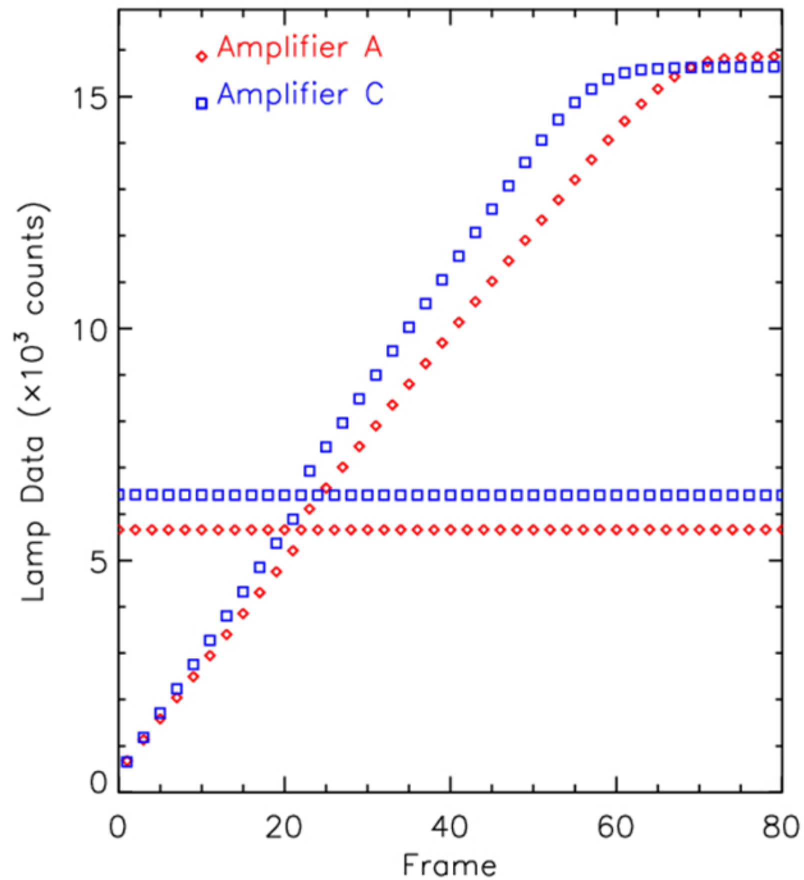
Negative irradiance calibration coefficient:

- *Value=-404.38 watt·sec/cm³/count*
- *position=[773,310]*

Region of Interest (ROI) for NM:
188 (spatial) × 294 (spectral)

Lamp Data: NM (Left) and NP (Right)

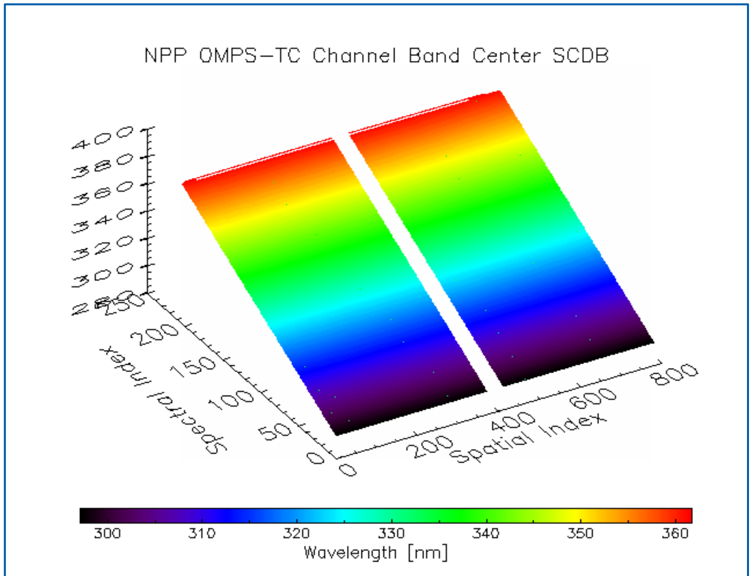


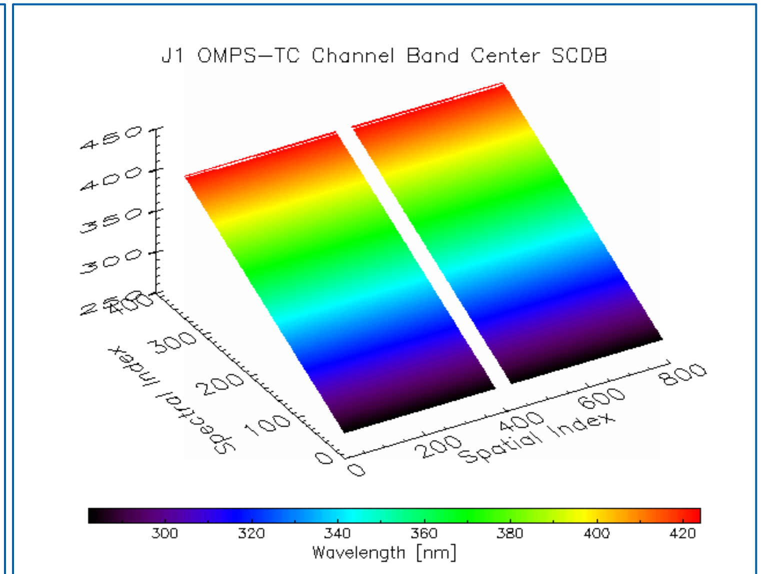


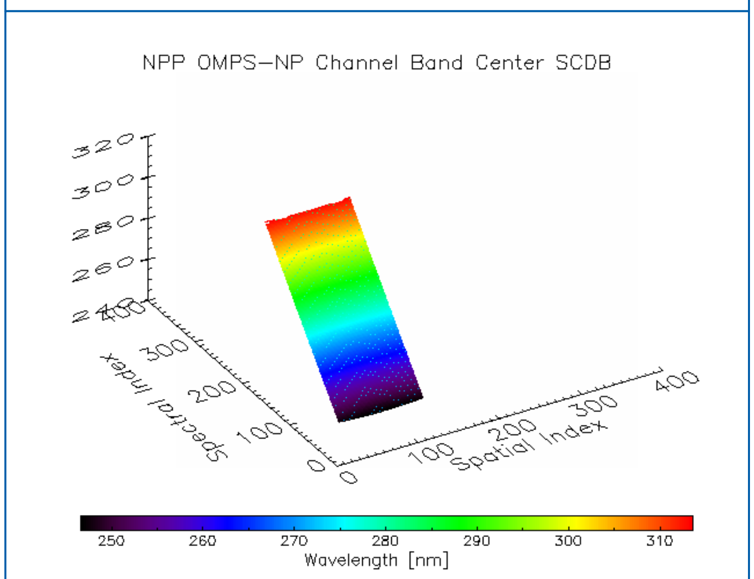
NM lower tie point (counts): 795,755,748,753
NM upper tie point (counts): 12000 for all four amplifiers

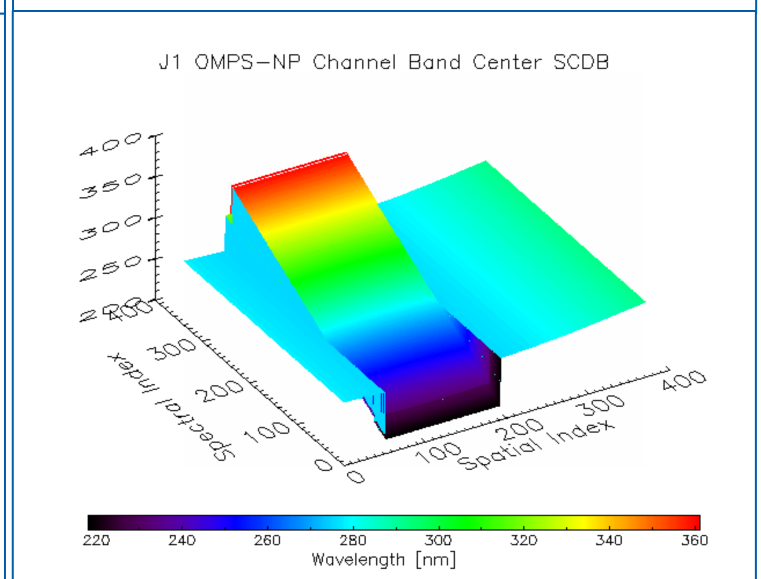
NP lower tie point (counts): 678, 656
NP upper tie point (counts): 12000 for both amplifiers

OMPS Channel Band Center SCDB: NPP and J1



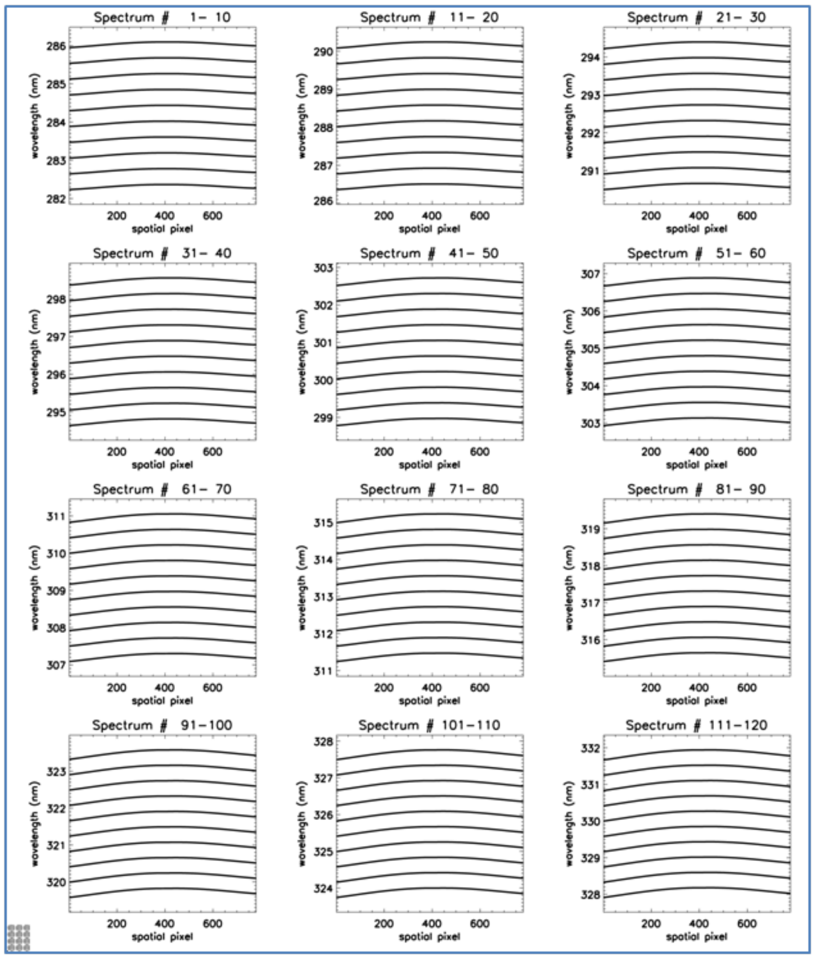




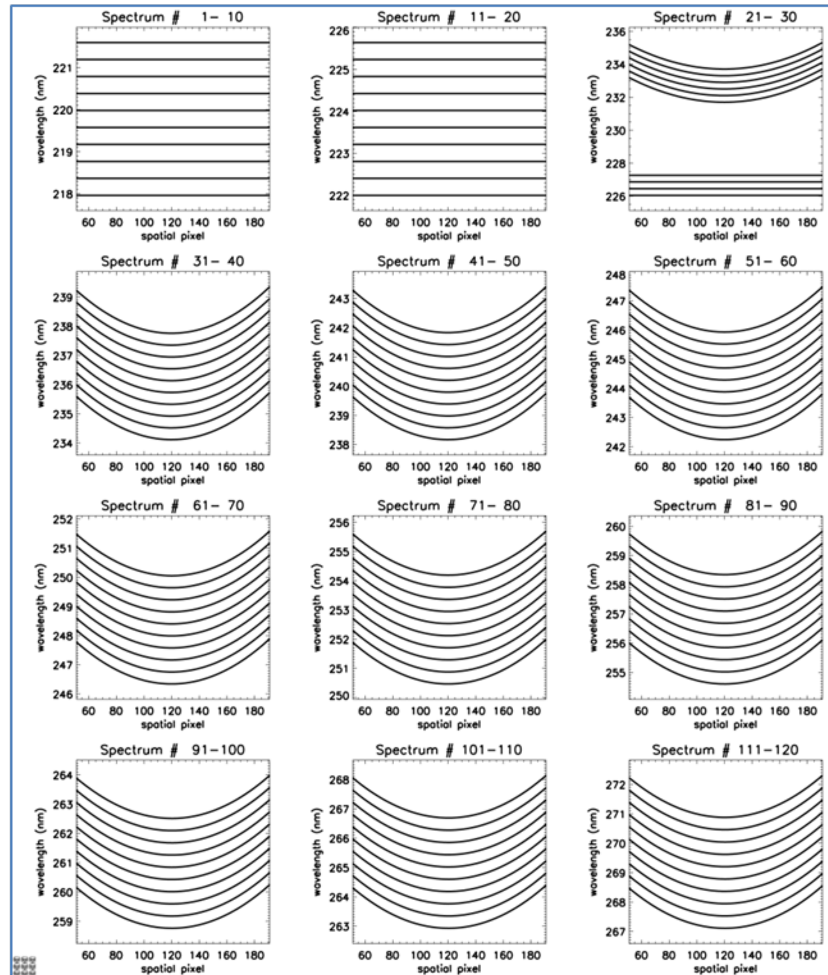


Spatial Distribution of J1 OMPS Band Centers

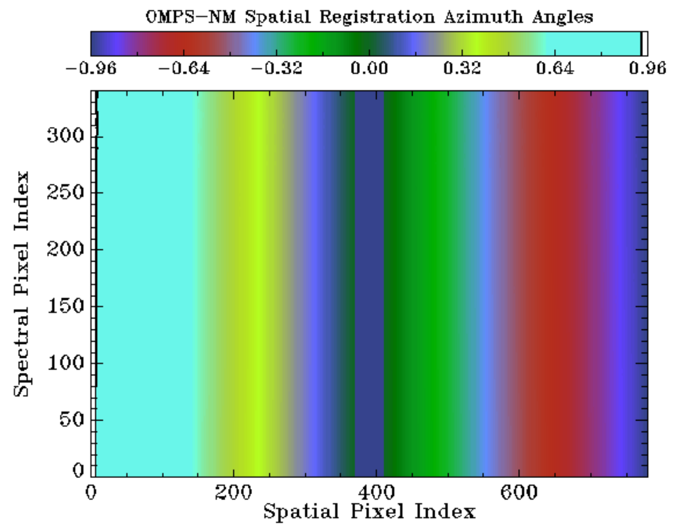
NM

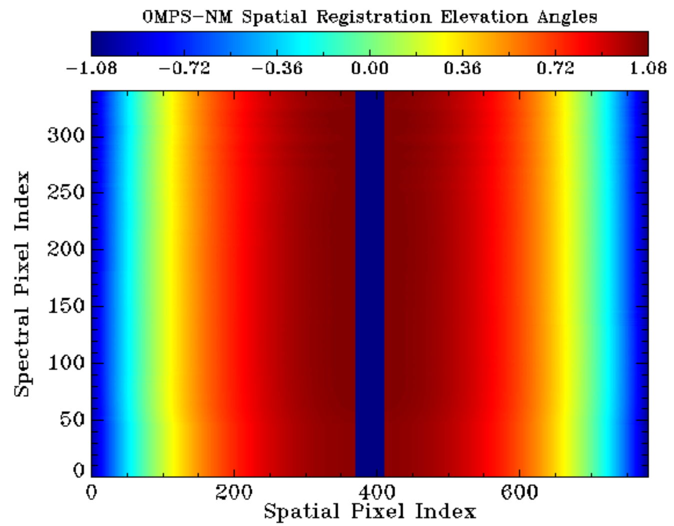


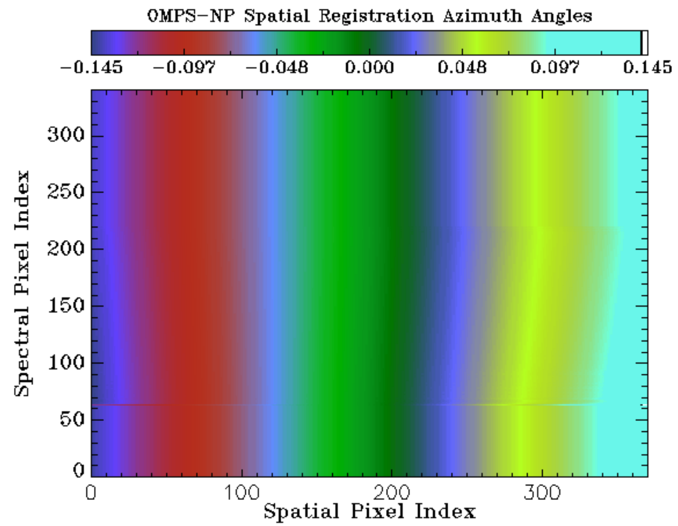
NP

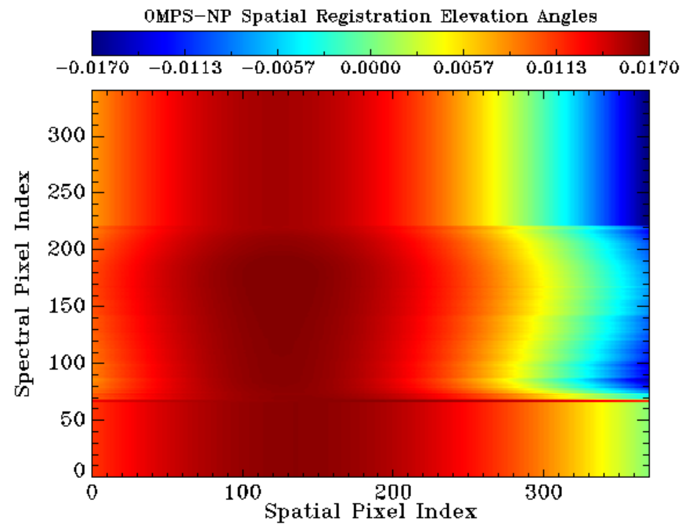


OMPS-NM Spatial Registration J1 SCDB









THE VALUE OF PERFORMANCE.

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Algorithm Lookup Tables

Path Forward and Schedule

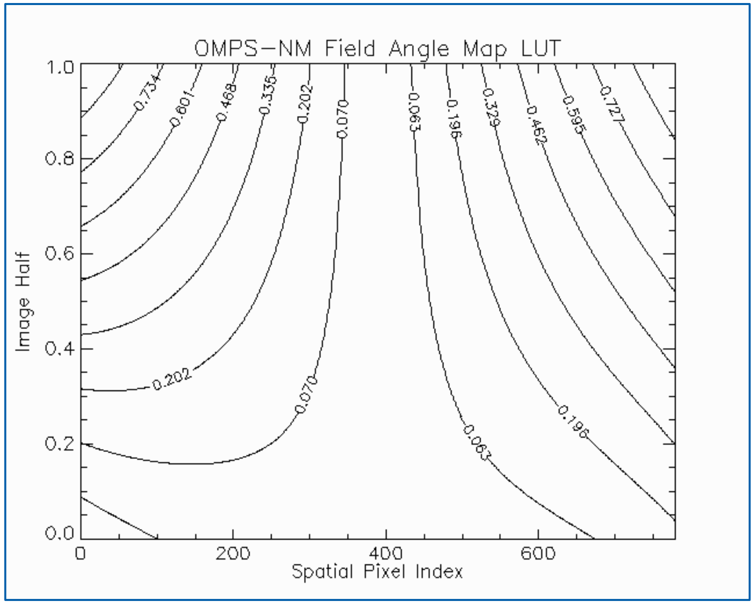
SDR Algorithm Lookup Tables

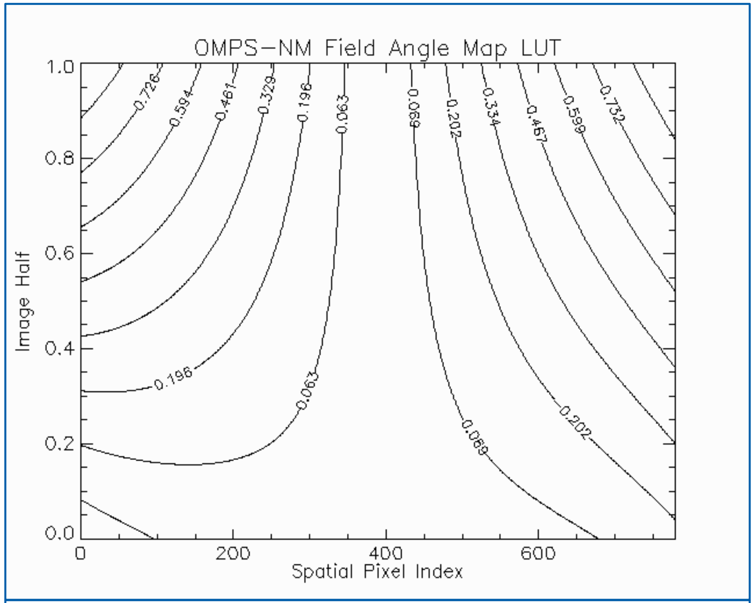
- OMPS algorithms do not use product SCDB directly
  - Algorithm lookup tables (LUTs) are generated from the SCDB which are then read and processed, as necessary
- SDR algorithm LUTs
  - Measurement: Earth View Sample Table, Macrotable, Timing Pattern
  - Spectrometric LUTs: Spectral Response, Spectral Registration, Wavelengths
  - Radiometric LUTS: Calibration Coefficients, CF-Earth, Darks, Linearity, Stray Light, Solar Irradiance, Observed Solar, Predicted Solar
  - Geolocation LUT: Field Angle Map
  - Table version LUT map OMPS NM and NP measurement tables to SDR algorithm LUT

Generate and Verify SDR Algorithm LUTs

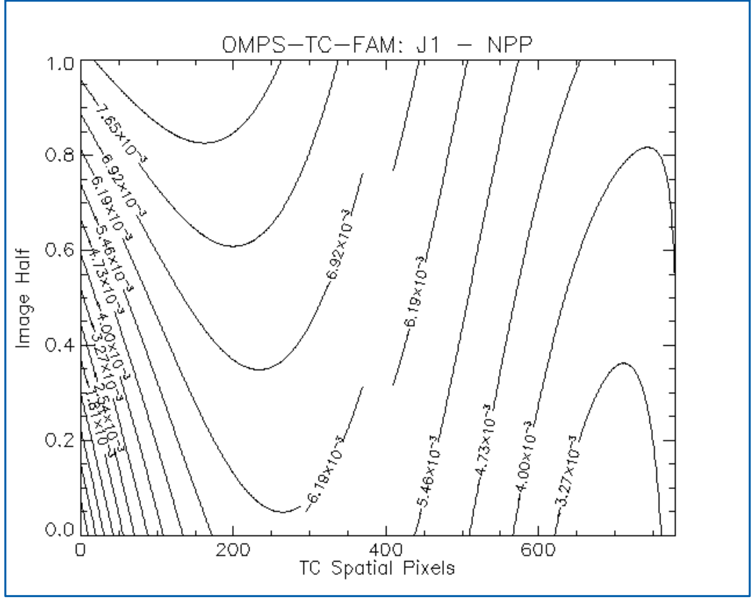
- NG code converts and formats SCDB contents to algorithm LUTs
  - Written in Matlab and IDL
  - Under CM control
  - Reads BATC provided SCDB
  - Construct Sample Tables and LUTs (BPS, CBC, IRD, RAD, SRG, ...)
  - Construct reference solar spectrum, convolved solar spectrum
- LUTs will be tested using prototype J1 SDR algorithm
  - NPP OMPS proxy measurements will be used where spatial and spectral domains overlap with J1 sensor
  - Synthetic datasets will be used to test spatial and spectral domain of J1 sensor beyond NPP sensor capabilities
    - AURA OMI proxy measurements could be used
      - Discuss with NOAA and NASA team members

Example of OMPS-NM Spatial Registration LUT





Figures show OMPS-NM spatial registration angle NPP LUT contours (upper left), J1 LUT surface (upper right) and the difference between J1 and NPP LUT (bottom right). The angular difference at nadir is $\approx 7\times10^{-3}$ rad. It corresponds to a linear shift in geolocation of ≈5 km km from a 720 km orbit. The 417 nm channel on J1 OMPS will allow the science team to correct nadir geolocation with much grater accuracy by using the VIIRS M1 band.



Path Forward

- Generate SDR algorithm LUTs
  - SRPM, CALCONST and FAM LUTs based on preliminary CBC, RAD (no_slcorr) and SRG SCDB, respectively, generated
  - Investigating details on generating the SRF LUT (based on BPS SCDB)
    - NPP scheme may still work after extending wavelengths to 417 nm
- J1 LUT evaluation
  - Process J1 SDR LUTs individually and collectively in ADL
    - Update macropixel calculation for OMPS-NP
    - Update SL correction for spectral sparse measurements on Feb 8 – 9
    - Other code changes to test J1 LUT (versus general J1 SDR), if necessary
  - Process Feb 8 – 9, 2014, NPP measurements
    - Nominal and higher spatial resolution EV measurements available in nominal APID
      - Open to suggestion on using other NPP measurements (e.g., limited spectral sample)
    - Remap Feb 8 – 9 STB to “J1-like” STB (i.e., move in spectral direction)

Path Forward

- J1 LUT evaluation
  - Process proxy (synthetic) measurements for full range of J1 sensor
    - Is it necessary?
    - If necessary, need to define dataset soon
- J1 LUT evaluation risks

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OMPS Nadir Profiler
Solar Activity and Mg II Index

L. Flynn
with input from
NOAA JPSS and NASA S-NPP Teams

May 13, 2014

Outline

- Definition
- GOME-2 Daily Time Series
- Solar activity presence in measurements
  - Earth View Residuals
  - Solar Spectra
  - Earth View Mg II Index
  - Solar activity of synthetics

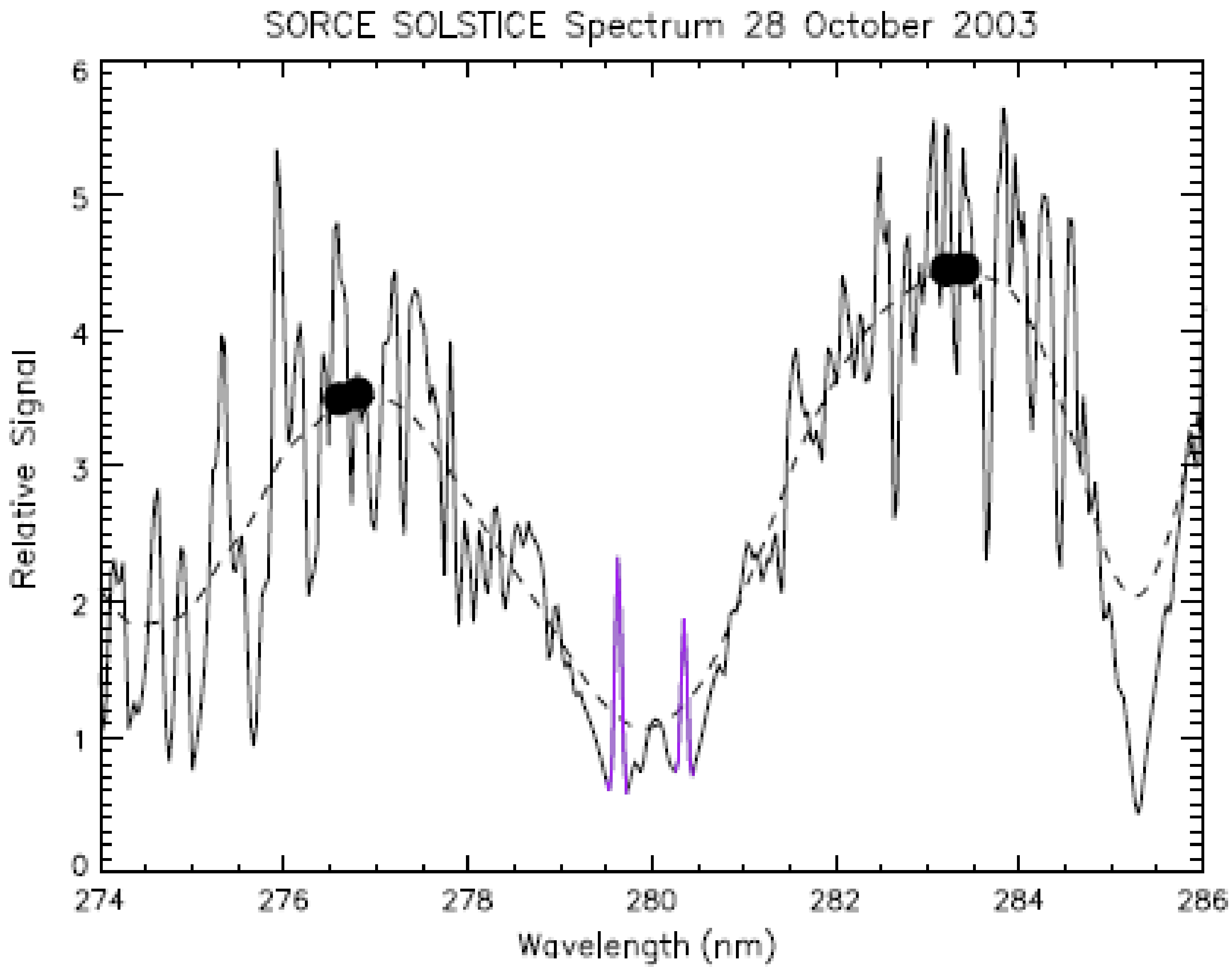
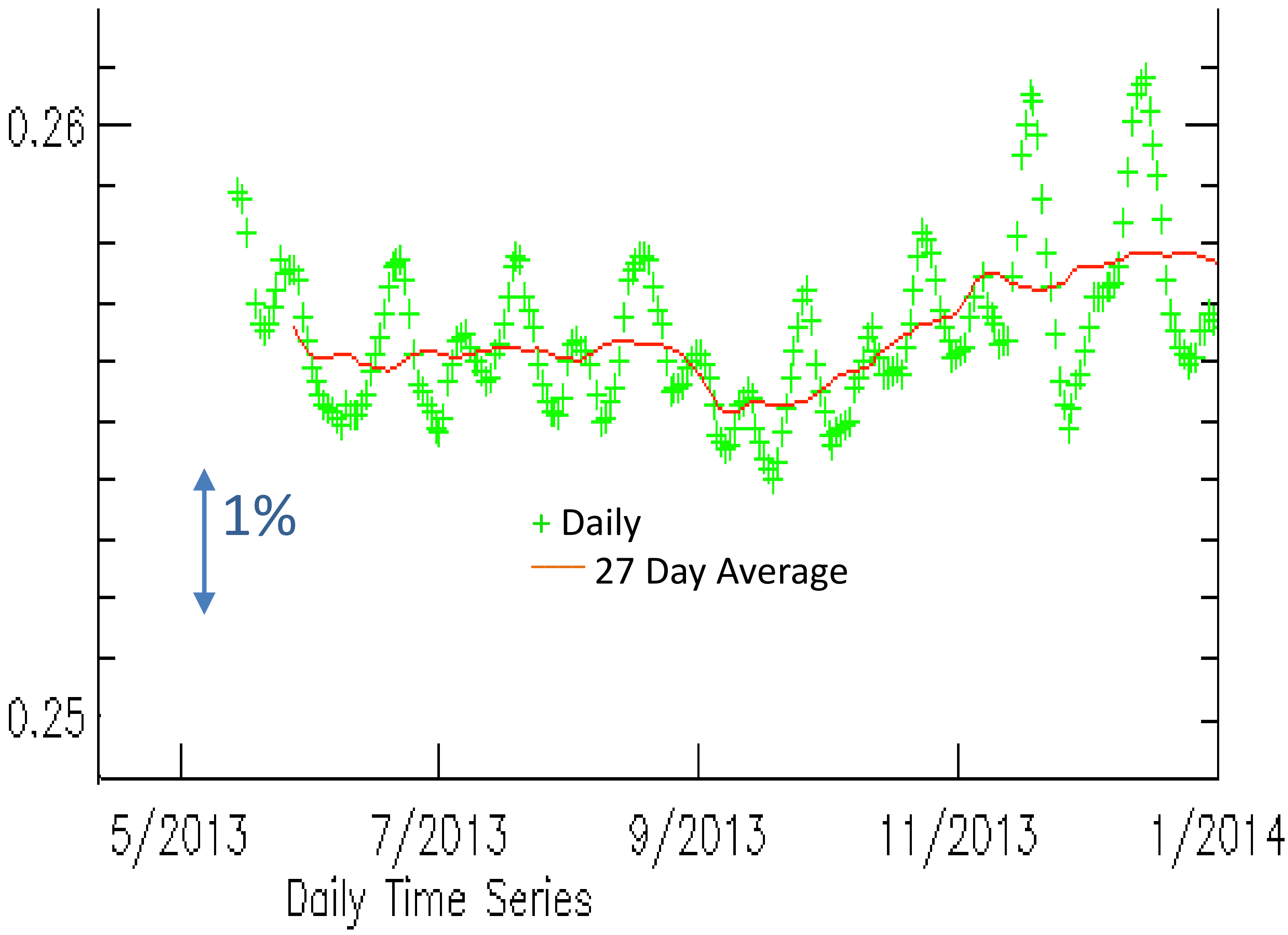


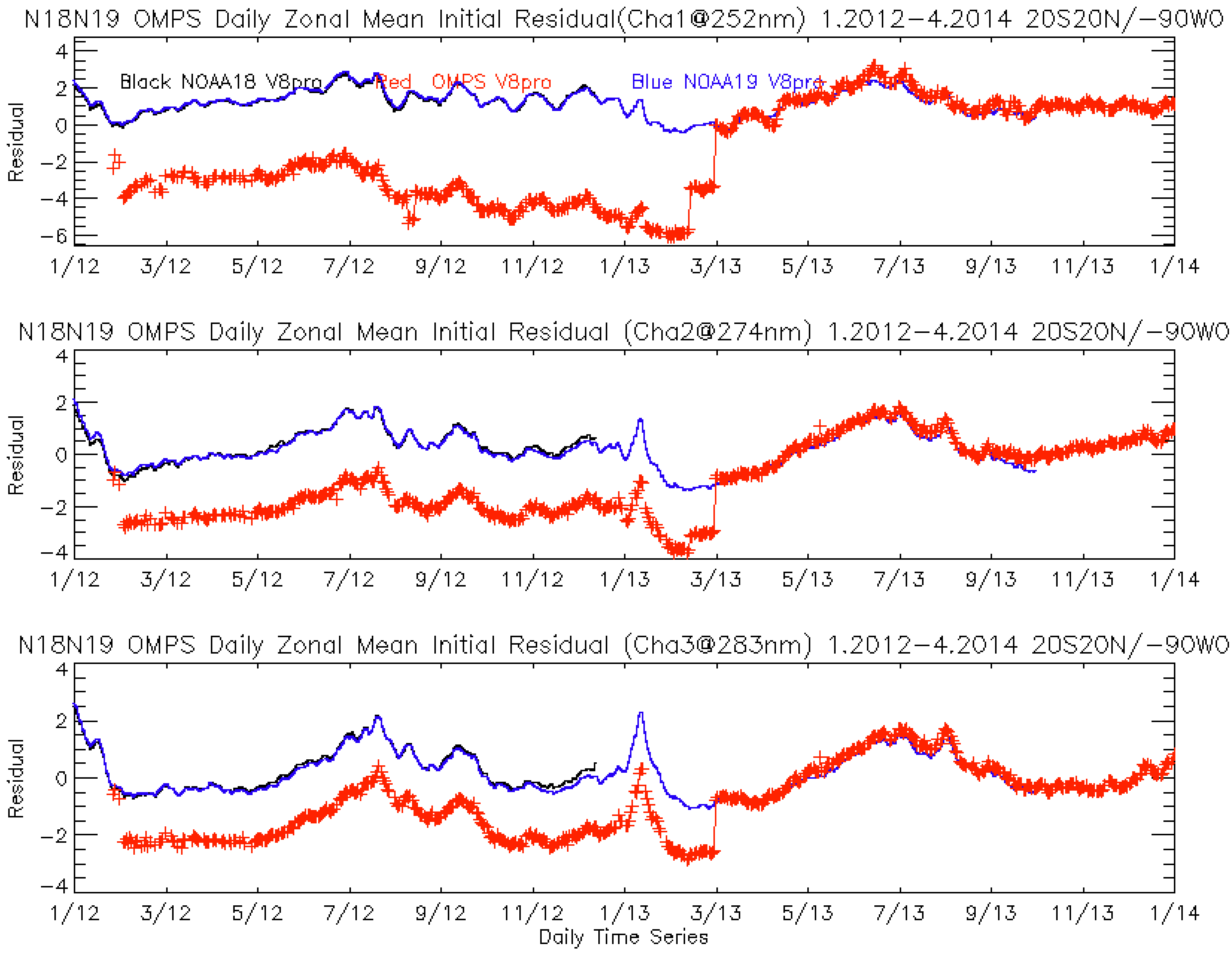
Fig. 2. The MgII doublet region as observed by SORCE SOLSTICE on 28 October 2003. The h & k emission cores are highlighted in purple. The dashed line is the spectrum after convolving it with a 1.1 nm triangular bandpass. Black dots indicate the wing irradiance values used to calculate the index.

The core radiances at the Mg II doublet are much more responsive to solar activity changes than the wings. By taking a ratio of measurements at 280 nm to those at 277 nm and 284 nm, on creates a Index that is insensitive to relative instrument changes that are linear with wavelength but responds to changes in solar activity.
The response depends on the spectral resolution and the choice of measurement locations.

