Evaluation of S-NPP Ozone Mapping Profiler Suite Nadir Instrument In-flight Performance

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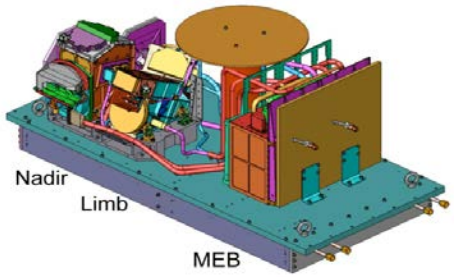
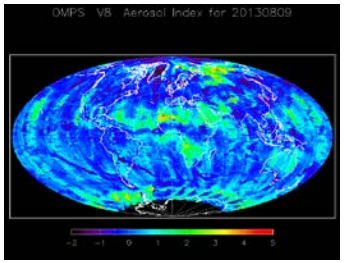
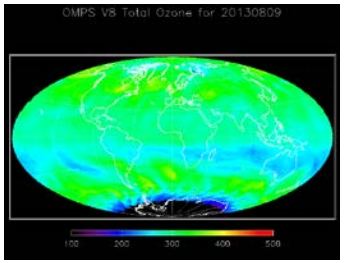


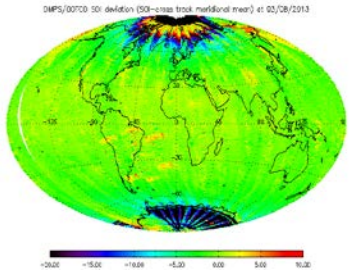
Curtsey of Ball Aerospace and Technologies Corp.



Aerosol Index



Ozone map



So2 index

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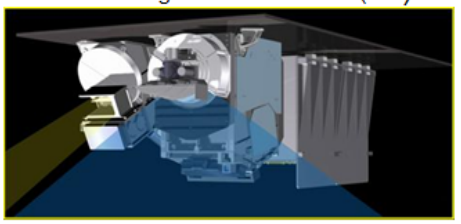
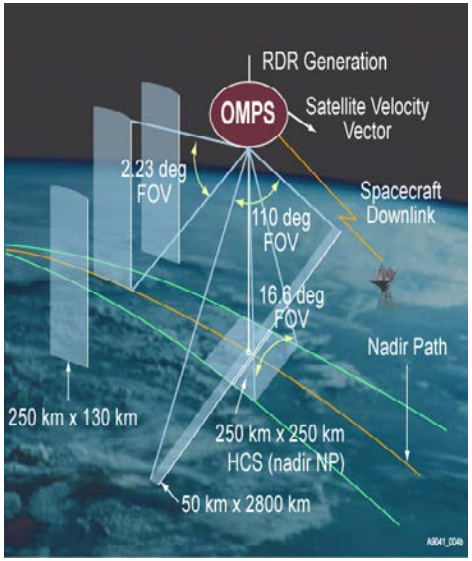
Instrument overview

- **Resolution**
  - Provides Total Column ozone data w/ 50x50 km FOV at nadir
  - Provides ozone profiles in a single ground pixel of 250x250 km at nadir
- **Configuration**
  - Push-broom 110 deg. cross-track FOV telescope
  - Two grating spectrometers
    - » NM covers 300 nm to 380 nm
    - » NP covers 250 nm to 310 nm
  - CCD optical detector for each spectrometer
- **Onboard Calibrators**
  - Light-emitting diode provides linearity calibration
  - Reflective solar diffusers maintain calibration stability
- **Products**
  - Provide globe maps every 24 hours of amount of ozone and volumetric concentration in a vertical column of atmosphere with a 4- days revisit

OMPS Integrated Sensor Suite (ISS)





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

OMPS Nadir performance specifications

Dominant contribution to accuracy

Spatial Properties

- Cross-track MTF at nadir >.5 at .01cycles/Km
- Cross-track TC macpx. IFOV nadir <3.44 degrees
- Cross-track TC FOV >110 degrees

Radiometric Accuracy

- Pixel-pixel radiometric calibration <.5%
- Non linearity 2% full well
- NL knowledge <.5%
- On-orbit wavelength calibration .01 nm
- Stray Light TC OOB + OOF response <2%
- Intra-orbit wavelength stability .02 nm
- Band Pass Shape Knowledge 2%
- Solar Irradiance < 7%
- Radiance <3%

Dominant contribution to precision

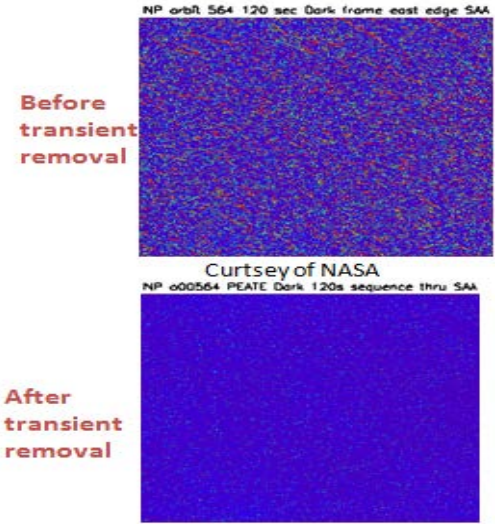
Radiometric Precision Terms

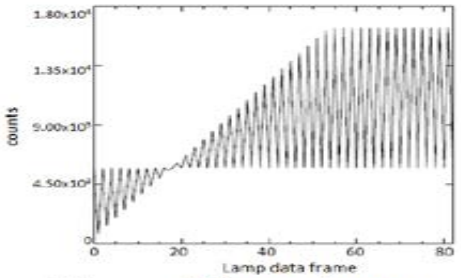
- SNR 1000 for TC, varies for NP
- Inter-orbital Thermal Wavelength Shift .02 nm

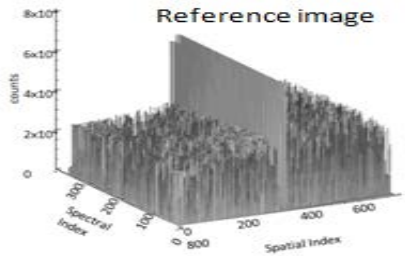
Geolocation Error Terms

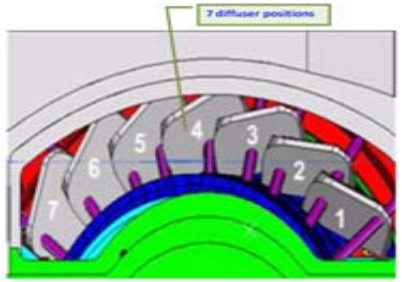
- Boresight alignment knowledge uncertainty between nadir instrument interface and nadir alignment reference <160 arcsec
- Total cumulative boresight alignment shift (between final ground calibration and on-orbit operations <500 arcsec

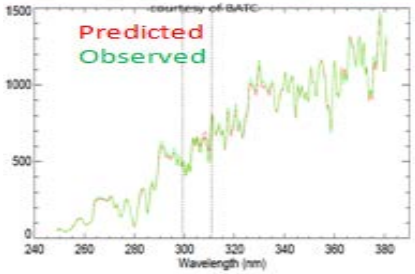
Sensor in-flight measurement and calibration









