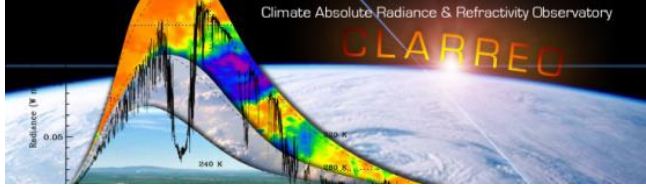

S-NPP VIIRS Reflective Solar Calibration Updates

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Outline

- **Background**
- **VIIRS Reflective Solar Calibration**
  - Activities and Methodologies
- **Calibration Performance and Improvements**
  - SD Degradation (H-factor)
  - RSB Calibration Coefficients (F-factors)
  - Detector Noise Characterization
  - Relative Spectral Response (RSR)
- **Summary**

Background

Visible Infrared Imaging Radiometer Suite

- Spacecraft: Suomi NPP
- Launch: **October 28, 2011**
- Spectral bands: 22 bands with wavelengths from 0.41 to 12.4 μm
- Spatial resolutions: 375 m for I bands and 750 m for M bands
- Heritage instrument: MODIS
- On-board Calibrators: SD, SDSM, BB, SV

- VIIRS on JPSS
  - JPSS-1 (L-2017) – Sensor TVAC testing completed
  - JPSS-2 (L-2020) – Under development
  - JPSS-3 and beyond

VIIRS and MODIS Spectral Bands

16 Moderate (radiometric) bands, 5 Imaging bands, 1 DNB

VIIRS Band	Spectral Range (um)	Nadir HSR (m)	MODIS Band(s)	Range	HSR
DNB	0.500 - 0.900				
M1	0.402 - 0.422	750	8	0.405 - 0.420	1000
M2	0.436 - 0.454	750	9	0.438 - 0.448	1000
M3	0.478 - 0.498	750	3 10	0.459 - 0.479 0.483 - 0.493	500 1000
M4	0.545 - 0.565	750	4 or 12	0.545 - 0.565 0.546 - 0.556	500 1000
I1	0.600 - 0.680	375	1	0.620 - 0.670	250
M5	0.662 - 0.682	750	13 or 14	0.662 - 0.672 0.673 - 0.683	1000 1000
M6	0.739 - 0.754	750	15	0.743 - 0.753	1000
I2	0.846 - 0.885	375	2	0.841 - 0.876	250
M7	0.846 - 0.885	750	16 or 2	0.862 - 0.877 0.841 - 0.876	1000 250
M8	1.230 - 1.250	750	5	SAME	500
M9	1.371 - 1.386	750	26	1.360 - 1.390	1000
I3	1.580 - 1.640	375	6	1.628 - 1.652	500
M10	1.580 - 1.640	750	6	1.628 - 1.652	500
M11	2.225 - 2.275	750	7	2.105 - 2.155	500
I4	3.550 - 3.930	375	20	3.660 - 3.840	1000
M12	3.660 - 3.840	750	20	SAME	1000
M13	3.973 - 4.128	750	21 or 22	3.929 - 3.989 3.929 - 3.989	1000 1000
M14	8.400 - 8.700	750	29	SAME	1000
M15	10.263 - 11.263	750	31	10.780 - 11.280	1000
I5	10.500 - 12.400	375	31 or 32	10.780 - 11.280 11.770 - 12.270	1000 1000
M16	11.538 - 12.488	750	32	11.770 - 12.270	1000

1 DNB

14 RSB
(0.4-2.3 μm)

Dual Gain Bands:
M1-M5, M7, M13

7 TEB

VIIRS Reflective Solar Calibration

- **Solar Calibration**
  - SD calibration through an attenuation screen every orbit
  - SD degradation tracked by the on-board SDSM initially operated daily and currently 3 times per week
- **Lunar Calibration**
  - Regularly scheduled at the "same" phase angle: -51° (initially at -55°)
  - Viewed through Space View (SV) port
  - Performed via spacecraft roll maneuvers
  - Collected via data sector rotation
  - Calibration referenced to the ROLO model

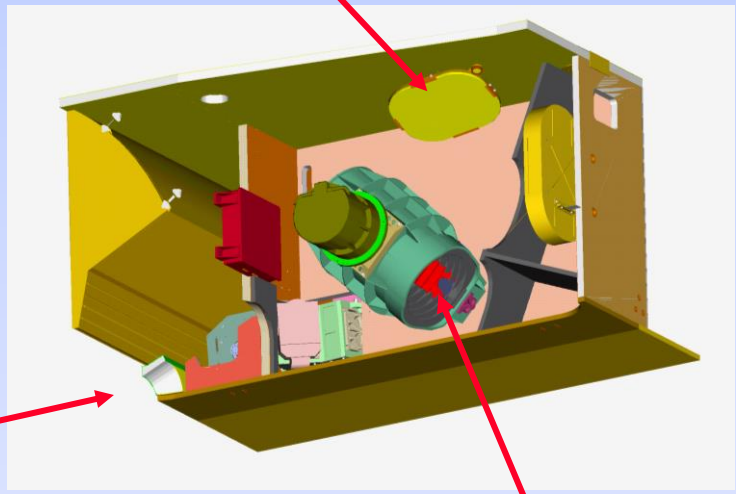
Solar Cal: Traceability and Accuracy; Lunar Cal: Stability

VIIRS Solar and Lunar Calibration Schematic

Solar Diffuser
Stability Monitor

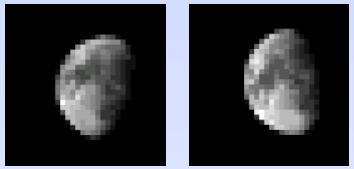
SD with a fixed screen
Solar calibration each orbit

Daily operation => 3 per week
(8 min => 5 min)
Future reduction of frequency
and operation time



8-9 / year

Spacecraft roll
maneuvers



Extended
SV Port

Rotating Telescope Assembly (RTA)

VIIRS Solar and Lunar Calibration Methodologies

EV

$$L_{EV} = F \cdot \left(c_0 + c_1 \cdot dn_{EV} + c_2 \cdot dn_{EV}^2\right) / RVS(\theta_{EV})$$

SD

$$L_{SD_Meas} \propto \left(c_0 + c_1 \cdot dn_{SD} + c_2 \cdot dn_{SD}^2\right)$$

$$L_{SD_Comp} \propto E_{SUN} \cdot BRDF_{SD}(t) \cdot \tau_{SDS}$$

$$F_{SD} = \frac{L_{SD_Comp}}{L_{SD_Meas}}$$

SDSM

Determine SD degradation

$$H_{SD} = \frac{dn_{SDSM_SD}}{dn_{SDSM_Sun}}$$

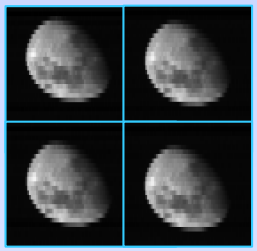
Moon

$$J_{Moon_Meas} \propto \sum_{s,d} [c_0 + c_1 \cdot dn_{Moon}(s,d) + c_2 \cdot dn_{Moon}(s,d)^2]$$