J. Space Weather Space Clim. 4 (2014) A04 DOI: 10.1051/swsc/2014001 M. Snow et al., Published by EDP Sciences 2014

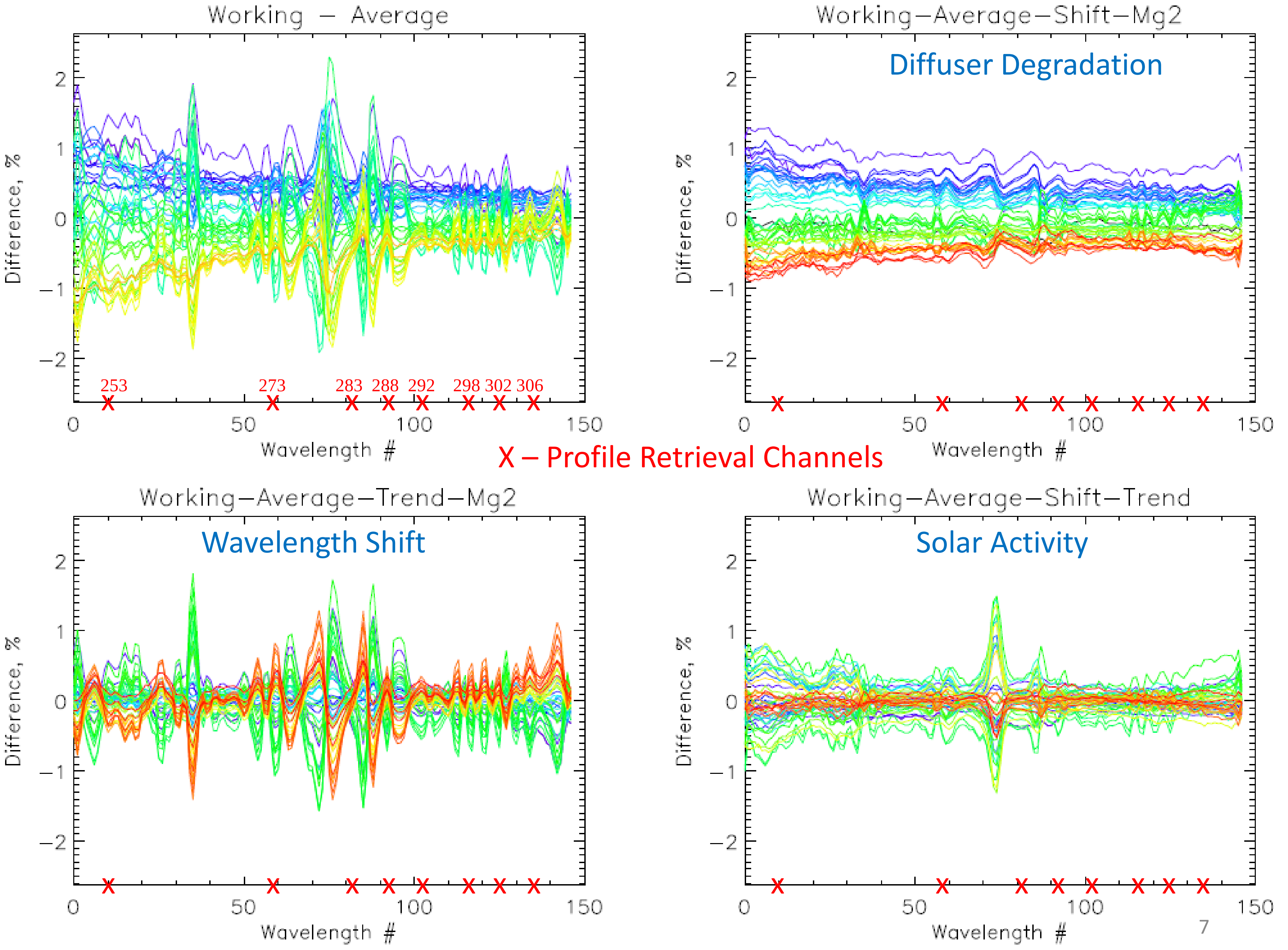
GOME-2 MetOp-B Mg II Time Series




N18N19 OMPS Daily Zonal Mean Initial Residual(Cha1@252nm) 1.2012−4.2014 20S20N/−90W0
Black NOAA18 V8pro
Red OMPS V8pro
Blue NOAA19 V8pro
Residual
4
2
0
−2
−4
−6
1/12
3/12
5/12
7/12
9/12
11/12
1/13
3/13
5/13
7/13
9/13
11/13
1/14
N18N19 OMPS Daily Zonal Mean Initial Residual (Cha2@274nm) 1.2012−4.2014 20S20N/−90W0
Residual
N18N19 OMPS Daily Zonal Mean Initial Residual (Cha3@283nm) 1.2012−4.2014 20S20N/−90W0
Residual
Daily Time Series

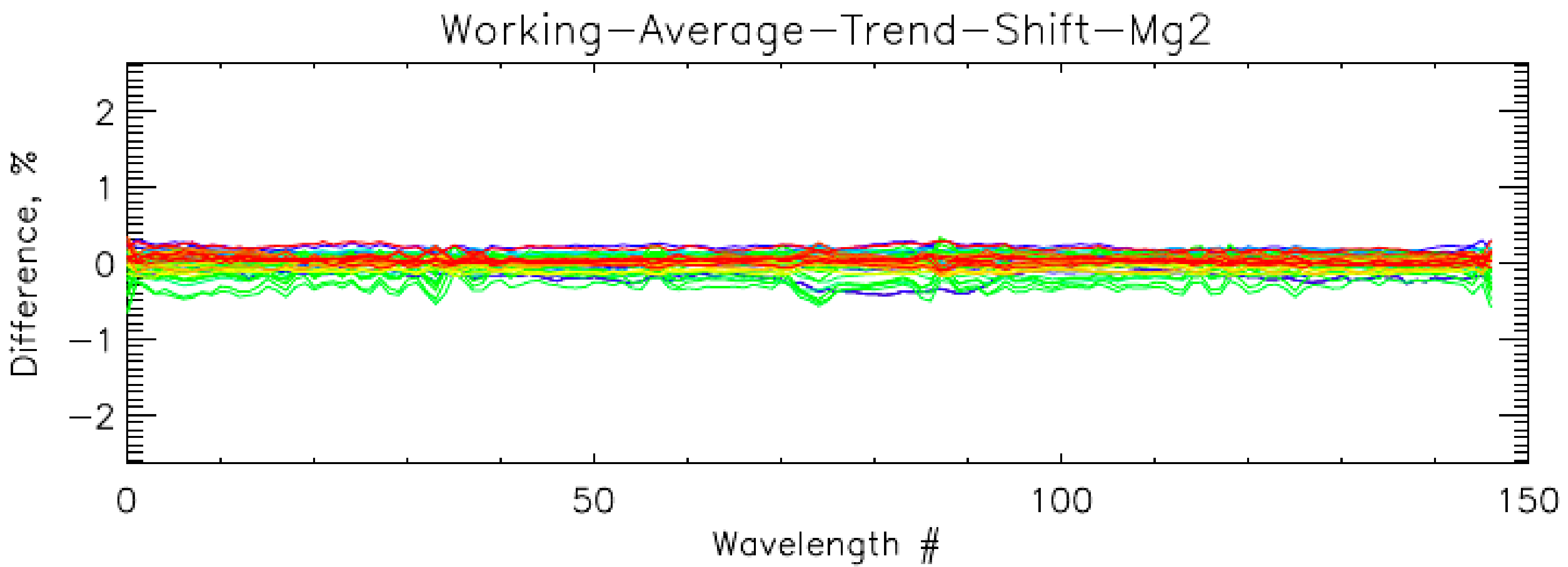
- Comparison of OMPS NP Working Diffuser Solar spectra to their average.
- Fits of the differences with a model using three patterns of the form:

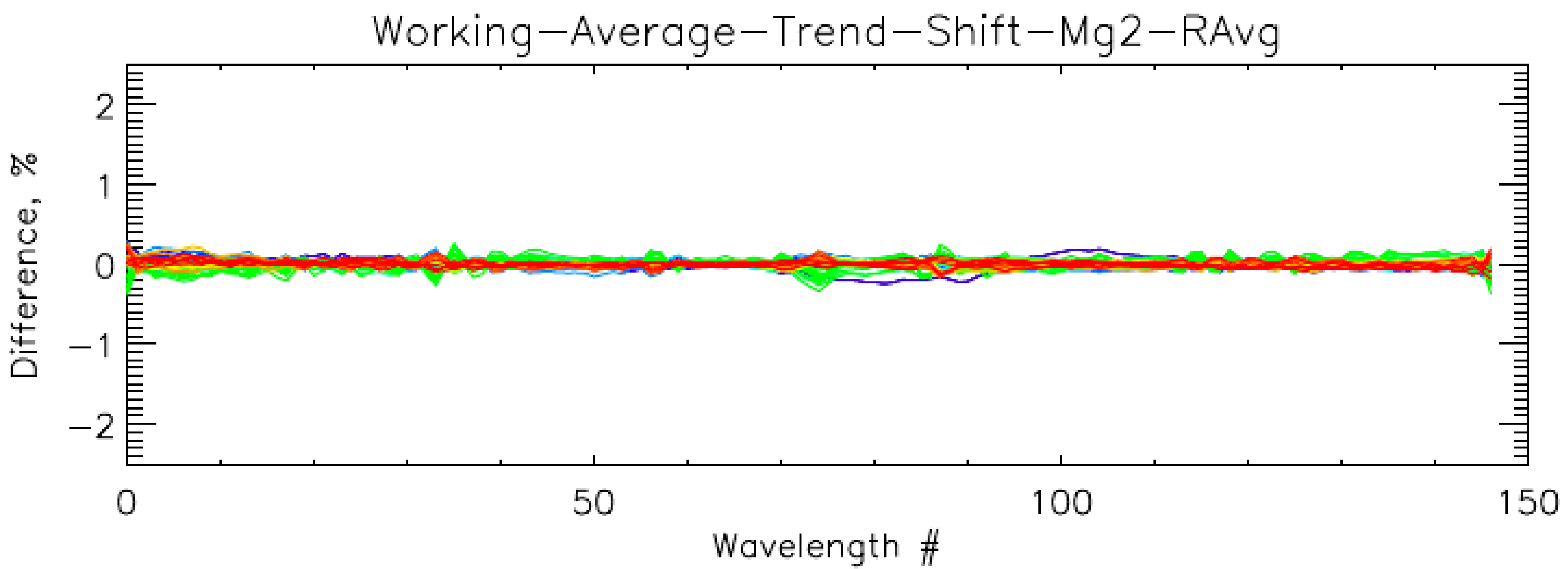
$$A1(t)*WavelengthShift(\lambda)+a2(t)*SolarActivity(\lambda)+t*Degradation(\lambda)$$



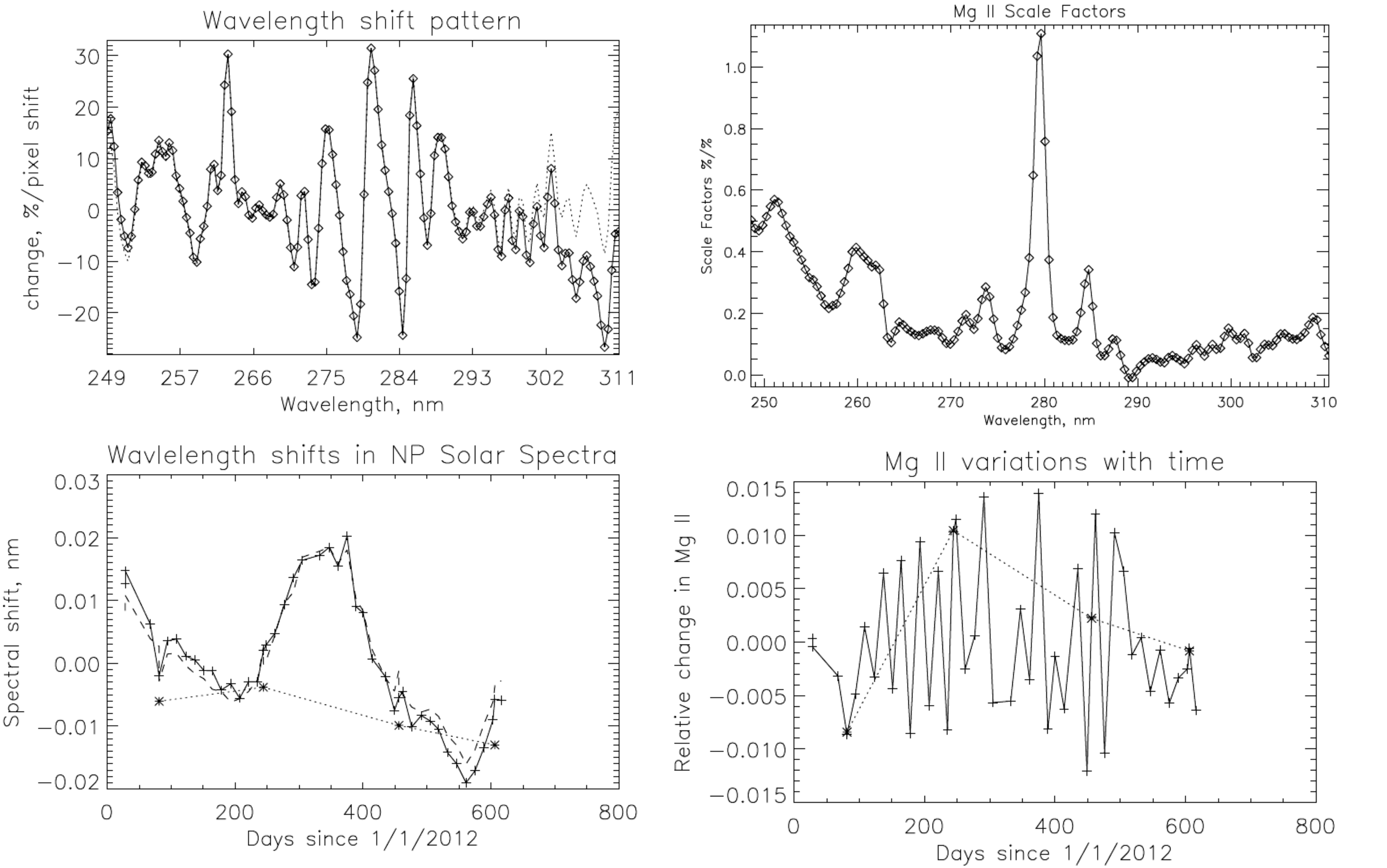
Working – Average
Working–Average–Shift–Mg2
Diffuser Degradation
Working–Average–Trend–Mg2
Wavelength Shift
Working–Average–Shift–Trend
Solar Activity
Difference, %
Wavelength #
253
273
283
288
292
298
302
306
X – Profile Retrieval Channels

OMPS NP Working Solar residuals after fits

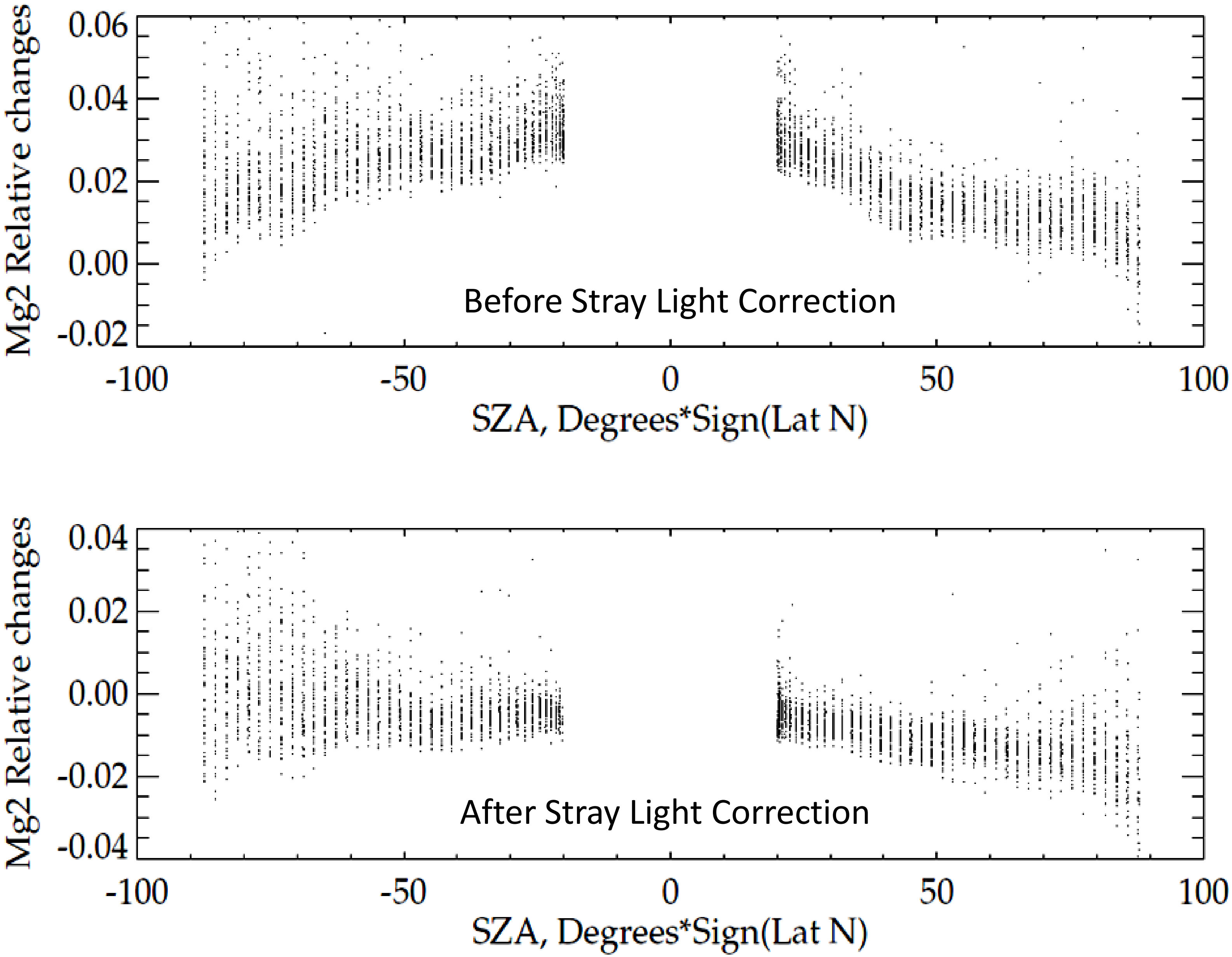




Wavelength shift and solar activity patterns in 44 Working and 4 Reference spectra

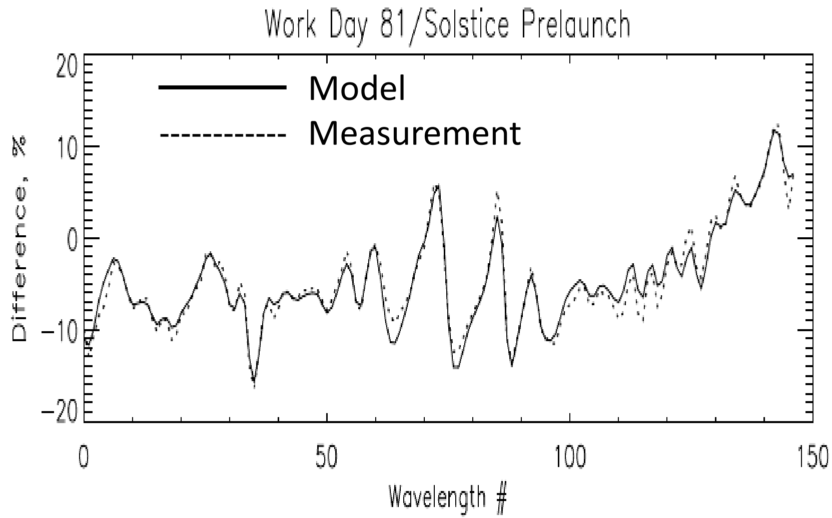


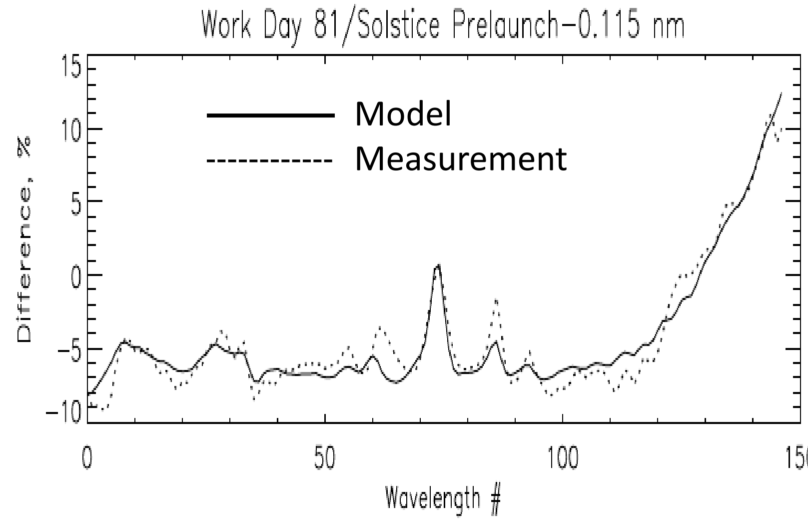
Earth-view Mg II Index for March 2014

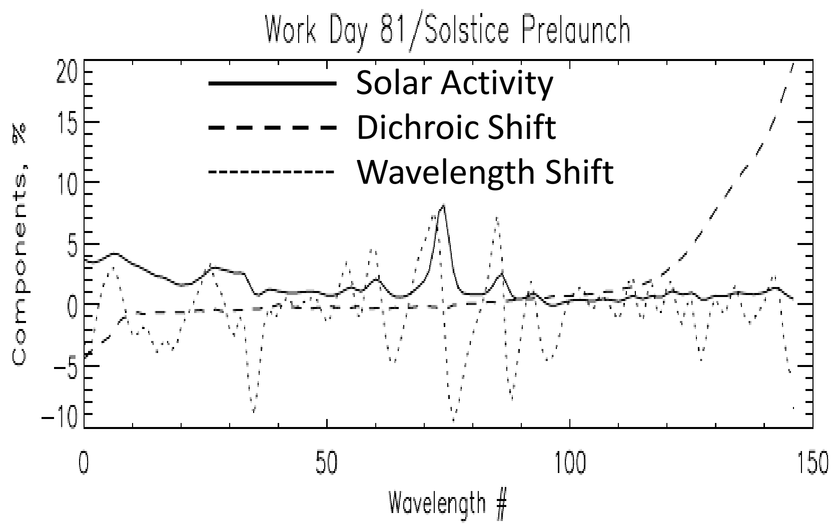


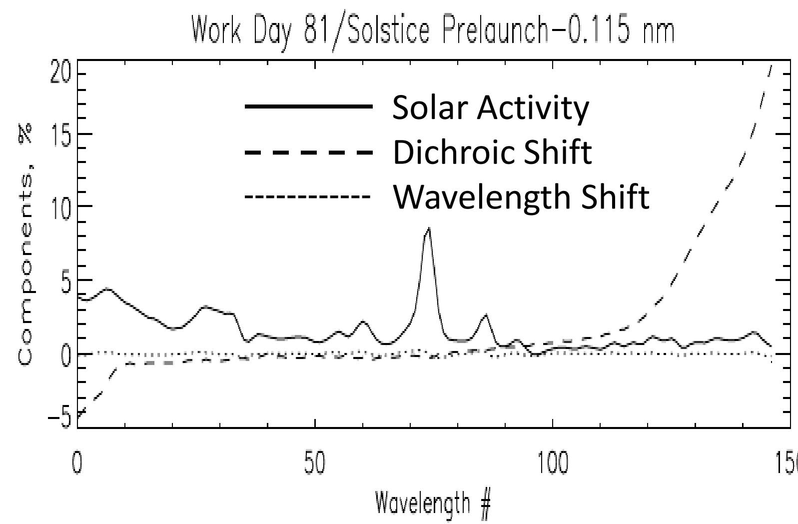
Comparison of OMPS NP Solar spectrum to synthetic from Solstice and prelaunch data. Fits of the differences with a model using three patterns of the form:

Meas/Synth = a0 + a1*WavelengthShift + a2*SolarActivity + a3*DihroicShift









Working Day 81 vs Solstice Synthetic (1.1% rmsr)

%offset	%Mg II	Shift nm	Dich nm
-7.3	7.3	-0.127	-0.349

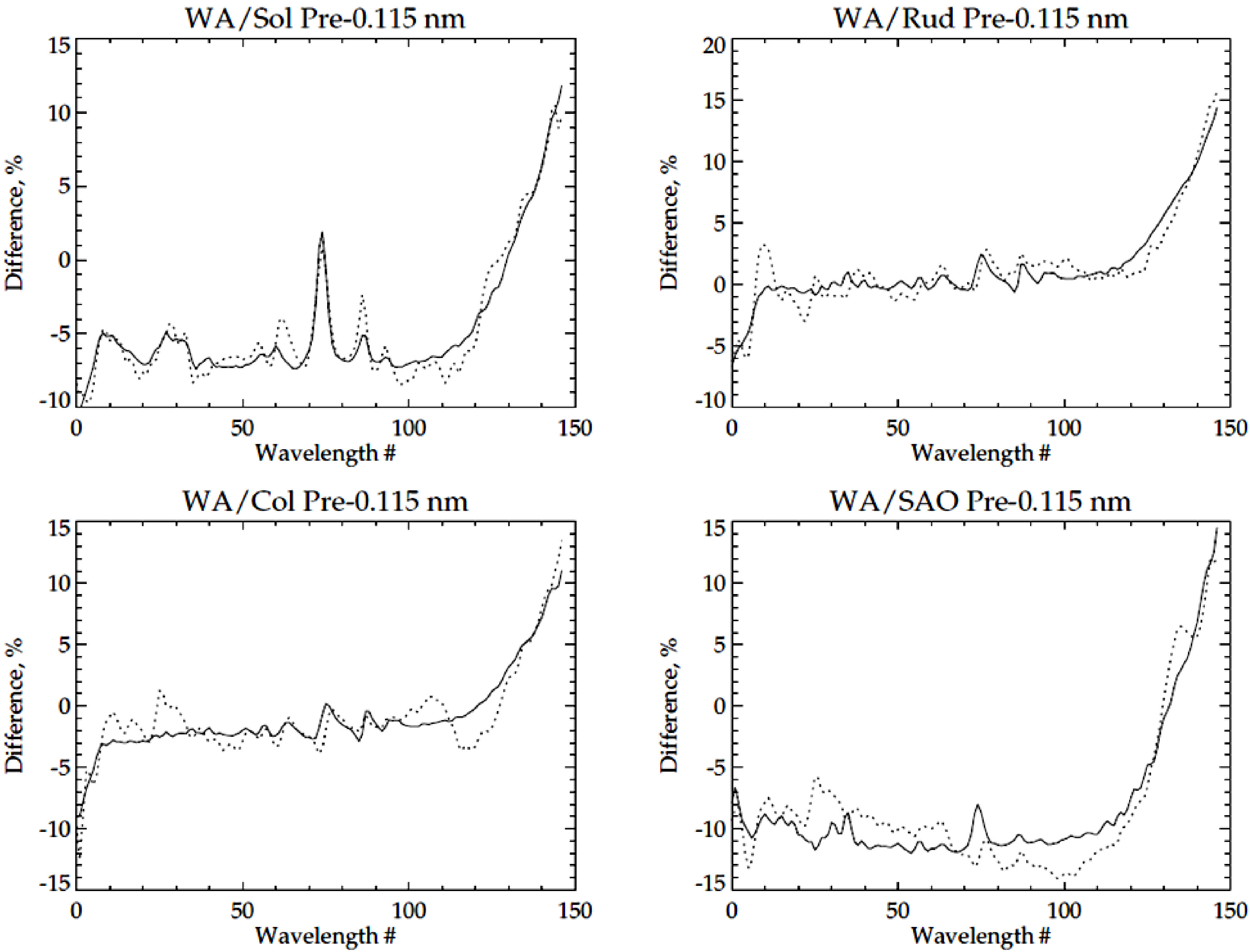
Working Day 81 vs Solstice Synthetic (1.1% rmsr)

%offset	%Mg II	Shift nm	Dich nm
-7.5	7.7	-0.004	-0.347

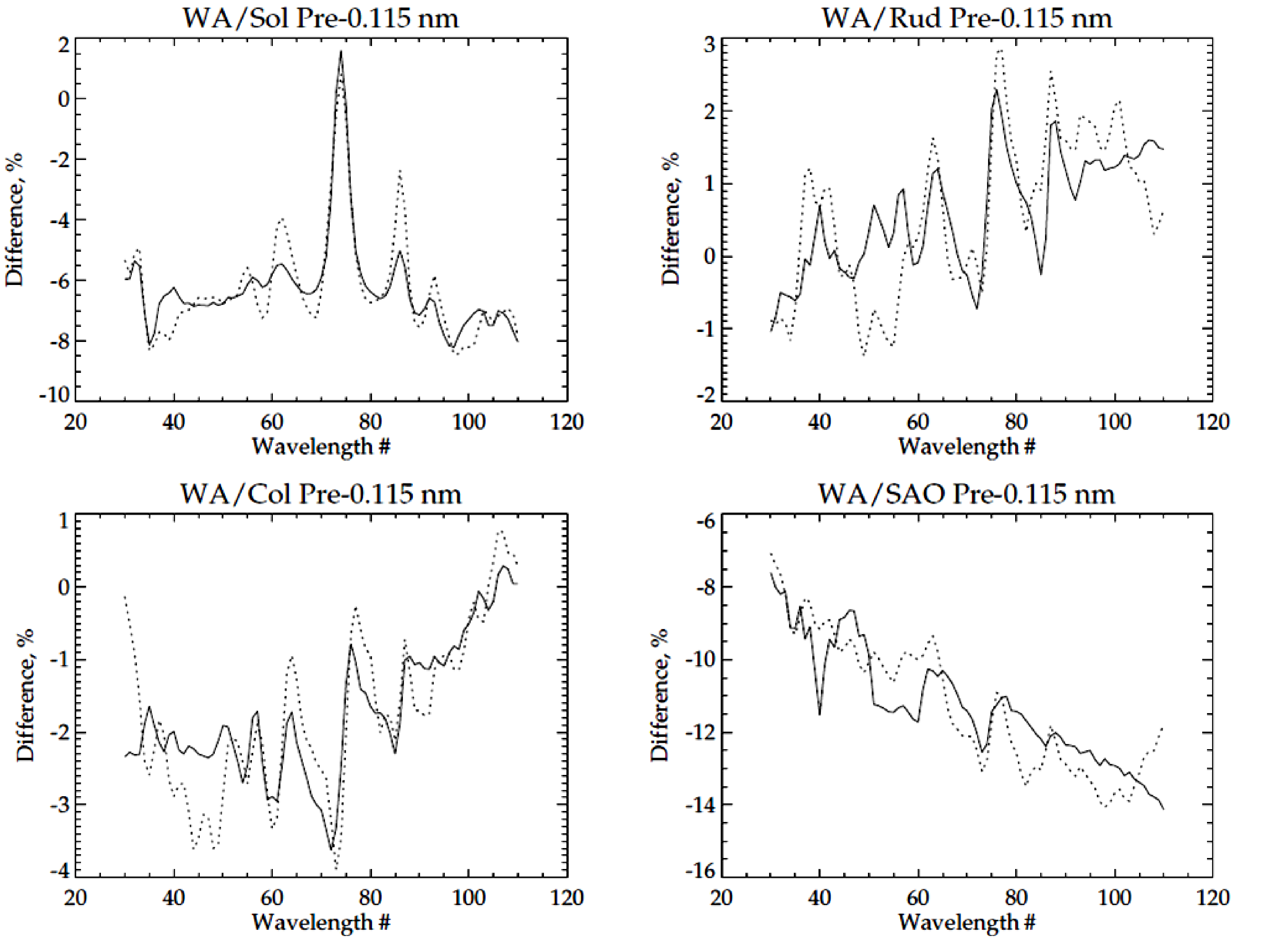
Summary and Conclusions

- The Earth View radiances at 253 nm and 273 nm respond to solar flux changes.
- These variations will be aliased as ozone changes if a constant Day 1 solar spectrum is used.
- Daily estimates of the Mg II Index changes can be combined with Scale Factors to provide estimates of the solar flux on a daily basis.
- Real solar variations will complicate analysis of solar measurements.

Backup Slides



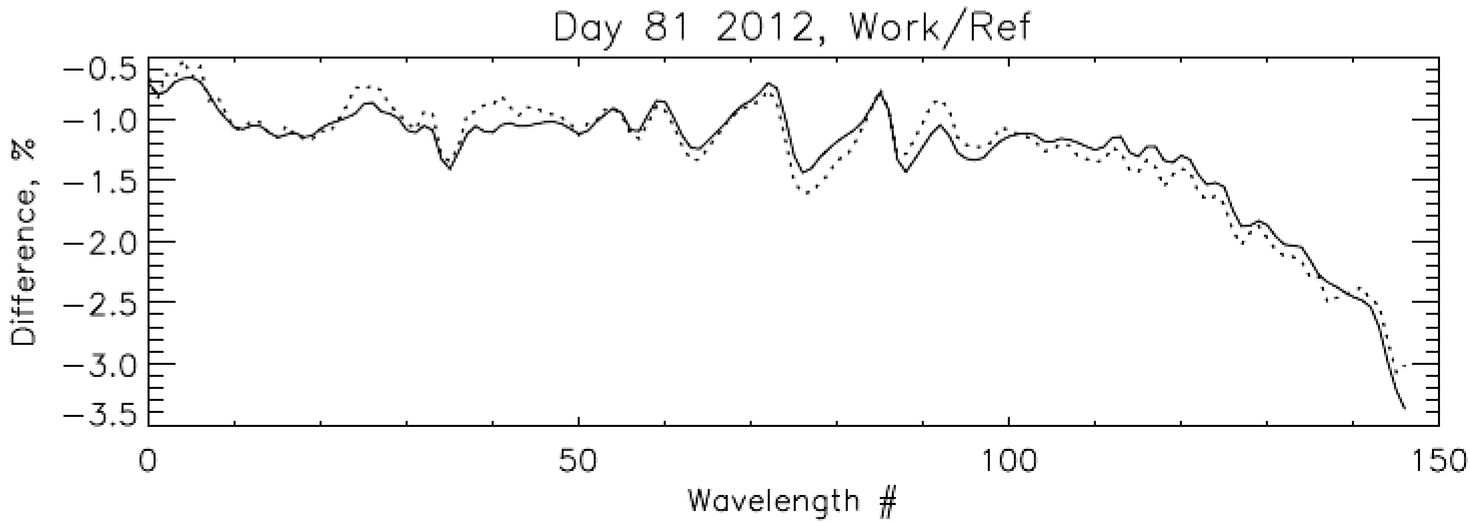
WA/Sol Pre-0.115 nm
WA/Rud Pre-0.115 nm
WA/Col Pre-0.115 nm
WA/SAO Pre-0.115 nm
Difference, %
Wavelength #

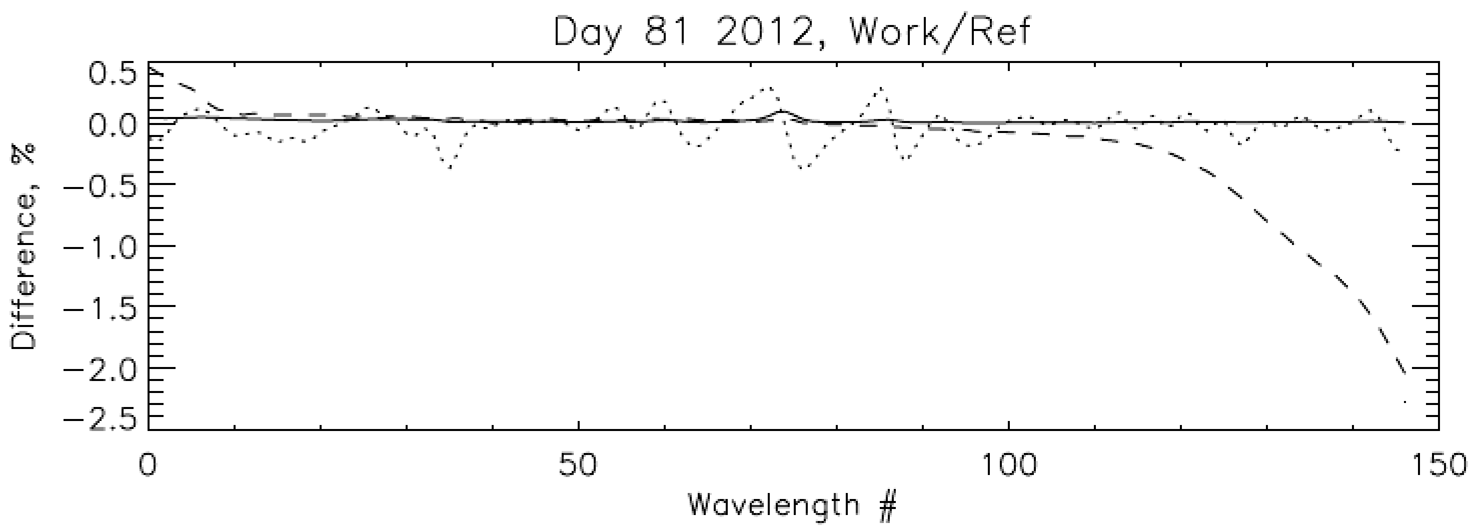


WA/Sol Pre-0.115 nm
Difference, %
Wavelength #
WA/Rud Pre-0.115 nm
Difference, %
Wavelength #
WA/Col Pre-0.115 nm
Difference, %
Wavelength #
WA/SAO Pre-0.115 nm
Difference, %
Wavelength #

Outline

- OMPS NP Solar Spectra – internal comparisons
  - Annual wavelength scale variations
  - Mg II and solar activity
  - Instrument throughput trending
- OMPS NP Solar Spectra – external comparisons
  - Absolute wavelength Scale
  - Comparisons to synthetics
  - Dichroic variations
- OMPS NM Intra-orbit wavelength scale

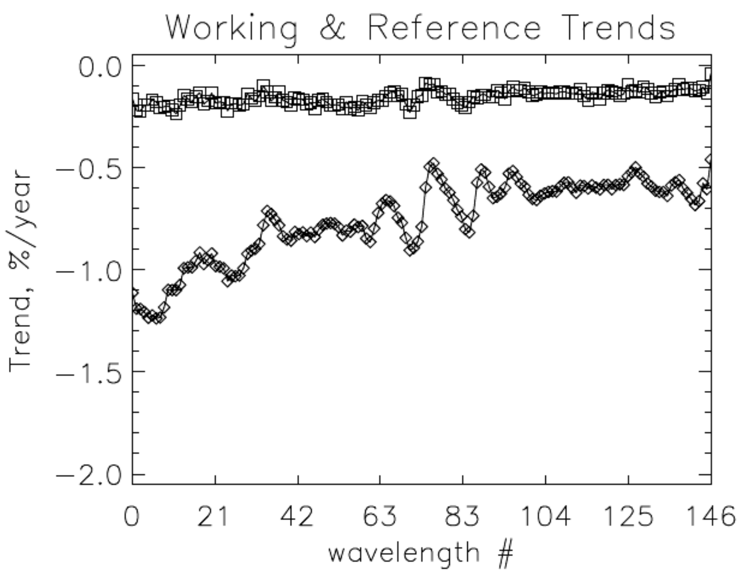


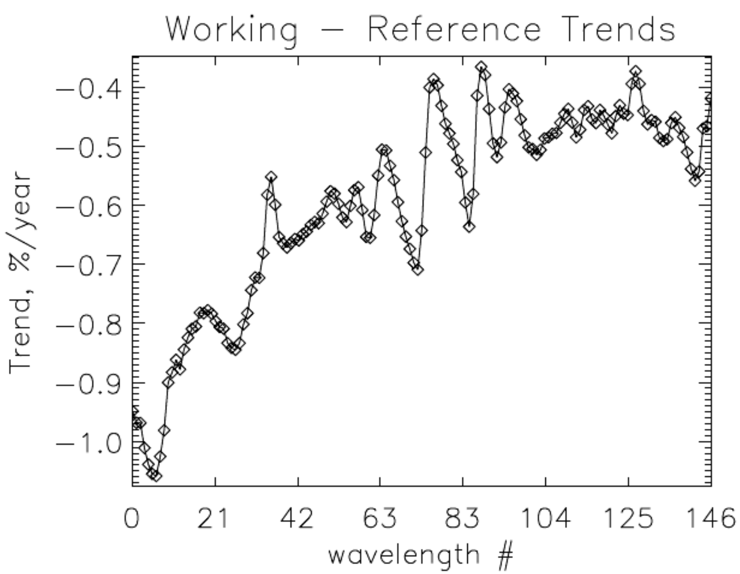


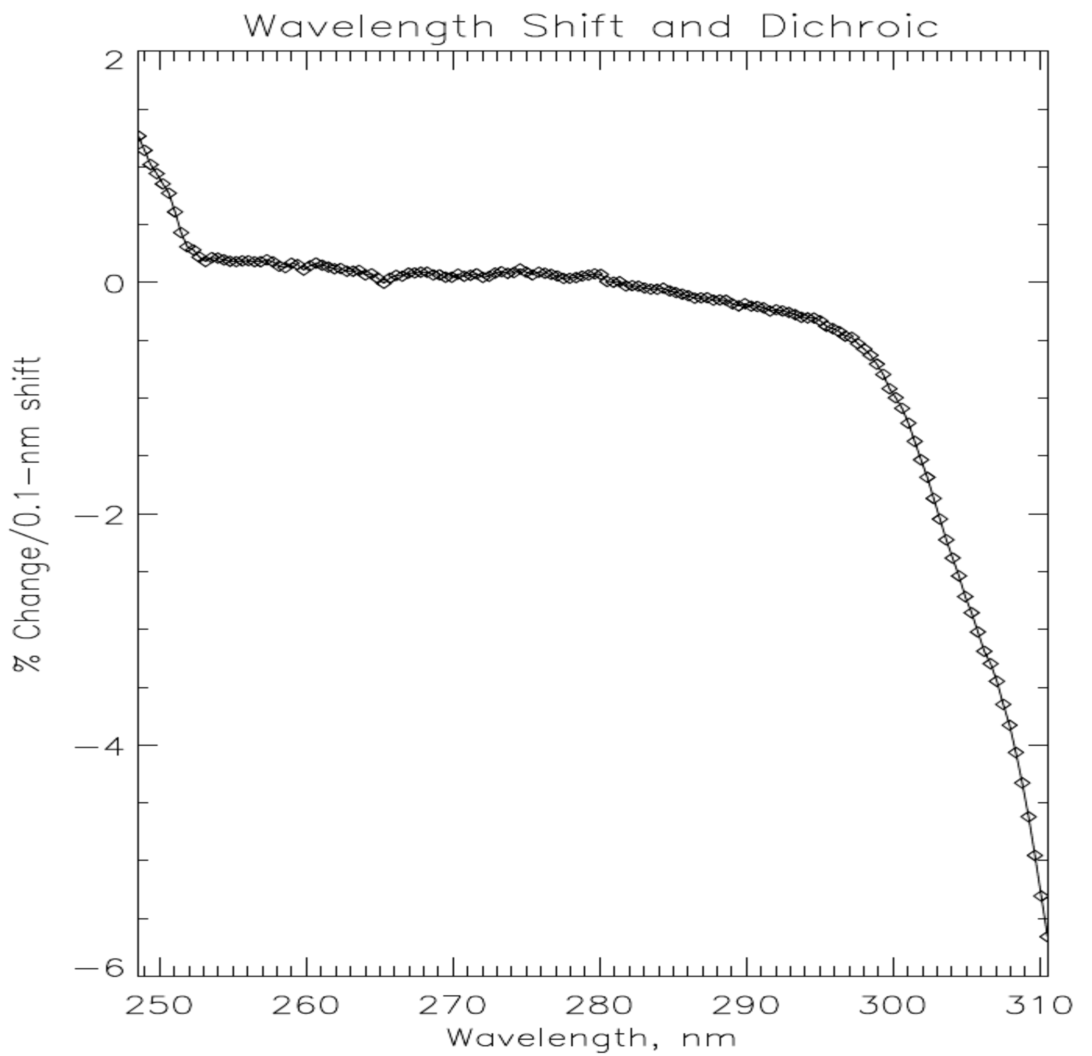
Working Day 81 vs Reference Day 81 (0.1% rmsr)