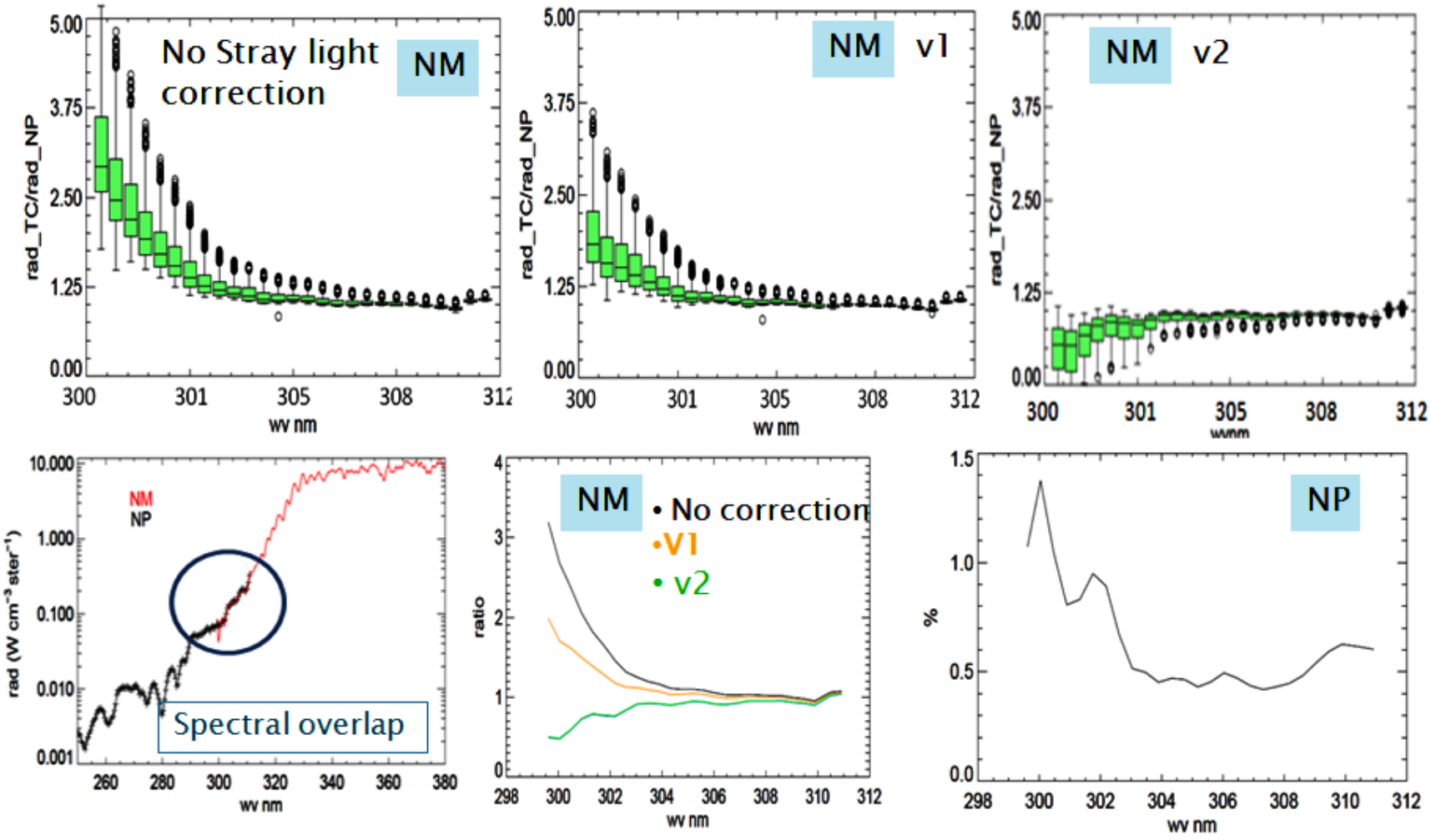


- Dark
  - Dark distribution
  - Dark generate rates
  - Electronic bias
  - Hot pixels
  - Dark Signal Non-uniformity (DSNU)
  - Readout noise
  - Dark smear
- Linearity
  - Nonlinearity
  - LED output drifts
  - Dynamic range
  - Calibrated accuracy
  - LED lamp warm up behavior
  - LED illumination uniformity
  - CCD gain
- Solar observation
  - Spectral variation
  - Wavelength variation
  - Sensor Noise
  - Optic degradation
  - Diffuser fine structure
  - Irradiance error

More:

- Sensor noise from EV observation
- Telemetry
- Stray light
- Cross-sensor EV radiance comparison
- Calibration table evaluation and trending
- PRNU

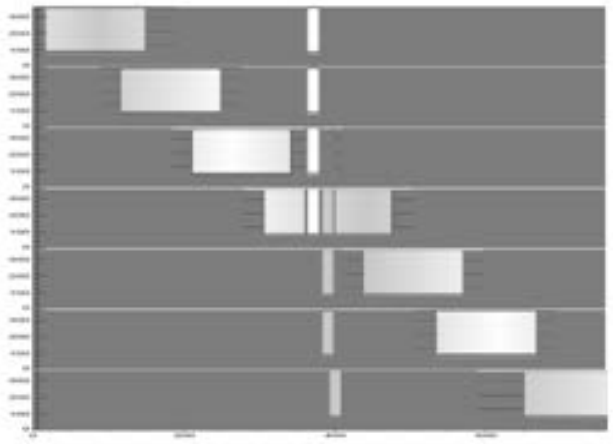
Stray light correction for nominal EV



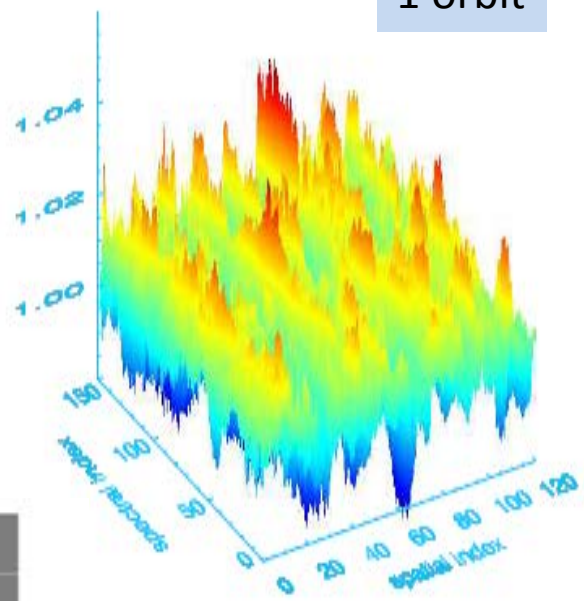
Modified solar measurement reduces view angle dependence

3orb Solar Every 2nd week

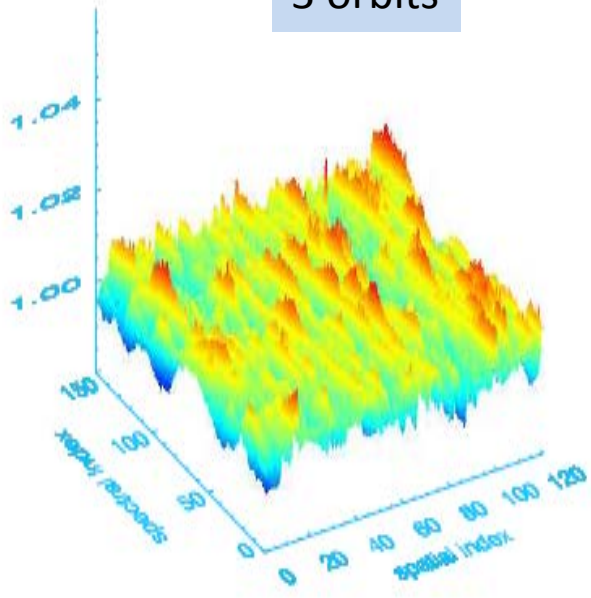
TC Solar (1,4,7)	57 images	Orbit 1
TC / NP Stor. Darks	37 images	
TC Solar 2	16 images	Orbit 2
NP Solar	16 images	
TC Solar 6	16 images	
TC / NP Open Darks	37 images	
TC Solar (1,3,5,7)	54 images	Orbit 3
TC / NP Closed Darks	37 images	