$$J_{Moon_Comp}$$

From ROLO

$$F_{Moon} = \frac{J_{Moon_Comp}}{J_{Moon_Meas}}$$

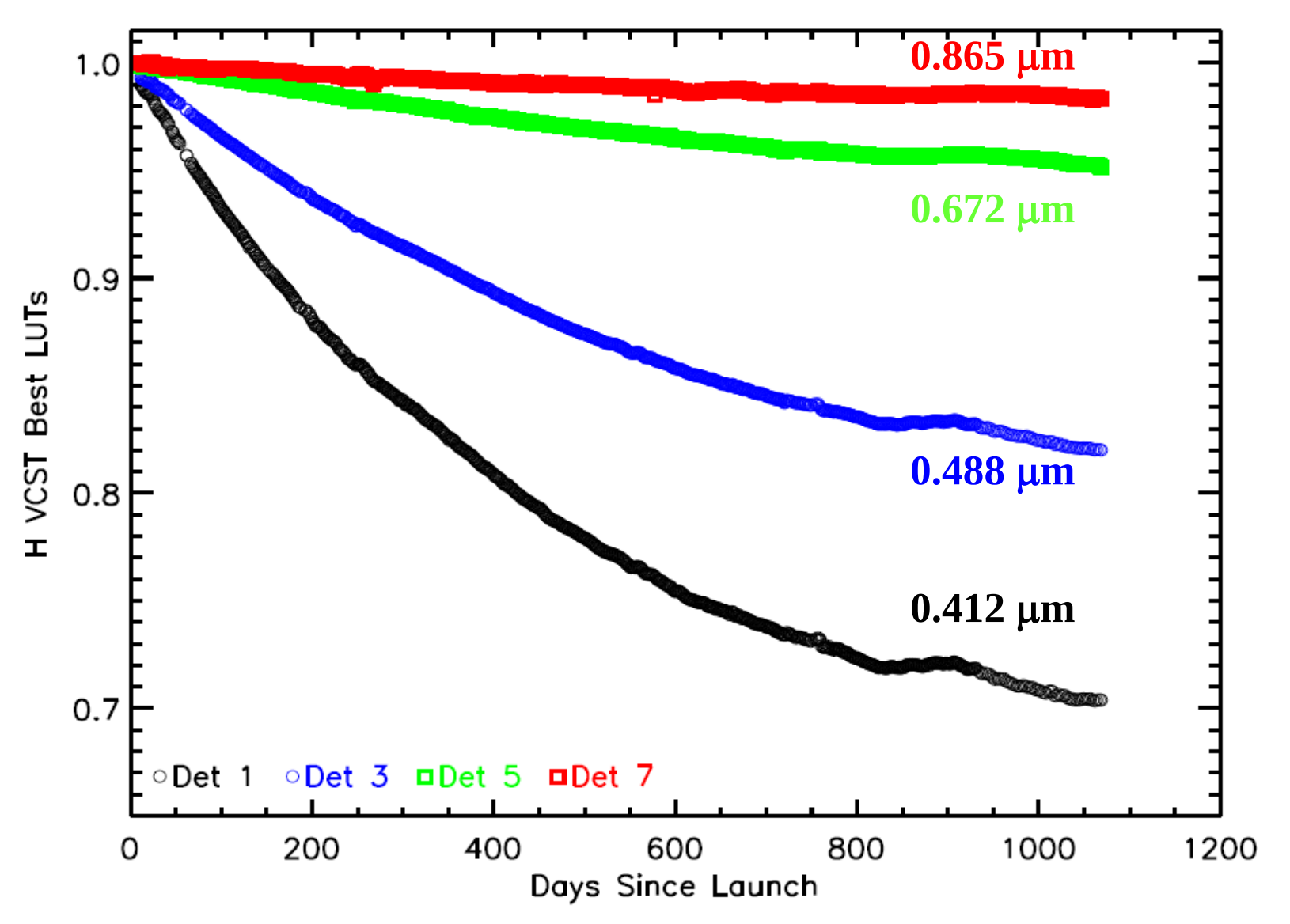


dn: VIIRS/SDSM detector "corrected" responses

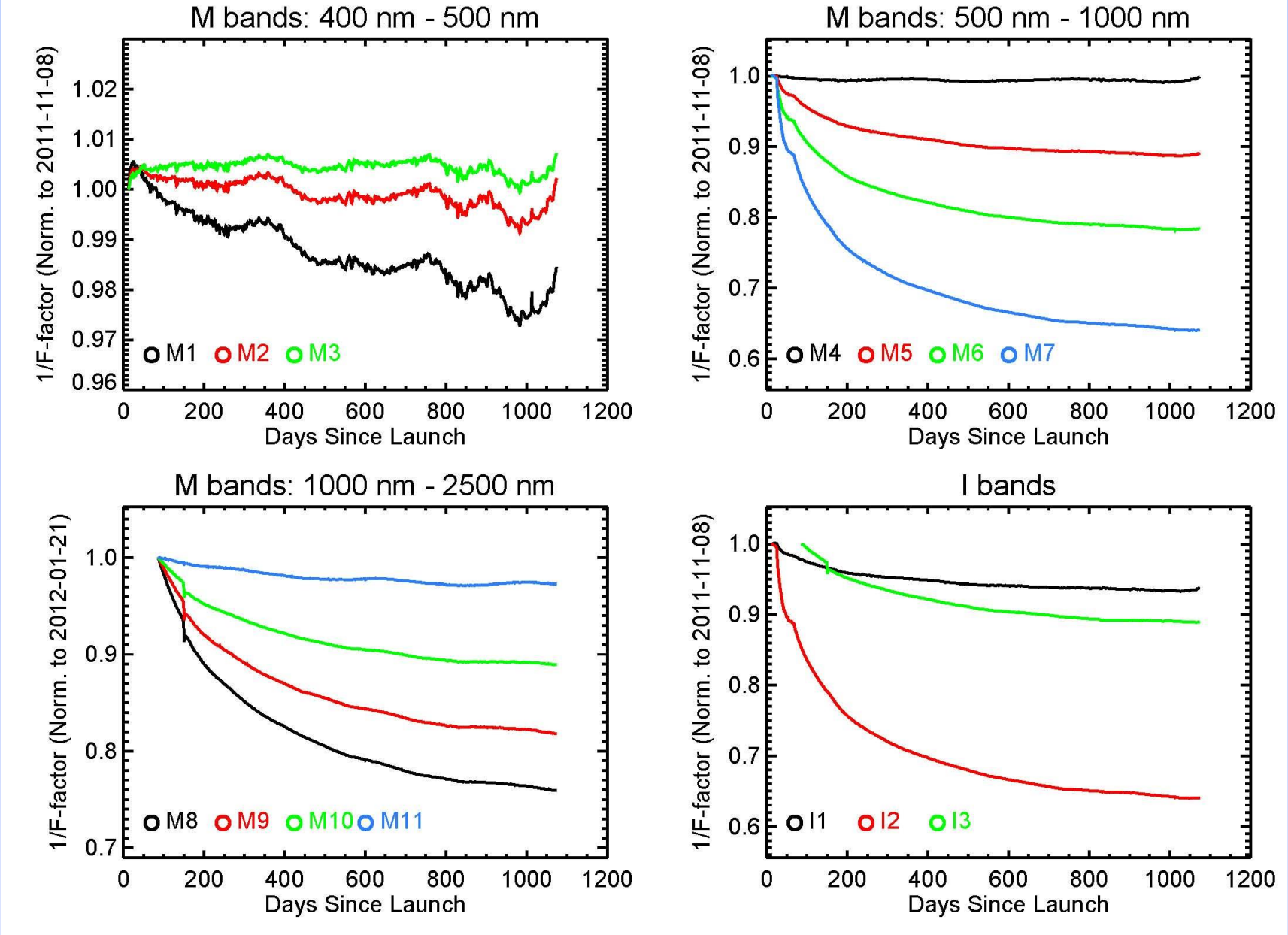
Performance Assessments and Improvements

- **Performance Parameters**
  - SD degradation (H-factors)
  - RSB response trends (F-factors) from SD and lunar observations
  - Signal to Noise Ratios (SNRs)
  - Relative Spectral Response (RSR)
- **Improvements**
  - SDSM screen (τ_{SDSM}) and SD screen (τ_{SD}) and BRF
    - Yaw maneuver data
    - Yaw maneuver and on-orbit data
  - Modulated RSR
    - Impact due to wavelength dependent RTA mirror degradation
  - Correction for the solar vector error (discovered in the IDPS SDR Geo library file)
  - DNB calibration and validation

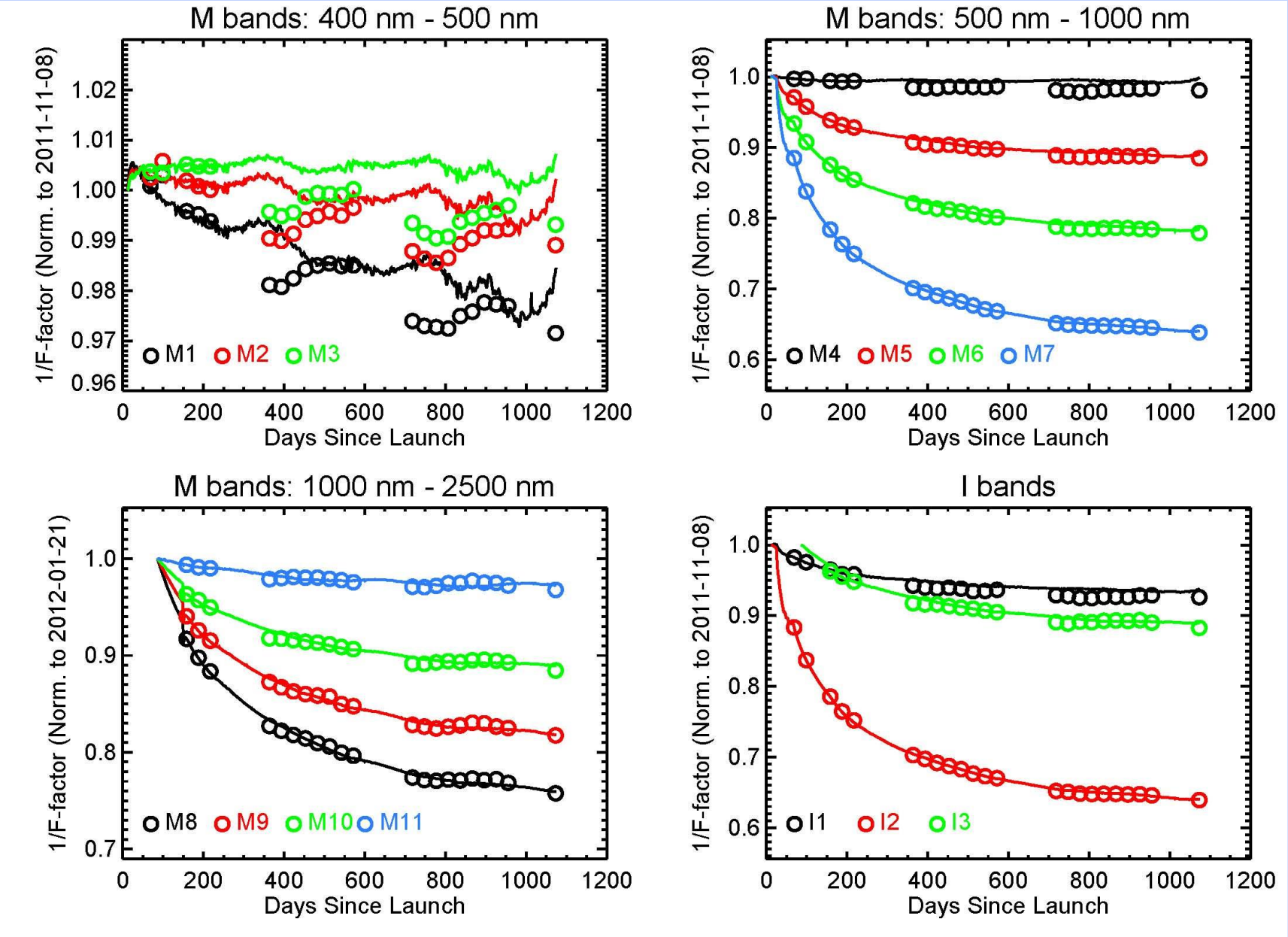
H-factors from SDSM - SD Degradation



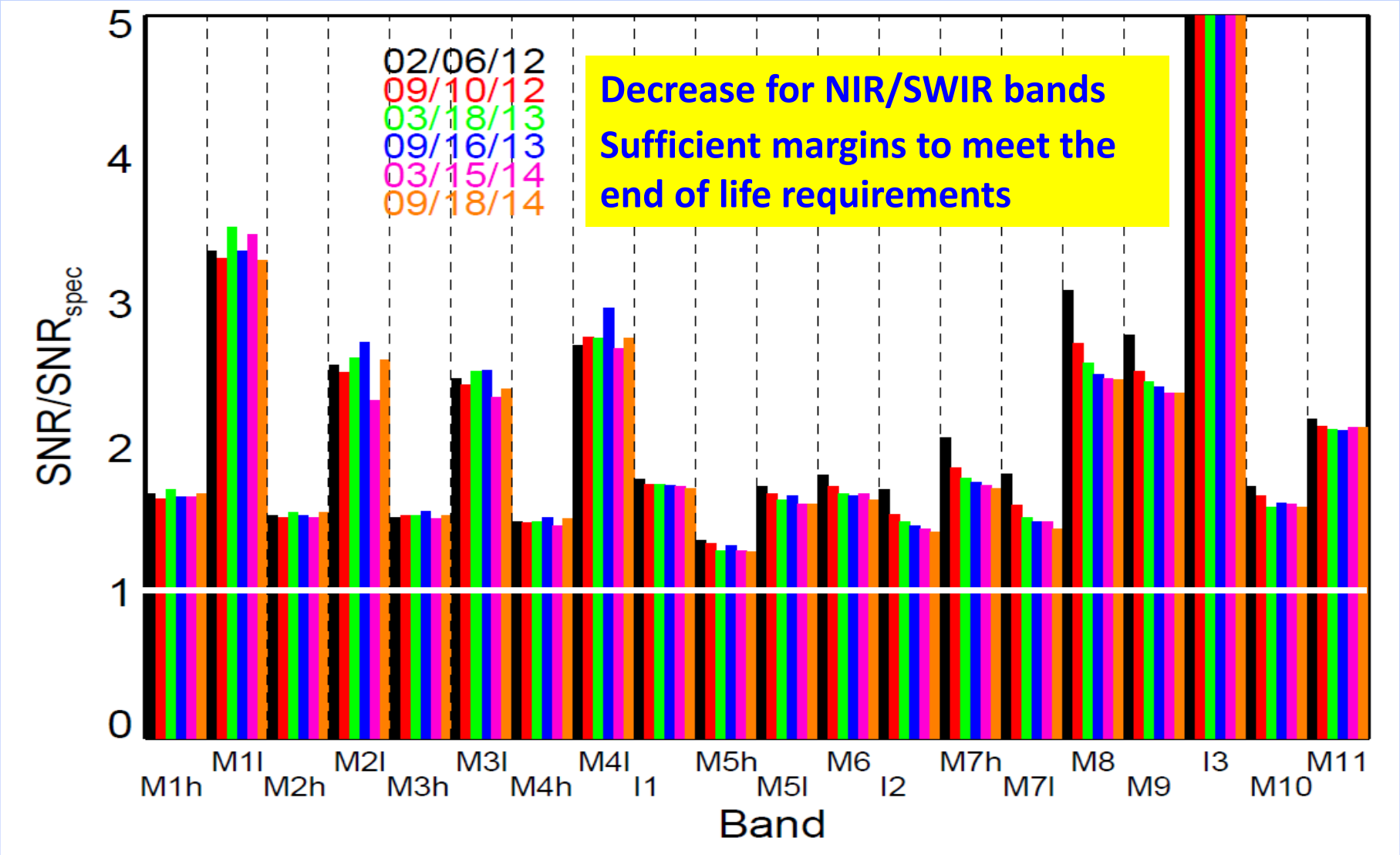
F-factors from SD (Detector Gains ∝ 1/F)