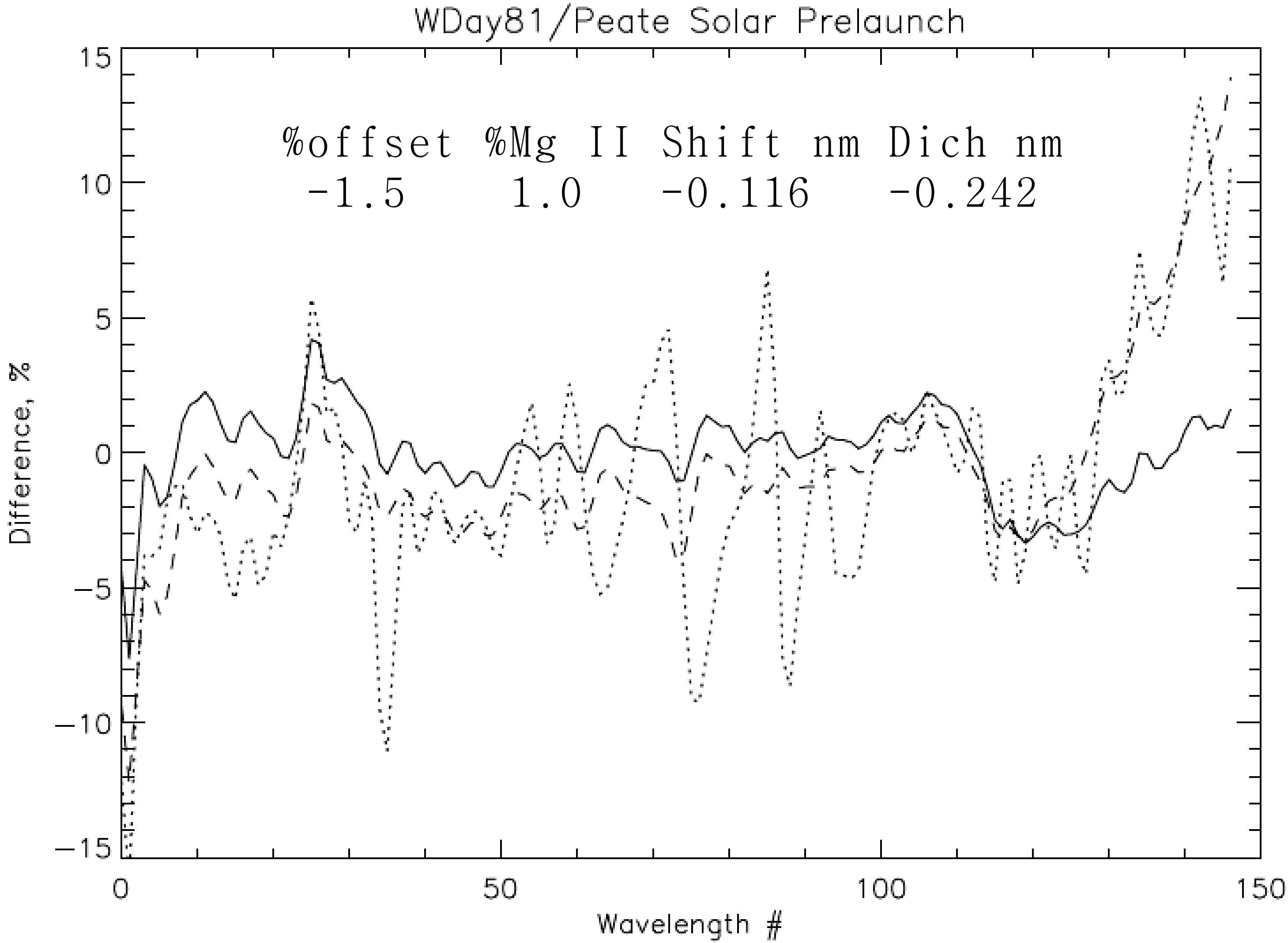
%offset	%Mg II	Shift nm	Dich nm
-1.1	0.1	-0.005	0.036

Trends in Solar from model fits and counts to radiance wavelength





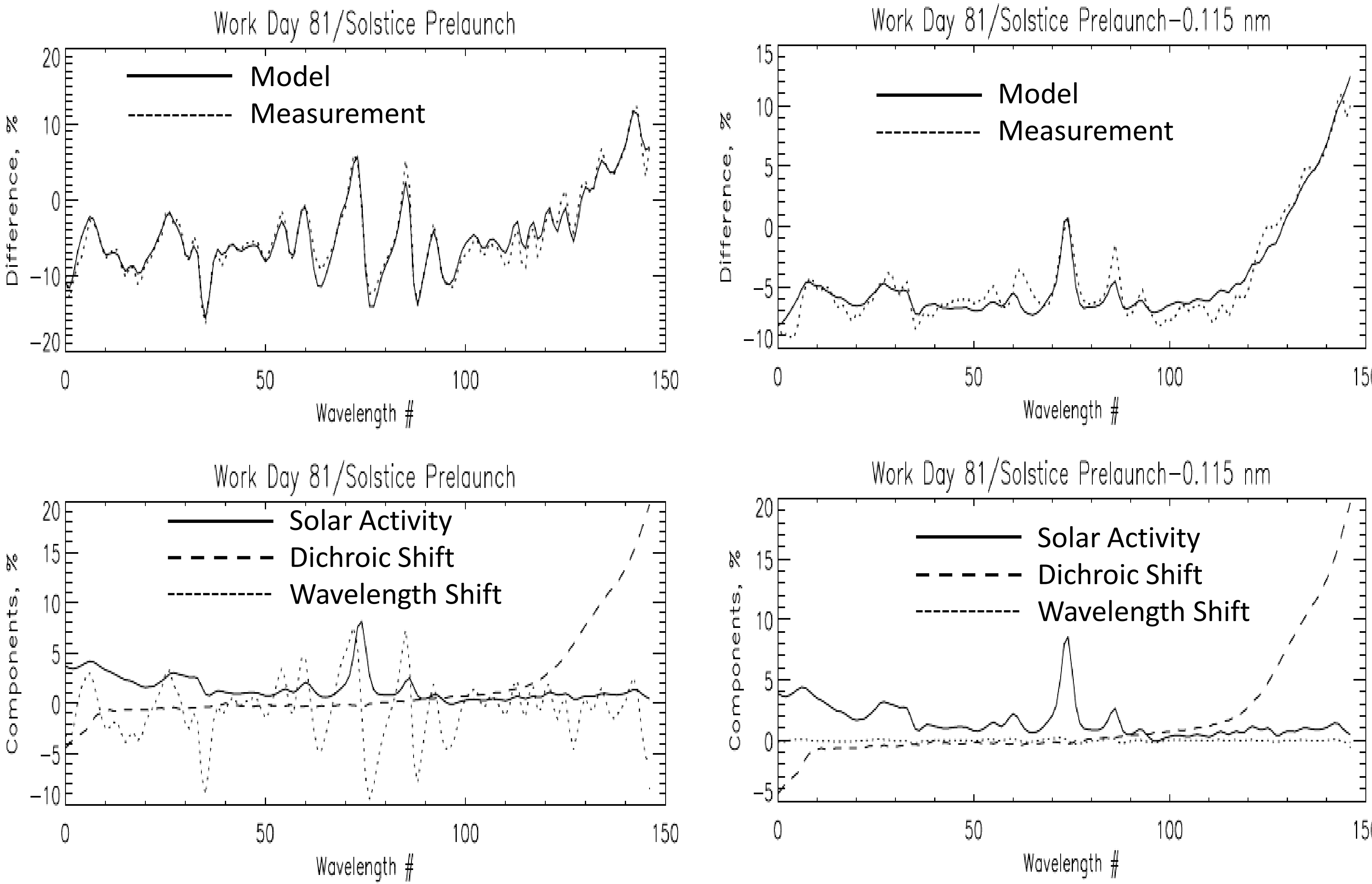




Synthetic solar created from the PEATE high resolution spectrum compared to the day 81 of 2012 Working Diffuser solar measurement using the pre-launch wavelength scale.
The dotted line is the relative difference (measured/synthetic - 1). The dashed line is after a uniform -0.12-nm shift of the wavelength scale without accounting for the dichroic. The solid line is after removing a -1.5% offset, a -1.0% Mg II activity term, a -0.242-nm counts to radiance shift (dichroic and other influences), and an additional 0.004-nm wavelength shift.

Comparison of OMPS NP Solar spectrum to synthetic from Solstice and prelaunch data. Fits of the differences with a model using three patterns of the form:

Meas/Synth = a0 + a1*WavelengthShift + a2*SolarActivity + a3*DihroicShift



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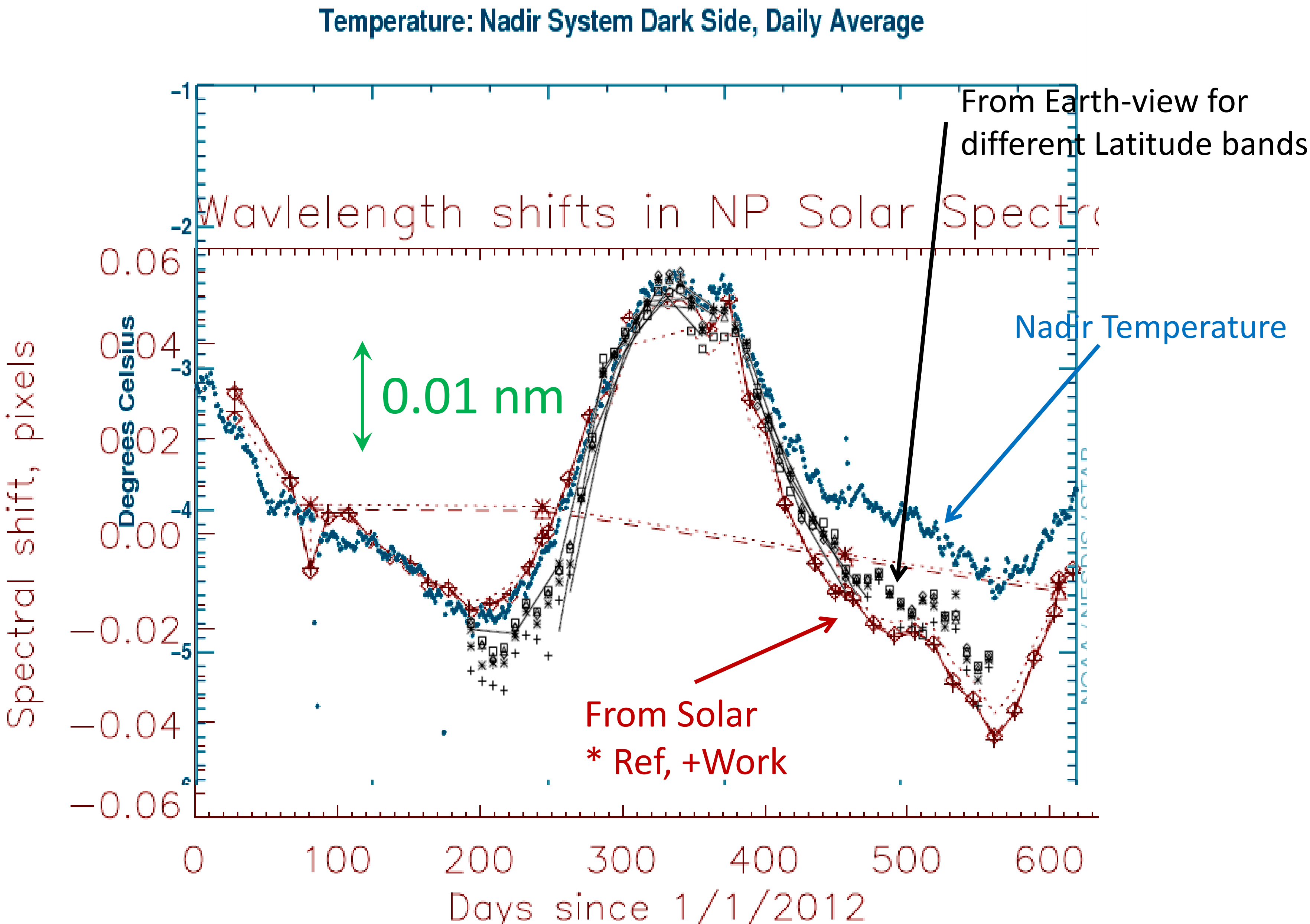
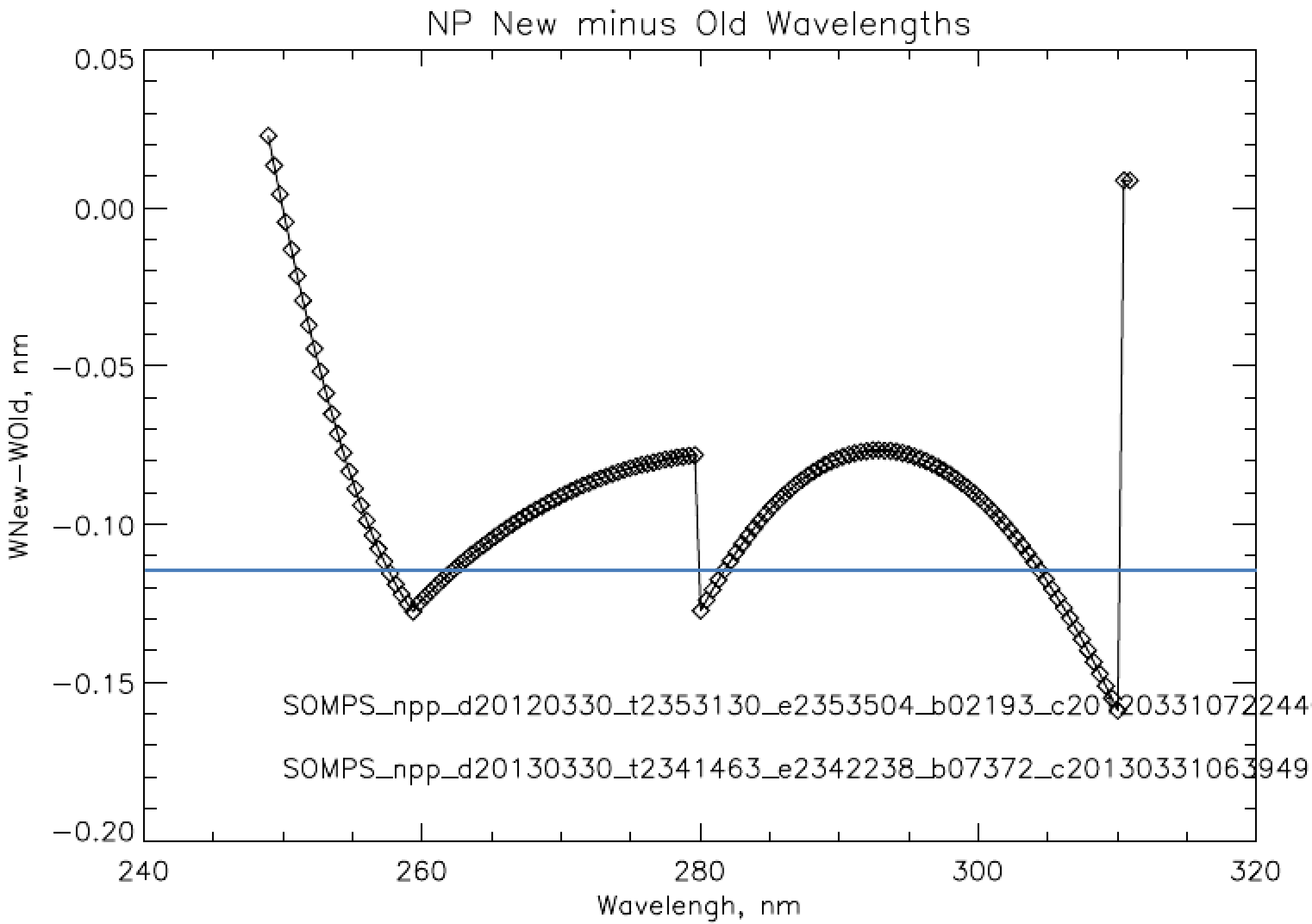
Working Day 81 vs Solstice Synthetic (1.1% rmsr)

%offset	%Mg II	Shift nm	Dich nm
-7.5	7.7	-0.004	-0.347

Comparison of OMPS NP Solar and Earth Wavelength Shifts & Temperatures



Change from pre-launch in current wavelength scale

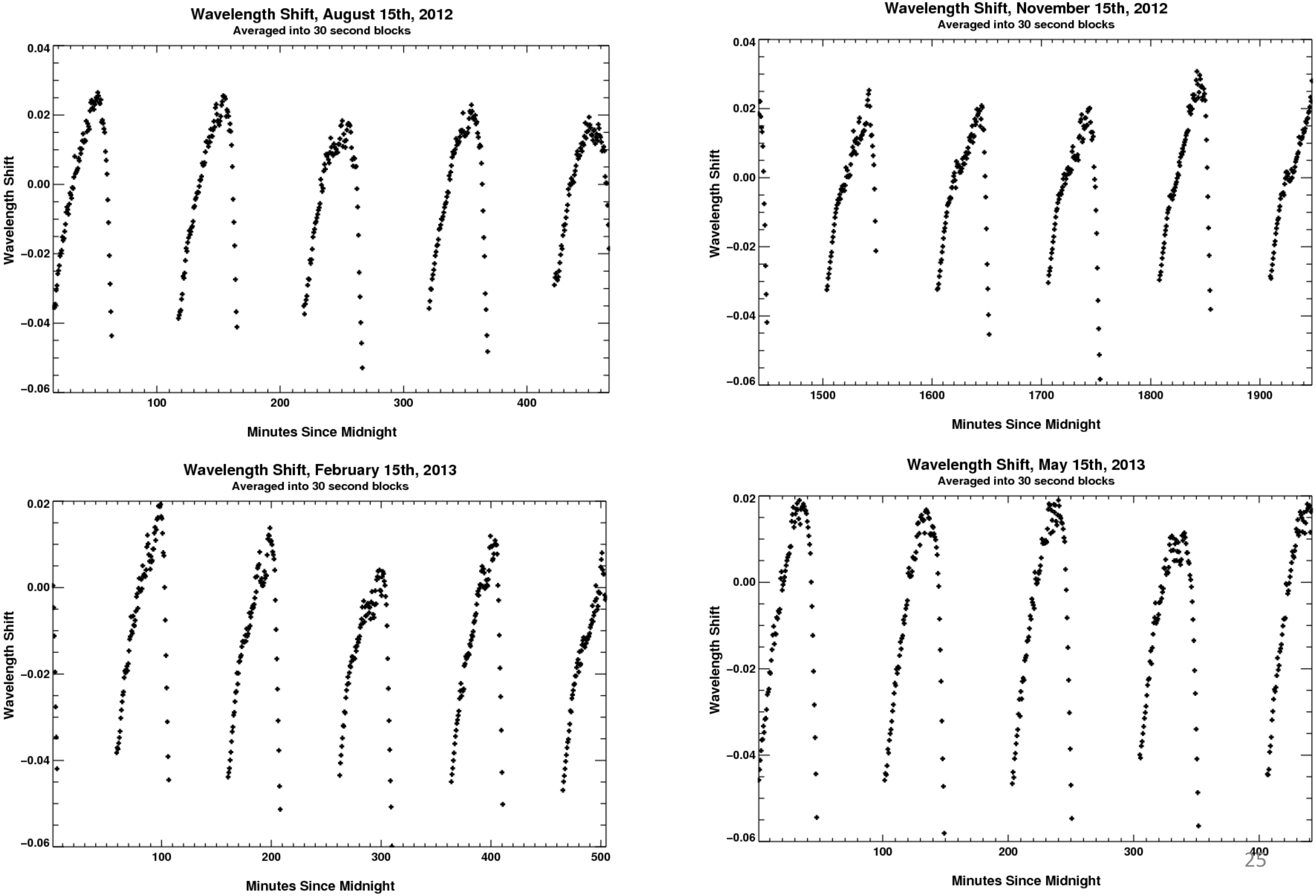


OMPS NM Intra-orbit Shifts

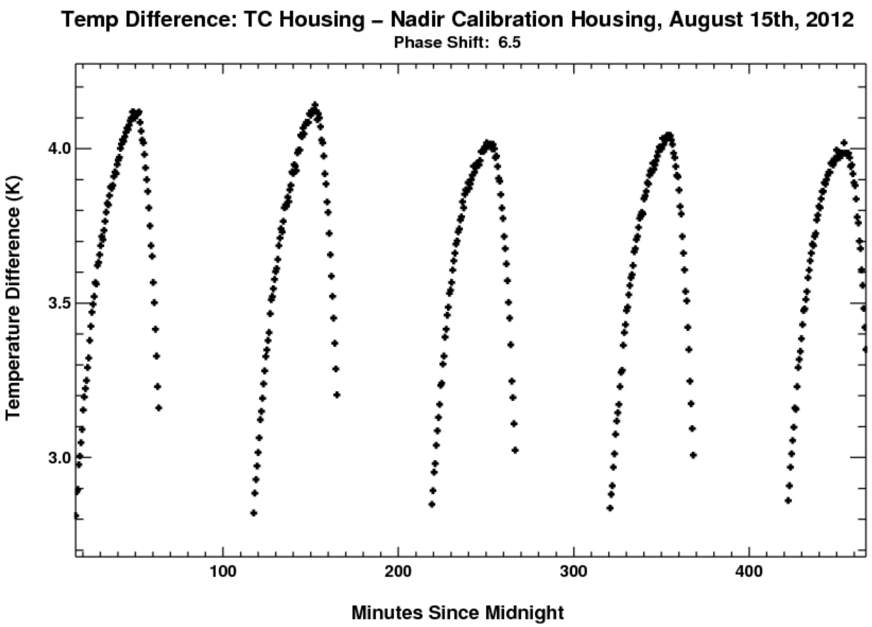
- The OMPS Nadir Mapper Earth-view measurements have been found to have intra-orbital shifts in the wavelength scales.
- They are associated with temperature gradients as the satellite's thermal exposure varies.
- The pre-launch models predicted shifts smaller than the 0.01 nm performance requirement.
- On-orbit analysis has detected shifts greater than +-0.02 nm from the orbital average. In addition, the solar measurements are taken at the northern terminator where solar thermal influences are at an extreme.
- We are implementing a measurement-based estimate of these changes on a granule by granule basis within the SDR algorithm to provide better knowledge of the wavelength scale to the total ozone retrieval algorithm.
- The evidence and then the approach are described in the following slides.

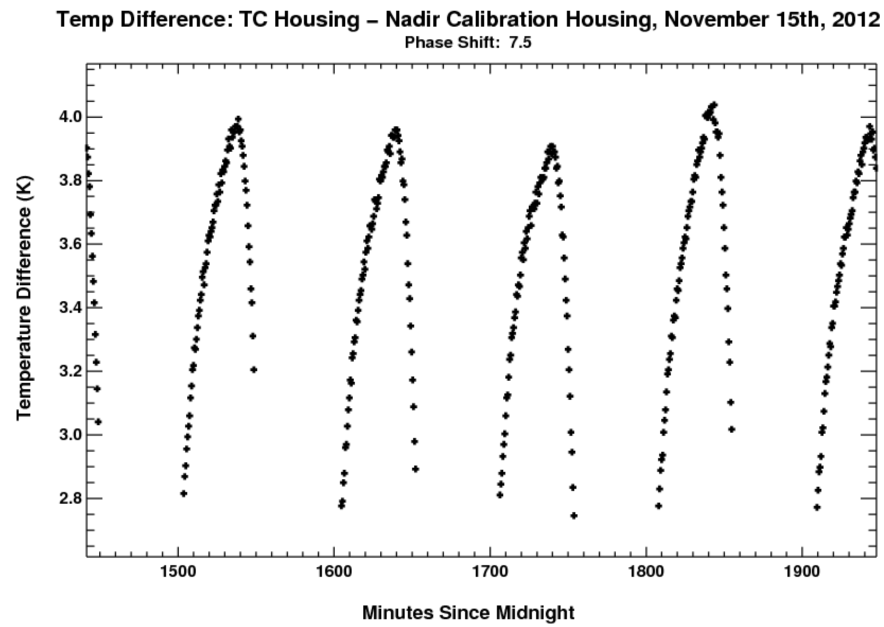
- The panels in Slide 14 show the estimated wavelength shifts for four orbits per day for one day every three months. The shifts are for a single cross-track position and computed relative to a fixed Day 1 solar spectrum.
- The panels in Slide 15 show the differences in two temperature sensors (TC Housing and Nadir Calibration Housing) for the same four days in Figure 1. These two sensors had differences with the best correlation to the results in Slide 14. The undifferenced temperature values have large annual cycles not seen in the spectral shift estimates. There is a lag (~5 minutes) between these particular temperature differences and the shift but the pattern coherence along orbit, among different orbits, and month after month is impressive.
- The two panels in Slide 16 compare shift estimates from two different methods and show the Cross-track dependence. The primary variations in the cross-track dependence of the shift are related to the spectral scales of the different cross-track solar references and are not thought to be an instrument effect.

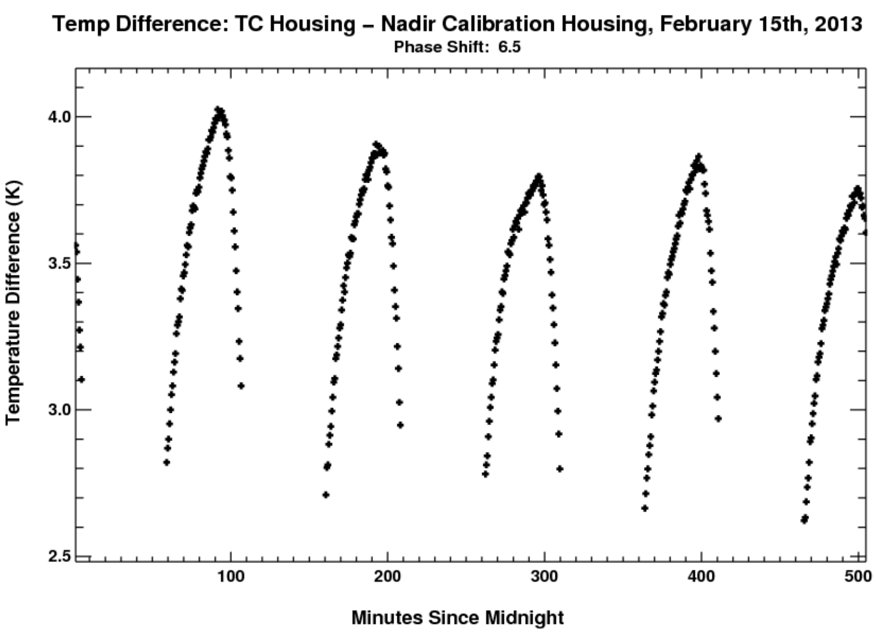
Wavelength scale shift estimates for the OMPS NM nadir FOV for first four orbits every four months

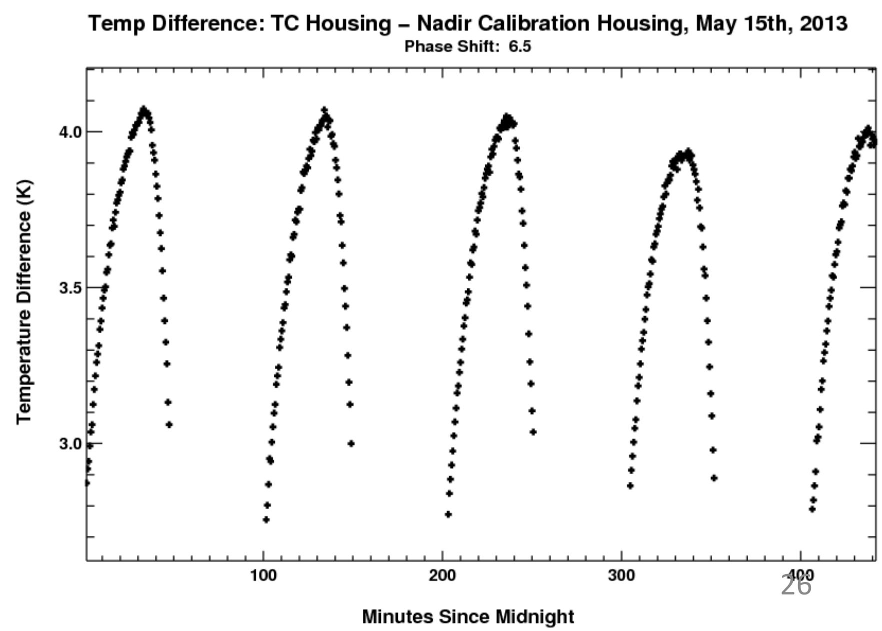


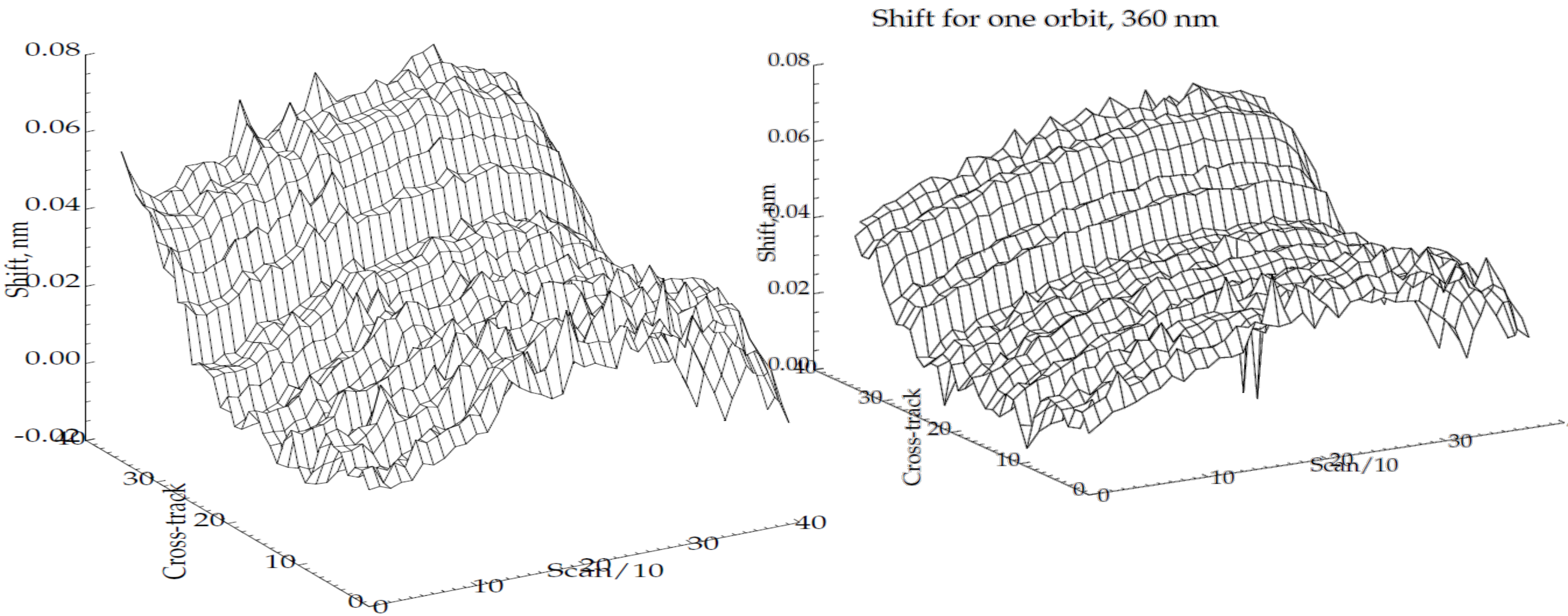
Select temperature differences for same orbits











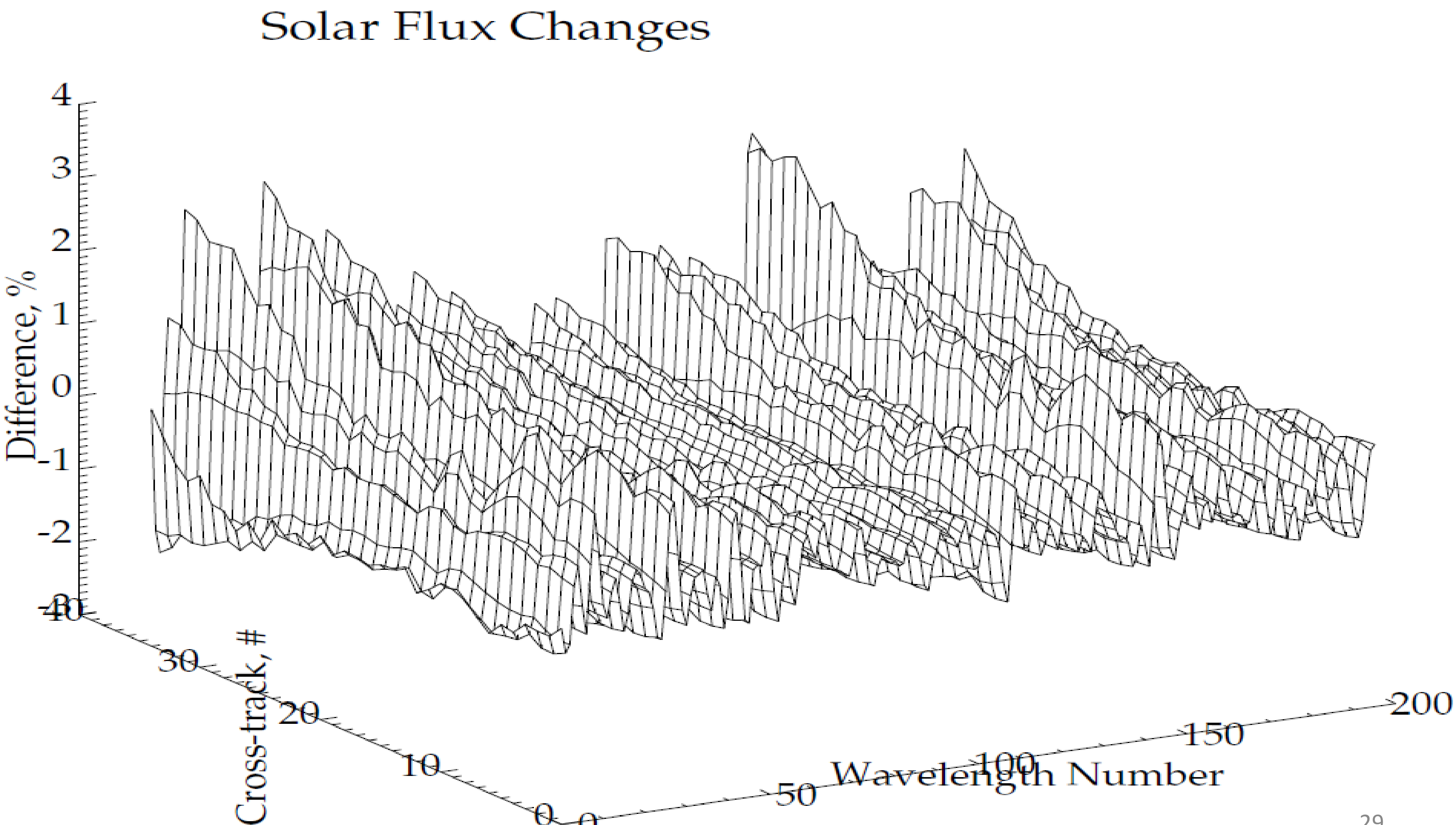
Comparison of cross-track and orbital patterns of estimated Earth radiance scales relative to the current day 1 solar from the proposed method using 346 nm to 380 nm with those from an analysis in an SO_2 product formulation. The two sets of results agree well in both along orbit and cross track variations. The results for every tenth scan are used to create the figures.