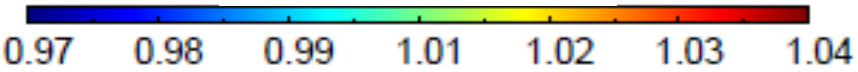
1 orbit



3 orbits

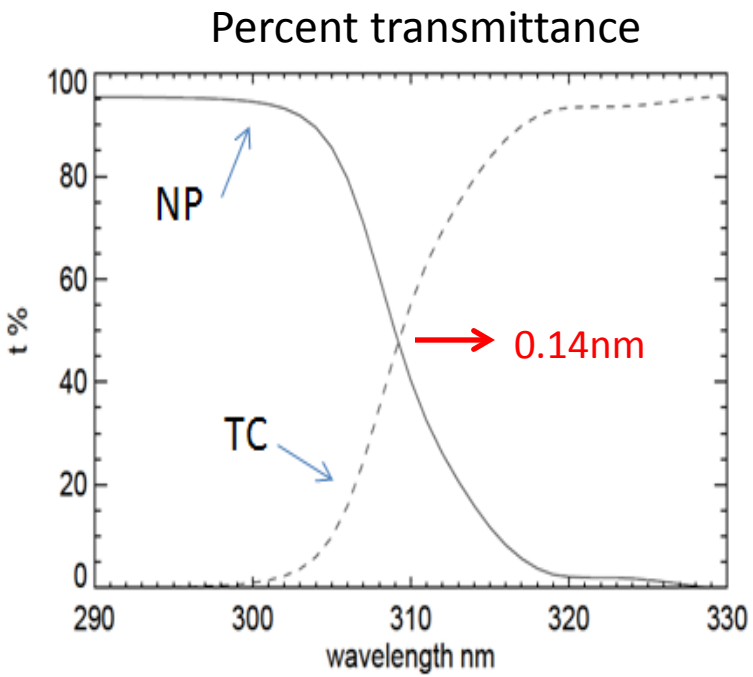


Ratio of solar data

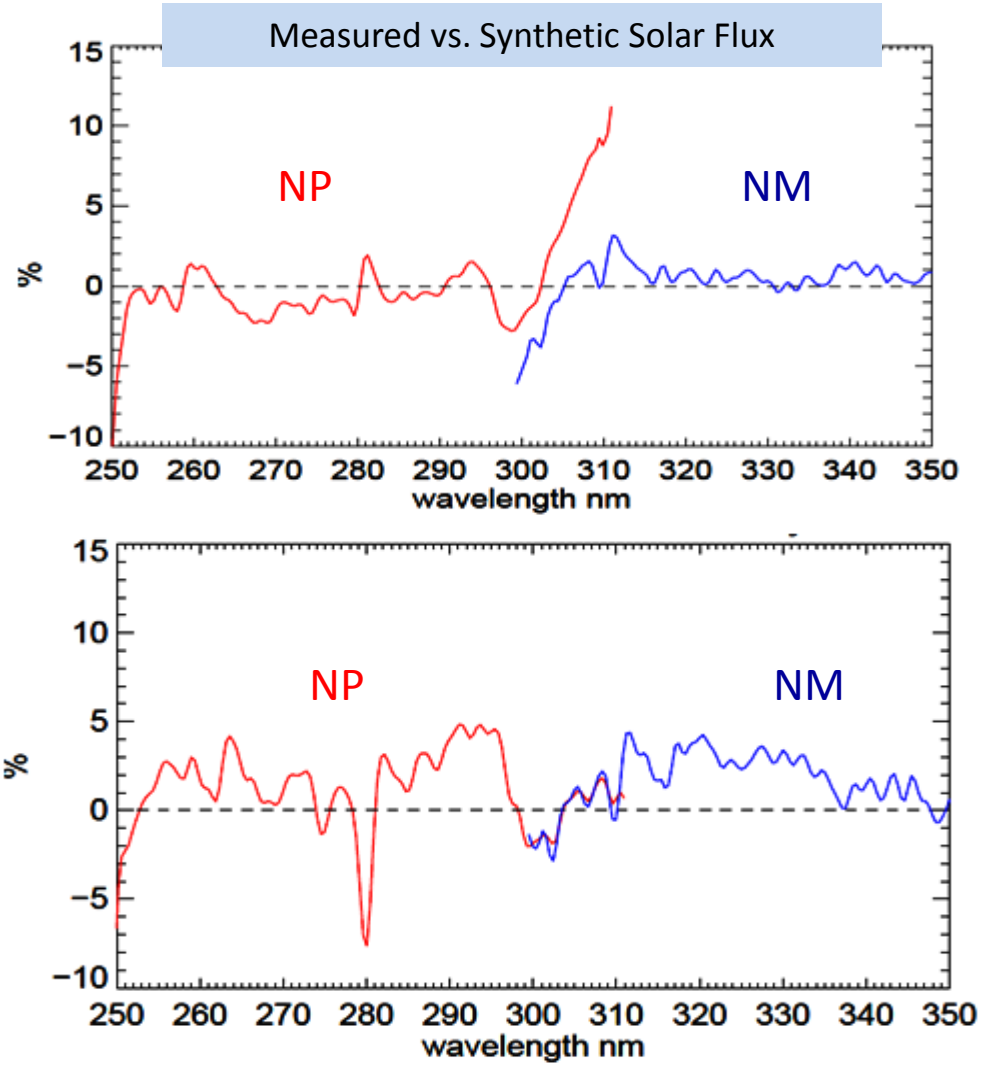


Data is being used to study diffuser feature

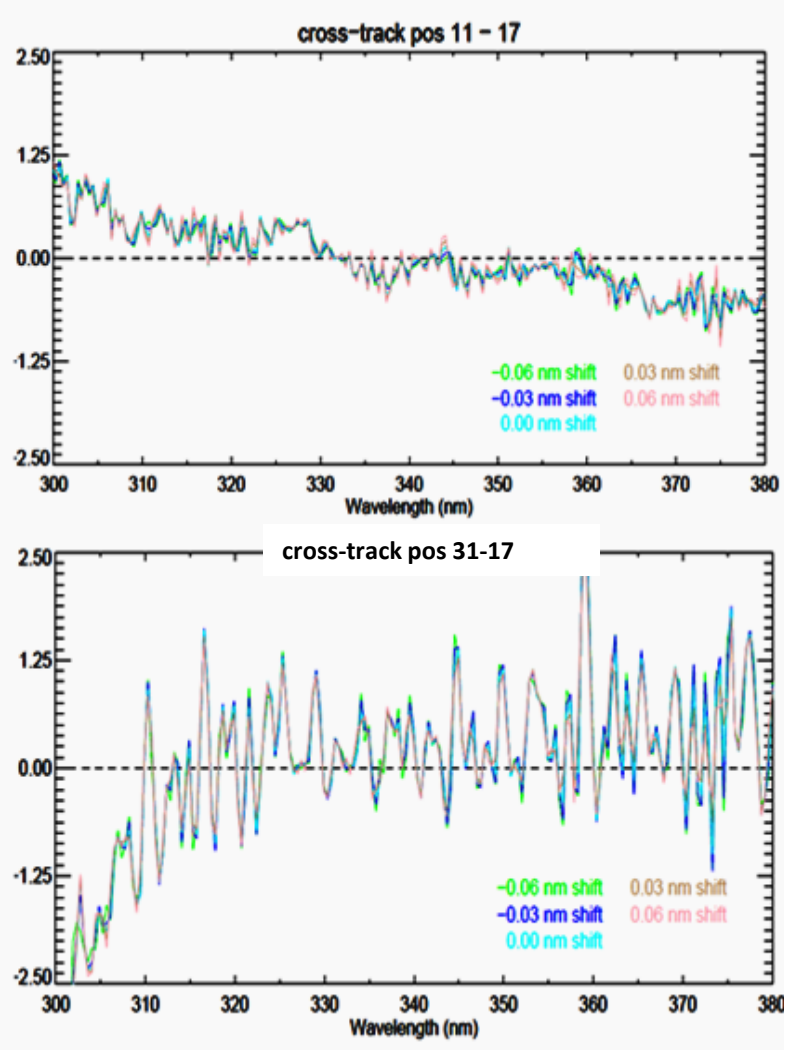
Wavelength changed at flight temperature

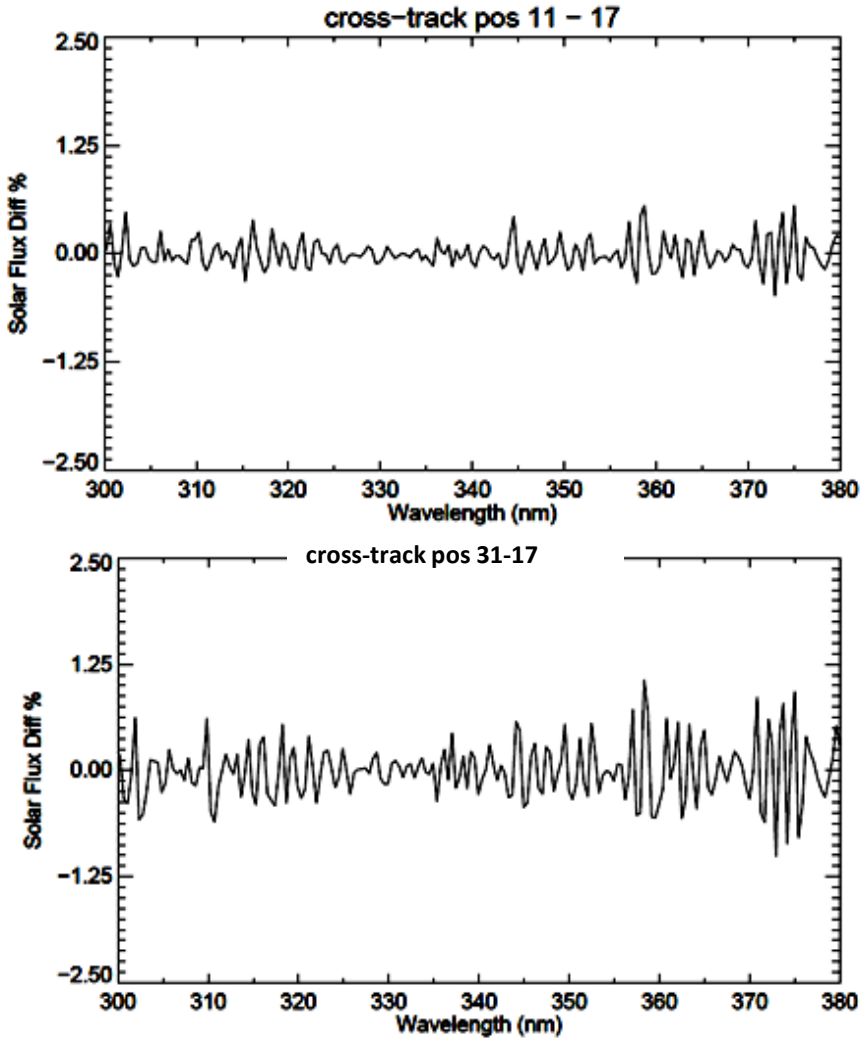


- Dichroic filter Trans/Refl curves shifted at flight temperature.