Comparison of F-factors from Solar and Lunar Calibration



Signal-to-Noise Ratios (SNR)



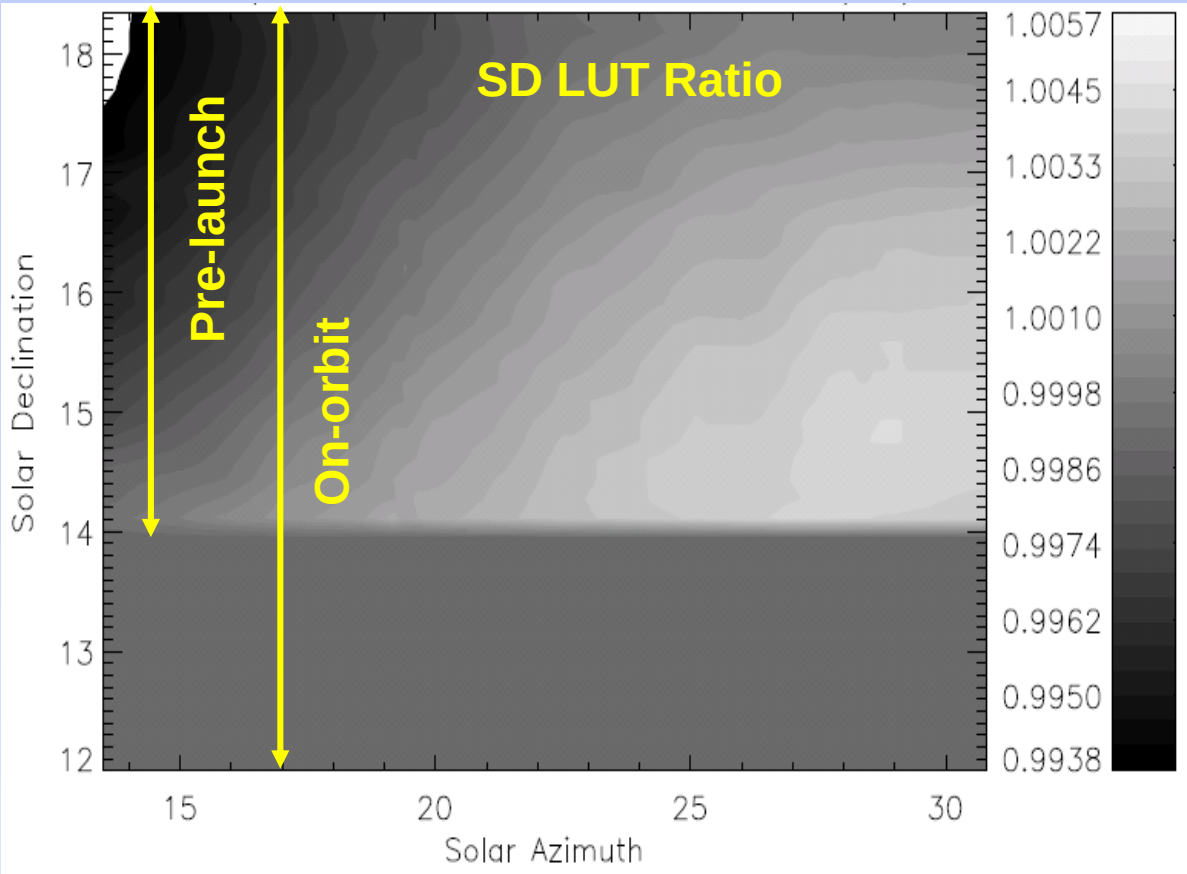
SNR/SNR$_{SPEC}$ > 1: performance better than specified requirements

SDSM Screen (τ_{SDSM}) and SD Screen (τ_{SD}) and BRF

Initial SD and SDSM LUTs derived from pre-launch measurements

On-orbit improvements made using data collected during SC yaw maneuvers

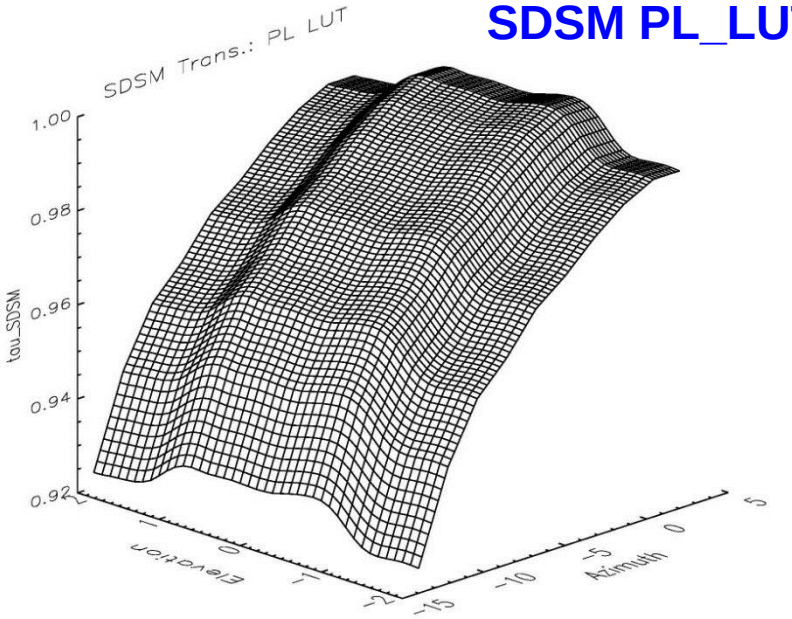
Latest improvements achieved by adding regular on-orbit calibration data to fill the gaps in yaws



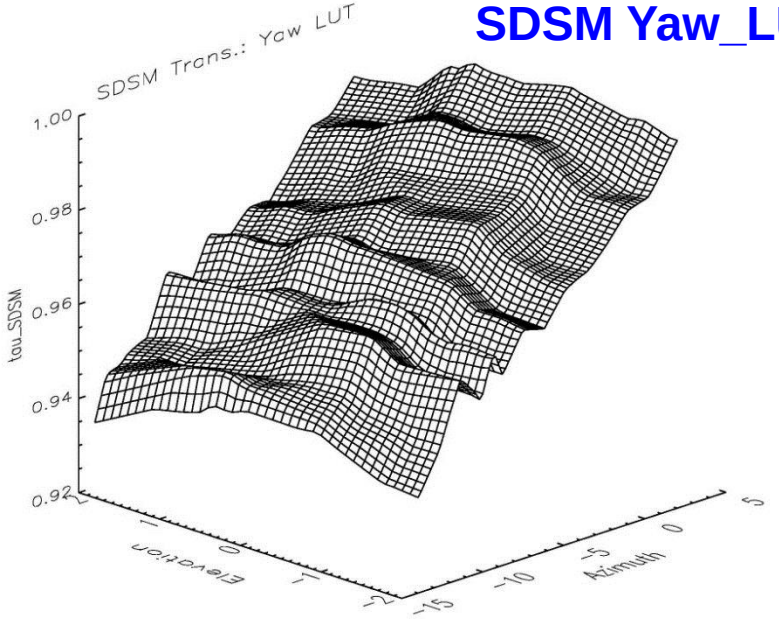
On-orbit LUT:

Larger range
Better resolution
Same wavelength

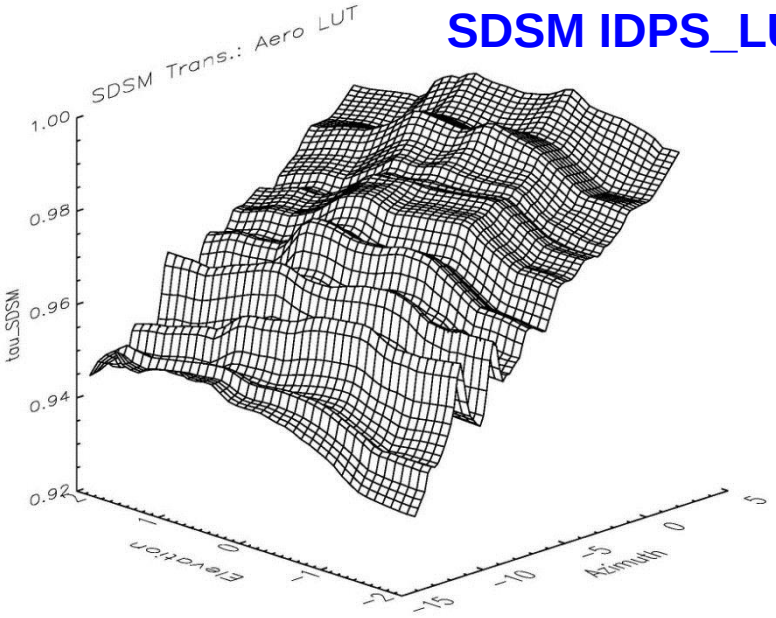
SDSM PL_LUT



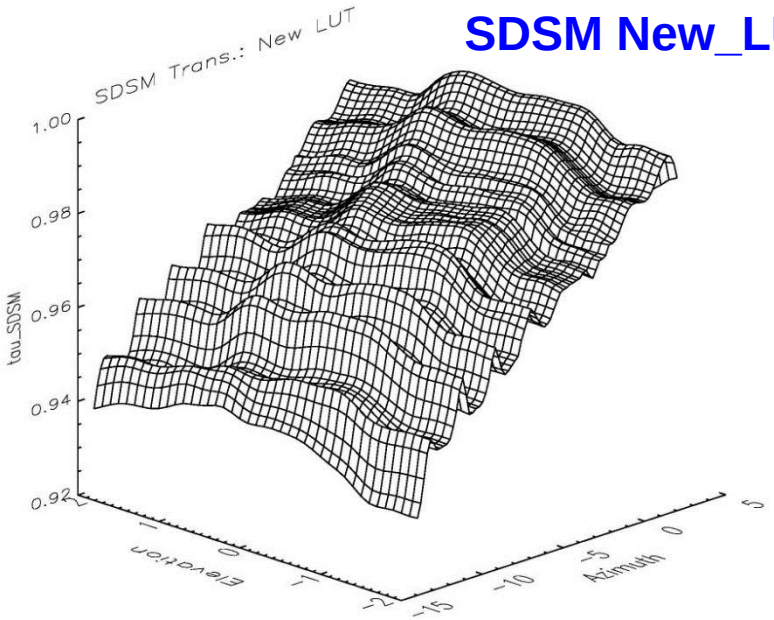
SDSM Yaw_LUT

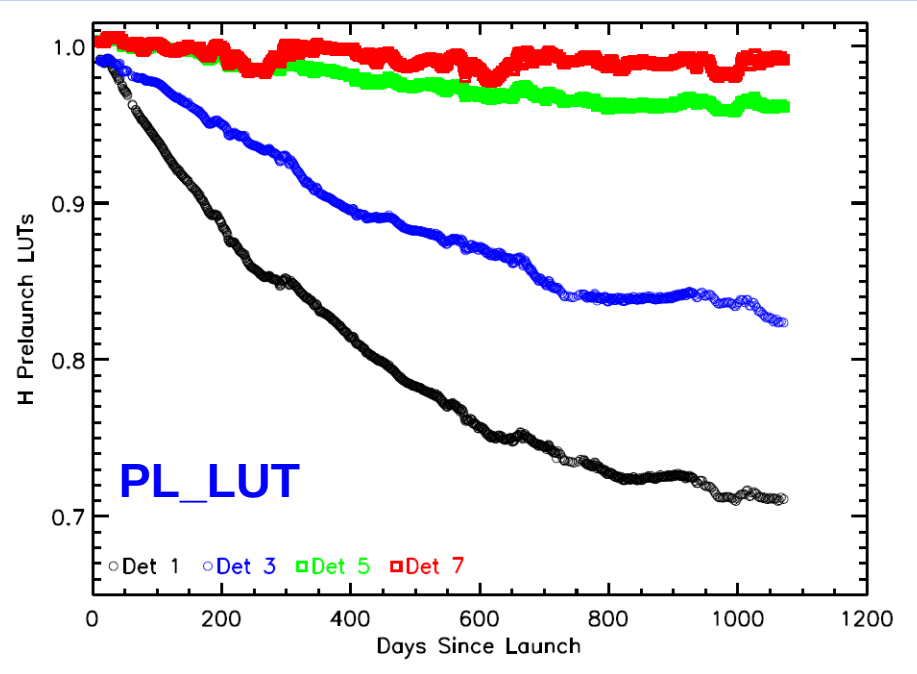


SDSM IDPS_LUT



SDSM New_LUT



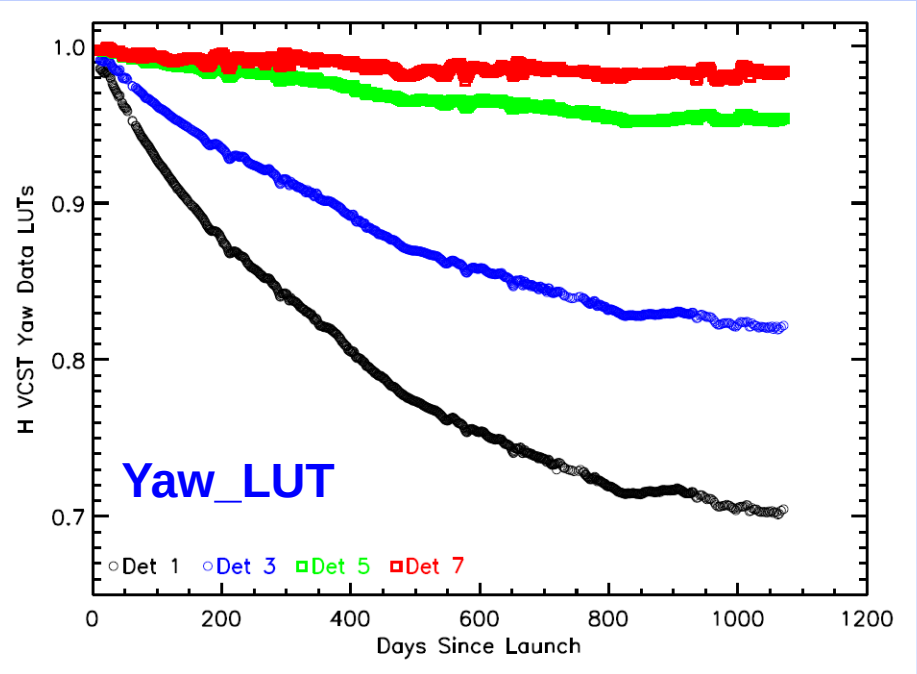


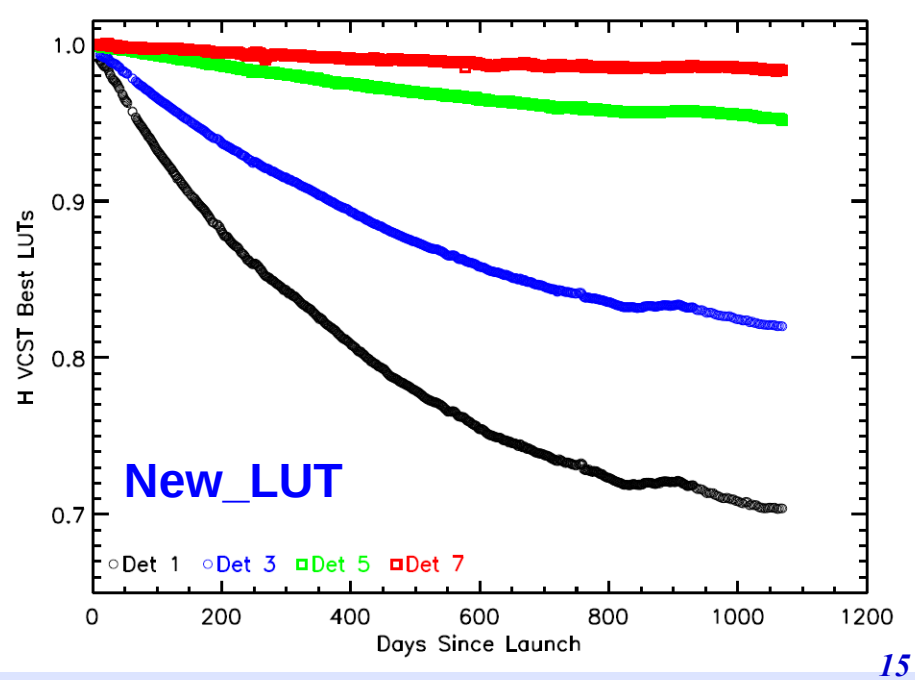
H-factors using LUTs derived from:

Pre-launch measurements

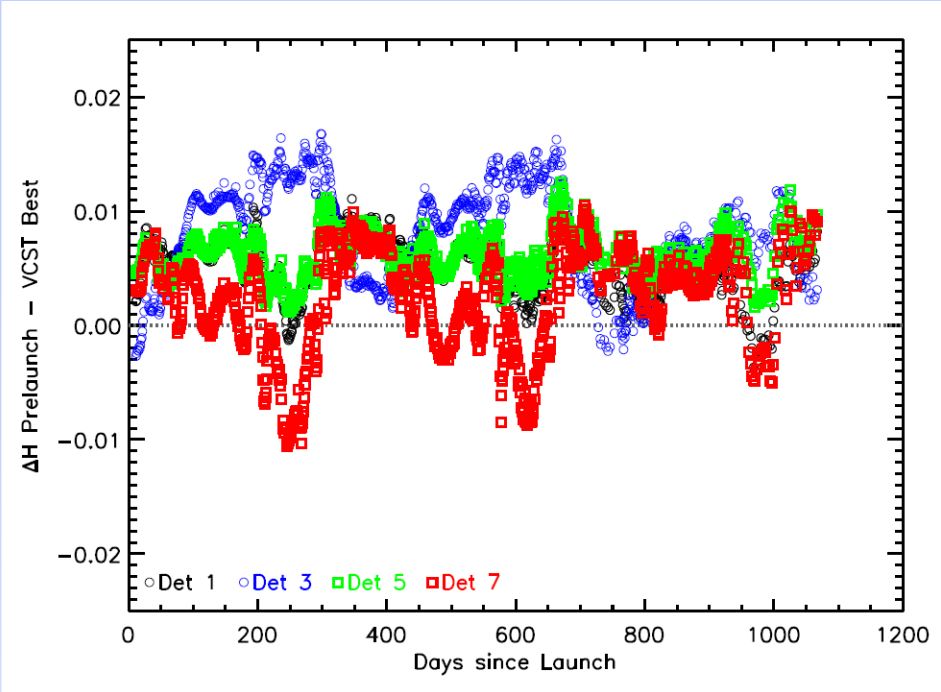
Yaw maneuver data

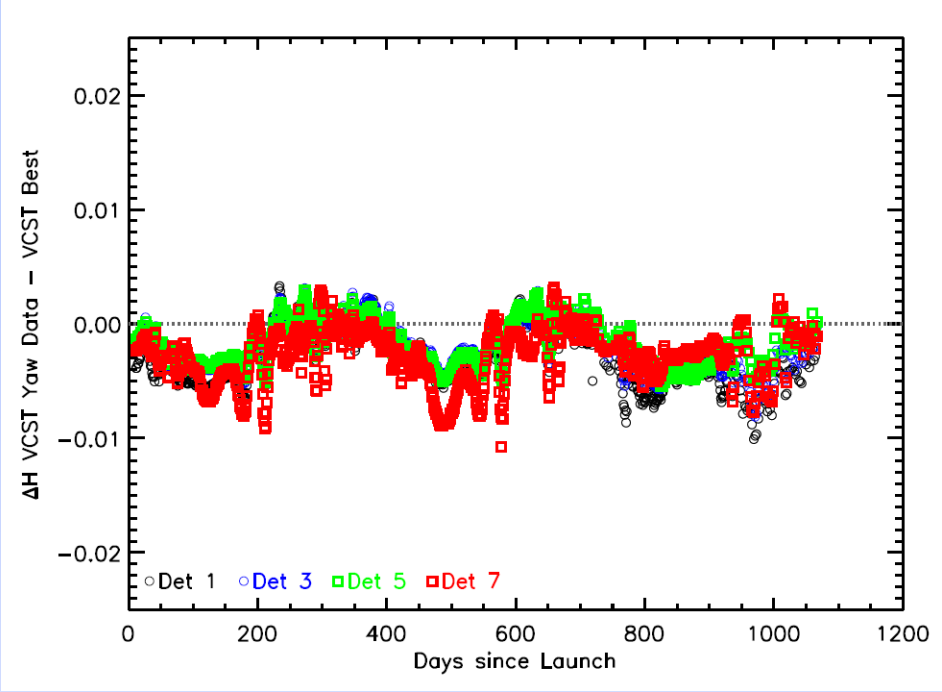
Yaw + selected on-orbit data





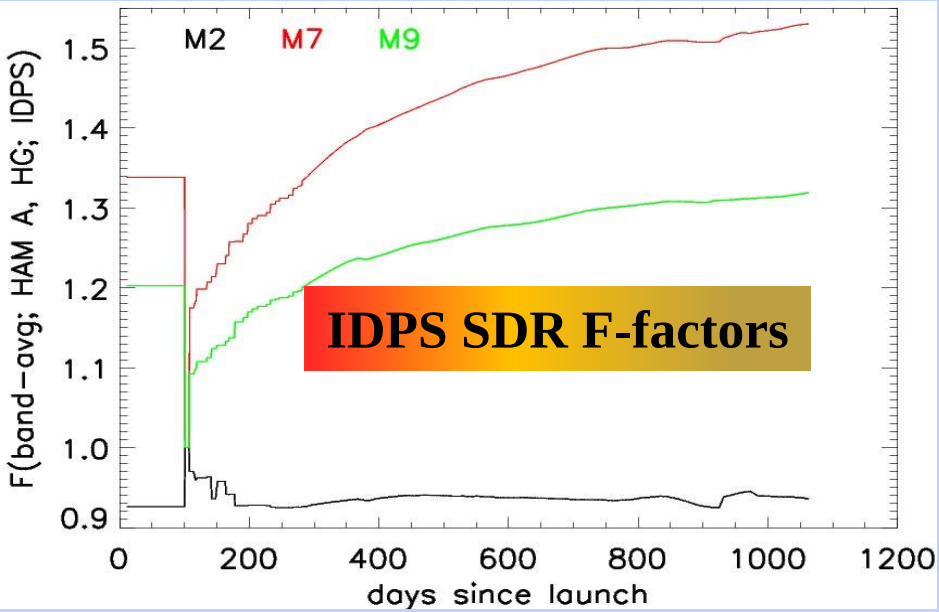
Comparison of H-factors derived from different LUTs