Backup

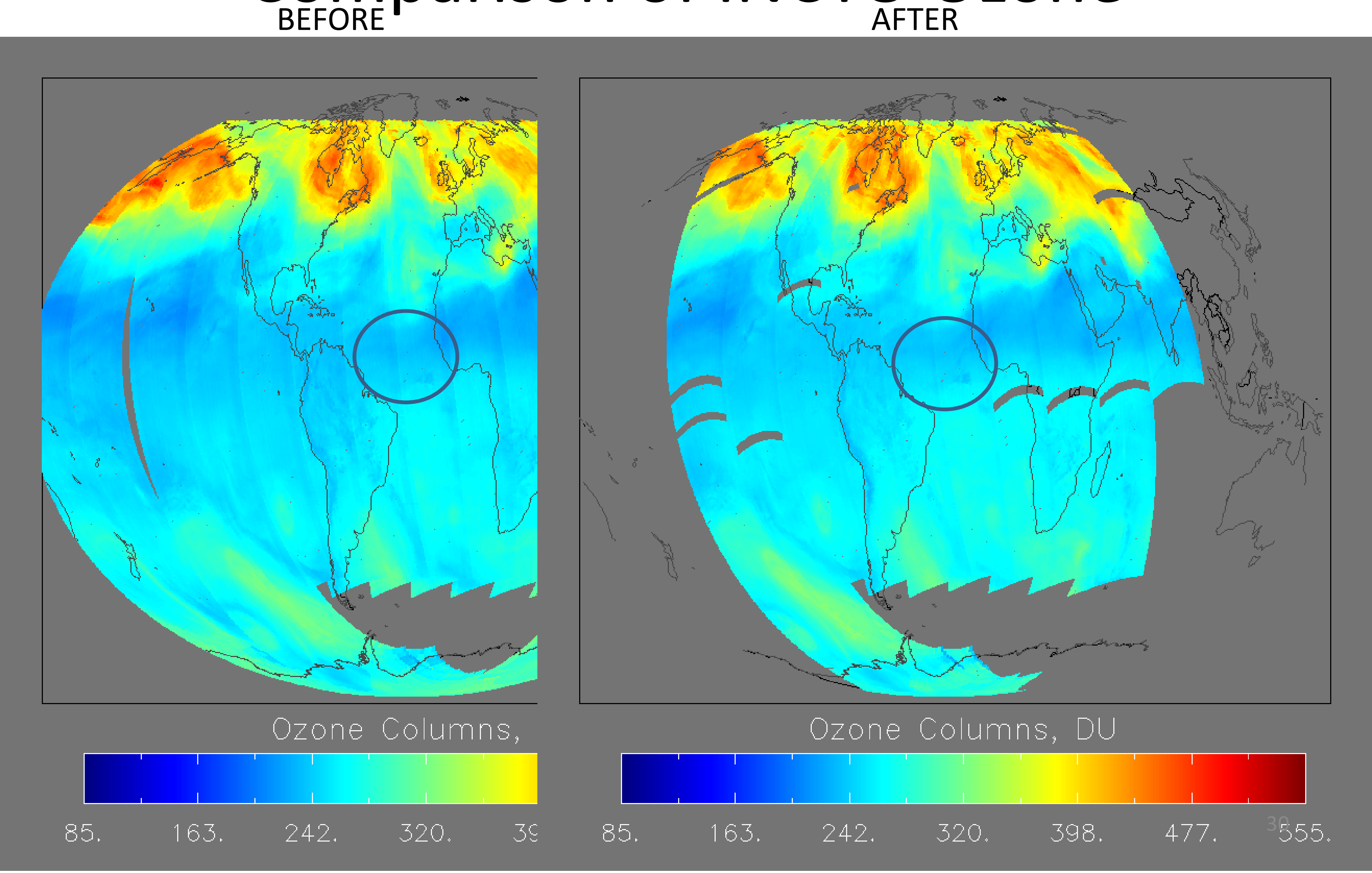
Comparison of Results for Test Granule

SOMTC_npp_d20130205_t1500128_e1500502_b06615_c20130205221511027836_noaa_ops.h5

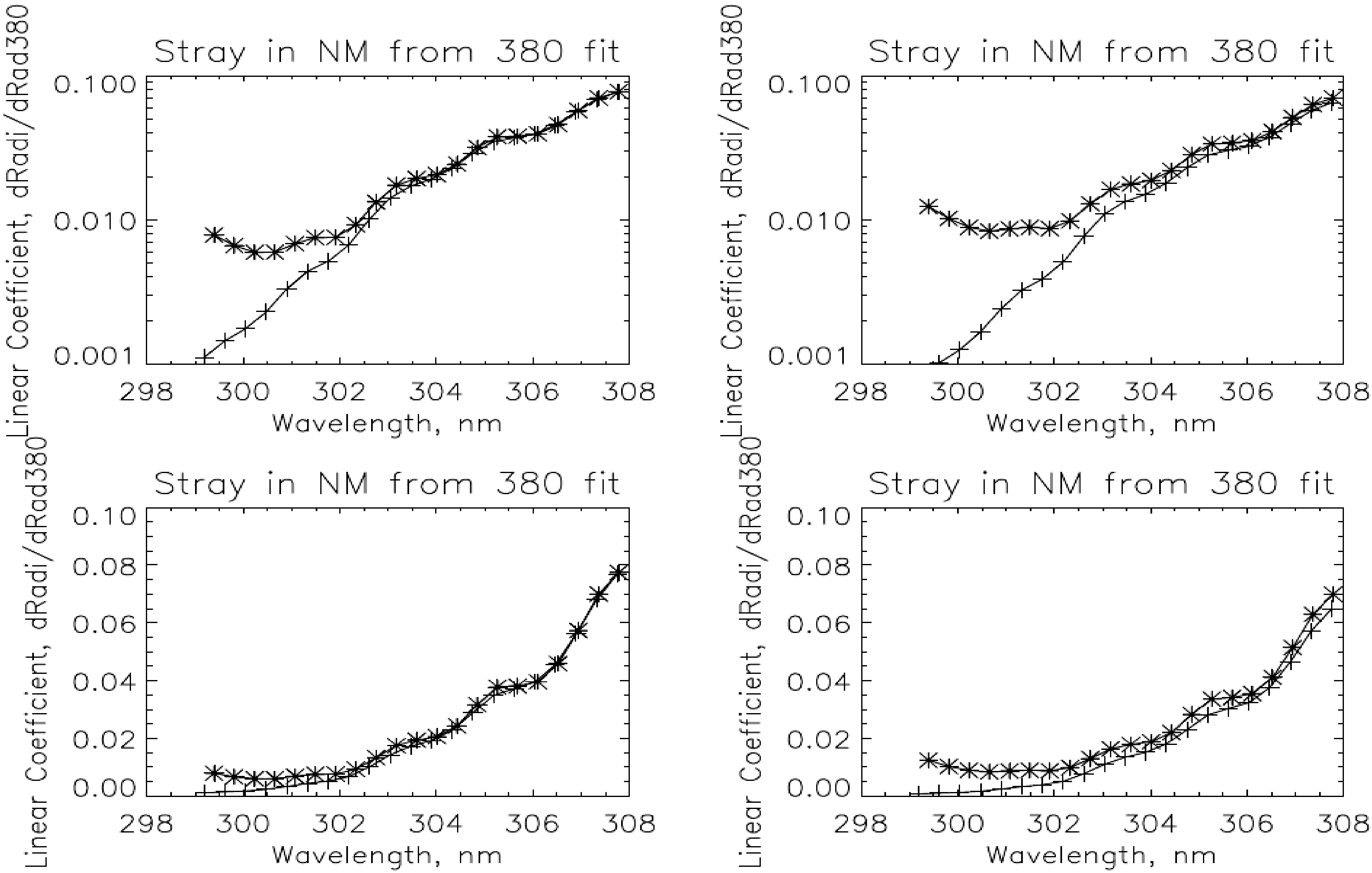
SOMTC_npp_d20130205_t1500128_e1500502_b06615_c20130812180617128986_ssec_cspp.h5



Comparison of INCTO Ozone



Notice reduced striping – better cross track consistency



A correlation study of 380 nm variations at small SZA versus variations at NP and NM channels below 308 nm. The method subtracts a smooth function of latitude from the radiances for all of the data sets and then looks for a linear relationship between the remaining variations at 380 nm with those for each of the target channels. At 380 nm, these variations are dominated by changes in the scene brightness. The figures on the left show the results for the current IDPS product. It has the stray light correction (but with the OOR set at 0). The figures on the right show the results for IDPS prior to the implementation of the stray light correction. The + symbols are for the NP channels and the * symbols are for the NM channels. The NP results show the expected fall off in sensitivity of radiances to scene brightness with decreasing wavelength (increasing ozone absorption.) These coefficients are in units of target radiance / source radiance .

Description of the Approach for OMPS NM Solar

The Earth radiance spectra have very similar features to the solar spectra over the 345 nm to 380 nm range, that is, there is little absorption by atmospheric constituents and modest wavelength dependence to scattering and reflectivity. Thus the Fraunhoffer structure is well-reproduced. These common features cancel in properly aligned/coregistered radiance/irradiances ratios so deviations from a flat albedo can be used to estimate the relative wavelength scale difference between a Day 1 Solar and a current Earth radiance measurement. The process is as follows:

1. Estimate the expected pattern in a solar spectrum that a wavelength shift would produce by using the day 1 solar spectrum at 0.42-nm resolution and the wavelength to wavelength variations. (Recall that the OMPS Nadir Mapper has 1.0-nm resolution)

This pattern is computed by finding the slope of a quadratic fit of the irradiances for three adjacent values and normalizing the irradiance/pixel slopes by the irradiance spectrum.

2. Estimate the expected pattern in the Earth spectrum that would be produced by inelastic scattering (Ring effect) contributions.

This pattern is computed by taking the reciprocal of the solar spectrum.

3. Find the normalized albedo patterns from non-smooth contributions.

This set of variations is determined by taking the radiance/irradiance ratio and normalizing by the averages of the two and removing a cubic polynomial in wavelength.

4. Remove similar smooth functions of wavelength from the patterns in 1. and 2. so that all three are relative quantities varying about zero.

This is performed by finding and removing polynomial fits for each pattern. Cubics are found to work well.
For the Earth-view spectra, this model component is designed to account for the smooth variations in Earth albedo due to the wavelength dependent effects of aerosols, elastic Rayleigh scattering, and cloud and surface reflectivity. Since we take a smooth pattern out of the Earth data we need to take it out of the other two patterns too.

5. Find the components in the normalized albedo related to the two patterns to estimate the wavelength scale shift between the Earth and solar spectra.

This is calculated by using the relative variations from 3. and 4. [the Earth albedo (radiance/irradiance ratios) using for measured radiances and the reported solar by using the two patterns (shift and Ring)] in a multiple linear regression.

Normalized Earth Albedo = C1 * Normalized Shift pattern + C2 * Normalized Ring Pattern

6. Use the coefficient for the shift pattern from 4. and the shift pattern to adjust the solar spectrum to the Earth wavelength scale and report the new solar spectrum and the shifted scale as outputs in the SDR product.

This simply uses the value of C1 and the shift pattern in 1. to create the adjusted output.

New Subroutine in the SDR Algorithm

OMPS_NM SDR 474-00077_OAD

Section 2.1.2.3.67 Subroutine sol_wscale_shift.f

This subroutine estimates the Earth-view radiances wavelength scale relative to the solar spectrum wavelength scale and returns the new wavelength scale and an appropriately adjusted solar spectrum.

Changes in the output

ALL_DATA.OMPS_TC_SDR_ALL.solarflux (SolarFlux*) contains the day 1 solar flux spectra as input and the wavelength-shifted solar flux spectra as output.

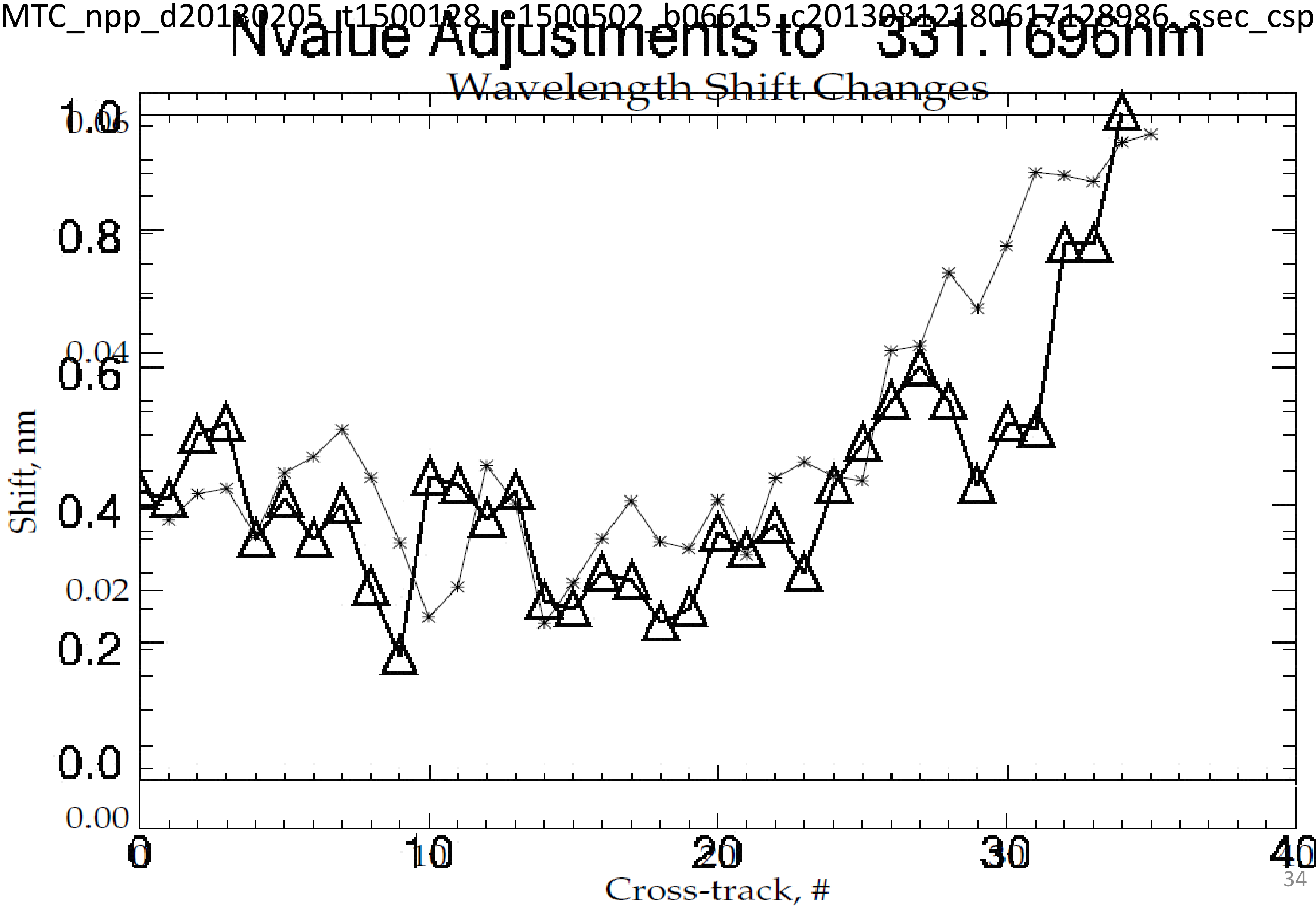
ALL_DATA.OMPS_TC_SDR_ALL.wavelengths (Wavelengths*) contains the day 1 solar flux wavelength scales on input and the earth radiance wavelength scales on output. The last spectral position (260) is overwritten with the shift in nm.

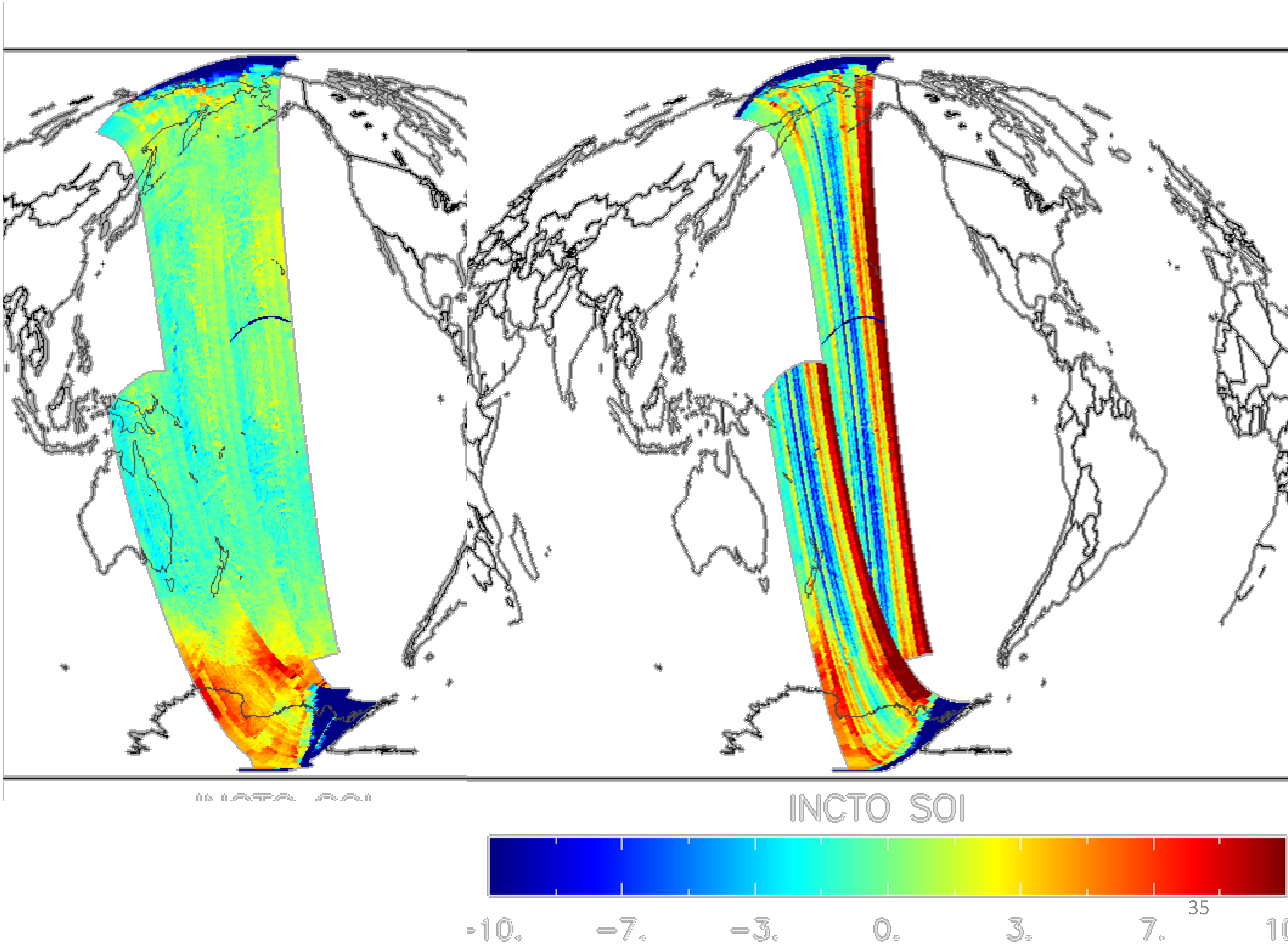
***CDFCB_X_Vol_3 Table 2.10.1.1-1, OMPS TC SDR Data Content Summary**

Comparison of Results for Test Granule

SOMTC_npp_d20130205_t1500128_e1500502_b06615_c20130205221511027836_noaa_ops.h5

SOMTC_npp_d20130205_t1500128_e1500502_b06615_c20130812180617128986_ssec_cspp.h5




INCTO SOI
-10.
-7.
-3.
0.
3.
7.

For each stage of Validation, the Calibration and Validation Team shall develop a Validation Package that includes the following:

Algorithm Assessment

Evaluation of algorithm performance to specification requirements

Evaluation of the effect of required algorithm inputs such as, but not limited to, the following:

Ancillary Data

Sensor Data Record(s)

Upstream Environmental Data Records

Upstream Intermediate Products

Look Up Tables (LUTs)

Processing Coefficient Tables (PCTs)

Error Budget

Quality Flag analysis/validation

Input from key users

Identification of the processing environment

IDPS Build Number and effectivity date

Version of LUT(s) used

Version of PCT(s) used

Description of environment used to achieve particular stage of Validated

Documentation

Current or updated ATBD

Current or updated OAD (algorithm-related redline updates, if applicable)

README file for CLASS

Product User's Guide (Recommended)

User Precautions

Identify known issues

List closed Discrepancy Reports between previous maturity milestone and current maturity milestone.

Provide assessment of outstanding Discrepancy Reports

Validation Stages	Definition
Validated Stage 1	Using a **limited** set of samples, the algorithm output is shown to meet the threshold performance attributes identified in the **JPSS Level 1 Requirements Supplement with the exception of the S-NPP Performance Exclusions**
Validated Stage 2	Using a **moderate** set of samples, the algorithm output is shown to meet the threshold performance attributes identified in the **JPSS Level 1 Requirements Supplement with the exception of the S-NPP Performance Exclusions**
Validated Stage 3	Using a **large** set of samples representing global conditions over four seasons, the algorithm output is shown to meet the threshold performance attributes identified in the **JPSS Level 1 Requirements Supplement with the exception of the S-NPP Performance Exclusions**
Validated Stage 4	Using a **large** set of samples representing global conditions over four seasons, the algorithm output is shown to meet or exceed the objective performance attributes identified in the **JPSS Level 1 Requirements Supplement with the exception of the S-NPP Performance Exclusions**

I am trying to sort out the interactions of the three subject complications and I have some comments, questions and observations.

The first observation is that the NP and NM wavelength scales as provided in Spring 2012 have approximately -0.1-nm shifts in the wavelength scales for both relative to the ground-based results. Since, as Glen notes, we have a pixel-based calibration for OMPS and the dichroic is wavelength-based in its action, there needs to be adjustments to both NP and NM and to both irradiances and radiances for these two shifts, or to the calibration coefficients. I know Colin has looked at a 0.15 shift for the NM (In the radiances only I assume?).

Are any adjustments applied to the NM or NP solar data for the -0.1 nm wavelength shift effects through the dichroic?

(Note: If not, then since the EV data are not currently adjusted for this effect of the shift, the errors should cancel in the ratios.)

The second observation is that both of the wavelength shifts I see in the data (intra-orbital for the NM and intra-annual for the NP) need corresponding adjustments for their interactions with the dichroic. (I find that including the effects of the shift on the dichroic throughput as coupled with a wavelength shift improves the fits of the NP working solar data.) I have not yet looked at the effects of the NM intra-orbital shifts from this interaction. (We could adjust the irradiances for the expected dichroic effects in the wavelength scale shift code as implemented at IDPS when we make the solar match the earth.)

The third observation is that there are still correlations between the NM radiances differenced with the NP radiances in the 300-310 nm interval and the scene brightness as determined from longer wavelengths. That is, the stray light correction (at IDPS w/o an OOR correction) is leaving a significant variation with a stray light signature. While this variation is apparent at low SZAs with scene brightness correlation analysis, it will also be present at higher SZAs with a different dependence as the relative radiance at longer and shorter channels changes systematically. Since this is dependent on the source wavelength it is hard to determine how it will vary along an orbit.

Are there any adjustments/corrections to the solar for the NM or NP for stray light?

What stray light corrections are currently in the PEATE Earth-View SDR processing?

How large are the planned OOR corrections for NM stray light? What are their scene brightness and SZA dependent aspects?

I think the first questions to answer are:

Have the solar spectra have been adjusted for the dichroic/shift interactions?

Have they have been corrected for stray light?

The next question is whether comparison of the two in the overlap region show what's expected given the answers to these two questions.

COMPARE SENSOR DATA RECORD FROM NADIR INSTRUMENTS OF OZONE MAPPING PROFILER SUITE, GOME-2 METOP-A/B, NOAA-19 SBUV/2 AND CRTM SIMULATIONS

Fred Wu[1], Jian Zeng[2], Mike Grotenhuis[2], Mark Liu[1], Larry Flynn[1], Trevor Beck[1], Eric Beach[3], Jianguo Niu[5], and Wei Yu[4]

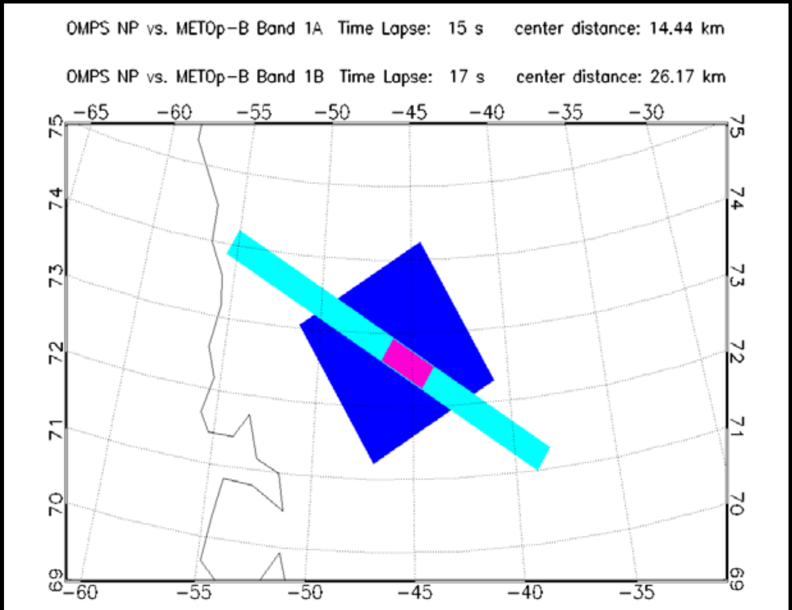
[1] NOAA/NESDIS/STAR, College Park, MD
[2] ERT, Inc. @ Center for Satellite Applications and Research, NOAA, College Park, MD
[3] IMSG, Inc. @ Center for Satellite Applications and Research, NOAA, College Park, MD
[4] IMSG, Inc. @ Office of Systems Development, NOAA, Suitland, MD
[5] SRG @ Center for Satellite Applications and Research, NOAA, College Park, MD

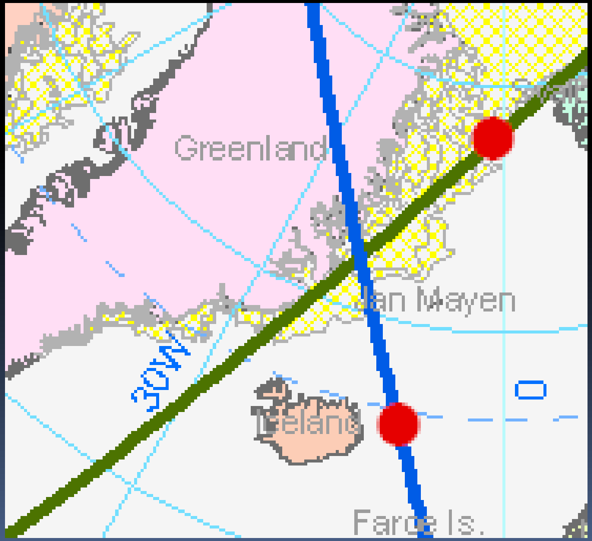
Outline

- Comparison with GOME-2 L1B
  - Analysis of influence factors such as homogeneity, distance, time lapse, SZA etc.
  - Long-term trending of SNO comparison (OMPS vs. GOME-2)
- Comparison with CRTM Simulations
- Comparison with SBUV/2

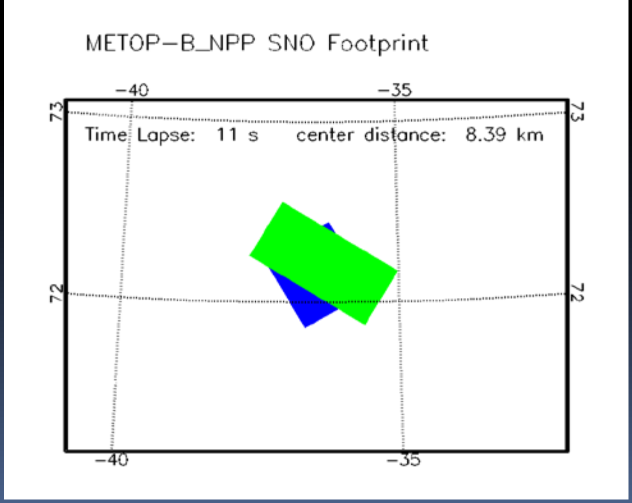
SNO Method

Simultaneous Nadir Overpass (SNO): Predictions for OMPS and METOp-A/B have been conducted at NOAA/NEDIS/STAR operationally. It predicts OMPS and METOp-A/B overpass locations and times, temporal and spatial distance between the two instruments, as well as solar zenith angles.

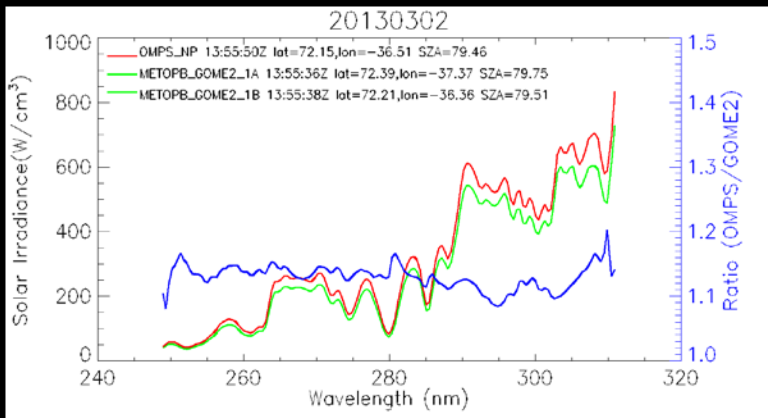


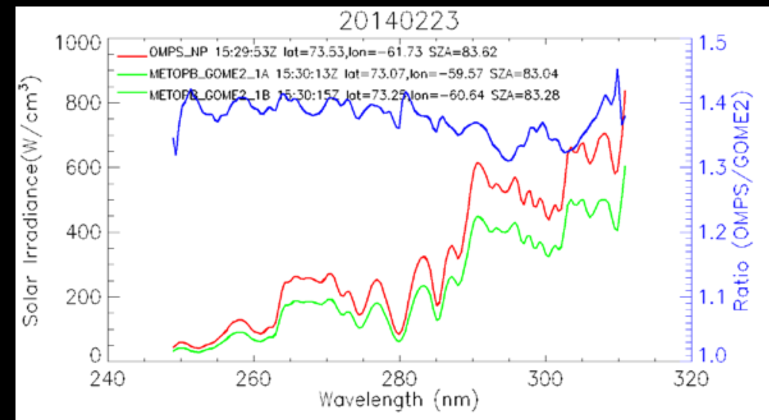


Courtesy of Changyong Cao

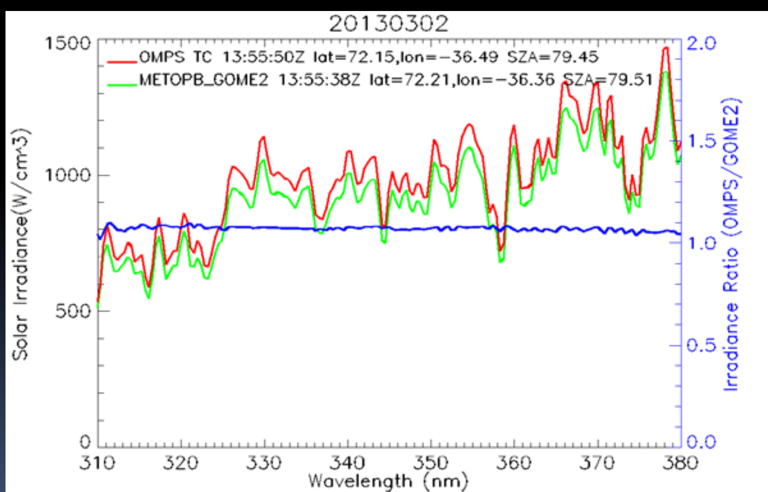


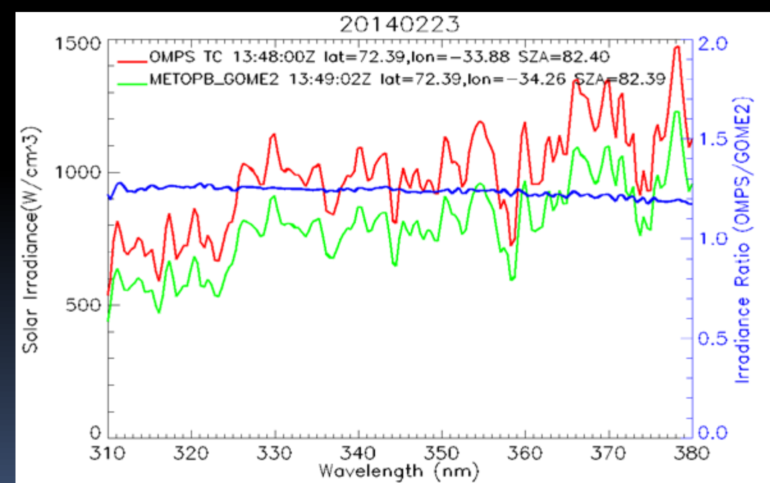
Solar Irradiance (GOME-2 METOp-B vs. OMPS NM/NP)





NP

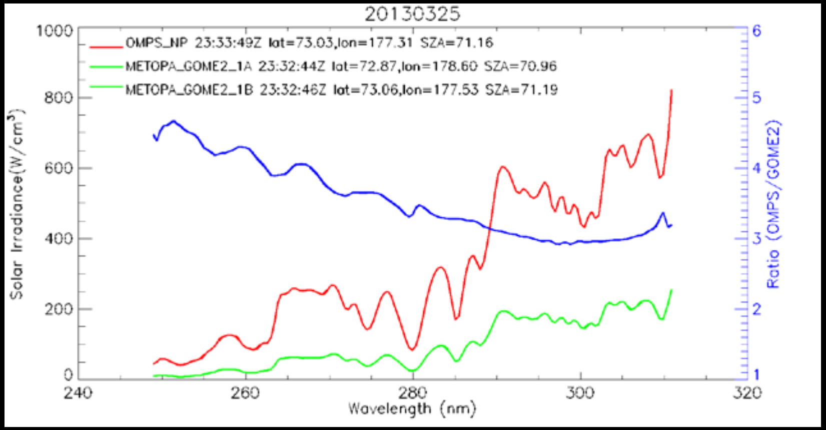


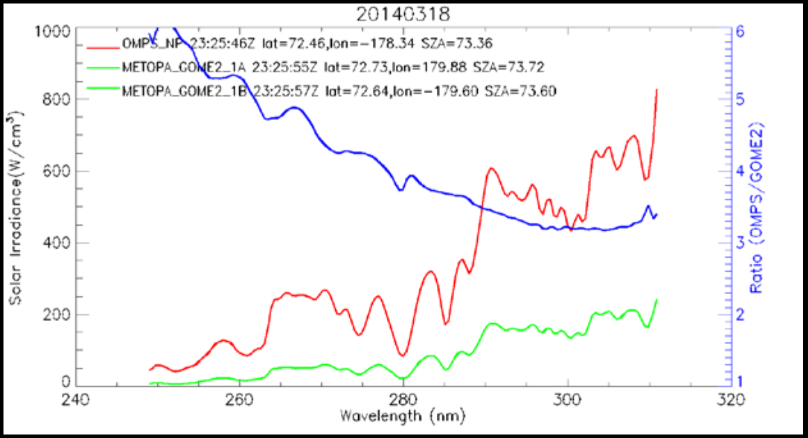


NM

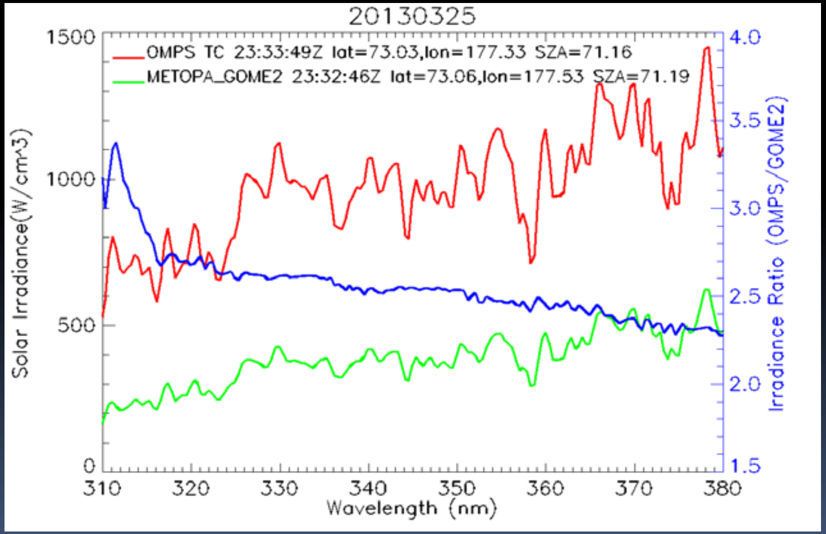
During past 12 months, solar irradiance signals of GOME-2 on METOp-B have degradated about 20% at band 1A and 1B, and about 10% at band 2B.

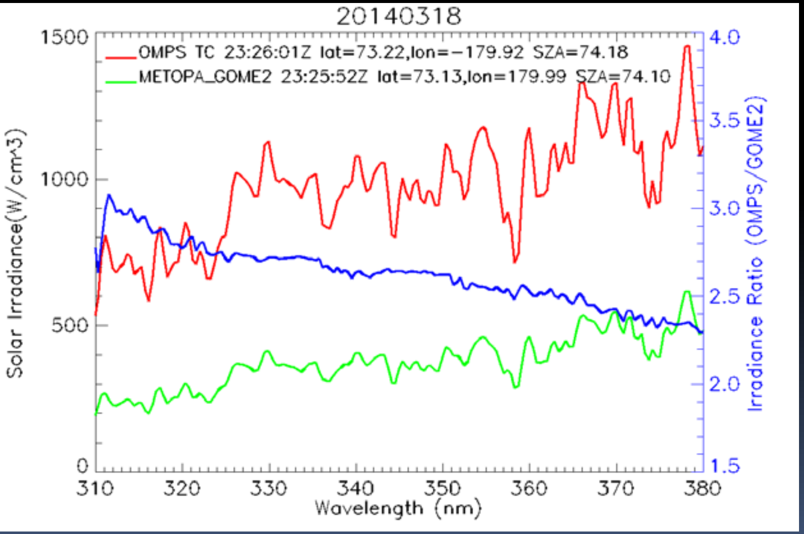
Solar Irradiance (GOME-2 on METOp-A vs. OMPS NM/NP)





NP

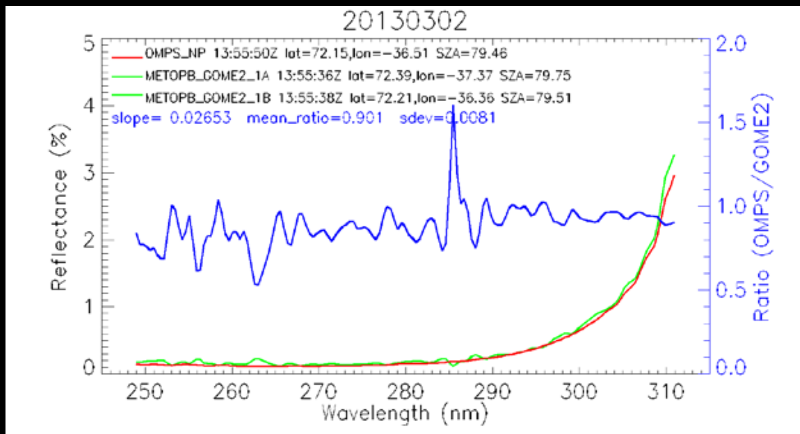


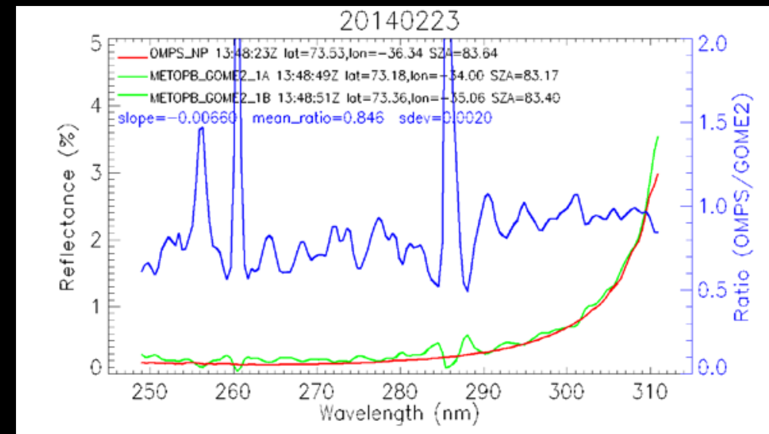


NM

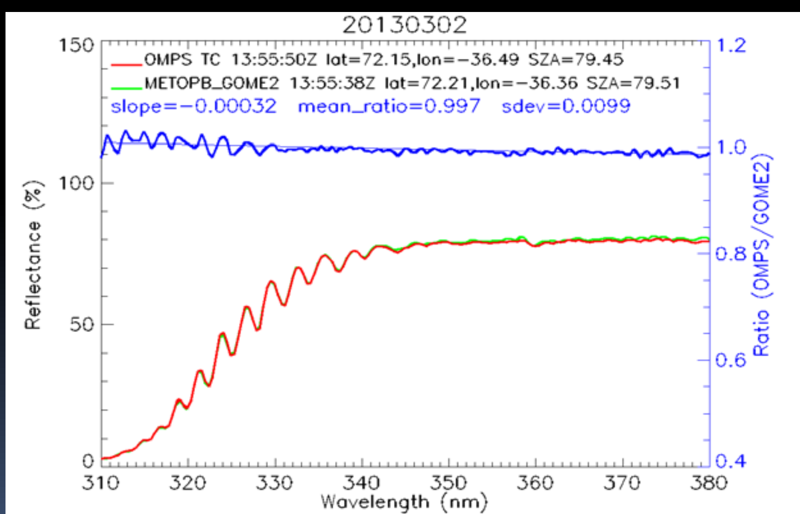
During past 12 months, solar irradiance signals of GOME-2 on METOp-A have degradated much more at band 1A and band 1B than at band 2B.