- Same effect on coefficients of Radiance and Irradiance.



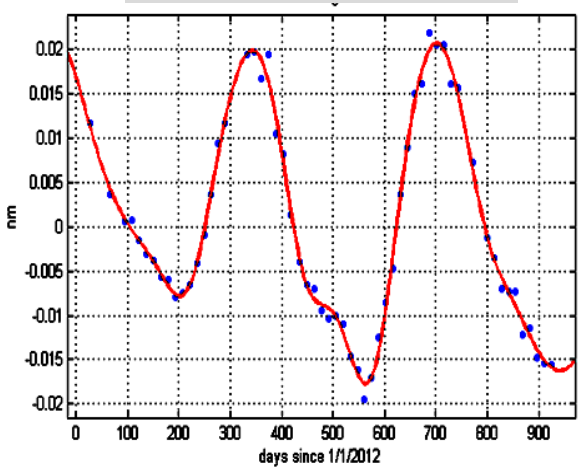
NM Cross-track position pattern from Solar data



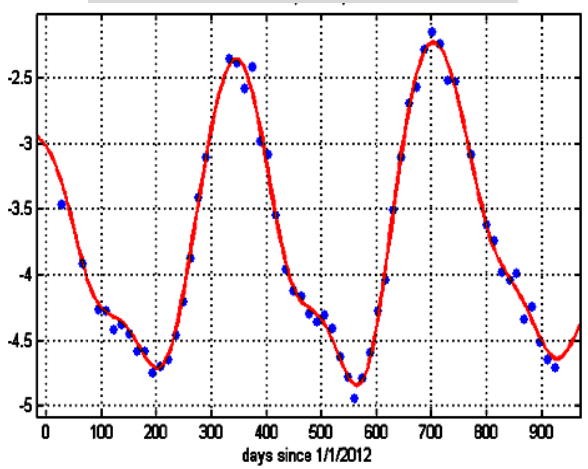


NP orbital wavelength changes from solar view

Wavelength variation nm

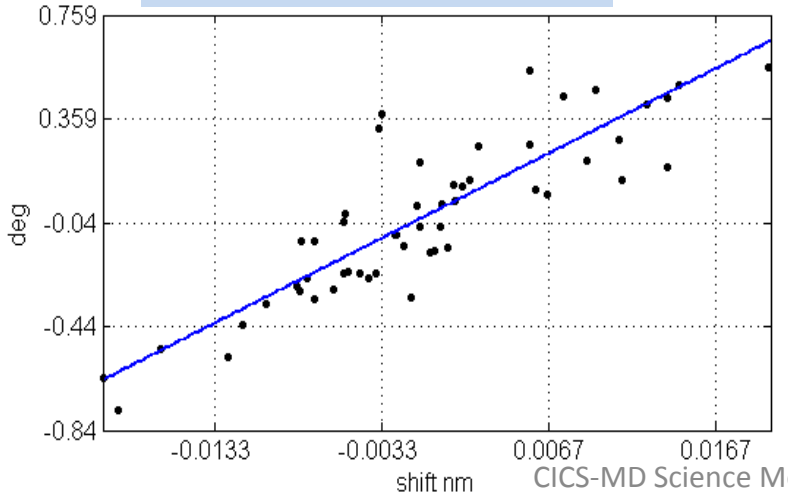


Telescope temperature deg



f(x) =
a1*sin(b1*x+c1) +
a2*sin(b2*x+c2) +
a3*sin(b3*x+c3) +
a4*sin(b4*x+c4)