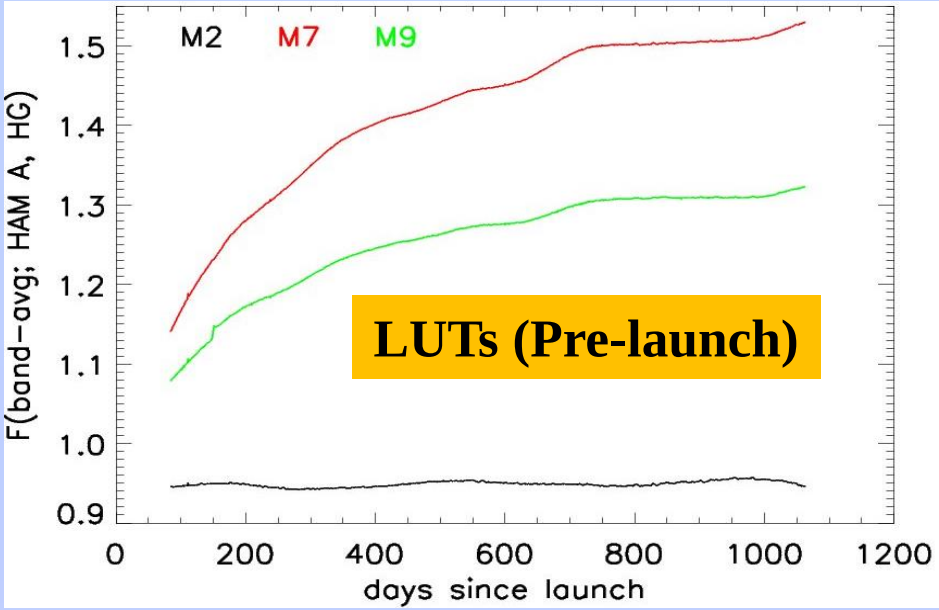


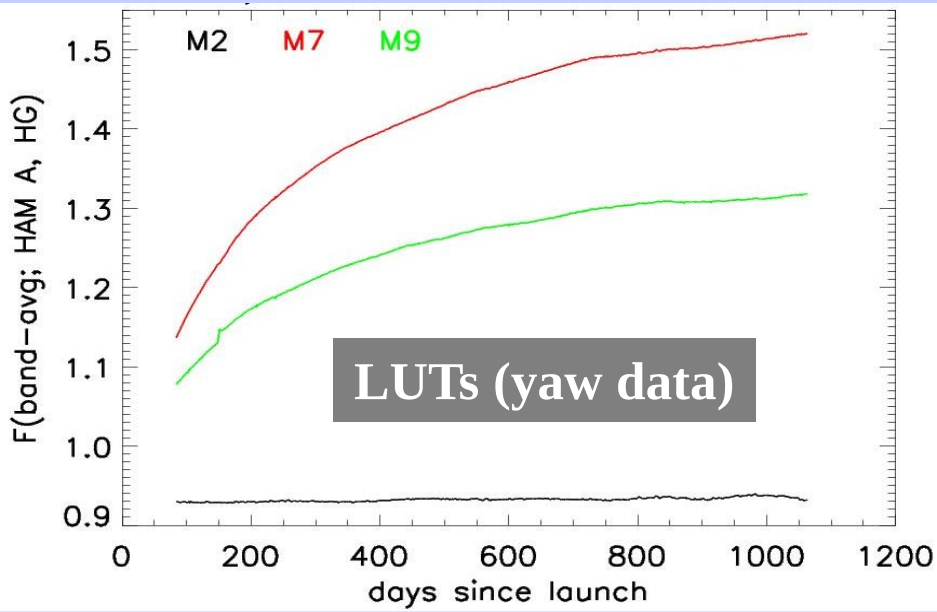


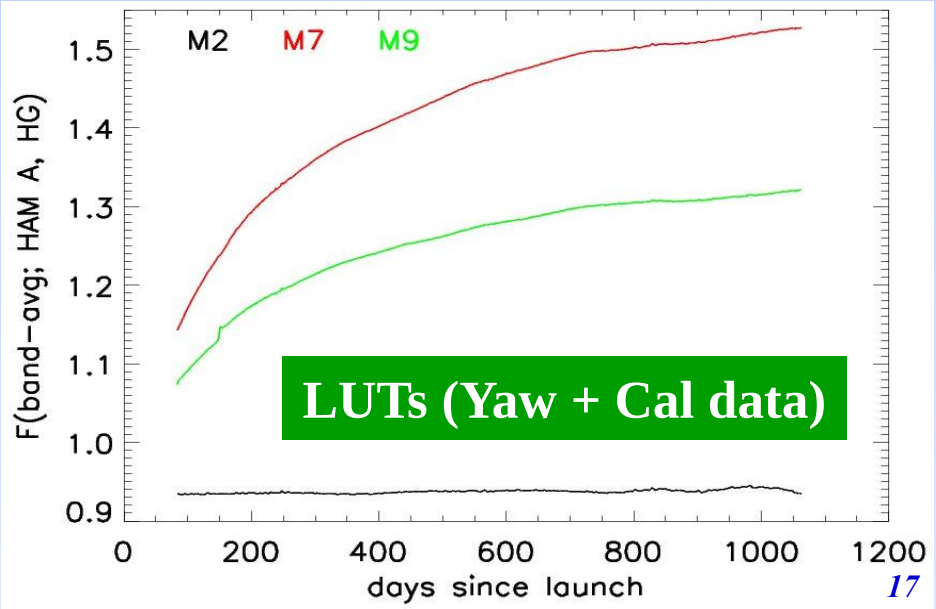
Progress: large adjustments => fine tunings