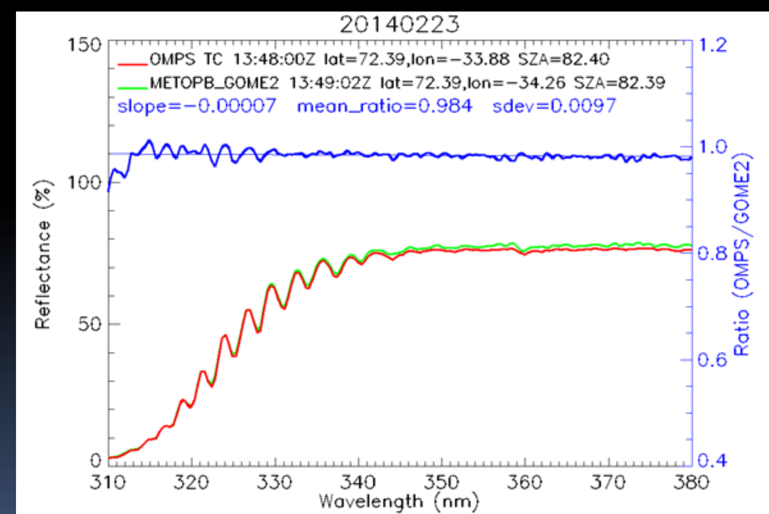
EV Reflectance (GOME-2 METOp-B vs. OMPS NM/NP)





NP

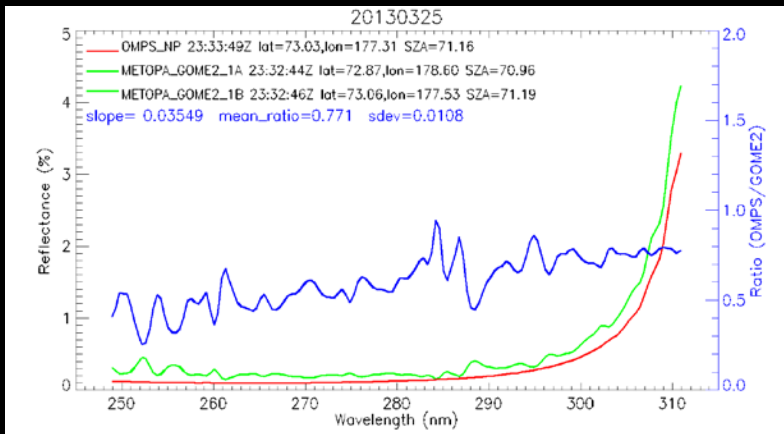


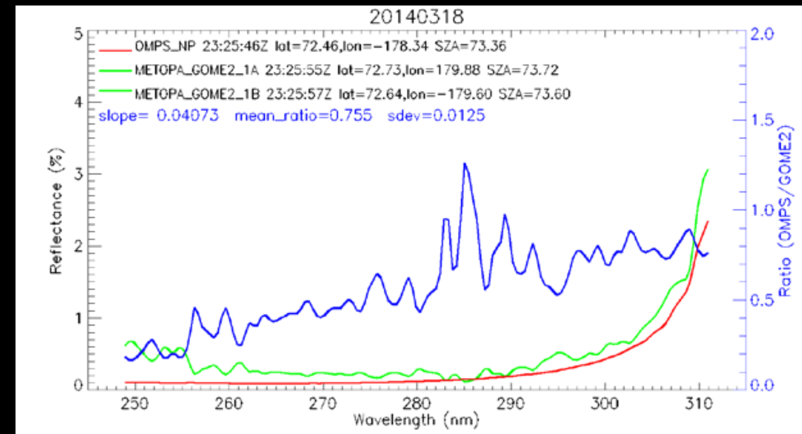


NM

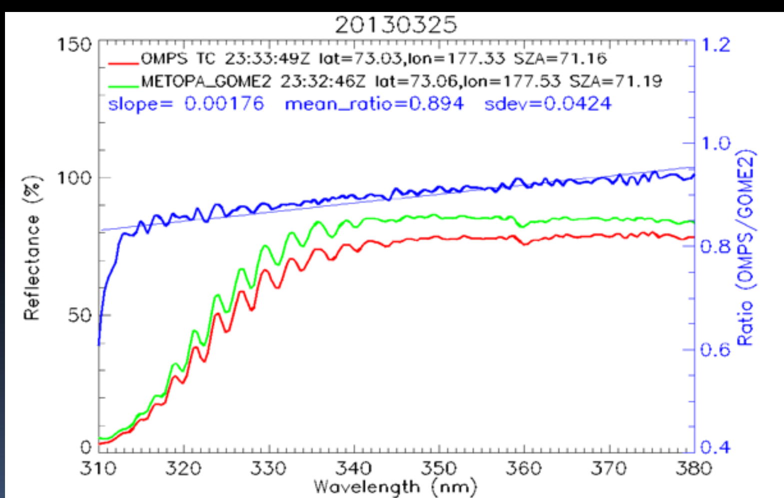
Large reflectance differences between OMPS NP and GOME-2 are found at around 286nm.

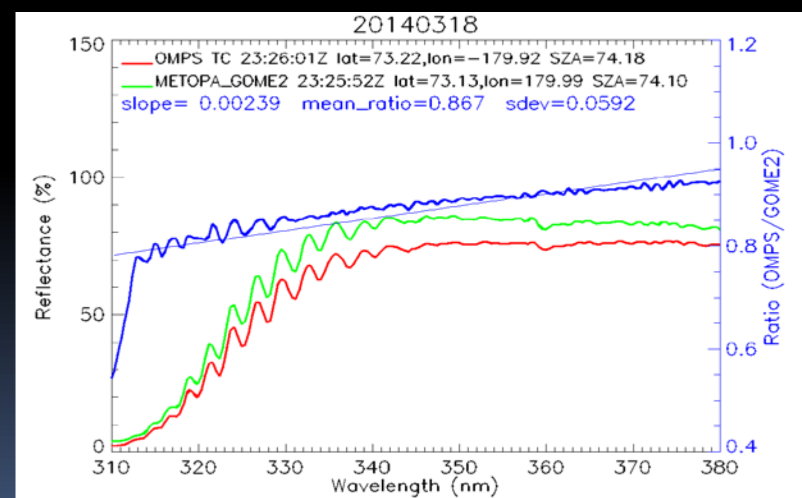
EV Reflectance (GOME-2 METOp-A vs. OMPS NM/NP)





NP

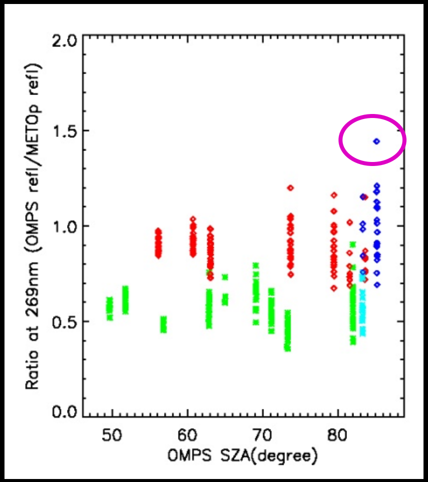




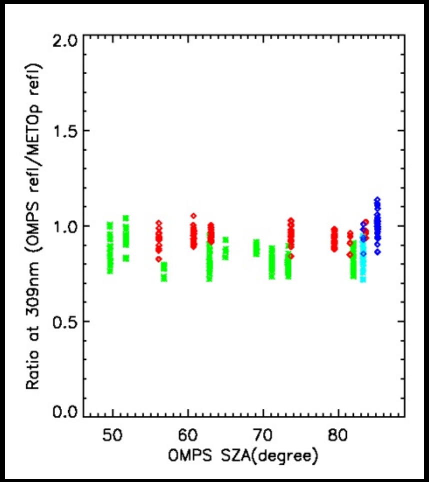
NM

Fortunately reflectance shows much better agreement between OMPS and GOME-2 on both METOp-A and METOp-B than radiance in past 12 months.

Factors of SZA and Reflectance at 309nm (NP 1)



SZA

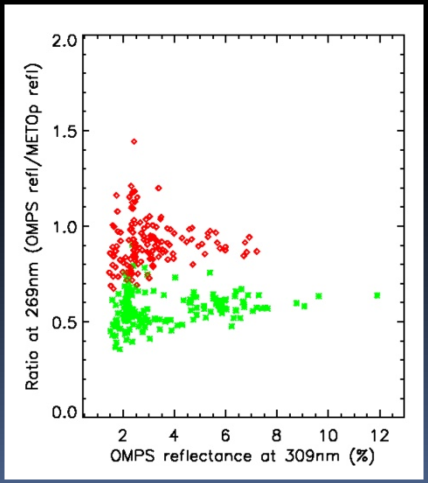


◊◊◊◊-----METOp-B, NH

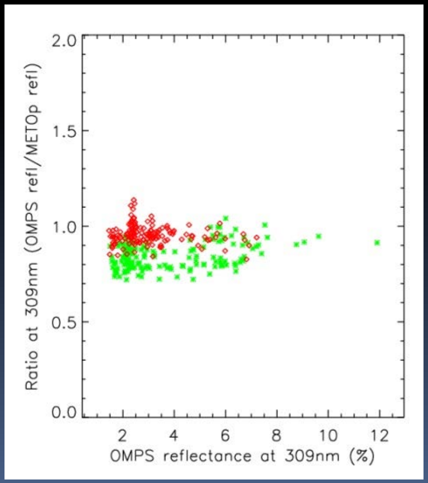
◊◊◊◊-----METOp-B, SH

****-----METOp-A, NH

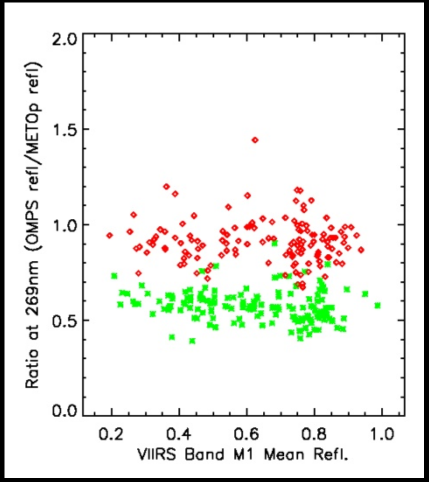
****-----METOp-A, SH



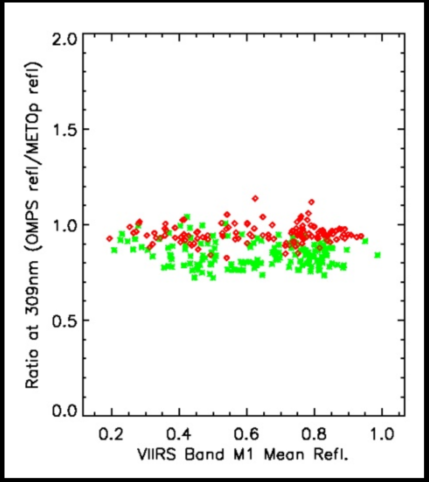
Refl_309nm

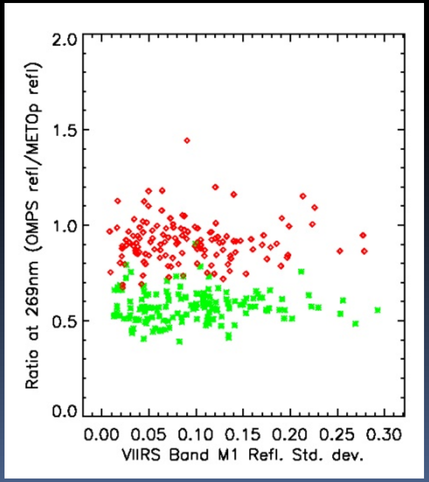


Homogeneous Tests by VIIRS Band M1(NP 2)

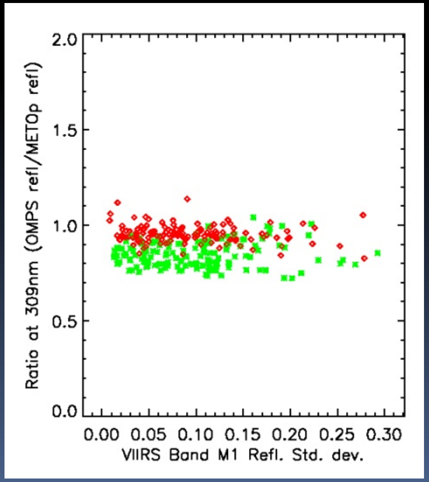


M1 refl. mean

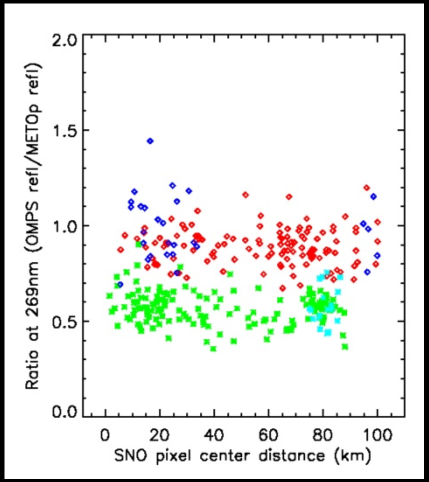


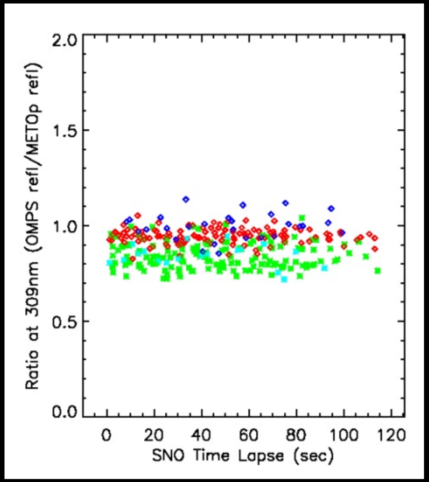


M1 refl. Std. dev.

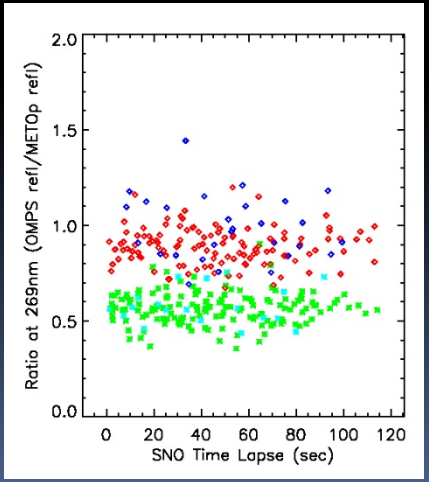


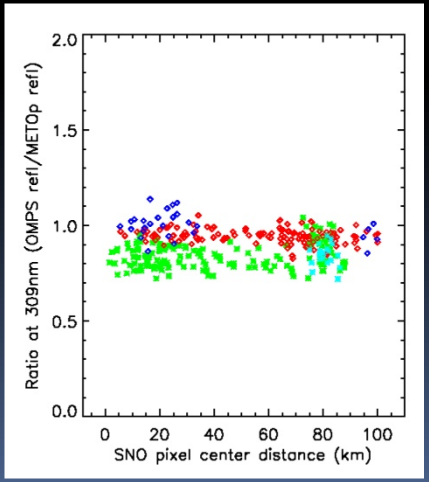
Factors of Temporal and Spatial Distance (NP 3)





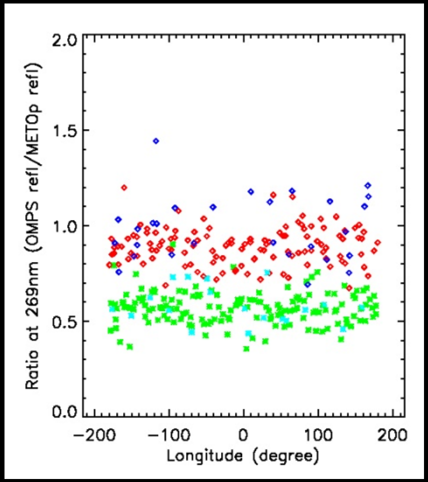
Temporal

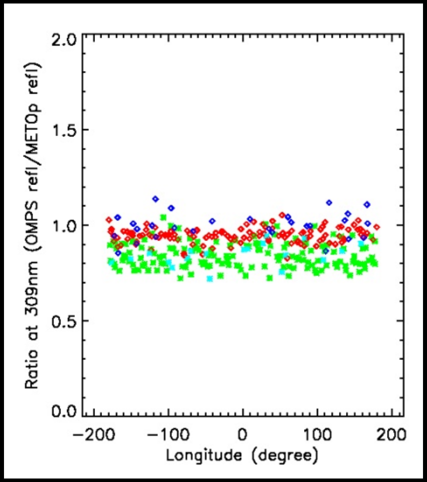




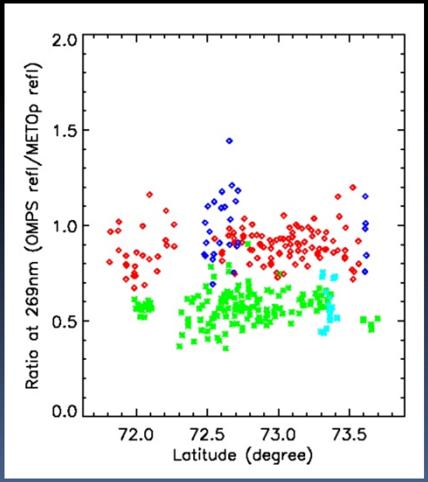
Spatial

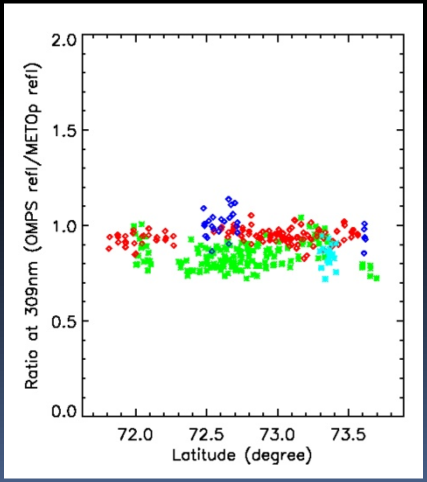
Factors of Geolocations (NP 4)





Longitude

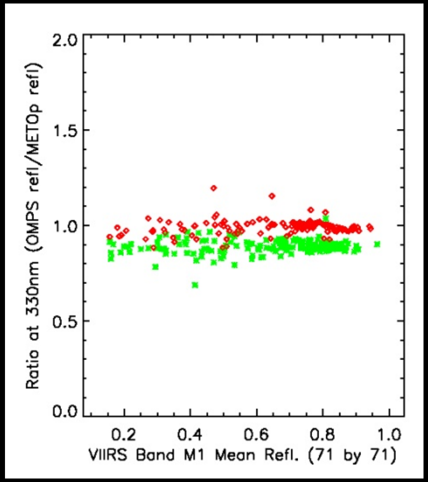


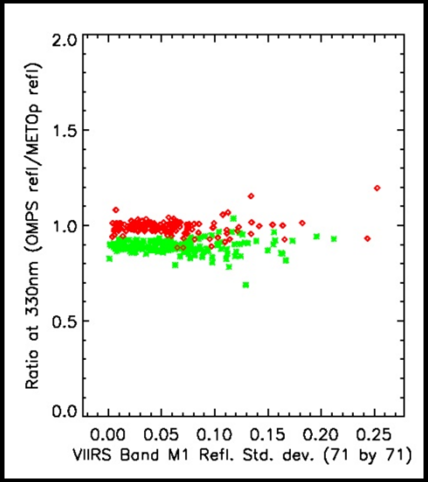


Latitude

Homogeneous Tests by VIIRS, Geolocations (NM 1)

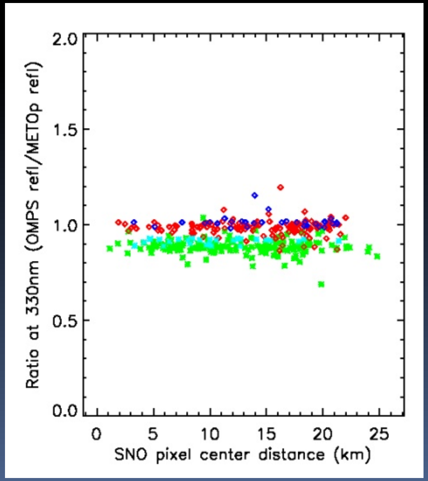
M1 refl. mean

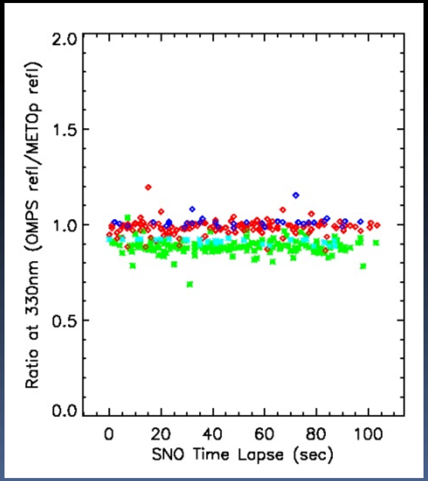




M1 refl. Std. dev.

Spatial

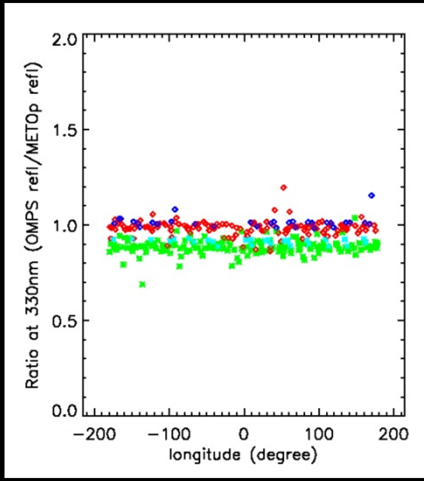


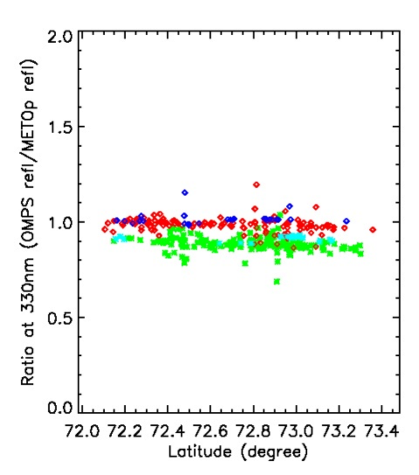


Temporal

Factors of Geolocations, SZA, and Reflectance at 380nm (NM 2)

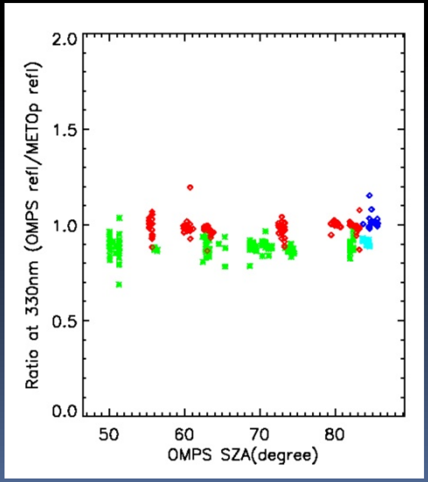
Longitude

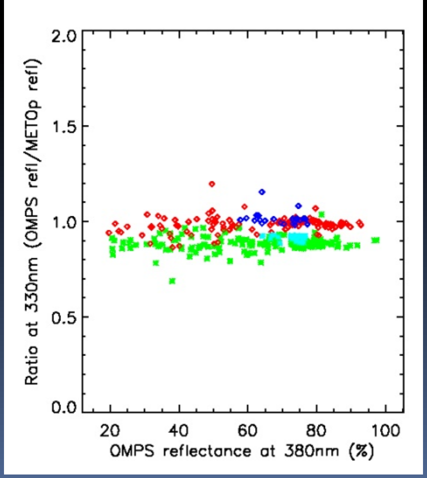




Latitude

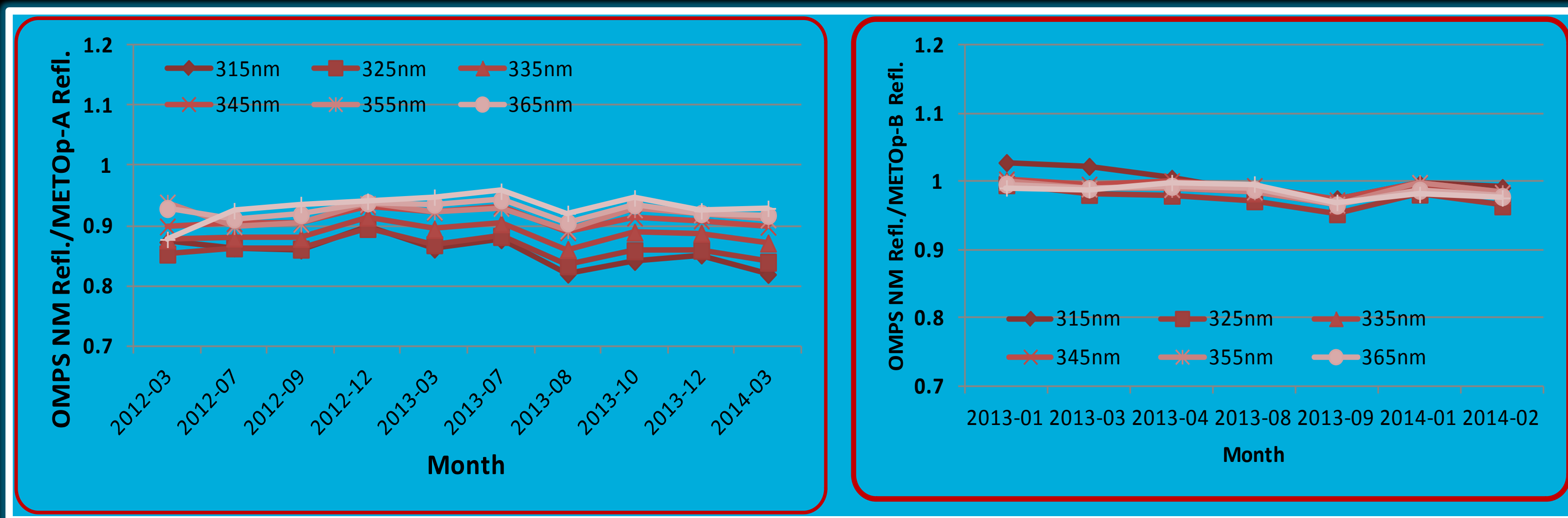
SZA





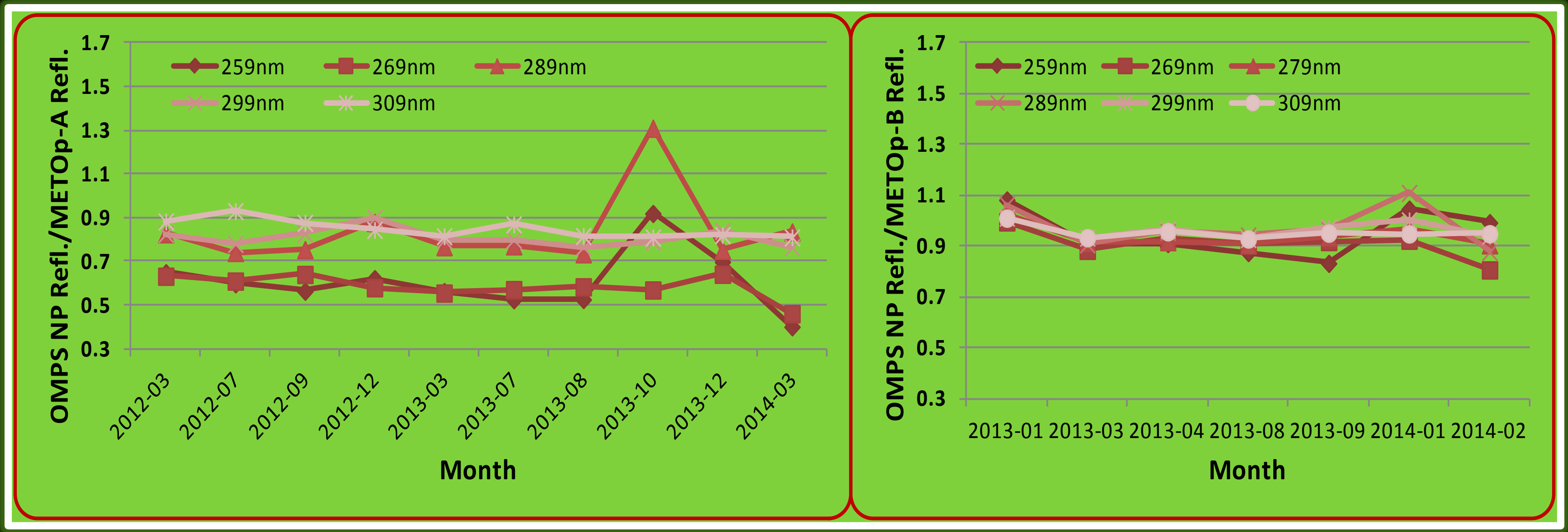
Refl_380nm

OMPS NM versus GOME-2 METOp-A (left) and METOp-B (right) at SNO



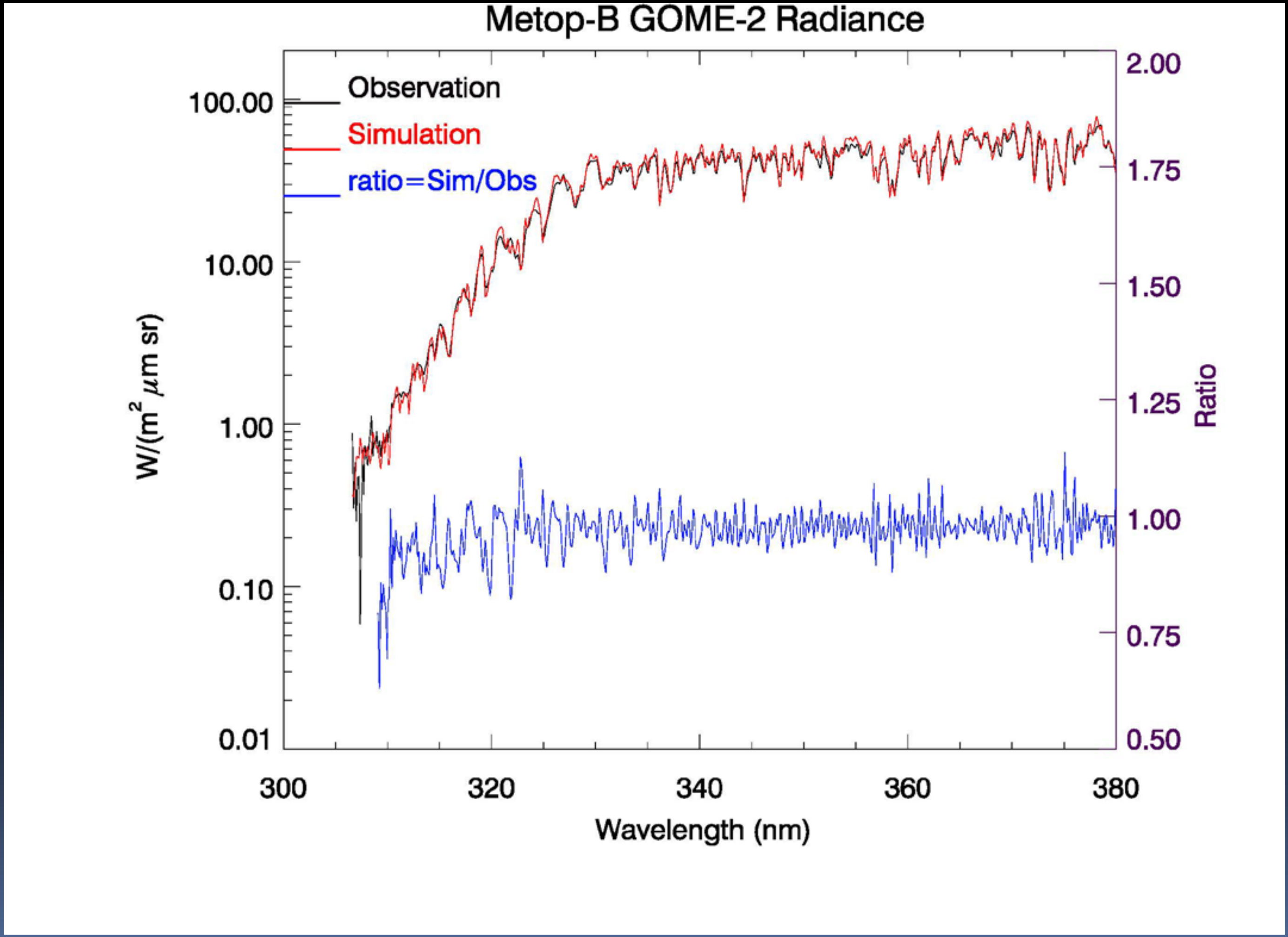
- The comparisons between OMPS and GOME-2 confirmed that the signals of GOME-2 on METOp-A have been degraded for both the earthshine and solar measurements by more then 50% after more than seven years in orbit. Since METOp-B was launched in September 2012, the comparisons show much better agreement.
- Also, the comparisons demonstrate that the GOME-2 has degraded more at shorter wavelengths than at longer wavelengths, which leads to the current 10-15% discrepancy in reflectance for shorter wavelengths.

OMPS NP versus GOME-2 METOp-A (left) and METOp-B (right)

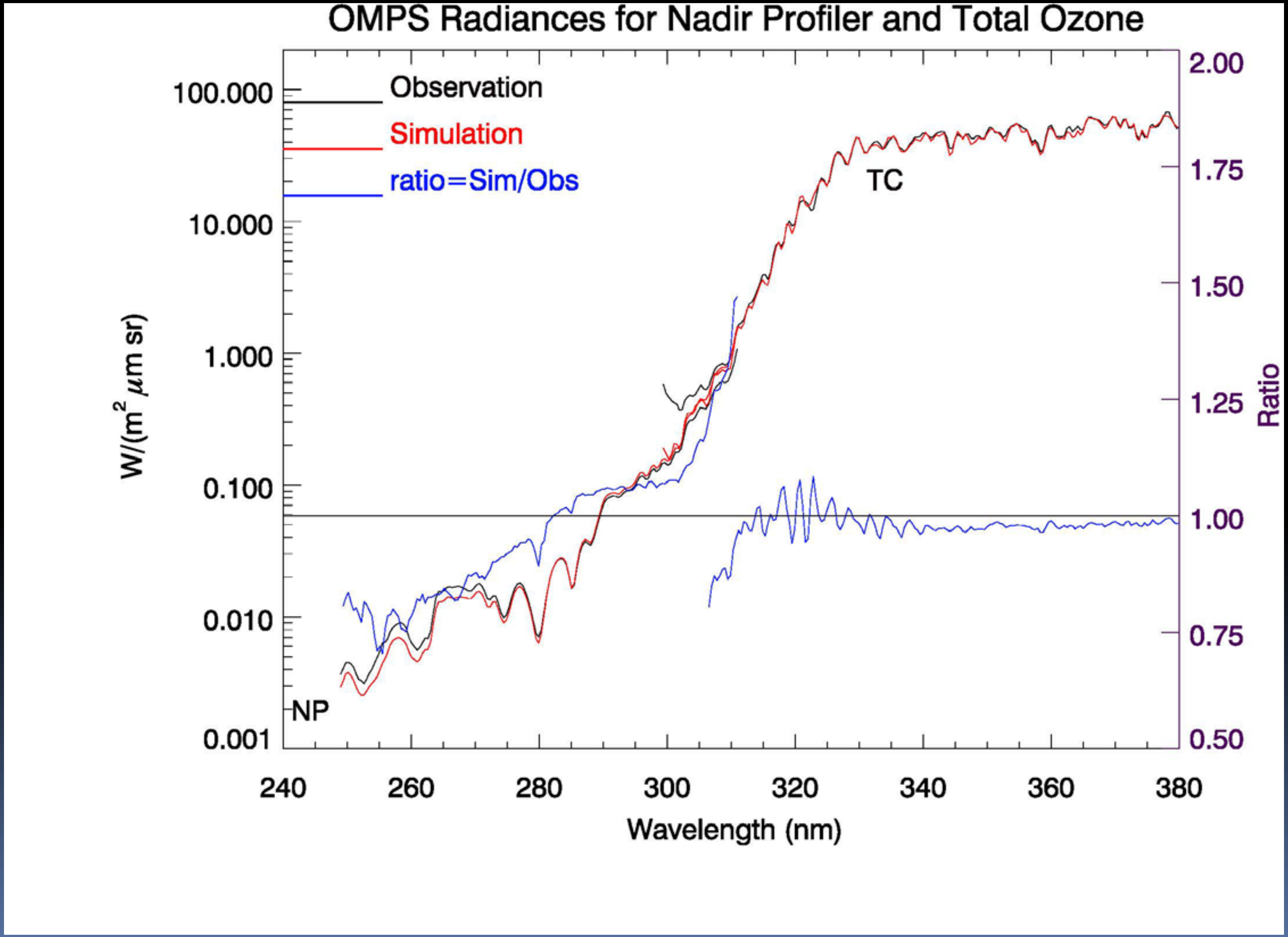


Despite the large FOV difference, the reflectance discrepancies between OMPS NP and band 1B of GOME-2 on METOp-B are within ~10%. For METOp-B band 1A, the discrepancies are a bit larger.