ΔTelescope Temp. vs. Δshift nm

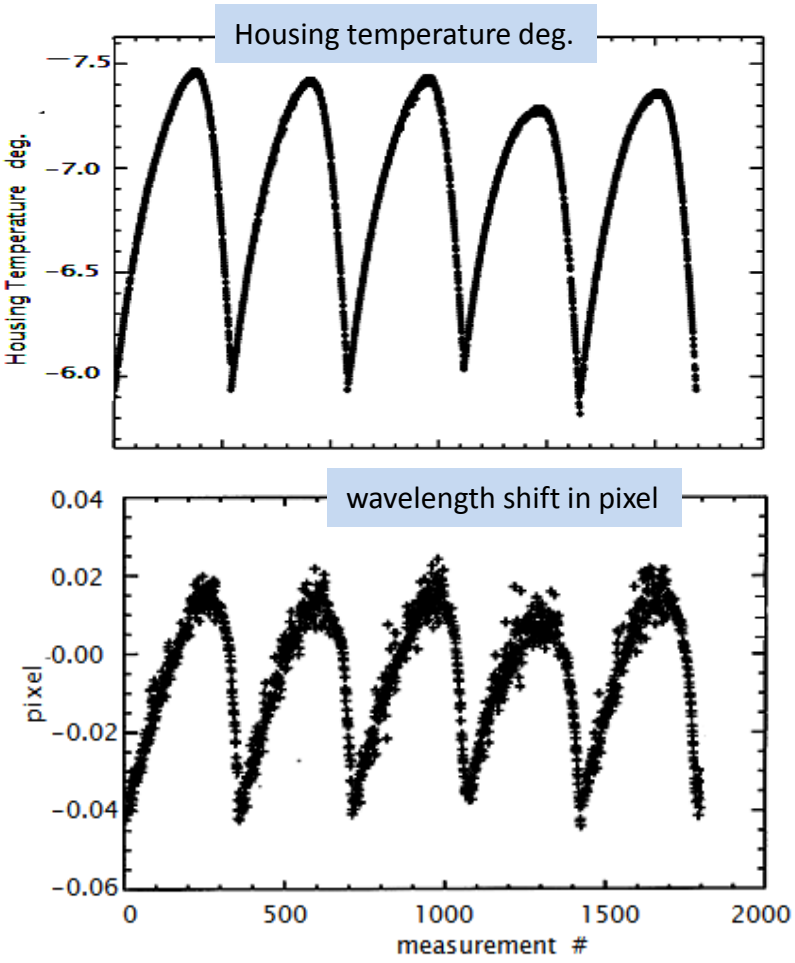


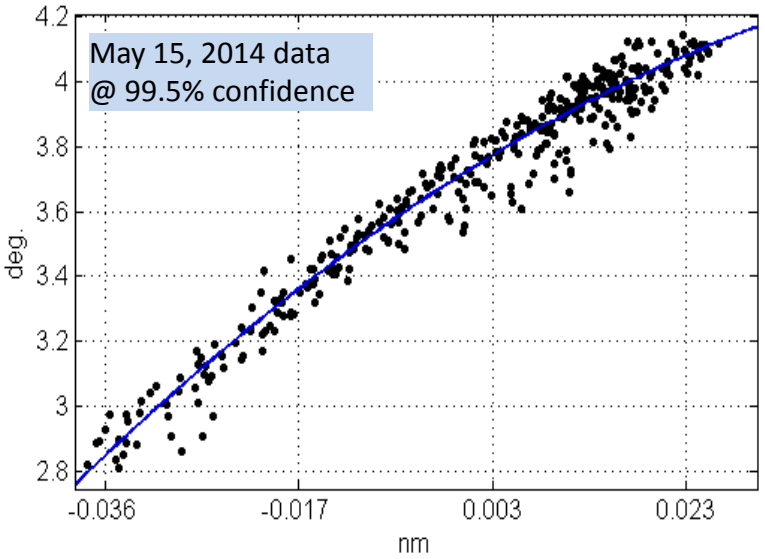
Linear model: f(x) = p1*x + p2

Coefficients (@ 95% confidence bounds):
p1 = 32.68 and p2 = 0.006929

Goodness of fit: SSE: 1.32
R-square: 0.8
RMSE: 0.1549

Intra-orbital wavelength changes from Earth view





f(x) = p1*x^2 + p2*x + p3
where x is normalized by mean -4.711e-05 (with 95% confidence bounds):

p1 = -0.04109 (-0.04257, -0.03961)
p2 = 0.3395 (0.3377, 0.3413)
p3 = 3.713 (3.71, 3.715)

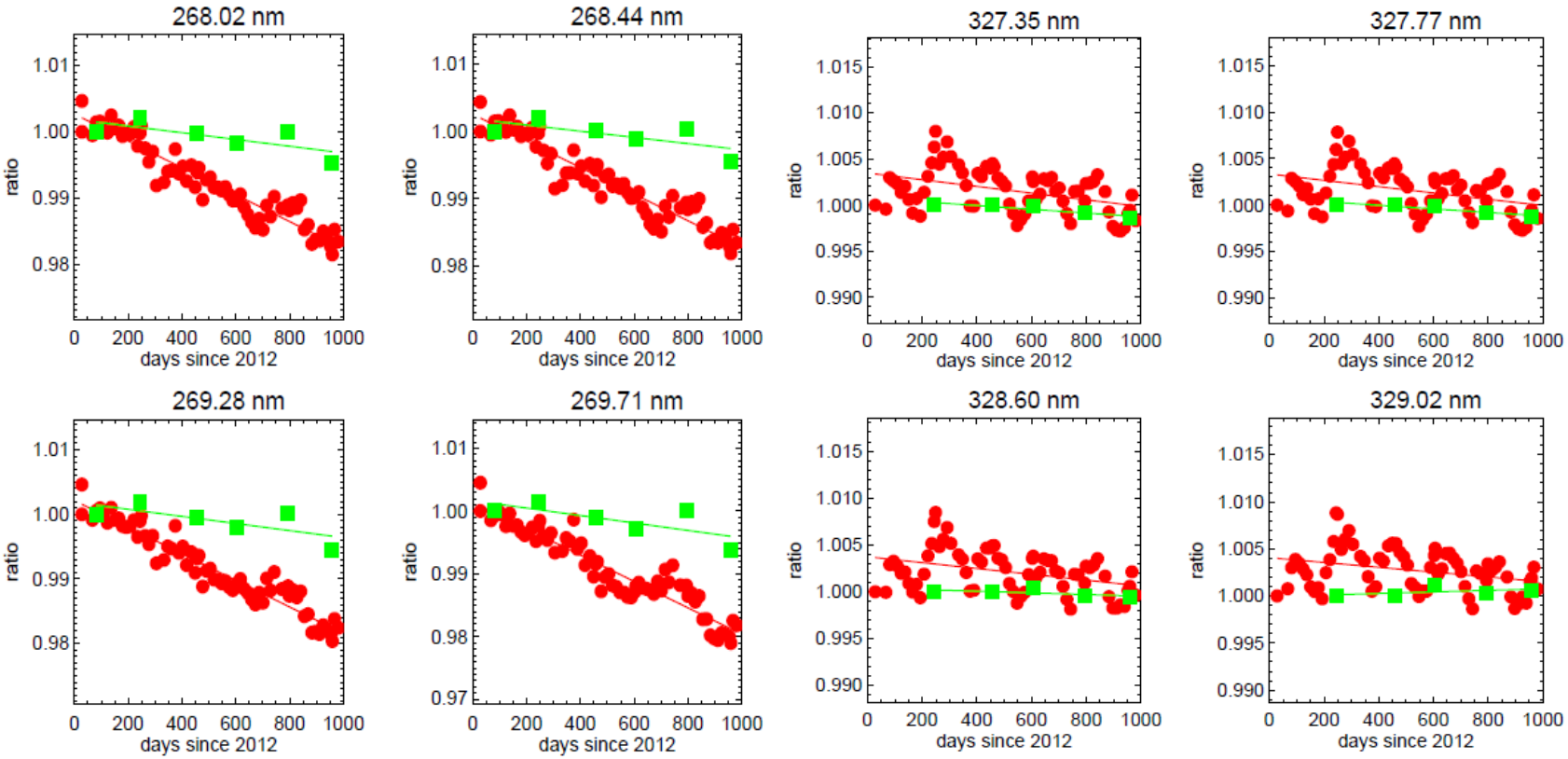
Goodness of fit: SSE: 32.43
R-square: 0.9641
RMSE: 0.06533