F-factors (detector responses) derived using different LUTs

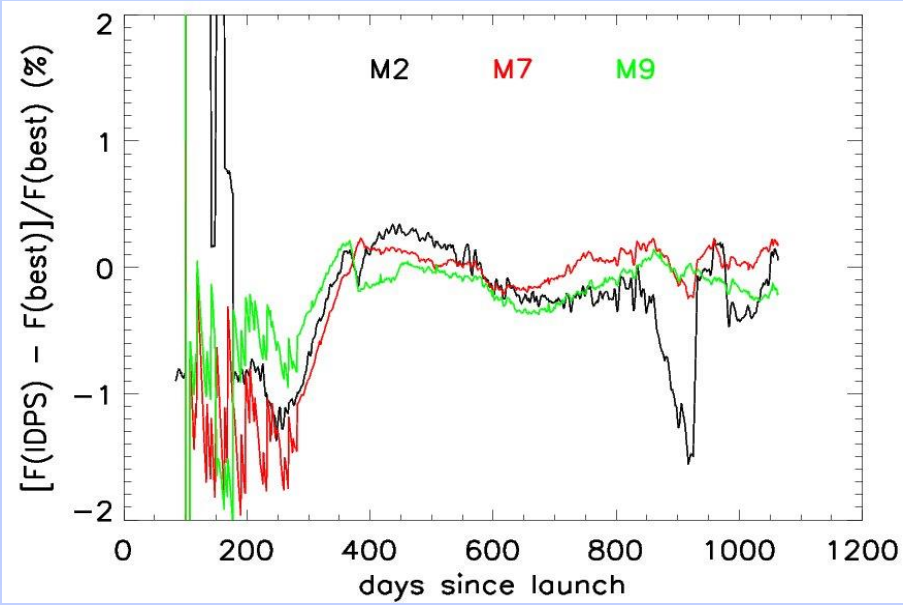


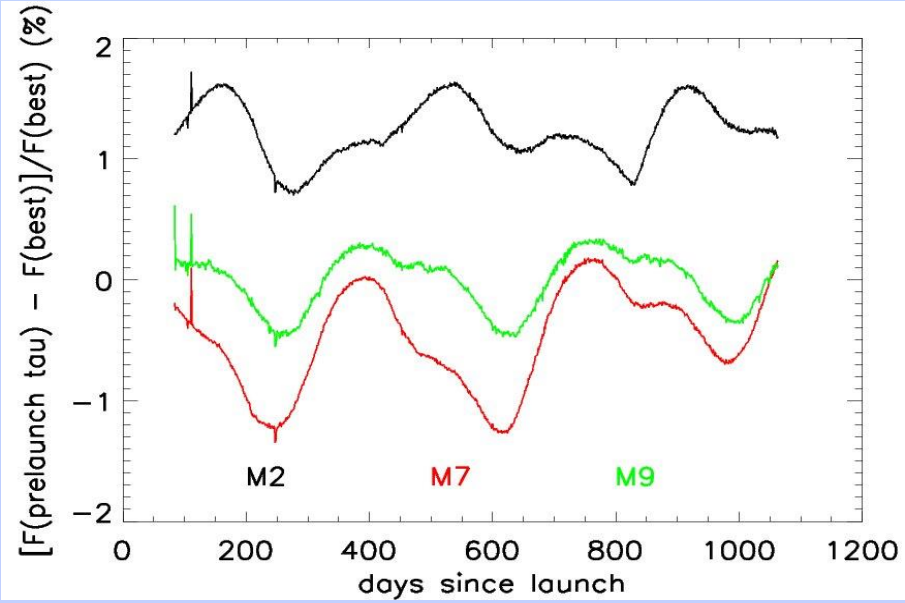


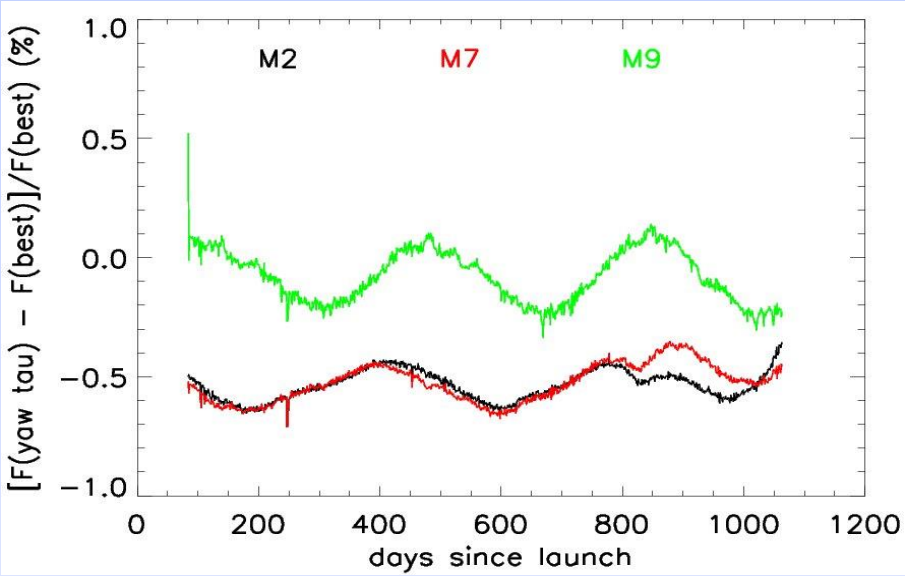




Comparison of F-factors derived using different LUTs



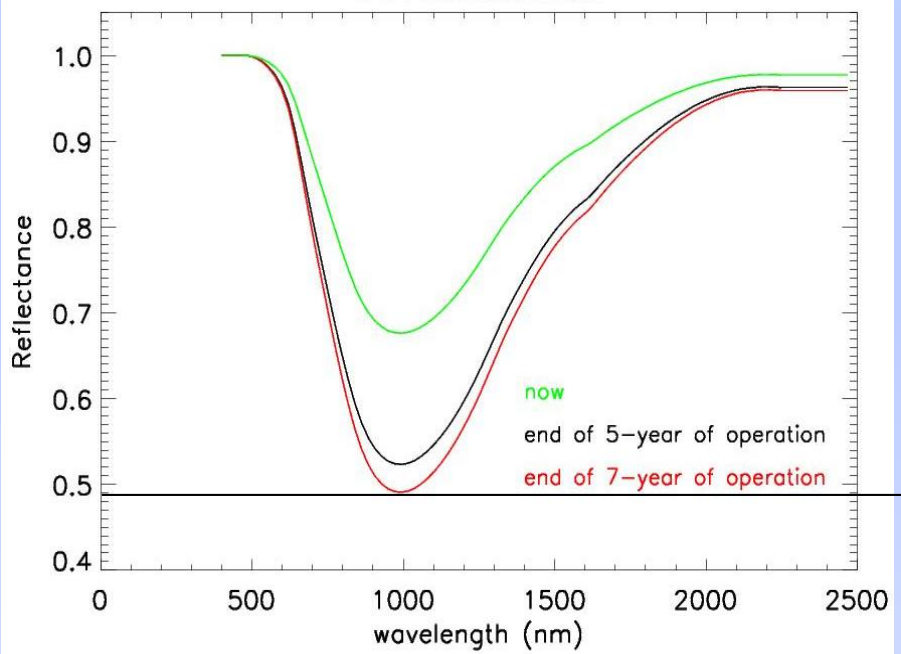




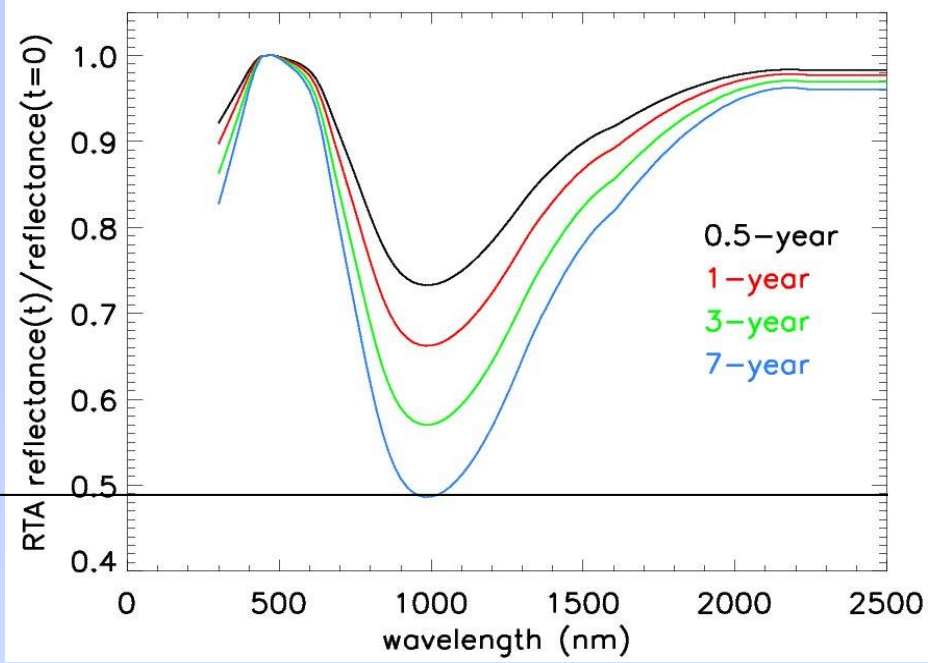
From ±1% to ± 0.5% level of adjustments

Model Predicted NIR/SWIR Response Degradation

Predicted in October 2012

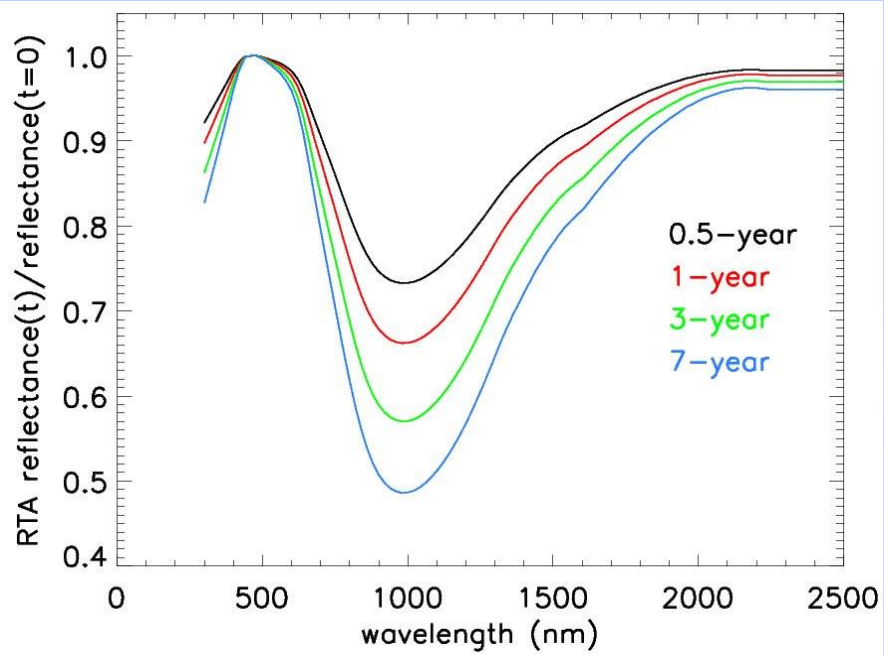


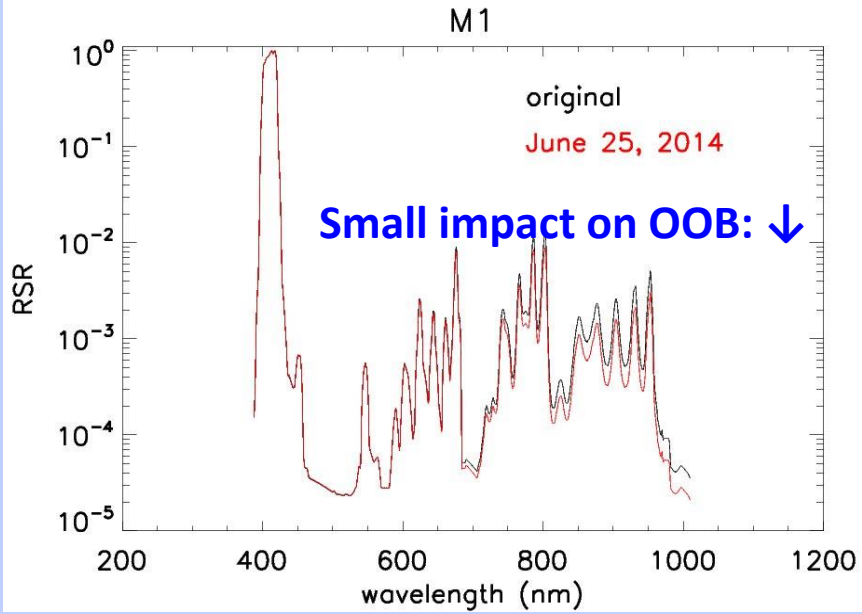
Current Prediction

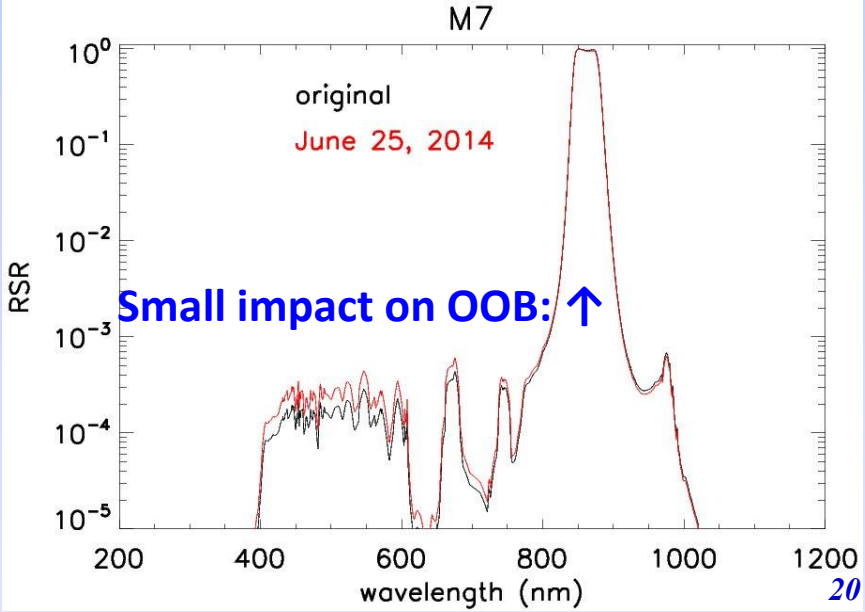


Modulated RSR and Calibration Impact

Mirror Degradation Impact on Sensor Relative Spectral Response (RSR) (IB and OOB)