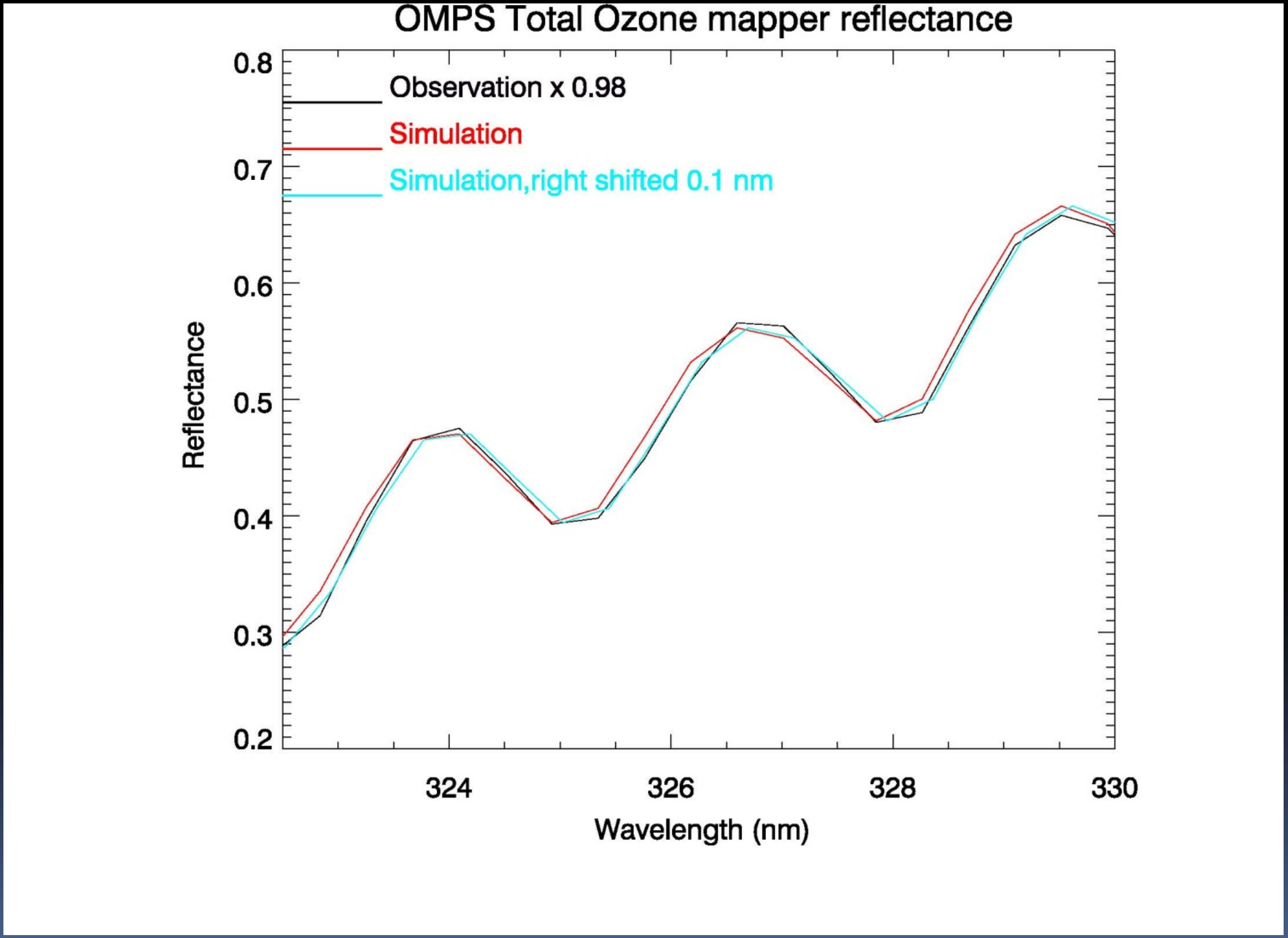
CRTM Simulated GOME-2 METOp-B EV Radiance



CRTM Simulated OMPS NM/NP EV Radiance

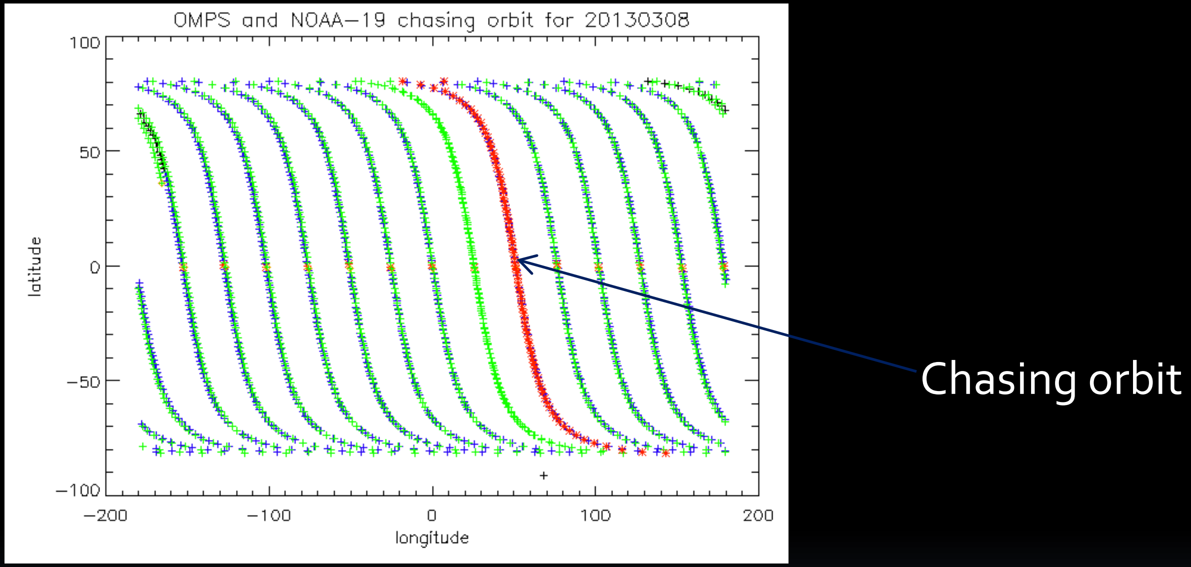


CRTM Simulated OMPS NM Reflectance



Suomi-NPP and NOAA-19 Chasing Orbits

- Periodically, the polar orbits of the Suomi-NPP and NOAA-19 spacecraft geographically and temporally align.



- This allows measurements from the NOAA-19 Solar Backscatter Ultraviolet Instrument (SBUV/2) and Suomi-NPP OMPS NM/NP to be directly compared.
- We define a chasing orbit as: equatorial crossing longitudes within 0.05 degrees, equatorial crossing times within 20 minutes

Chasing Orbit Comparisons on ICVS

Suomi-NPP OMPS NM/NP and NOAA-19 SBUV/2 chasing orbit comparisons are available on the NOAA/STAR Integrated Calibration/Validation System (ICVS) website: http://www.star.nesdis.noaa.gov/icvs/

OMPS Equator crossing date	OMPS crossing time	SBUV/2 crossing time	OMPS crossing longitude(degrees)	SBUV/2 crossing longitude(degrees)
01/28/2012	08:12:21	08:19:03	78.16	78.19
03/29/2012	04:05:05	04:12:34	139.83	139.86
04/10/2012	08:44:08	08:51:56	70.05	70.03
04/22/2012	13:23:10	13:31:14	0.27	0.23
07/16/2012	23:37:28	23:46:17	-153.42	-153.37
08/10/2012	10:37:13	10:45:50	41.77	41.78
08/22/2012*	16:57:48	17:06:35	-53.39	-53.37
09/03/2012	23:18:22	23:27:17	-148.54	-148.51
10/10/2012	20:01:21	20:10:59	-99.30	-99.34
10/23/2012	05:45:07	05:55:30	114.60	114.57
11/16/2012	21:49:31	22:00:05	-126.49	-126.48
11/29/2012	05:51:38	06:02:15	112.98	113.02
12/23/2012	23:37:18	23:48:30	-153.42	-153.44
01/05/2013	07:39:20	07:50:30	86.08	86.11
01/17/2013*	17:22:54	17:34:30	-59.80	-59.83
01/30/2013	03:06:48	03:18:26	154.25	154.24
02/11/2013	12:50:40	13:02:17	8.29	8.34
02/24/2013	00:16:00	00:28:08	-163.02	-163.05
03/08/2013	09:59:52	10:11:51	51.03	51.07
03/20/2013	21:25:13	21:37:34	-120.28	-120.27
04/02/2013	08:50:31	09:03:13	68.42	68.37
04/27/2013	05:59:31	06:12:16	111.22	111.26
05/09/2013*	17:24:43	17:37:43	-60.05	-60.02
05/22/2013	04:49:53	05:03:07	128.69	128.70
06/03/2013*	16:15:00	16:28:24	-42.55	-42.54
08/30/2013	08:39:03	08:53:51	71.68	71.68
09/11/2013	21:45:53	22:00:43	-124.98	-124.94
10/07/2013	01:40:57	01:56:21	176.33	176.33
11/01/2013	05:35:52	05:51:36	117.70	117.71
11/13/2013	20:24:00	20:40:06	-104.28	-104.30
11/26/2013	11:12:20	11:28:28	33.69	33.71
12/09/2013	03:42:19	03:58:48	146.25	146.23
01/28/2014	21:41:51	21:59:15	-123.38	-123.42
02/10/2014*	14:11:43	14:29:07	-10.78	-10.77
04/28/2014	08:25:02	08:43:56	76.35	76.31

*: Data may be affected by SAA

Using max(Δlongitude) = 0.05 degrees and max(Δtime) = 20 minutes, there are 35 chasing orbit comparisons since Jan. 28, 2012

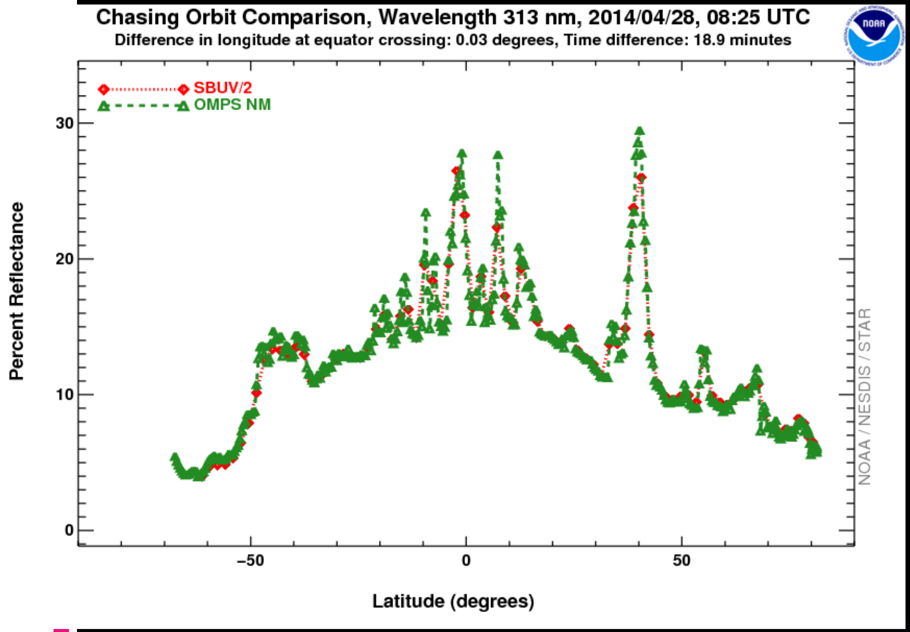
Data Adjustments

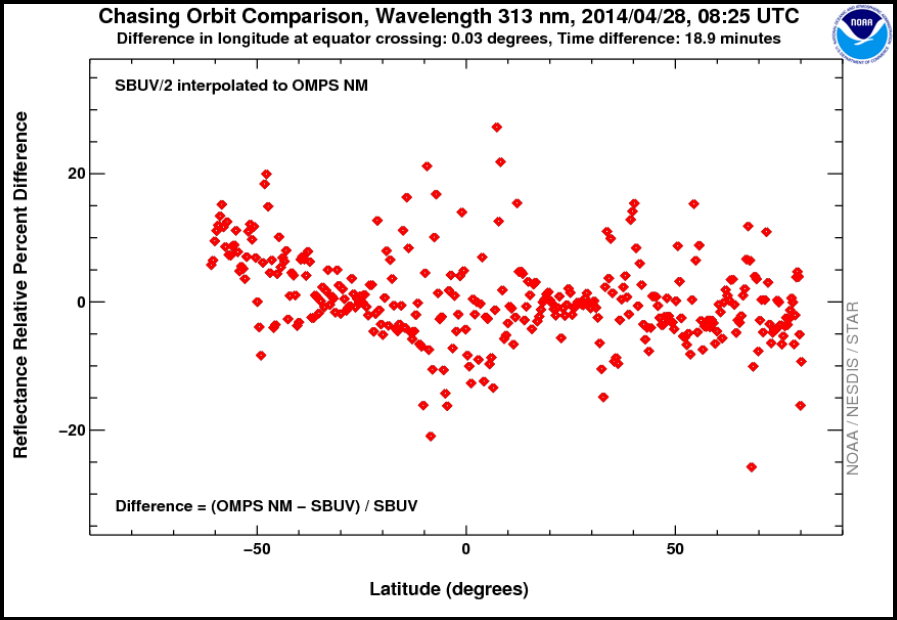
To provide more accurate OMPS-SBUV/2 comparisons:

- The SBUV/2 measurement solar zenith angle and latitude for each channel are interpolated given the SBUV/2 channel scanning scheme
- The NM data are spatially averaged to better match the SBUV/2 spatial footprint (NM cross-track nadir pixel width: ~ 50 km, SBUV/2: ~160 km)
- For relative difference comparisons, the SBUV/2 data are spatially interpolated to match the OMPS latitudes
- All measurements are converted to reflectance (albedo)

Most recent Chasing Orbit: April 28, 2014

OMPS Nadir Mapper:





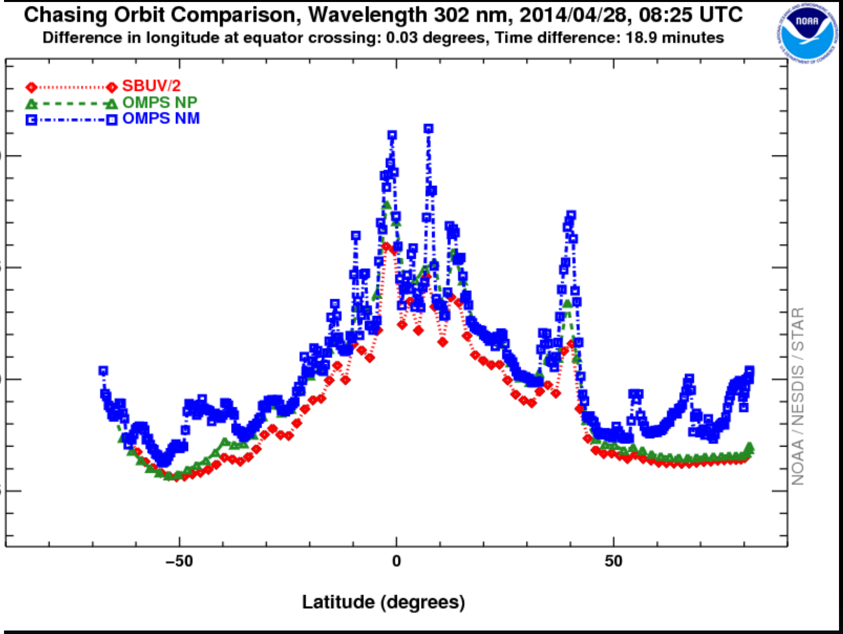
Reflectance

OMPS NM Difference Relative to SBUV/2

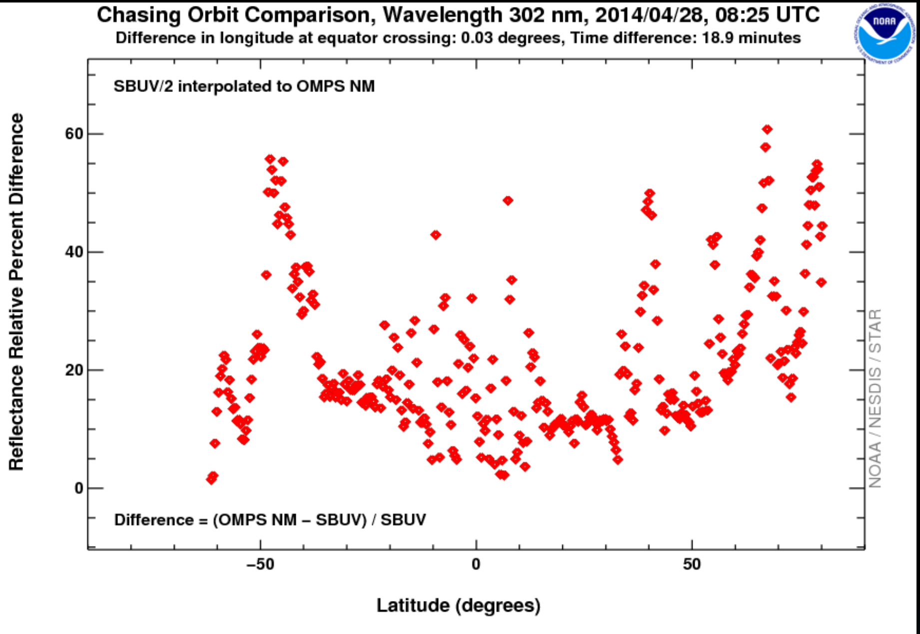
Differences generally within +/- 10%: true for SBUV/2 channels 8-12 (306 nm – 343 nm)

Most recent Chasing Orbit: April 28, 2014

OMPS Nadir Mapper @ SBUV/2 Channel 7 (302 nm):



Reflectance

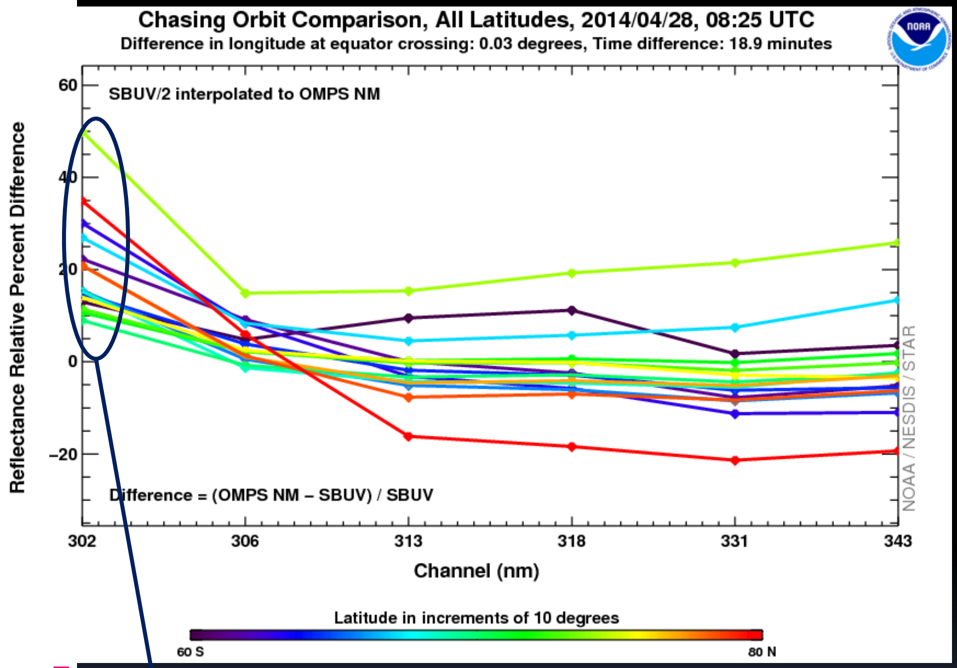


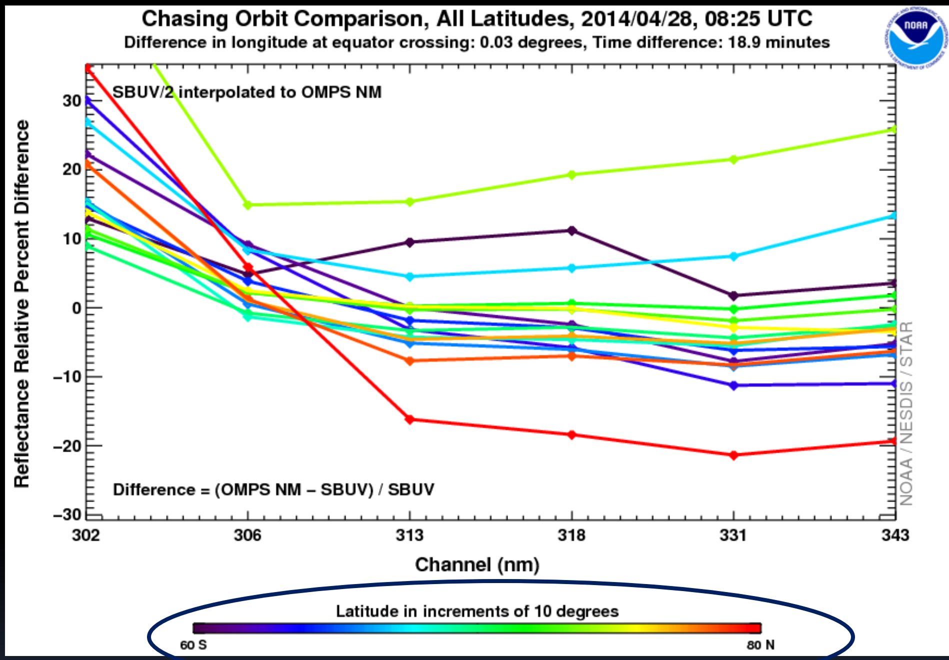
OMPS NM Difference Relative to SBUV/2

Large differences: thought to be due to NM stray light contamination, for which a correction will be implemented soon

Most recent Chasing Orbit: April 28, 2014

OMPS Nadir Mapper, all channels:



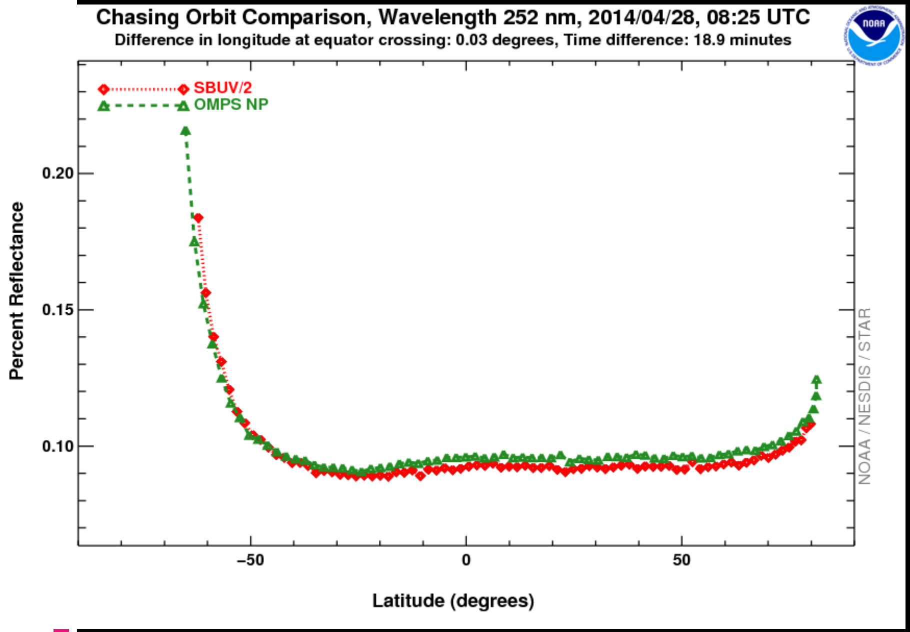


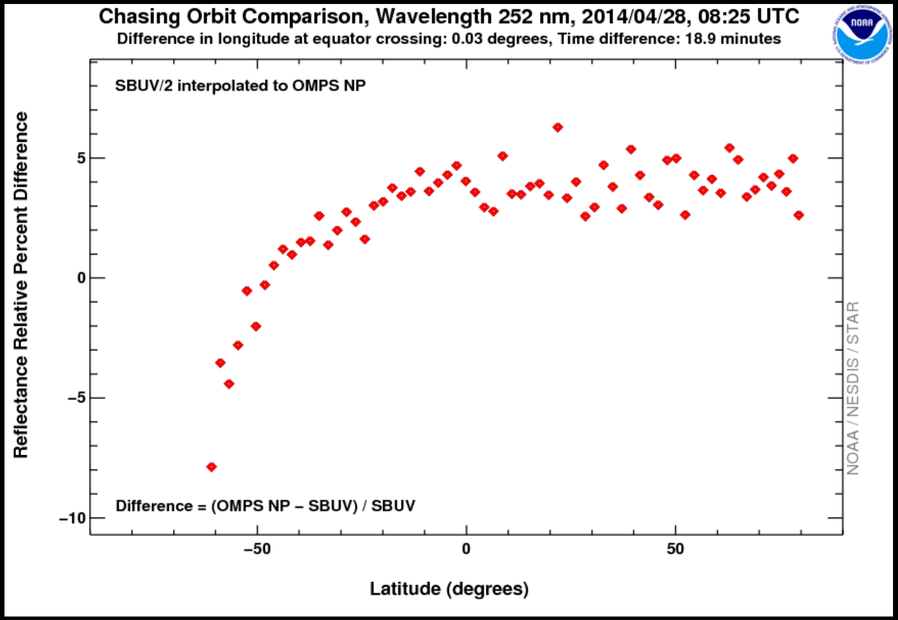
As mentioned before, large differences @ SBUV/2 Channel 7 (302 nm)

Color indicates latitude

Most recent Chasing Orbit: April 28, 2014

OMPS Nadir Profiler:





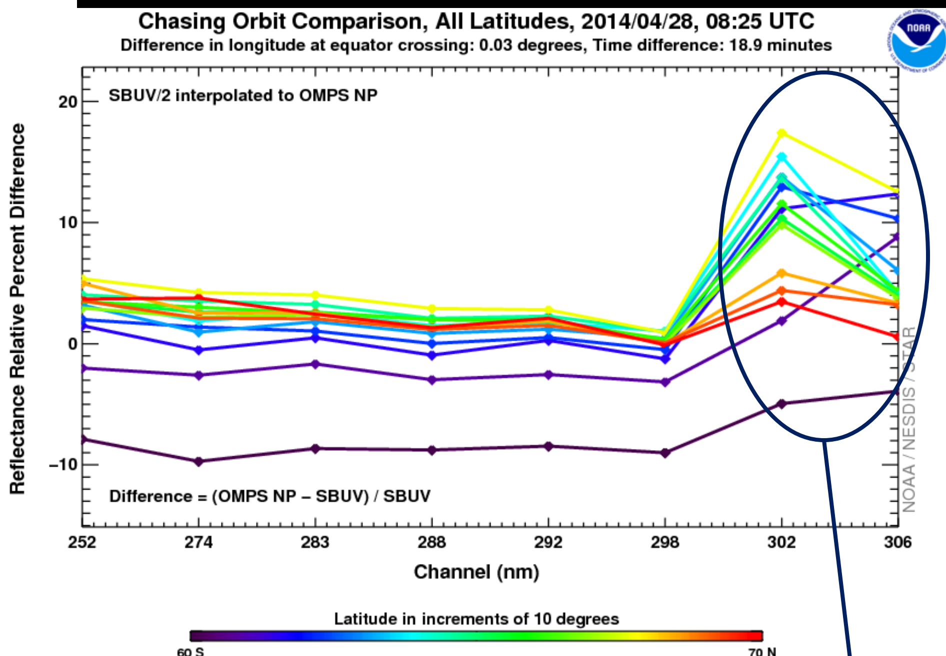
Reflectance

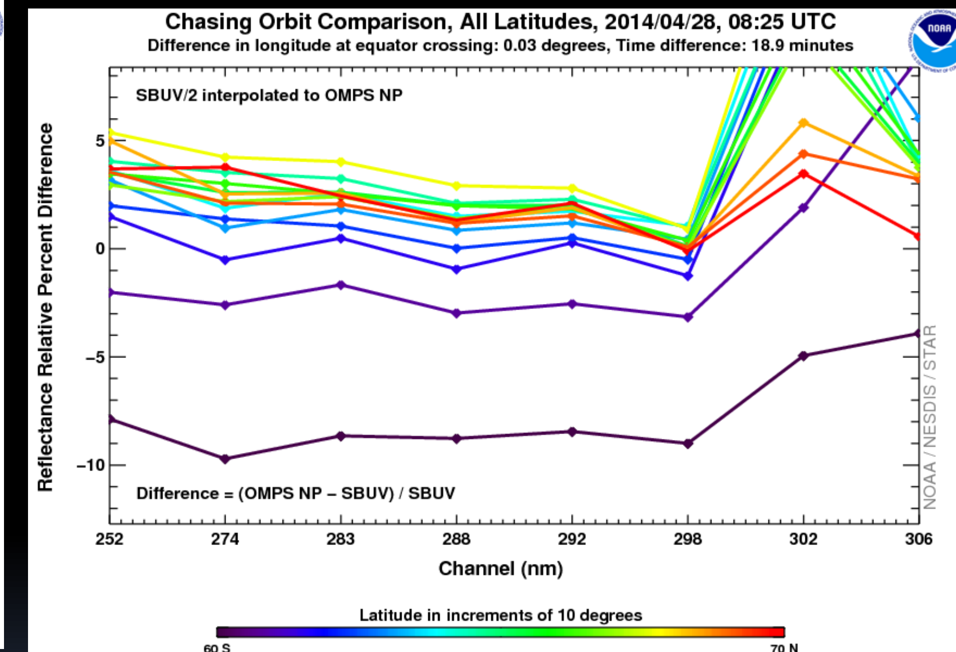
OMPS NP Difference Relative to SBUV/2

Differences within +/- 10%: true for SBUV/2 channels 1-6 (252 nm – 298 nm)

Most recent Chasing Orbit: April 28, 2014

OMPS Nadir Profiler, all channels:





Large differences @ SBUV/2 Channels 7 and 8 (302 and 306 nm)

Thought to be due to NP stray light, as well as a shift in the dichroic filter. Corrections will be implemented for these issues.

Chasing Orbit Results

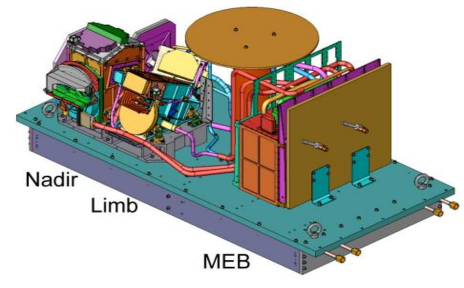
Results from April 28, 2014 are typical of results from other recent chasing orbits:

- NM, 306 – 343 nm: differences generally within +/- 10%
- NM, 302 nm: large differences (10-50%), thought to be due to stray light contamination, for which a correction will be implemented
- NP, 252 – 298 nm: differences within +/- 10%
- NP, 302 - 306 nm: larger differences (10-15%), thought to be due to dichroic shift and stray light, for which corrections will be implemented

Provided differences are relative to SBUV/2 measurements

Conclusions

- Comparisons with radiance from other sensors or radiative transfer model provide additional means of evaluating OMPS SDRs.
- None of the sensors needs to be perfect or superior. The assumption is that there errors are independent of each other so proper interpretation of the differences may reveal issues on either side.
- These tools will be further developed and used for S-NPP & J1.



S-NPP Ozone Mapping Profiler Suite Nadir Sensor Performance Monitoring

*C. Pan[1], X. Wu[2], L. Flynn[2], M. Grotenhuis[3], T. Beck[2], B. Das[4]

1 University of Maryland, College Park, MD 20740
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3 ERT, Inc. @ Center for Satellite Applications and Research, NOAA, College Park, MD
4 IMSG, Inc. @ Center for Satellite Applications and Research, NOAA, College Park, MD

2014 STAR JPSS Science Team Meeting
May 12-16, 2014
NOAA Center for Weather and Climate Prediction (NCWCP) in College Park, MD 20740

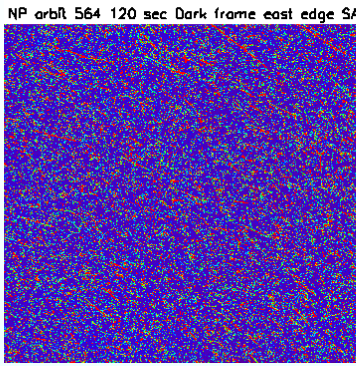
Topics

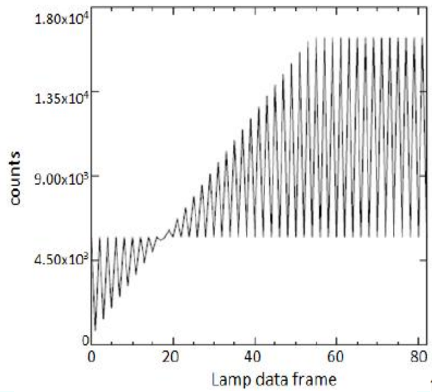
- Dark current
  - Dark distribution
  - Dark generate rates
  - Electronic bias
  - Hot pixels
  - Dark Signal Non-uniformity (DSNU)
  - Readout noise
- Solar observation
  - Spectral smile
  - Wavelength variation
    - from ground to orbit
    - Intra-orbit variation
    - trending
  - Noise
  - Degradation
- Linearity
  - System non-linearity
  - LED data noise
  - LED output drifts
  - Dynamic range of detector response
  - Calibrated accuracy
  - LED lamp warm up behavior
  - LED illumination uniformity
  - CCD gain
- Sensor noise from EV observation
- Telemetry
- Stray light
- Cross-sensor stability comparison
- Calibration table evaluation and trending

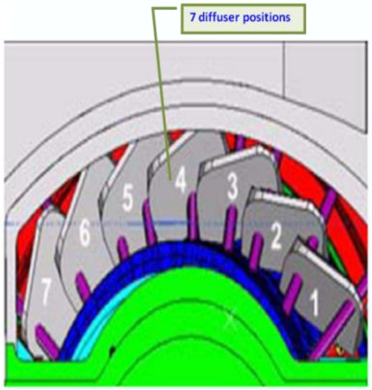
In-flight data collection

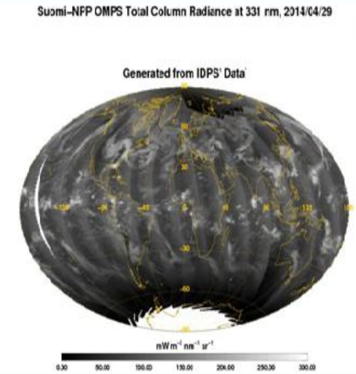
NP Dark Calibration | NM Linearity Calibration | Solar Calibration | Earth radiance

Before transient removal



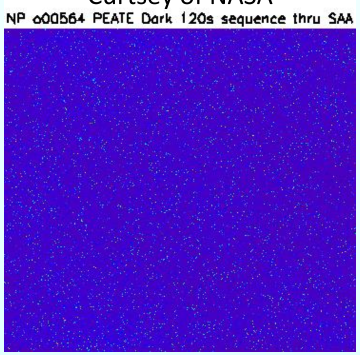


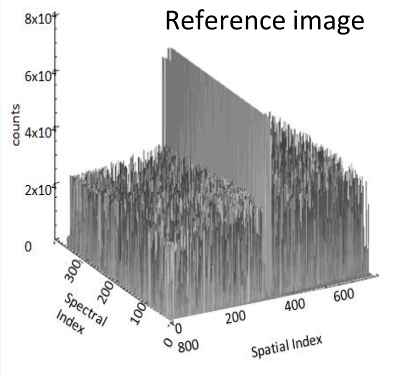


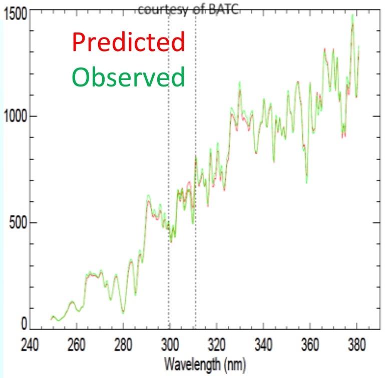


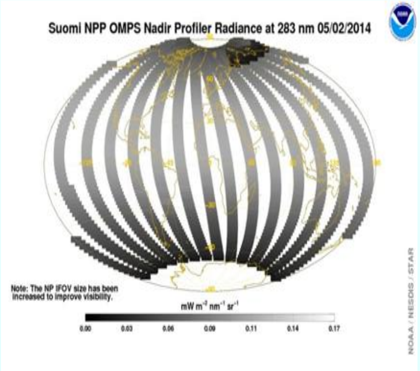
Curtsey of NASA

After transient removal



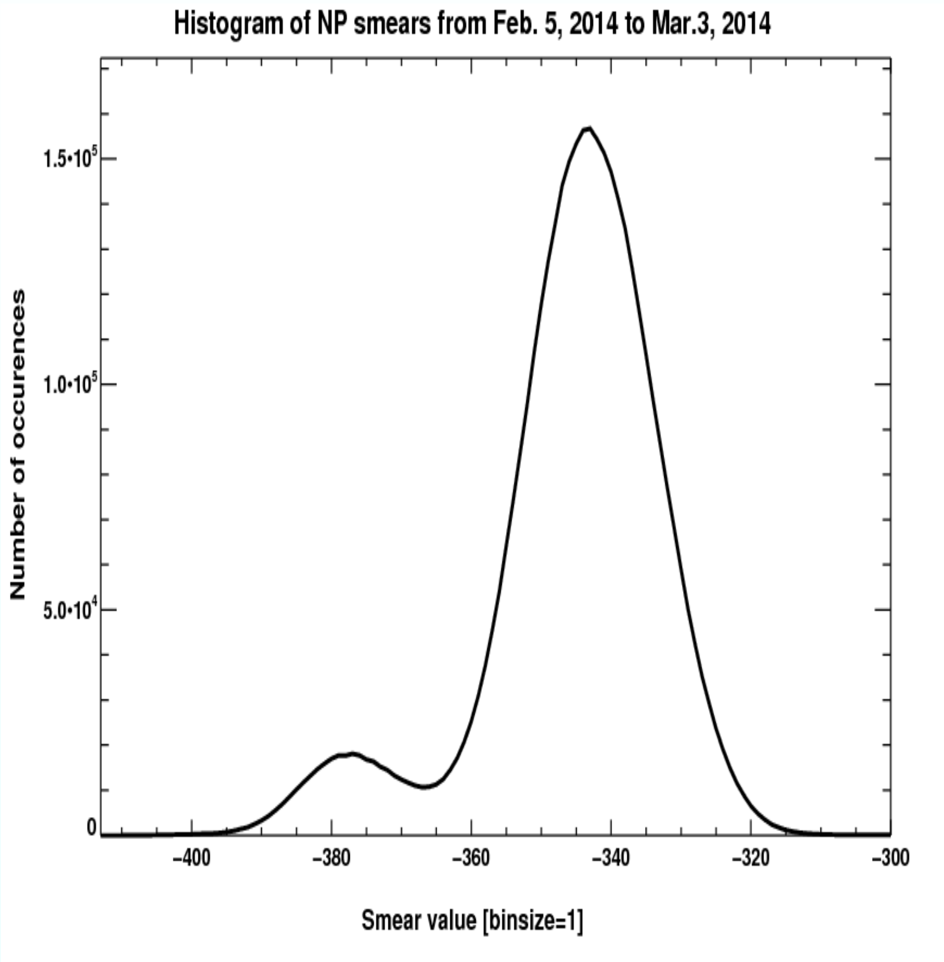






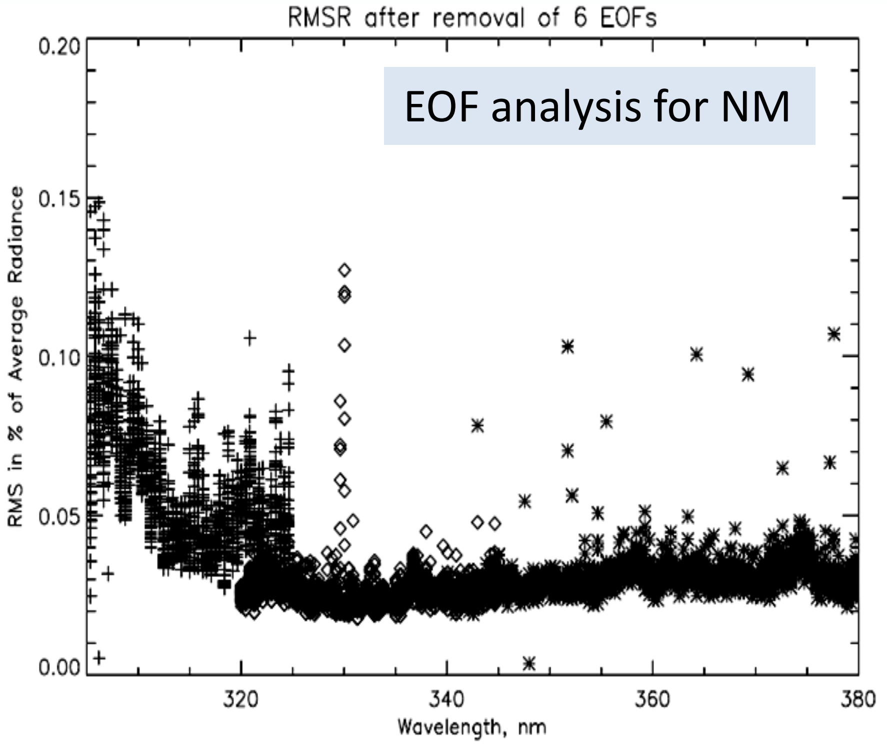
- Independently perform sensor data end-to-end analysis
- Trend and validate calibrated LUTs
- Evaluate a LUT via. ADL test prior to uploading to IDPS
- Earth radiance trend and validation via. Cross-sensor comparison