Optical throughput change < 1%

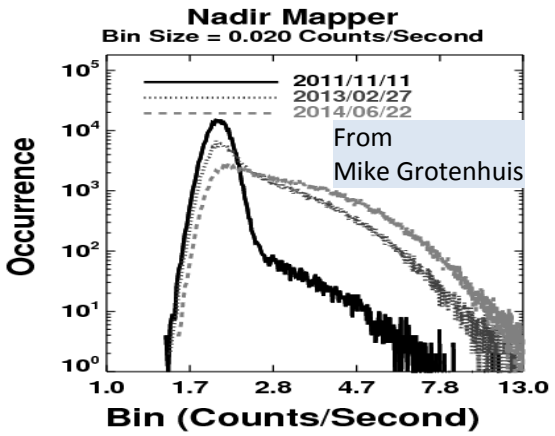
NP

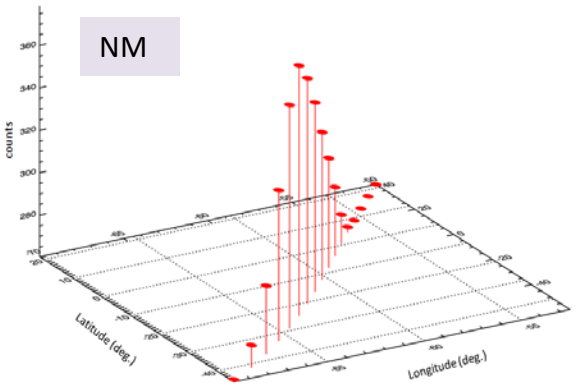
Reference Working

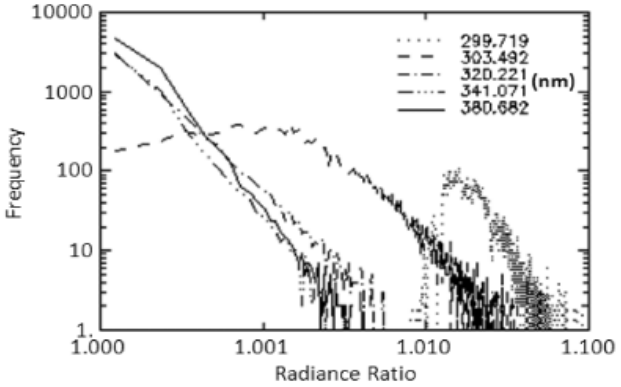
NM

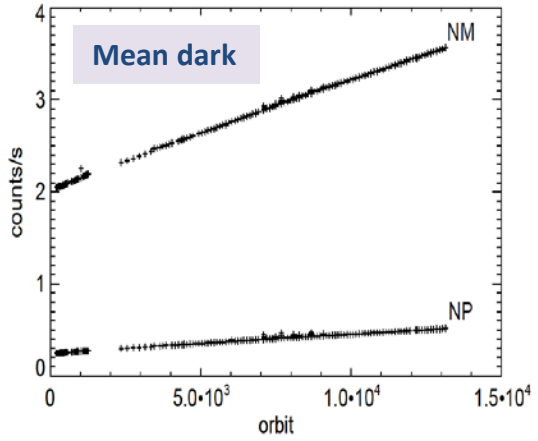


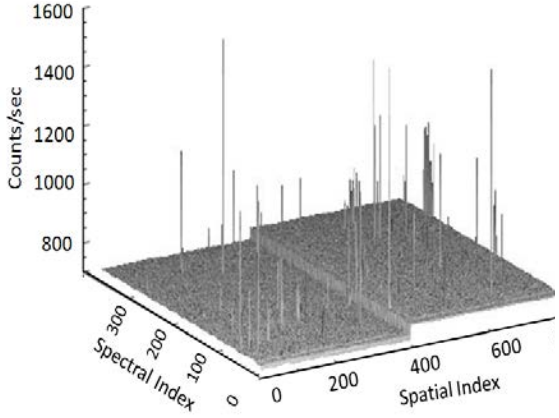
Effects of dark increase and transients