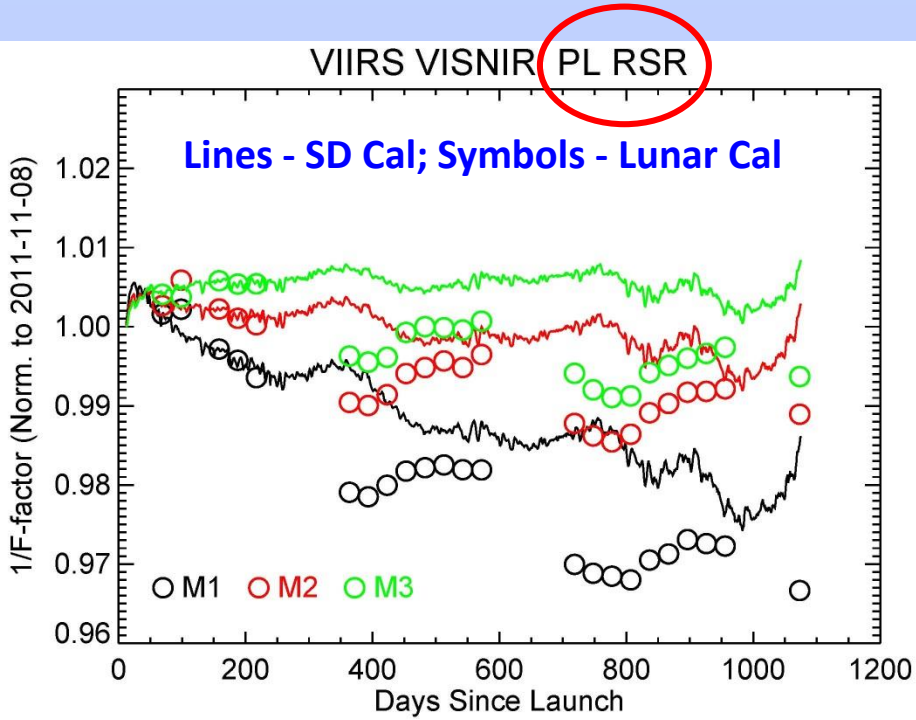


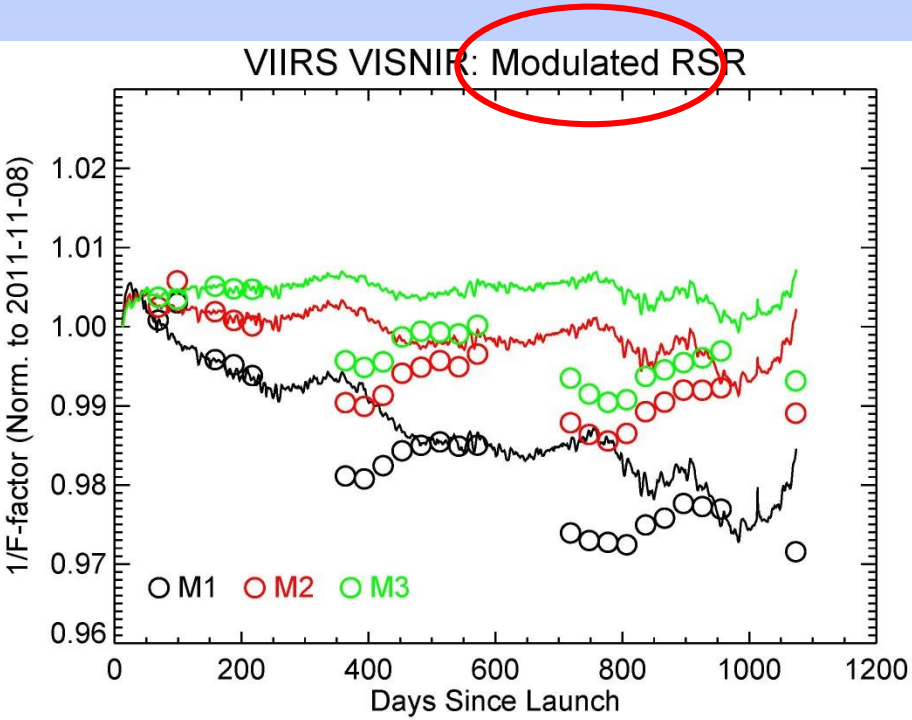


λ dependent optics degradation

Modulated RSR and Calibration Impact

Modulated RSR should be applied to both solar and lunar calibration





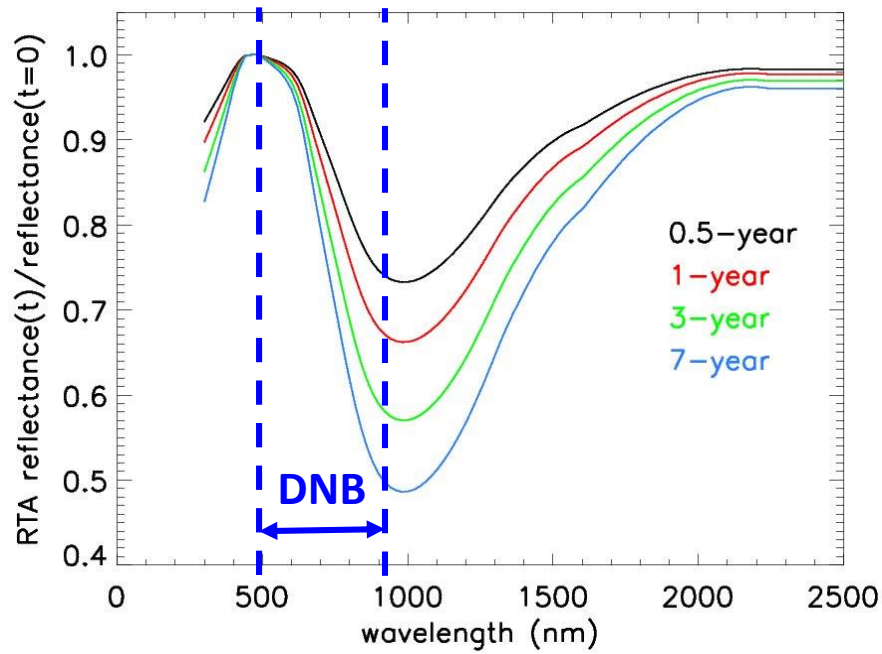
Empirical adjustment (or fitting) can make SD or Lunar calibration agree better, but …

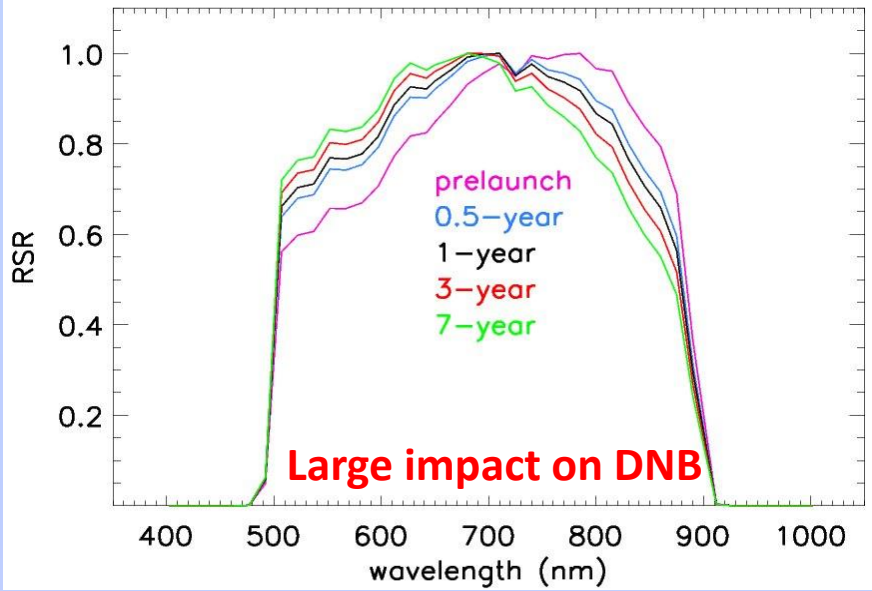
Future effort needed to understand and resolve seasonal variations

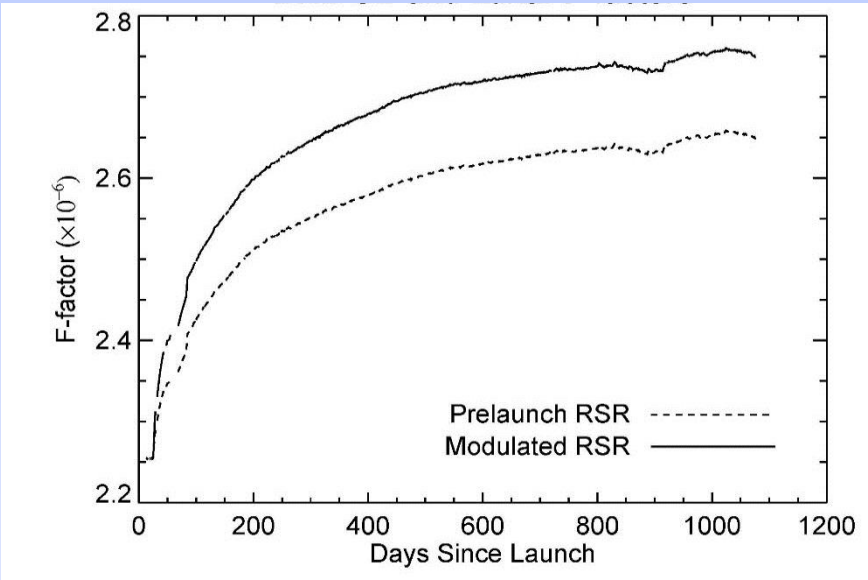
- Lunar model
- SD calibration

Modulated RSR and Calibration Impact

Mirror Degradation Impact on Sensor Relative Spectral Response (RSR) (IB and OOB)