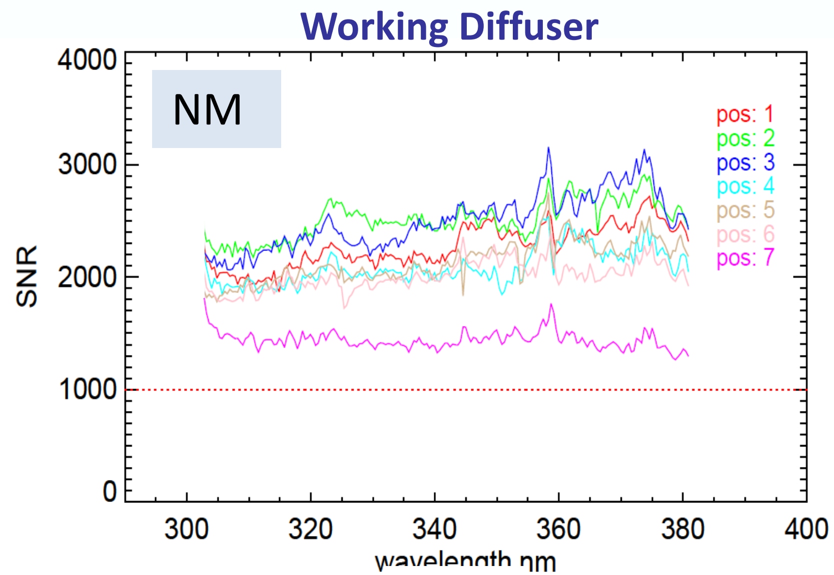
Negative Smear in NP SDR

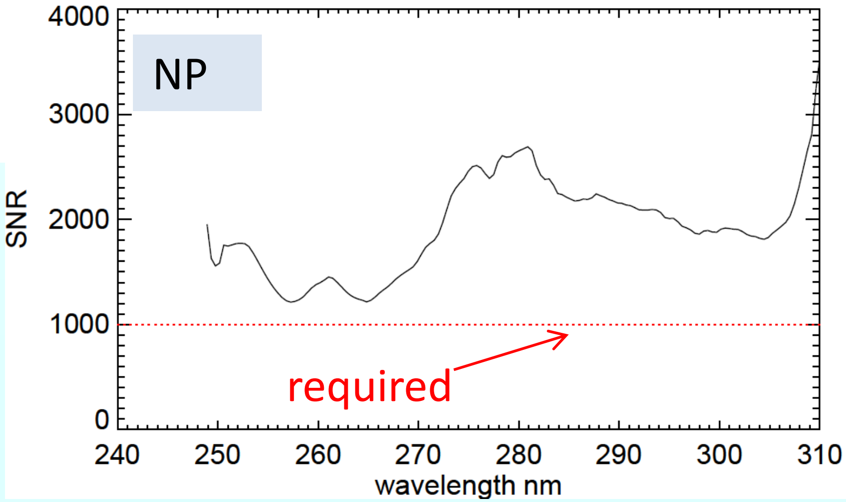


Nearly all NP smear data in the EV SDR are negative. An investigation led to the discovery of an error in the ground software related to the NP smear/bias correction

Sensor noise meets requirement

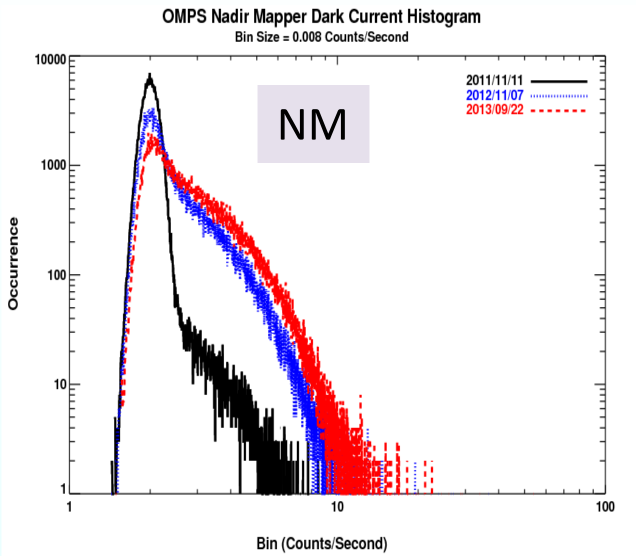


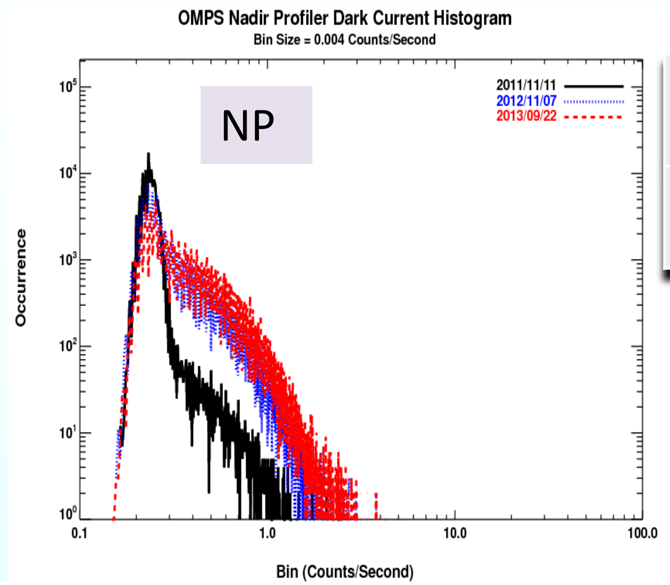


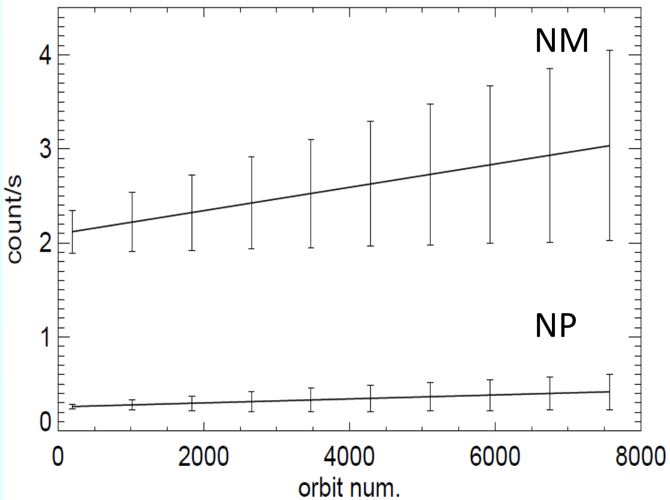


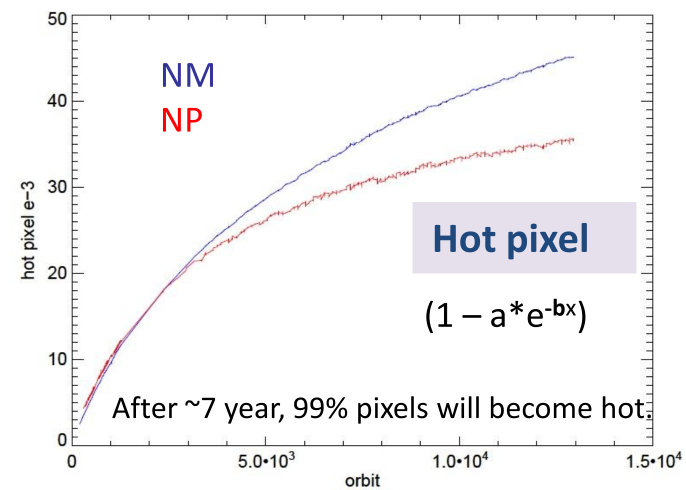
- Earth view noise < 0.01 % RMSR
  -Noise in the SAA has an influence for NP @ wavelength < 290 nm
- Solar view SNR > 1000
  - SNR from reference diffuser has a similar pattern and also meets the requirement.

Dark changes as expected









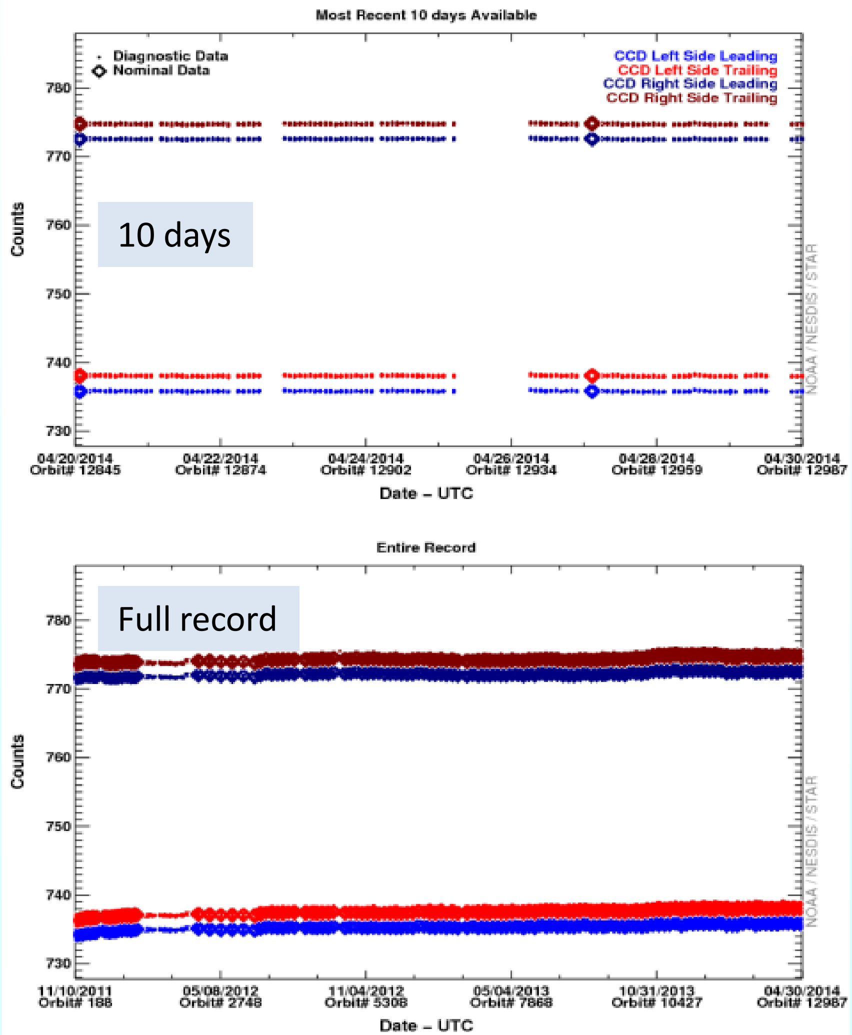
DC – 1 orbit weekly

NM / NP Closed Darks	21 images
NM / NP Storage Darks	9 images

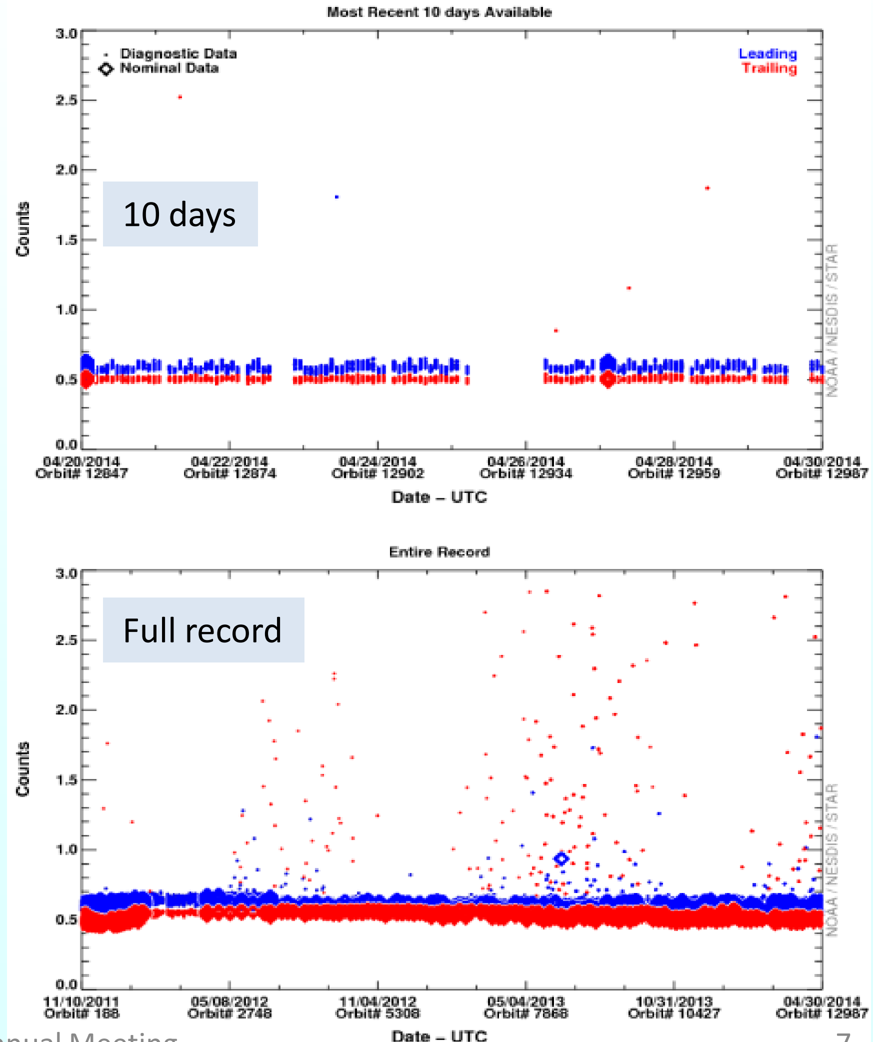
- Weekly increase in mean: ~0.6% for NM and 0.8% for NP, resulting in uncertainties ~0.03% for NM and 0.1-0.5 % for NP.
- The change in dark has negligible impact on the dynamic range of the sensor response for at least 7 years.

NM bias and dark readout noise

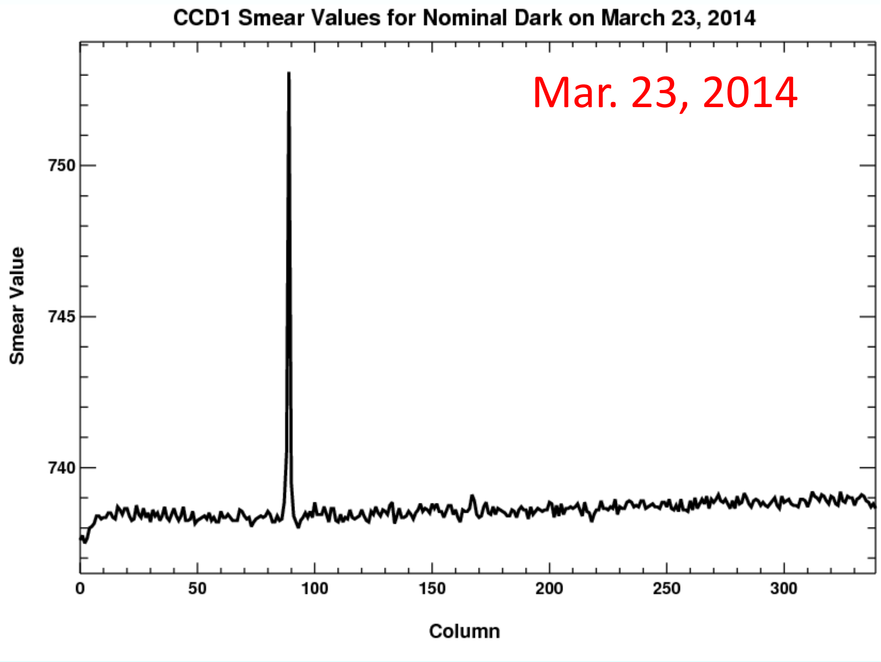
Bias

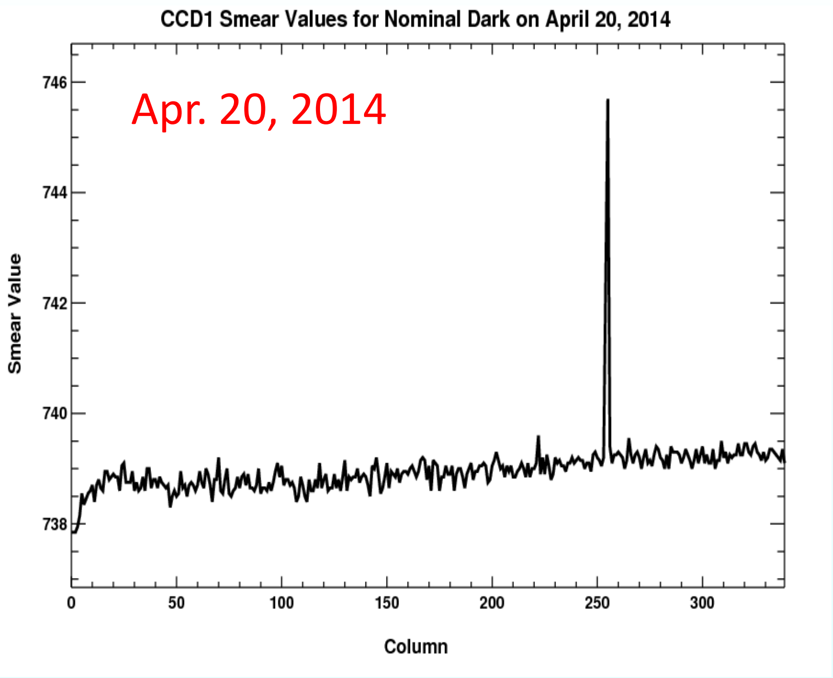


Readout noise



NM Anomalous Smear Values





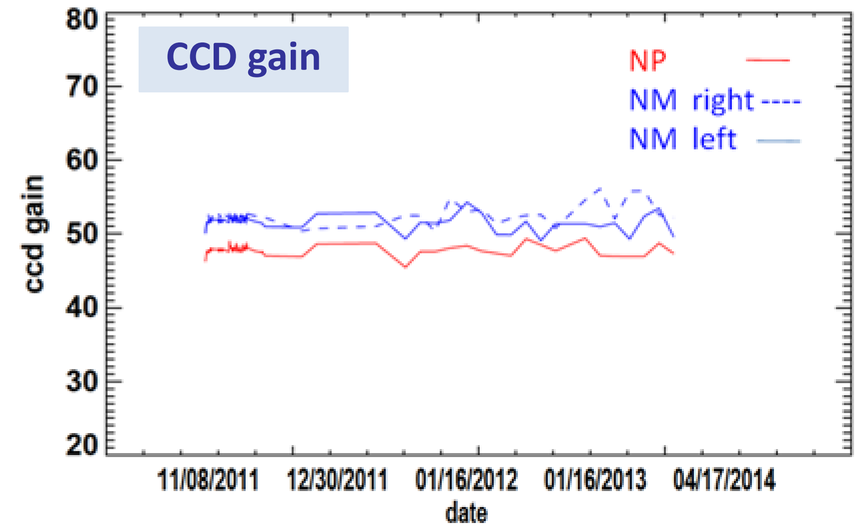
Anomalies smear values were discovered from NM CCD1 storage region. These were automatically detected.

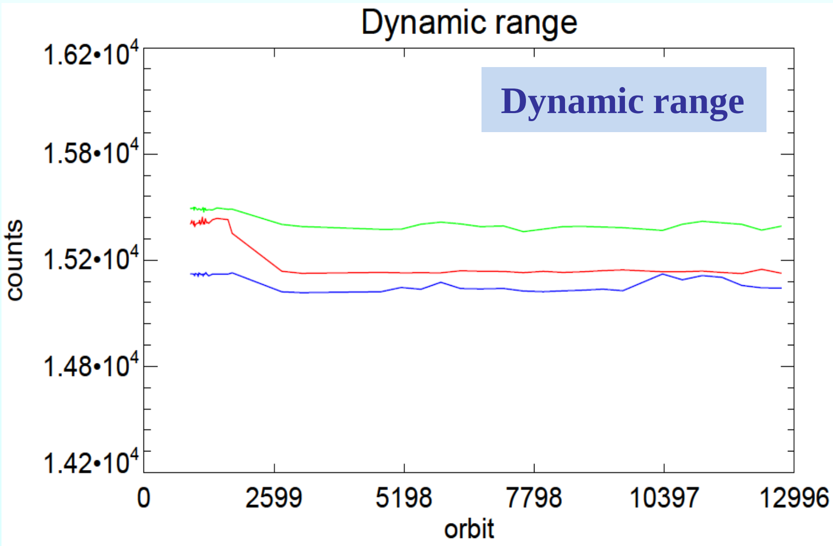
The calibration team is working on an algorithm to improve transient detection.

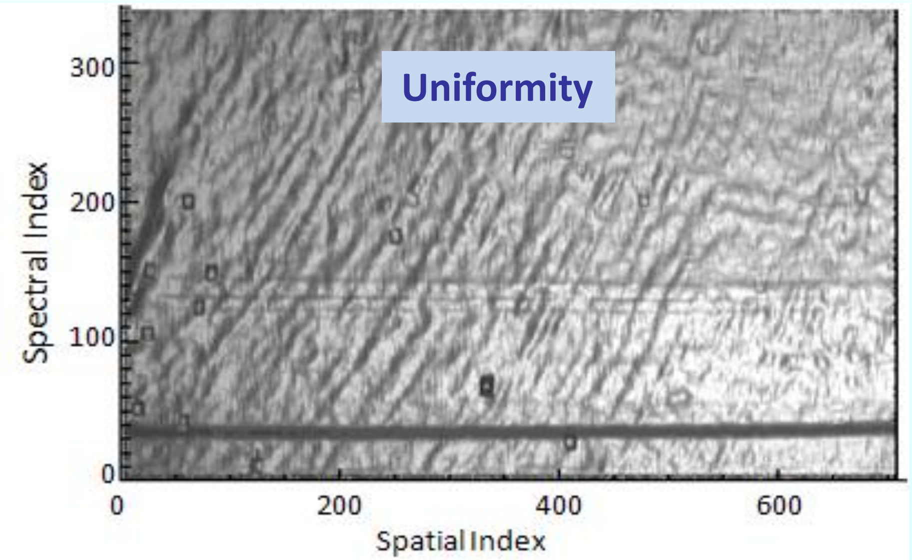
Linearity characterization

EVLED_Closed – 1 orbit Every 4th week

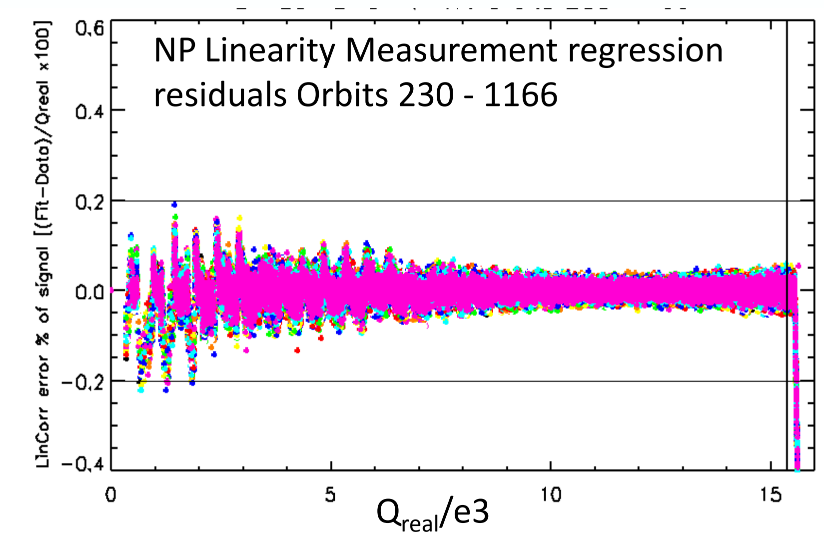
NP Lamp Warmup	50 images
NP Linearity	83 images
NP FF Lamp	1 image
NM Lamp Warmup	50 images
NM Linearity	83 images
NM FF Lamp	1 image

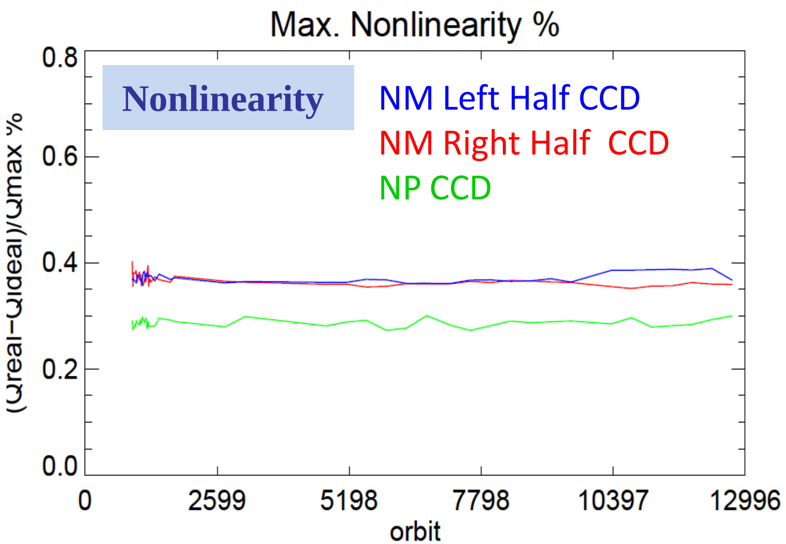


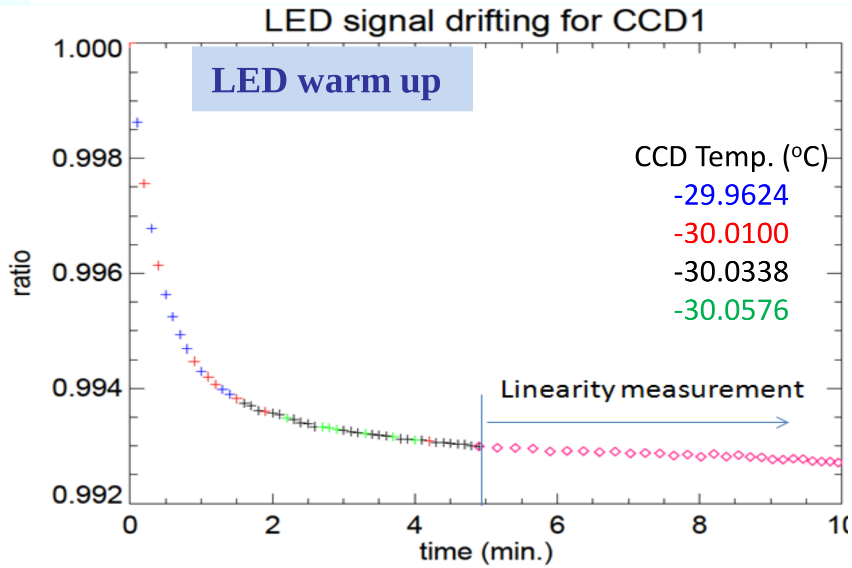


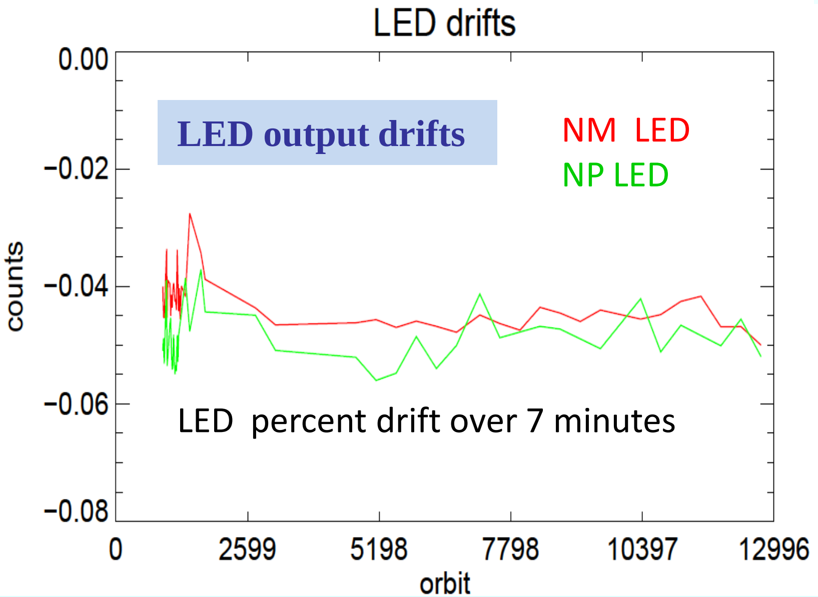


System linearity meets requirement





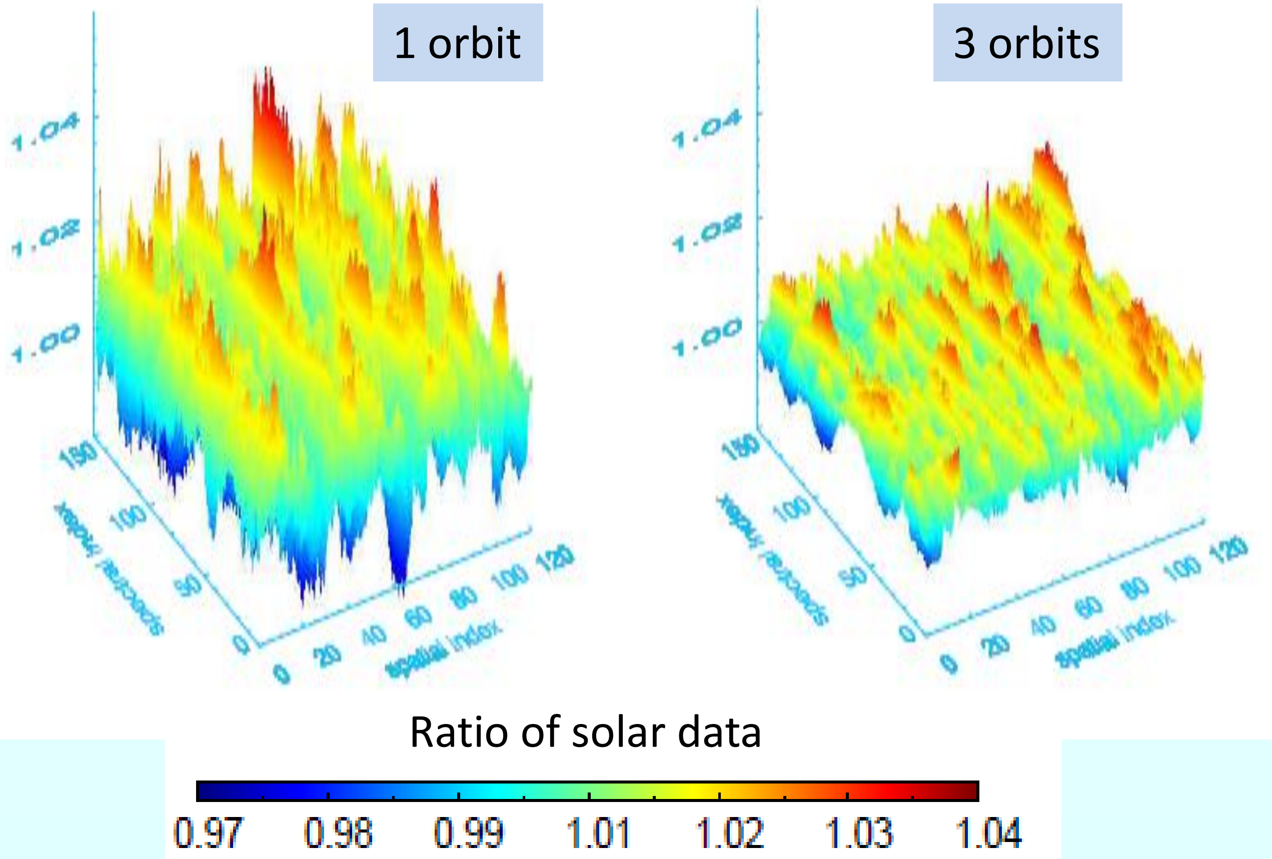




Modified solar measurement reduces view angle dependence

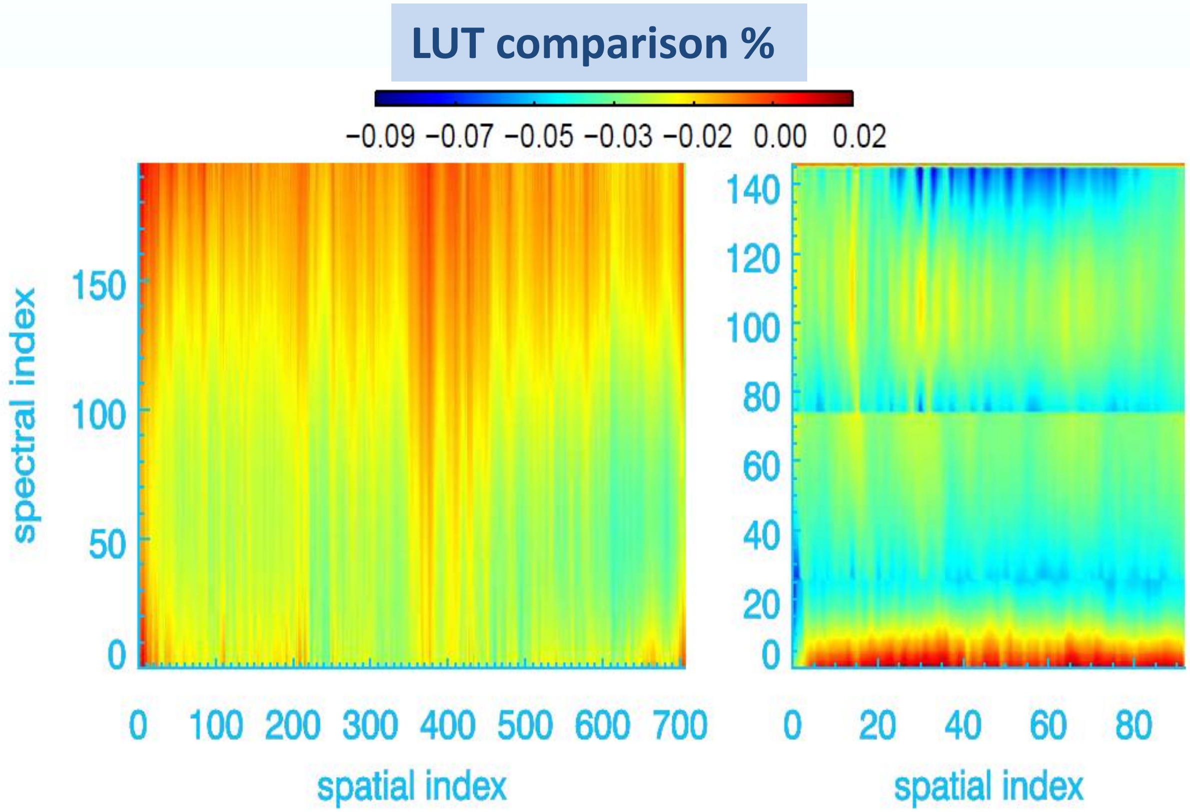
3orb Solar Every 2nd week

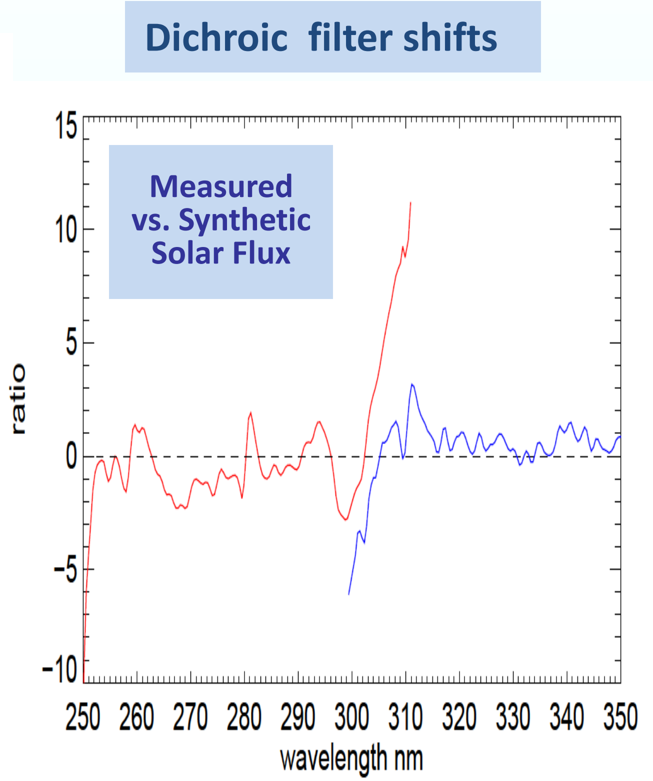
TC Solar (1,4,7)	57 images	Orbit 1
TC / NP Stor. Darks	37 images	
TC Solar 2	16 images	Orbit 2
NP Solar	16 images	
TC Solar 6	16 images	
TC / NP Open Darks	37 images	
TC Solar (1,3,5,7)	54 images	Orbit 3
TC / NP Closed Darks	37 images	



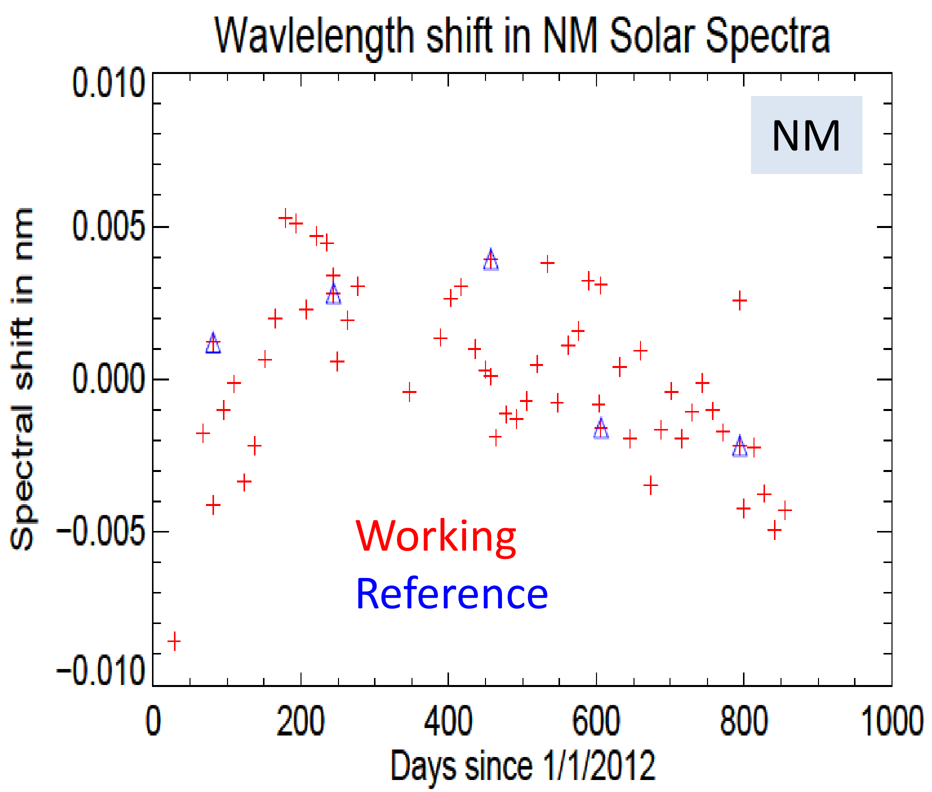
Data is being used to study diffuser feature