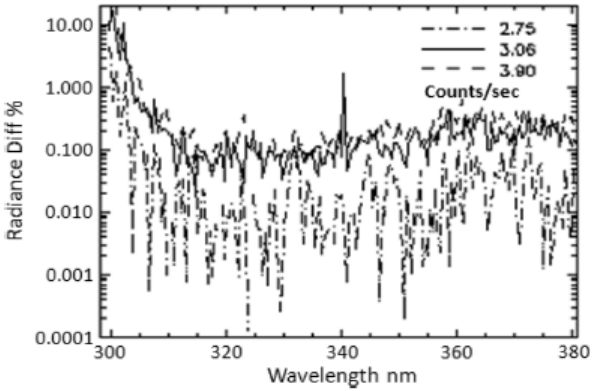






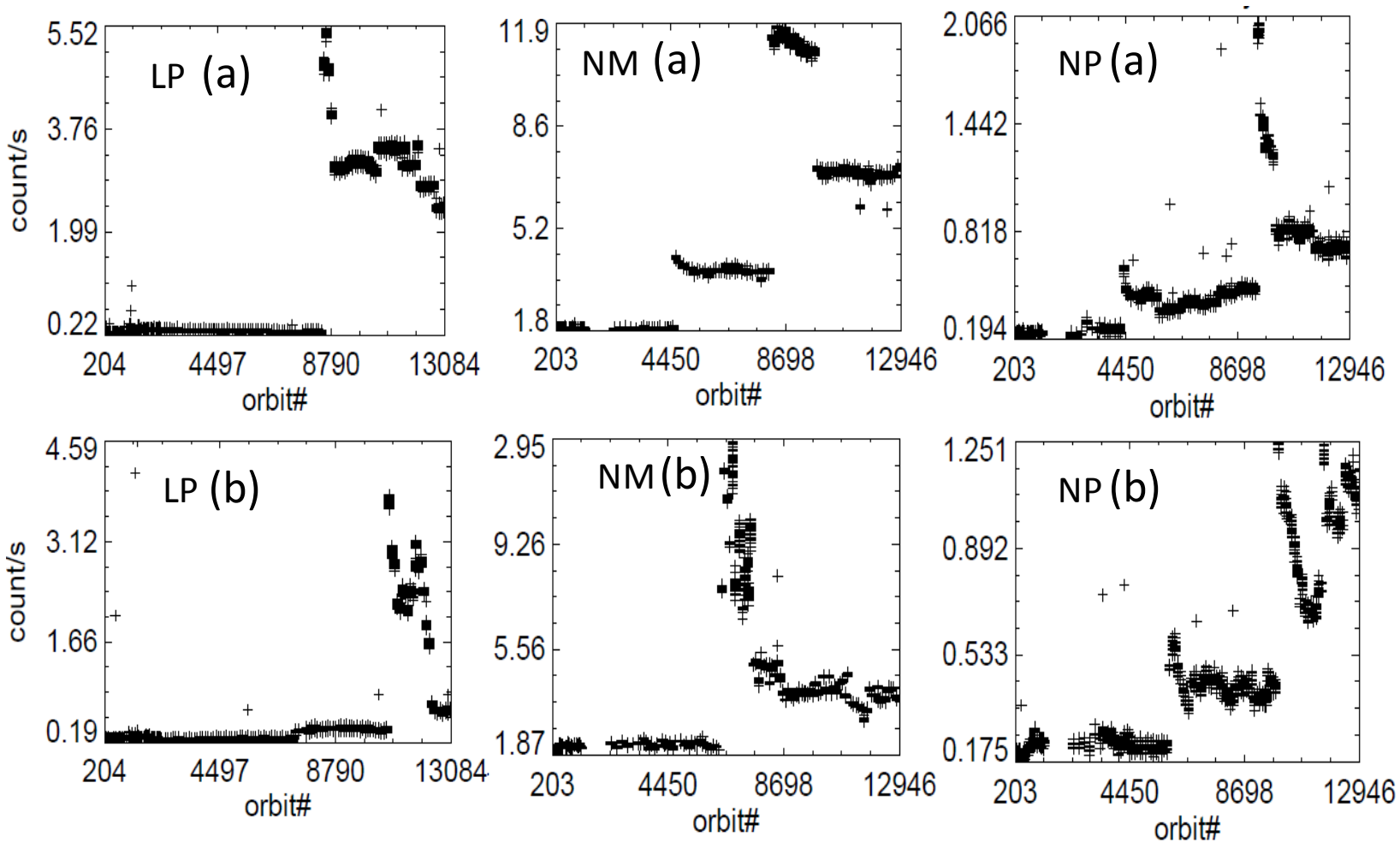






Weekly increase in mean: ~0.6% for NM and 0.8% for NP, resulting in uncertainties ~0.03% for NM and 0.1-0.5 % for NP.

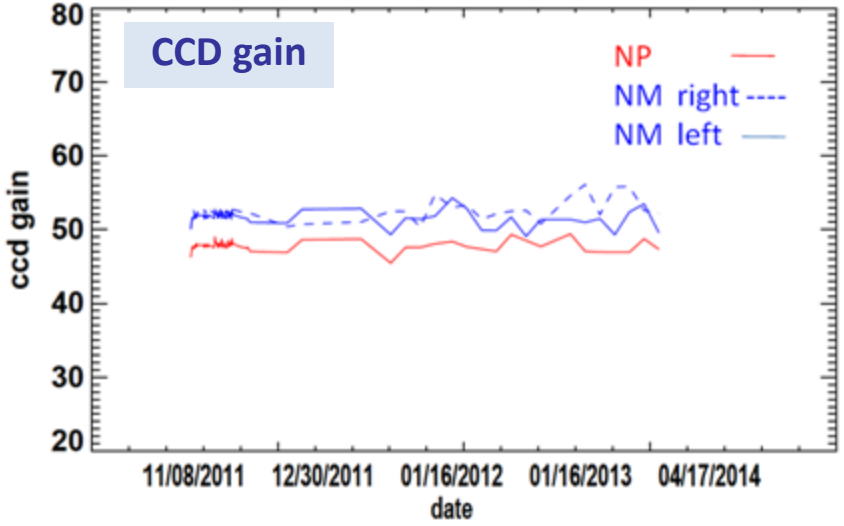
Random Telegraph Signal (RTS) complicates sensor calibration