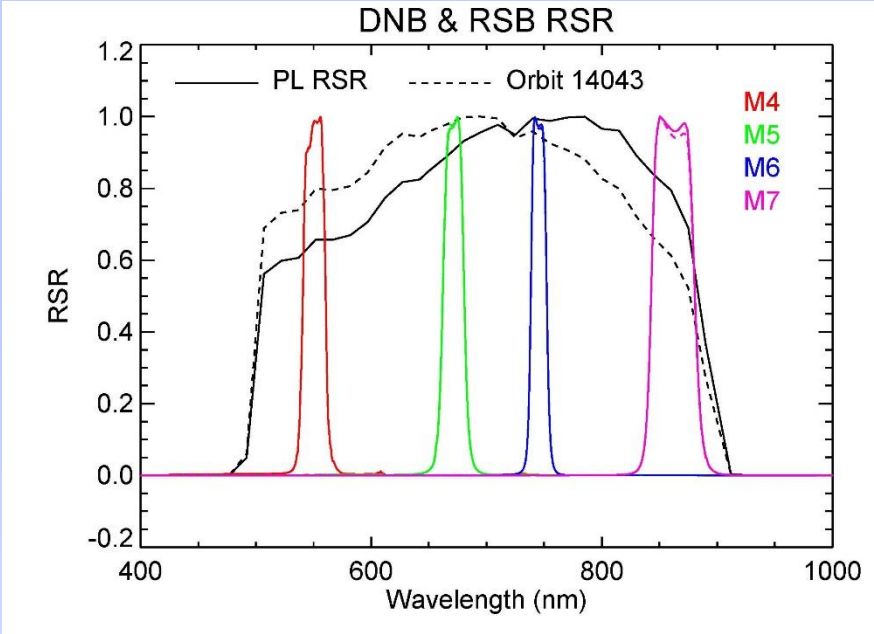


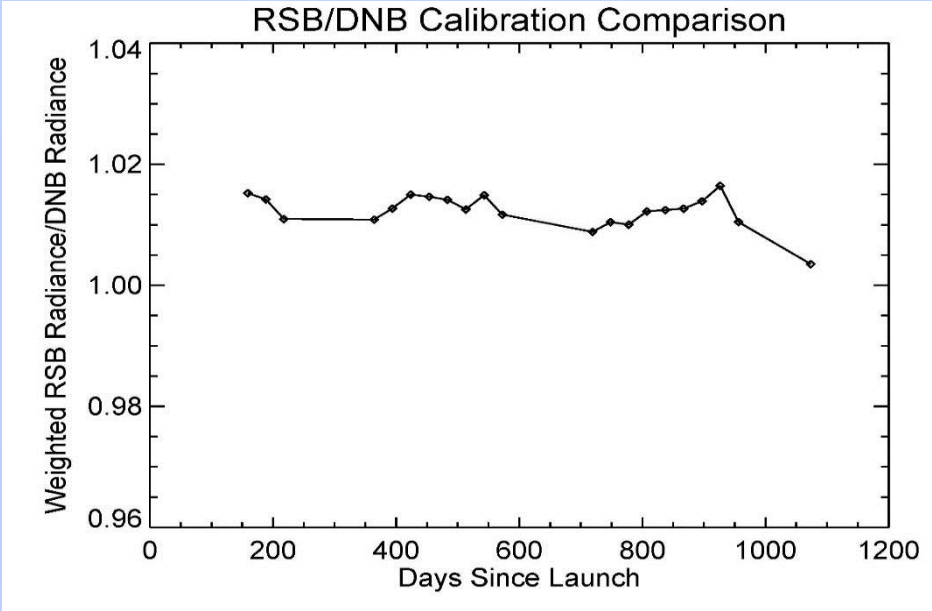


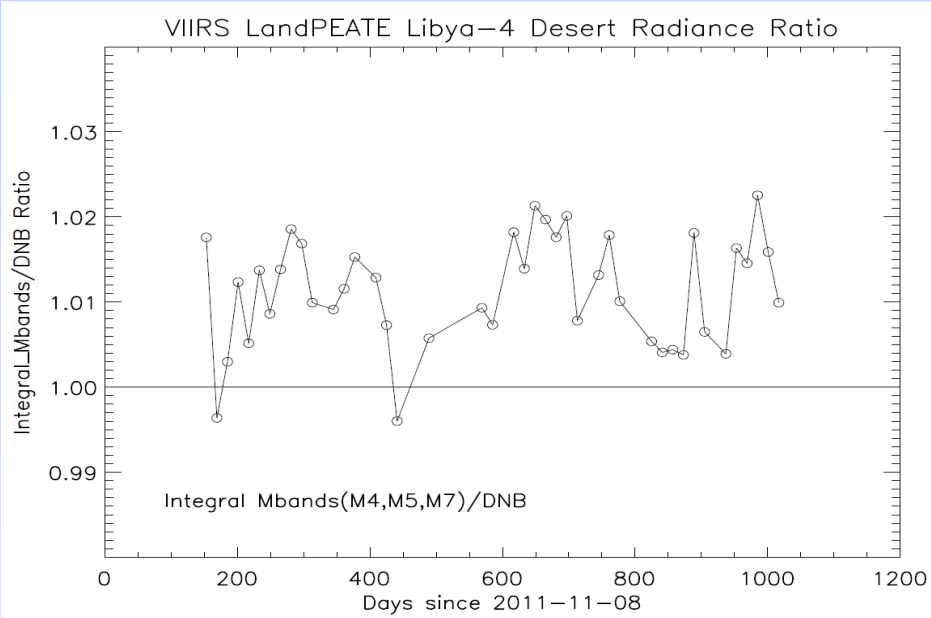


λ dependent optics degradation

DNB and RSB Calibration Inter-comparison

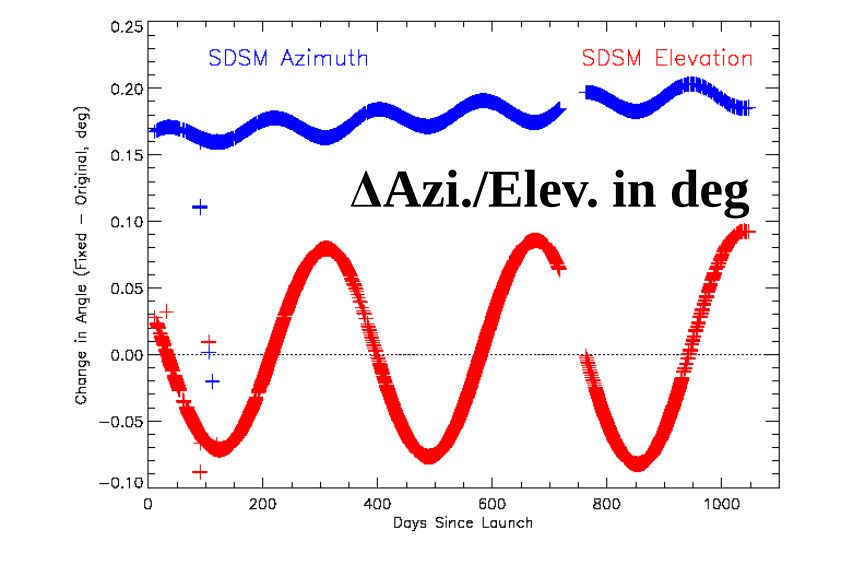


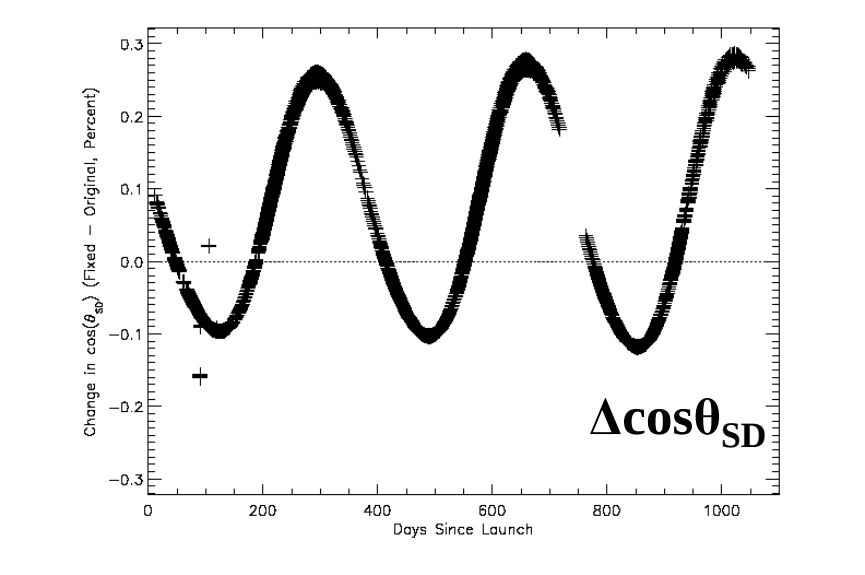




Using M-bands to validate DNB calibration performance

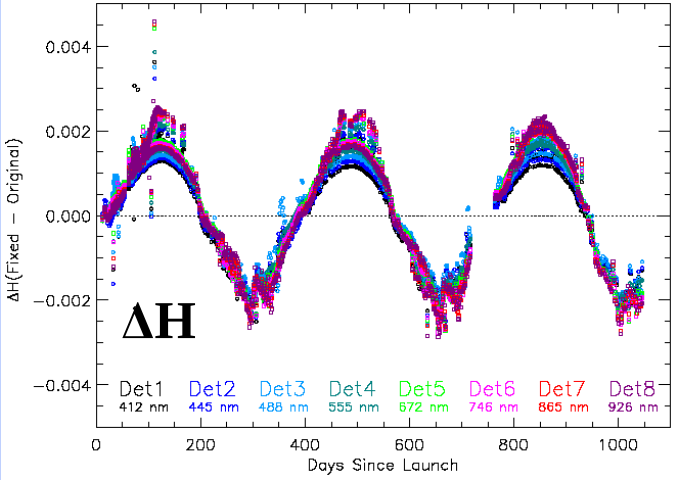
Solar Vector Error (in SDR Common Geo Library)

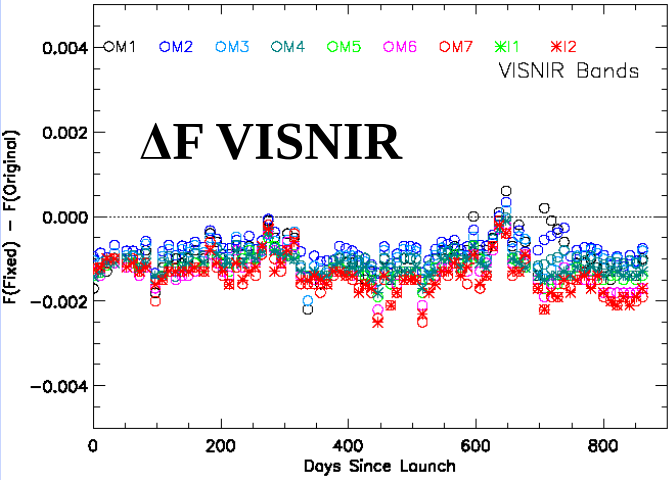


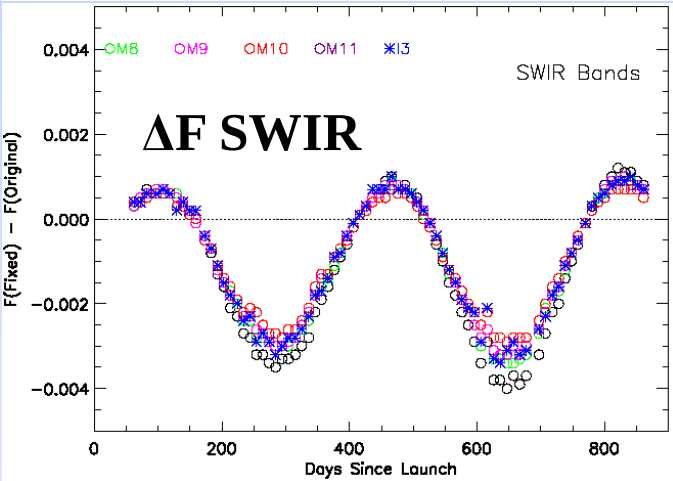


- A mismatch of ECI (Earth-Centered Inertial) frames when computing the transformation to spacecraft frame library leads to a slight, but important (~0.2 deg.) error in the solar angles used in the RSB radiometric calibration.
- The correction for the error has been applied to evaluate the effect on the RSB calibration.
- The cos θ_{SD} factor is used in the H- and F-factor calculations.

Correction for Solar Vector Error







- The correct solar vector is used to re-evaluate the entire algorithm, including developing a new screen based on the new solar vectors.
- The change in the H-factors (top frame) are mainly due to the change of the $1/\cos\theta_{SD}$ term in the calculation.
- The VISNIR F-factors have a $\cos\theta_{SD}$ term, too, which cancels the effect from the H-factors.
- For the SWIR bands, no SD degradation correction applied, so the $\cos\theta_{SD}$ term is not cancelled out. This seasonal oscillation of ~0.5% is in the uncorrected F-factors (bottom frame), but is small compared to the overall change in F.

Summary

- **VIIRS solar and lunar calibration performance has been satisfactory, enabling sensor on-orbit changes to be tracked and corrected**
- **A number of improvements have been made for S-NPP VIIRS RSB solar and lunar calibration**
  - Improved calibration LUTs
  - Modulated RSR (in SD and lunar calibration)
  - Improved DNB calibration and validation
- **Future effort**
  - Understand and resolve small difference between SD and lunar calibration
  - Monitor and improve SWIR calibration
  - Develop consistent calibration LUTs for the entire mission
  - Improve calibration inter-comparison of S-NPP VIIRS and Aqua MODIS RSB

Status of VIIRS SDR and LUTs

- **IDPS VIIRS SDR Code/LUTs (radiometric)**
  - 20 major code versions post launch (current version: Mx8.5); numerous LUT updates.
  - Improved LUT update strategy (on demand -> weekly -> automated).
- **Support Land PEATE SDR Code/LUTs and data reprocess (C1.0 and C1.1)**
  - Independent validation and improvements for SDR code/LUTs.
  - 19 sets of LUTs for VISNIR/SWIR and DNB delivered to Land PEATE for data reprocess and SDR/EDR assessments.
    - Jan 31, 2013: LUTs from Jan 2012 to Jan 2013 generated using IDPS algorithm Mx6.3 but with smoothed functions to remove outliers.
    - Nov 13, 2013: LUTs from Jan 2012 to Oct 2013 generated with calibration improvements based on Mx6.4, including SD/SDSM screen transmission, SD BRDF, RTA mirrors degradation model, modulated RSRs, and smoothed fitting functions.
    - Mar 12, 2014: LUTs from Jan 2012 to Nov 2013 generated with "best" sensor characterization improvements based on Mx7.2 algorithm for Land PEATE reprocess **Collection 1.1**, including DNB Stray Light Correction algorithm and smoothed fitting functions.
    - Oct 15, 2014 – Latest LUTs update for the month of Sep 2014.
  - Future work includes solar vector error correction, update of SD/SDSM screen transmission and SD BRDF LUTs, and update of SD degradation and Cal F-LUT.

CLARREO Related Activities

Jack Xiong attended GSICS Joint Meeting on Research and Data Working Groups at Eumetsat, Darmstadt, Germany (March 24-28, 2014) and gave a presentation on "*From Aqua MODIS to S-NPP VIIRS - Reflective Solar Calibration Reference*" and a presentation on "*MODIS and VIIRS lunar observations*"

Jim Butler and Jack Xiong attended the GSICS Executive Panel meeting in Guangzhou, China (May 16-17, 2014). Jim Butler presented the NASA Report to the GSICS Executive Panel, which included a briefing on CLARREO Status.

Support and participate GSICS organized "Lunar Calibration Workshop"

Wu, A, X. Xiong, Z. Jin, C. Lukashin, B. Wenny, and J. Butler, "*Sensitivity of inter-calibration uncertainty of the CLARREO reflected solar spectrometer features*," accepted for TGRS

Efremova, B., Wu, A., Xiong, X., and Butler, J. "*CLARREO calibration uncertainty assessment tool: status and path forward*," Proc. SPIE 9218, Earth Observing Systems XIX, 92181U (2014), doi:10.1117/12.2061962