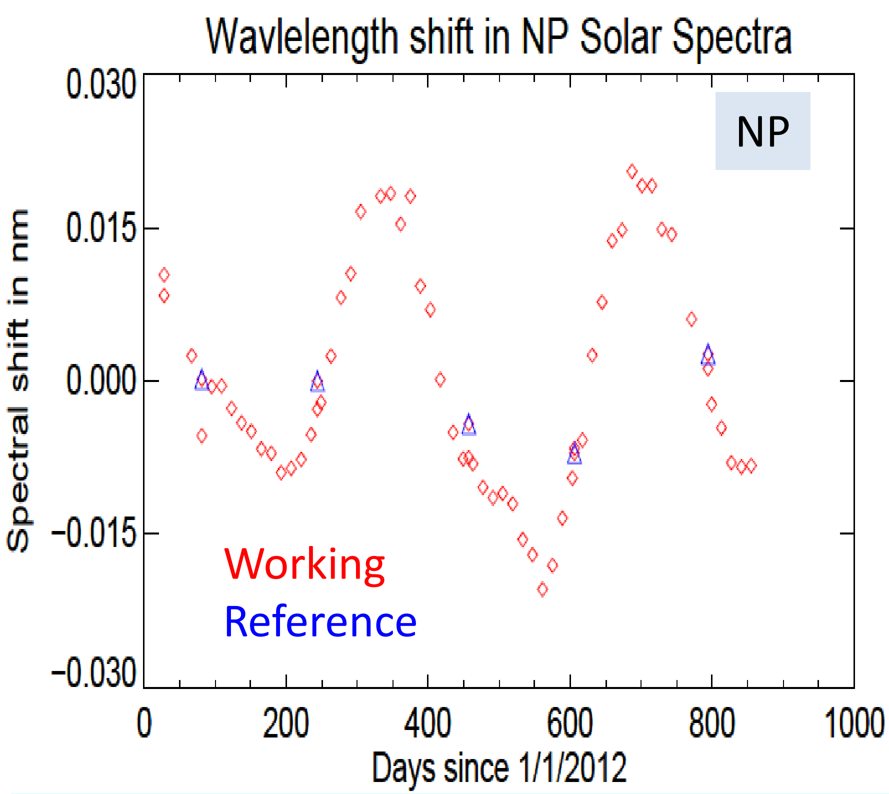
Wavelength shifted from ground to orbit





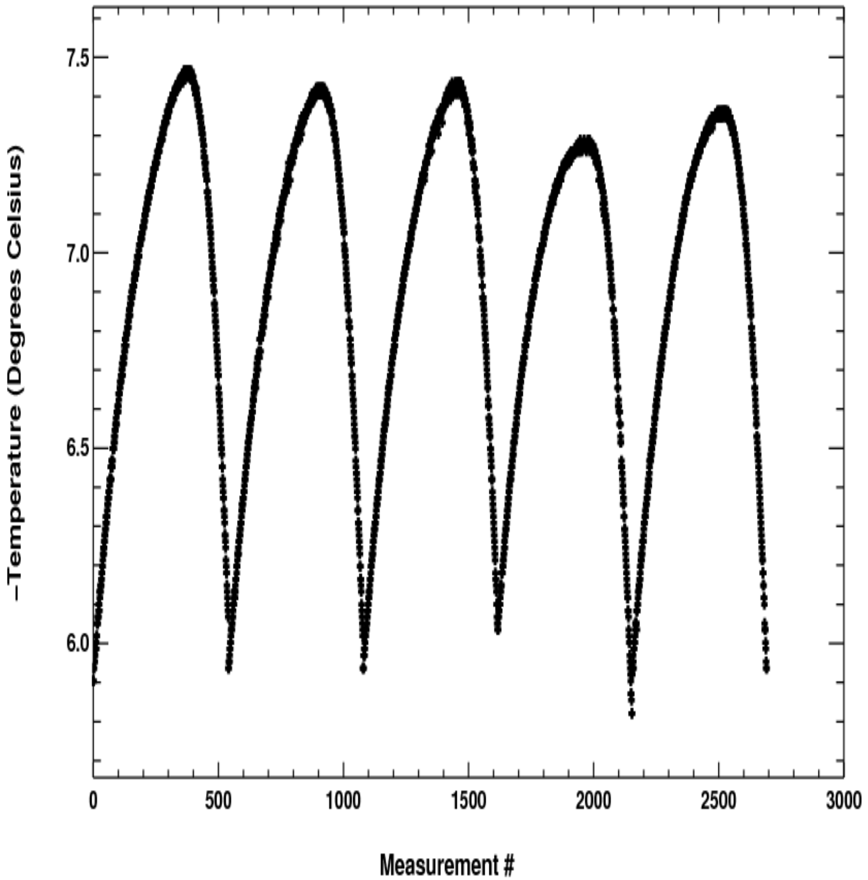
Orbital wavelength changes < ±0.02nm



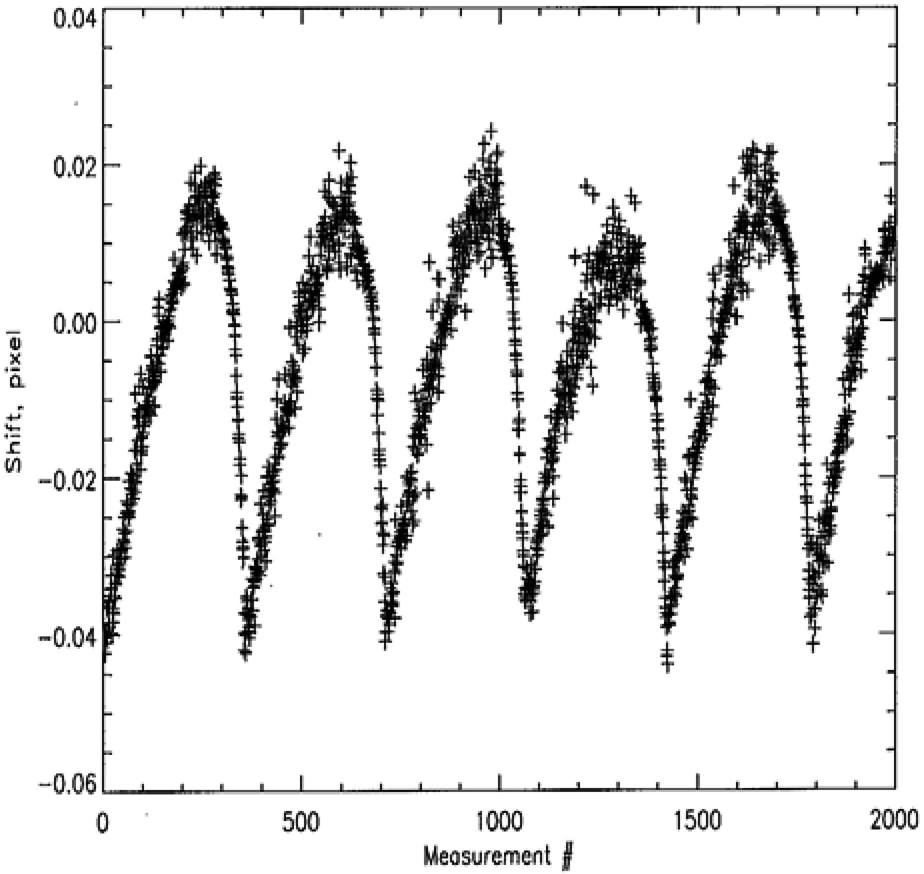


NM intra-orbit wavelength variation <±0.025nm

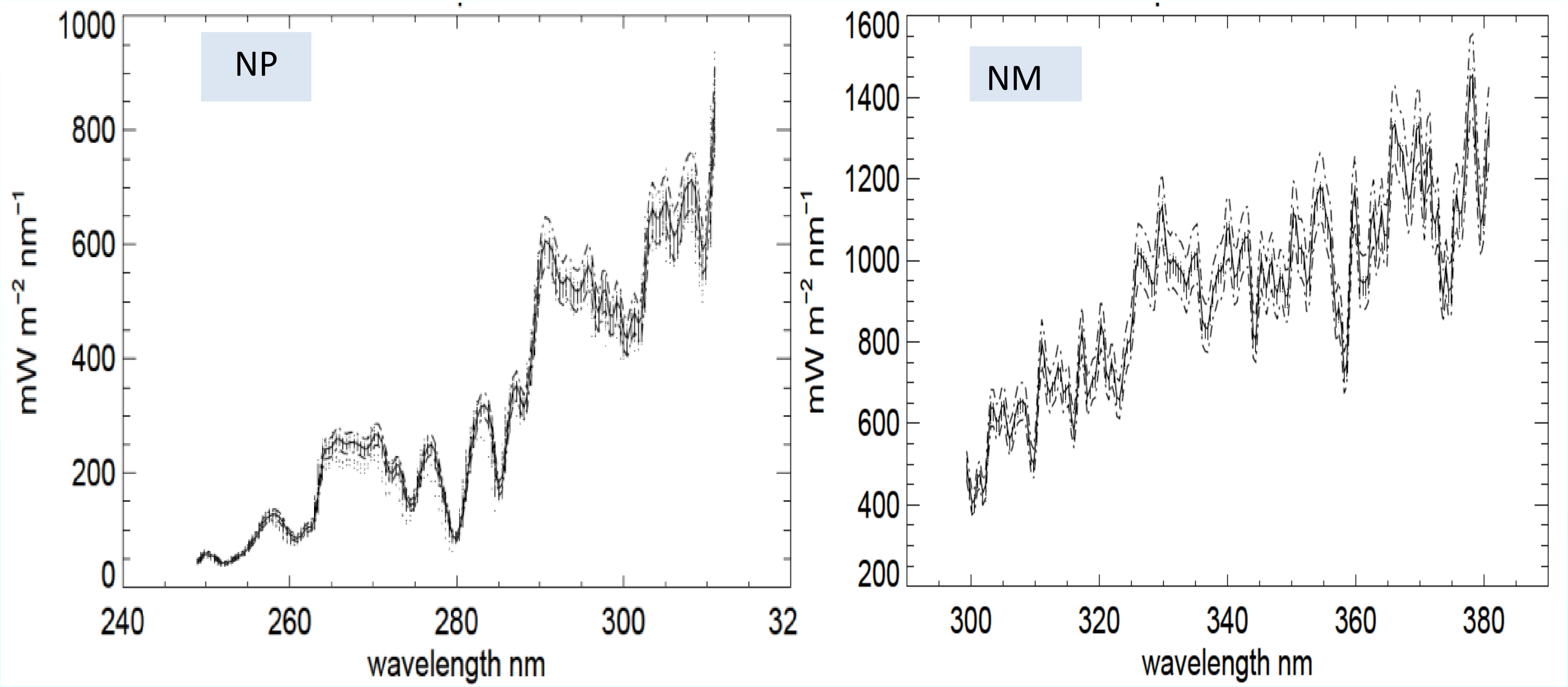
NM housing temperature (^oC)



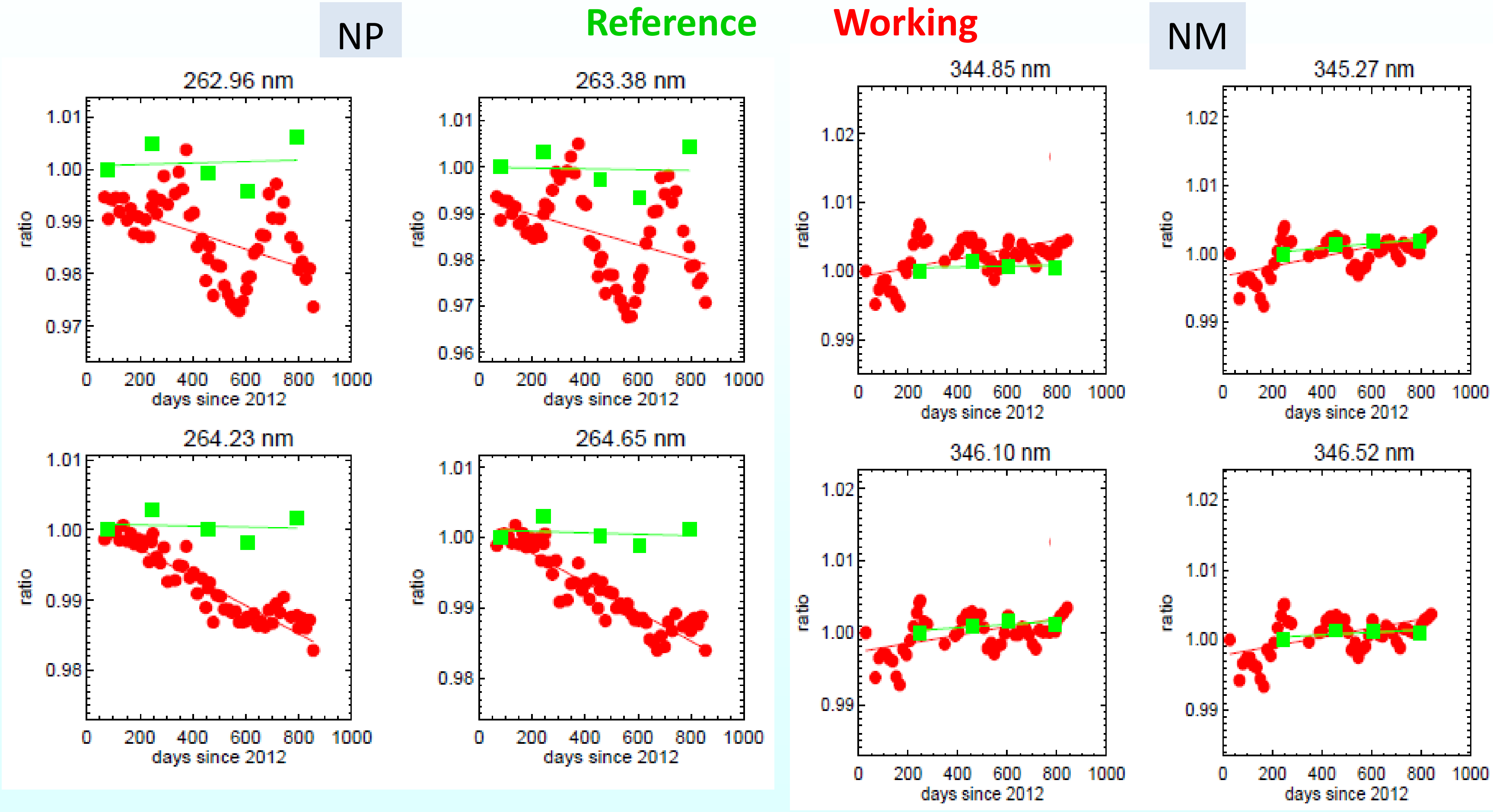
Intra-orbital wavelength shift in pixel



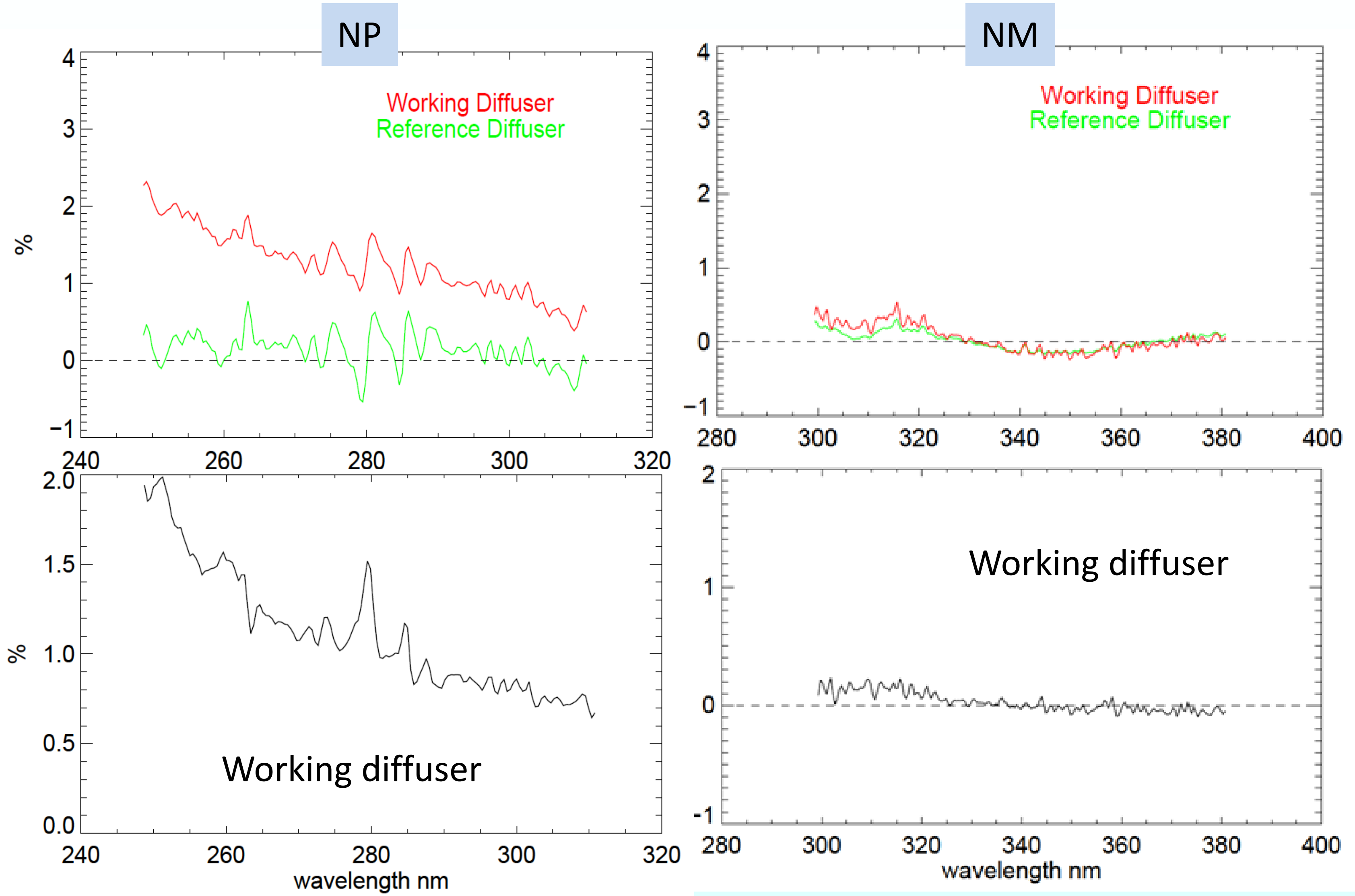
Solar irradiance uncertainty <7%



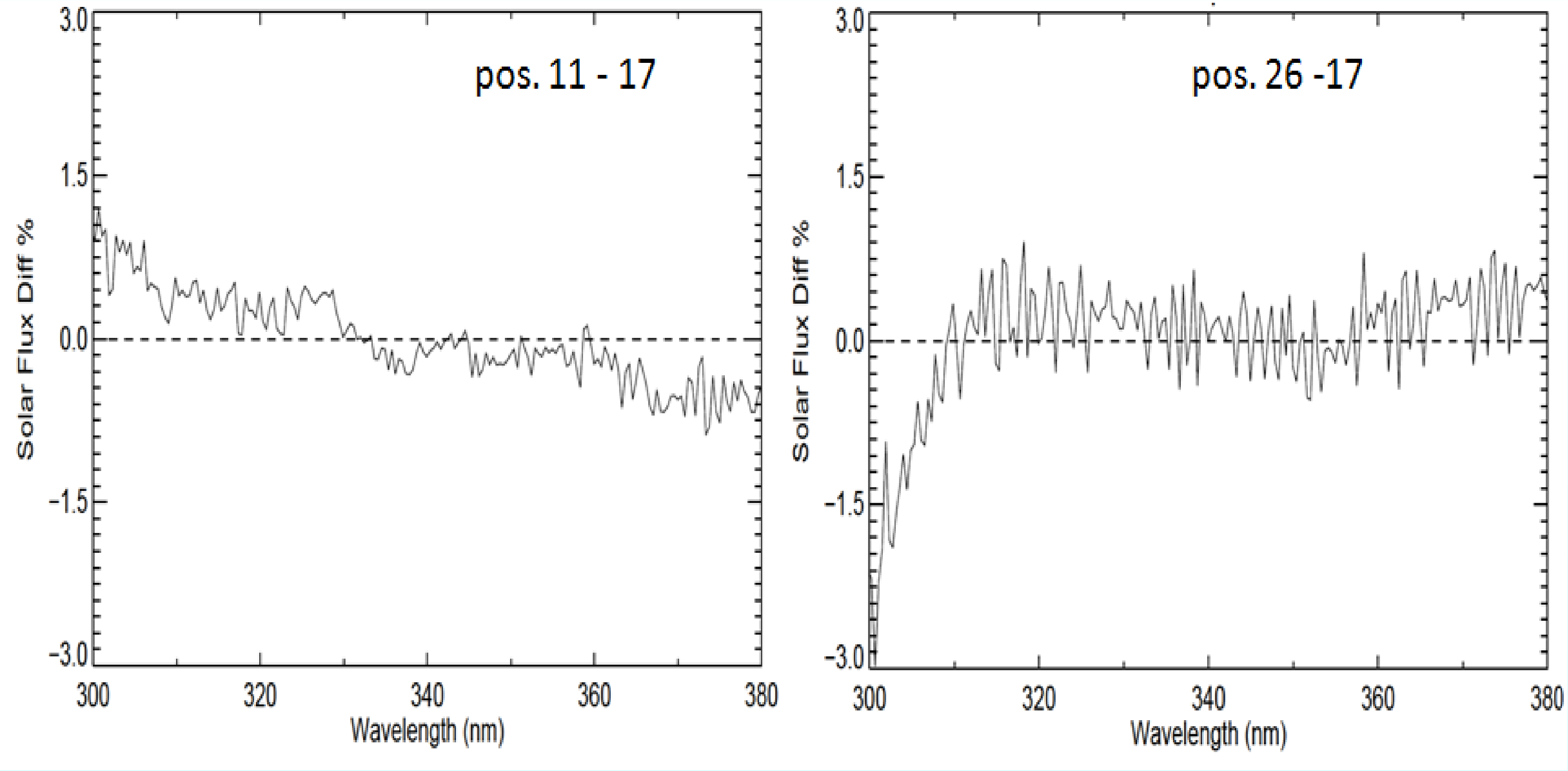
Optical throughput trending



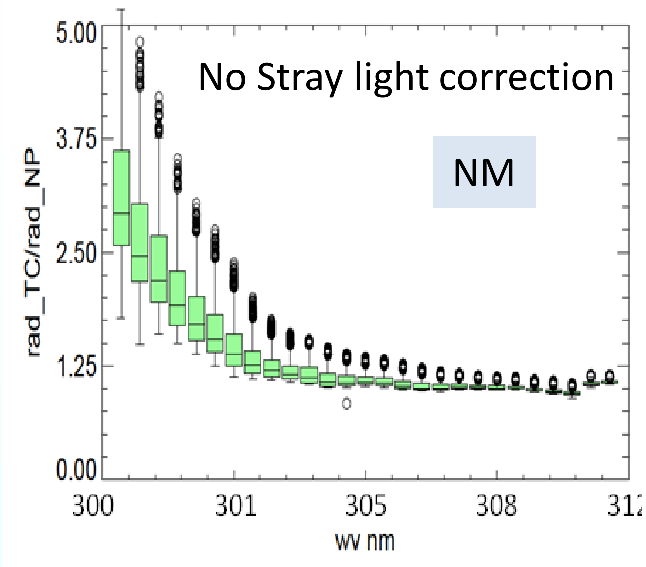
Sensor optic degradation < 0.5%

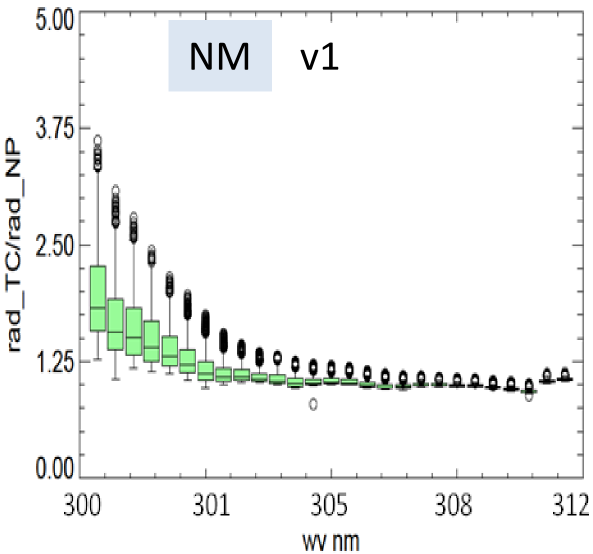


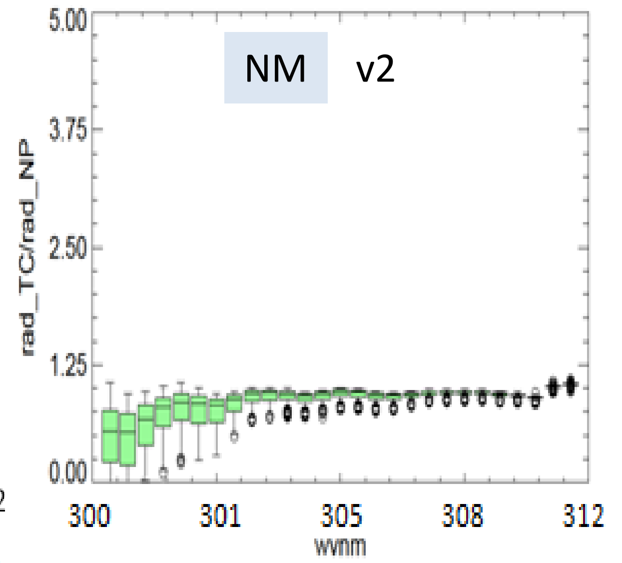
Cross-track position pattern in solar flux

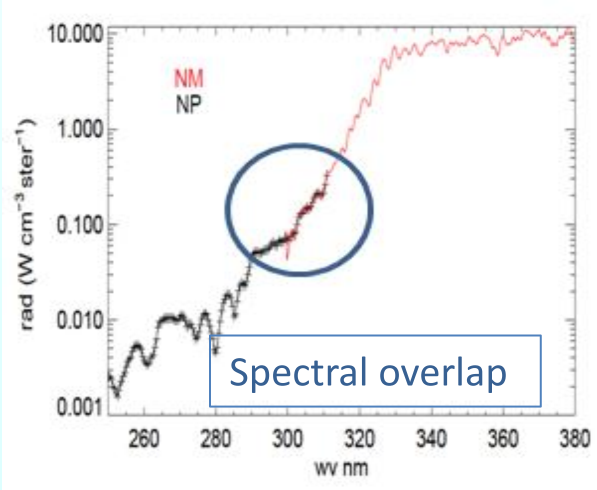


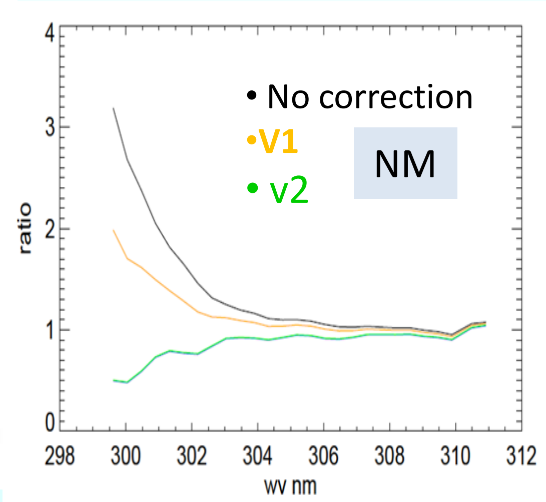
Stray light correction

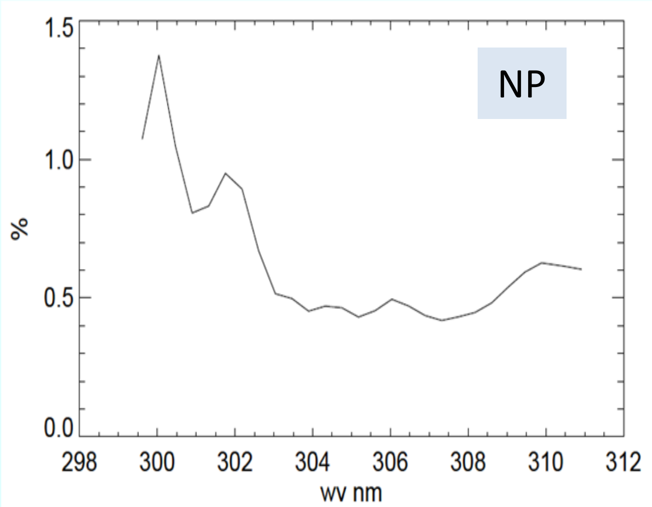












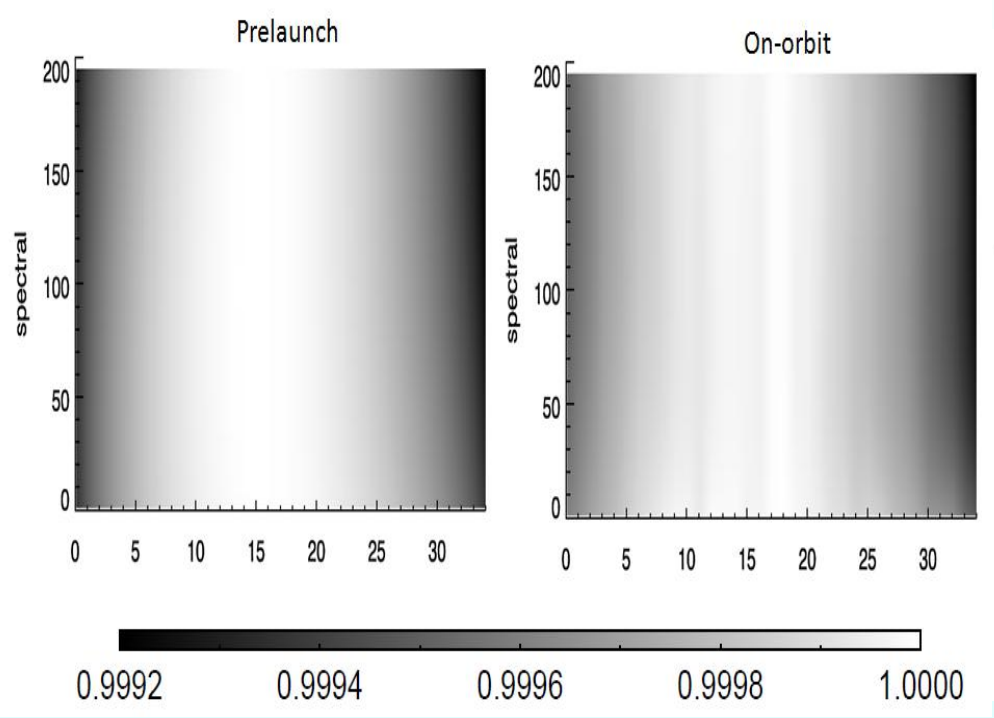
Summary

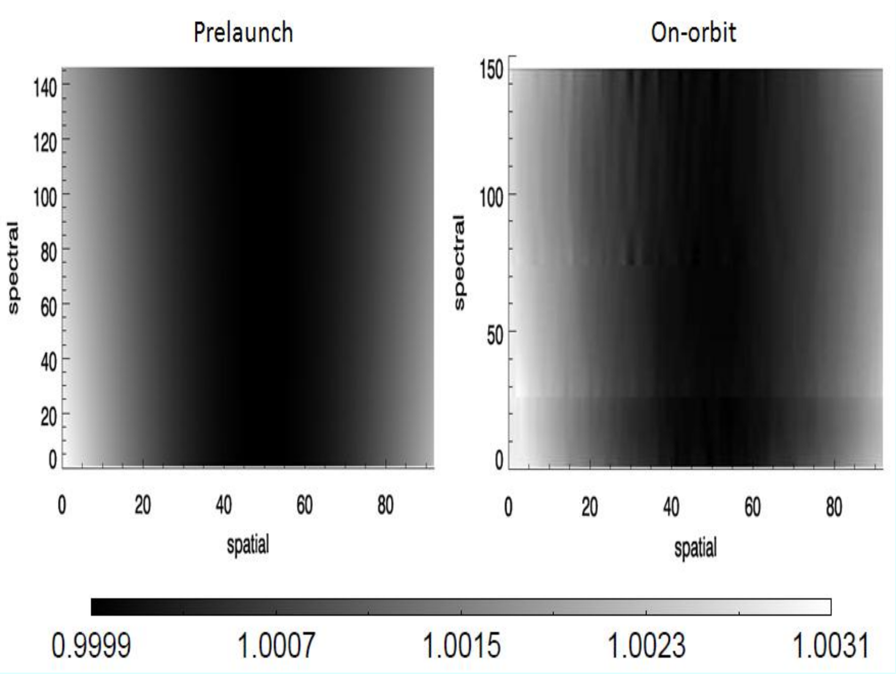
Parameters	Specification/Prediction Value	On-Orbit Performance
Non-linearity	< 2% full well	< 0.46%
Non-linearity Accuracy	< 0.2%	±0.2%
On-orbit Wavelength Calibration	< 0.01 nm	0.15-0.25 nm
Stray Light NM Out-of-Band + Out-of-Field Response	For NM ≤ 2	average < 2%
Intra-Orbit Wavelength Stability	Allocation (flow down from EDR error budget) = 0.02 nm	~ 0.02 nm
SNR	1000	> 1000
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 (for NP) 46 (for NM)	47 (for NP) 51 (for NM)
Absolute Irradiance Calibration Accuracy	< 7%	< 3% in 300-310 nm: up to ~10 % for both NM and NP
Absolute Radiance Calibration Accuracy	< 8%	< 5% in 300-310 nm: up to ~6 % for NM and NP
Normalized radiance Calibration Accuracy	< 1%	< 1%

“Spectral smile” is small

NM <0.2 nm

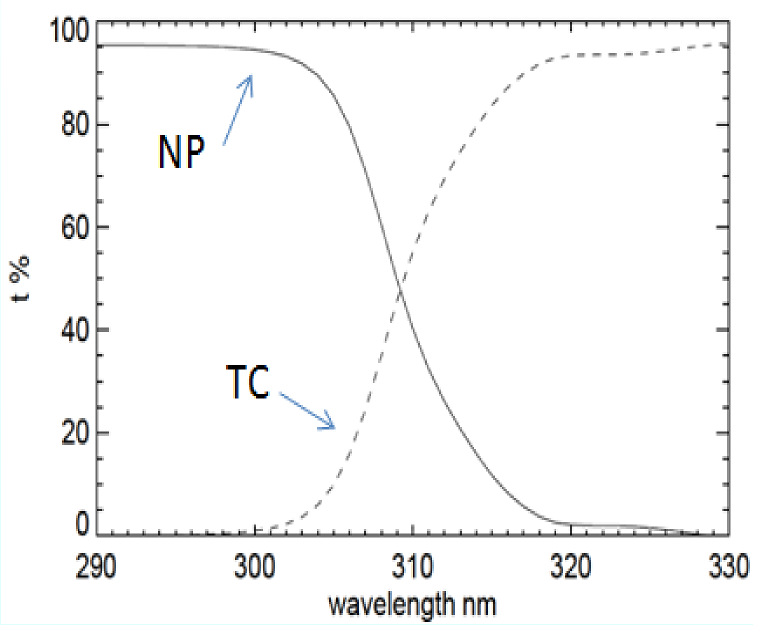
NP < 0.7 nm

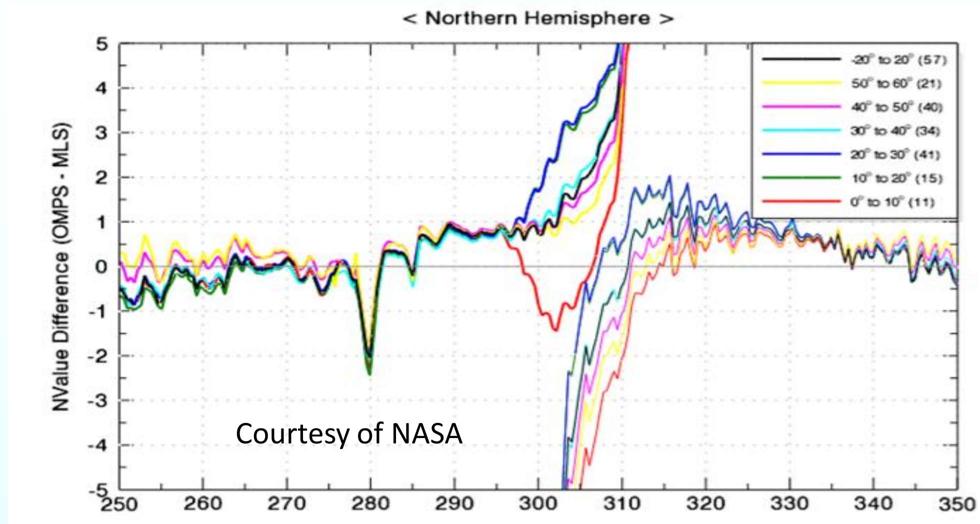


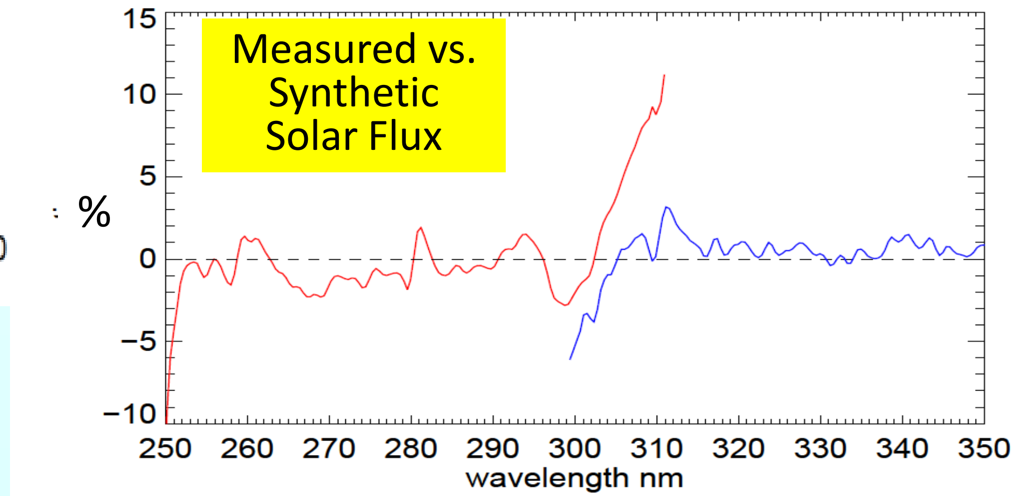


Dichroic shifted from ground to orbit

Percent transmittance







OMPS SDR calibration tables

Table Description	Table Type	Delivery Status
NM & NP Day 1 Solar	LUT	Once (will be repeat)
NM & NP Wavelength	GND-PI	Once(will be repeat)
NM & NP CF Earth	GND-PI	Monthly (ceased)
NM & NP Dark Tables	GND-PI	Weekly
Diagnostic Flight Sample Tables	SCT	When necessary
Earth-view Flight Sample Tables	SCT	Once
Earth-view Ground Sample Tables	GND-PI	Once
Calibration Flight Sample Tables	SCT	Once
NM & NP Radiometric Coefficients	LUT	TBD
NM Stray Light Coefficients	LUT	Once
NP Stray Light Coefficients	LUT	Once
NM & NP Linearity (Flight & Ground)	SCT/GND-PI	Not planned
NM & NP Flat Field	SCT	Not planned