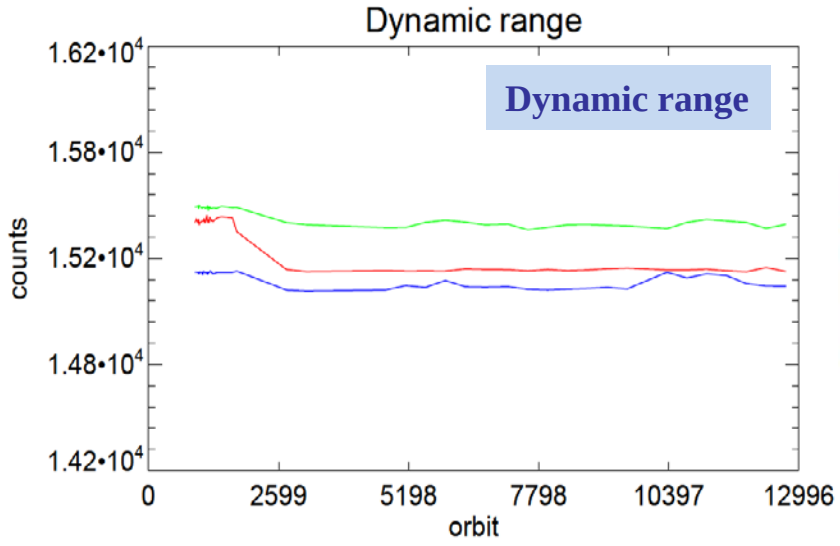


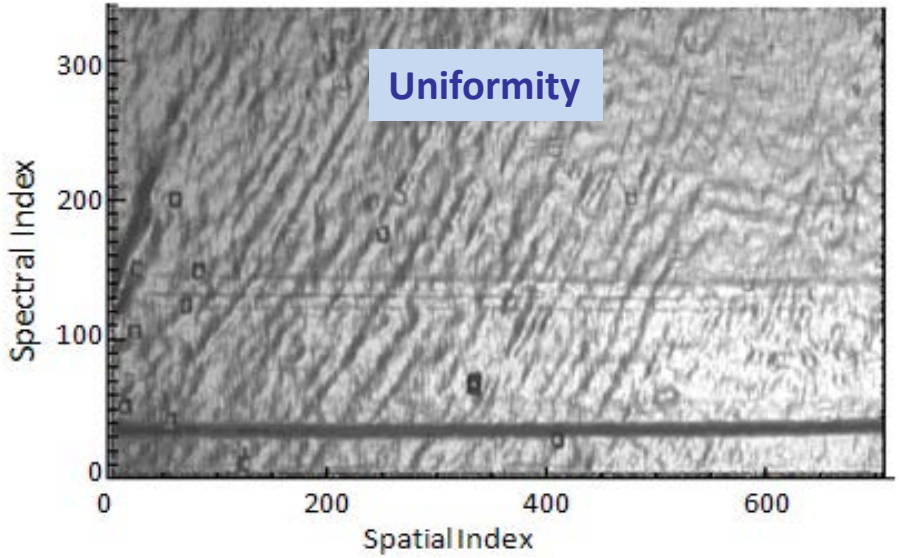
Linearity characterization

EVLED_Closed – 1 orbit Every 4th week

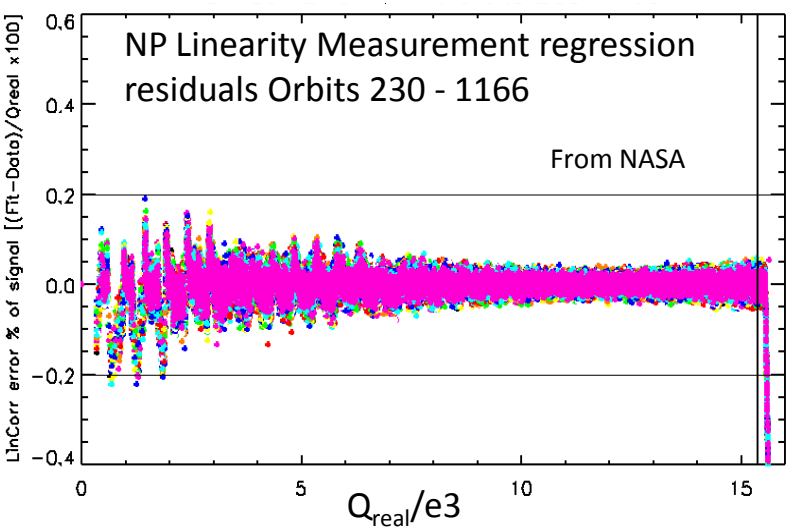
NP Lamp Warmup	50 images
NP Linearity	83 images
NP FF Lamp	1 image
NM Lamp Warmup	50 images
NM Linearity	83 images
NM FF Lamp	1 image

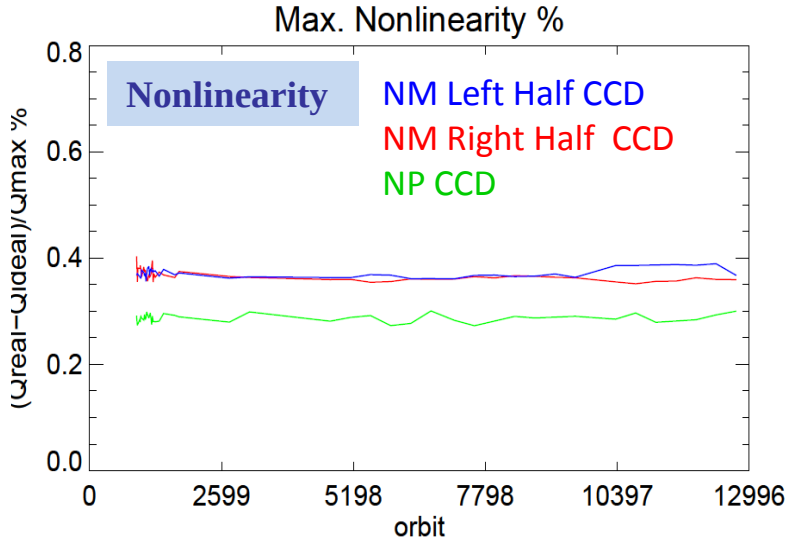


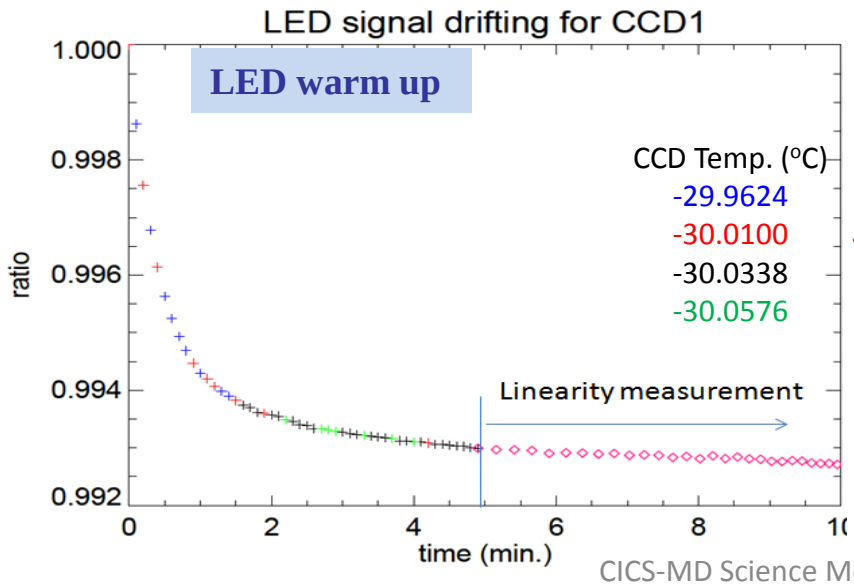


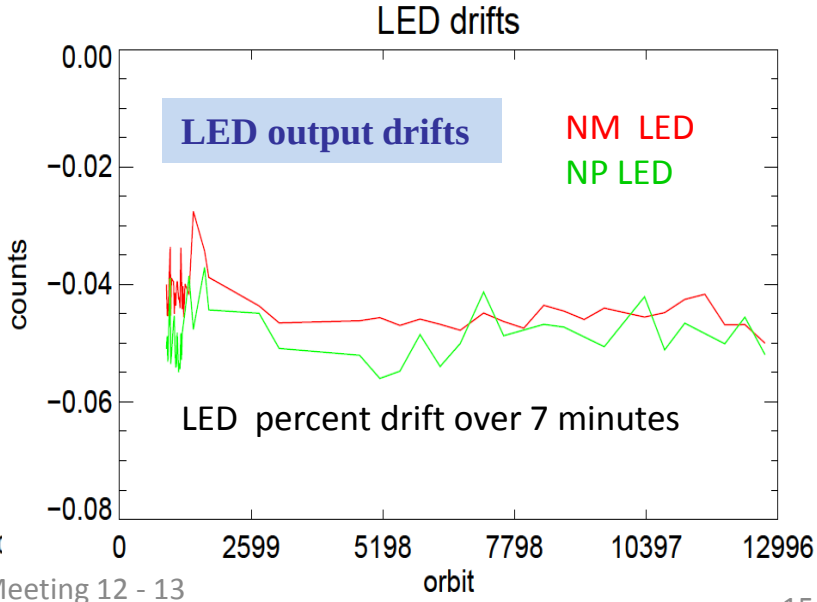


System linearity meets requirement









Summary

- Two sets of comprehensive algorithms have been developed to characterize in-flight sensors and evaluate sensor performance
- Sensors are performing well
  - The sensor orbital performance is stable and generally meets the system. requirements and agrees with the prelaunch results.
  - Optical degradation is less than 1% in the 3-year operation.
  - High resolution data 17x17km for NM and 50X50 for NP are our current focus.
    - Sensor noise monitoring.
    - IDPS Codes modification.
    - Calibration tables (especially the stray light calibration) generation.
- Stray light characterization for higher FOVs is under going
- Temperature change after launch causes dichroic filter shifted
- Wavelength shifts cause data products problems
  - Determine wavelength shift as a function of temperature.
  - Determine cross-track difference and apply a soft calibration.