Reducing Onboard Calibration Uncertainties for S-NPP VIIRS RSB

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Acknowledgements:

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S-NPP/JPSS VIIRS SDR Team

MODIS Characterization Support Team (MCST), NASA GSFC

JPSS STM, NOAA, College Park, MD, May 14, 2014

Outline

- **Background**
- **RSB On-orbit Calibration**
- **Calibration Improvements and Discussions**
  – New SD and SDSM screen transmission (or VF)
  – Correction for the solar vector error
  – Impact assessment due to modulated RSR and mitigation strategy
  – Lunar calibration improvement (working with USGS and CNES)
  – SWIR Calibration (MODIS lessons)
- **Future Work and Summary**

Background

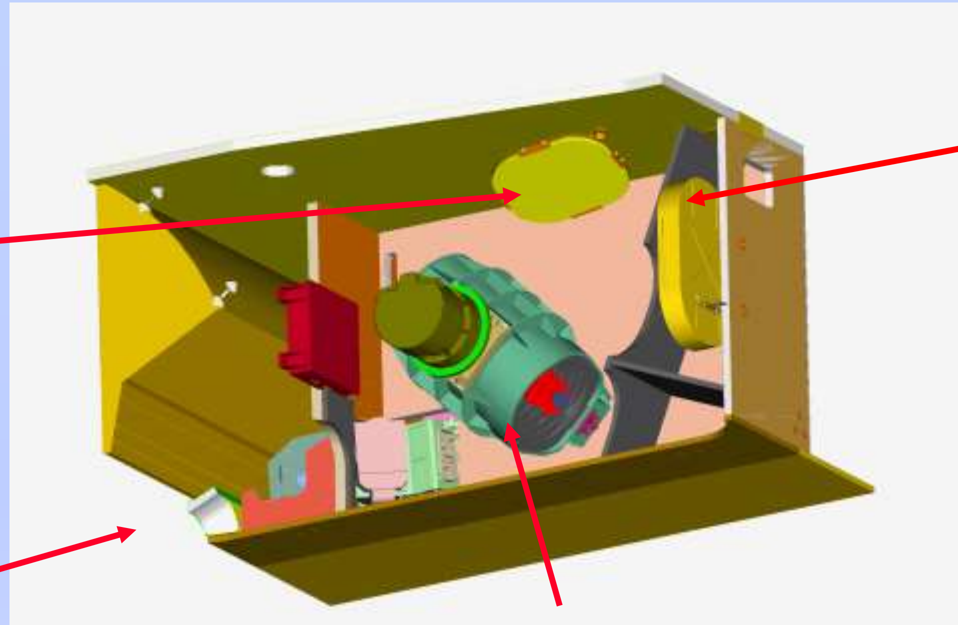
Visible Infrared Imaging Radiometer Suite (VIIRS)

- **Key instrument on S-NPP and future JPSS satellites**
  - S-NPP launched on October 28, 2011
  - JPSS-1 launch in 2017
    - Sensor ambient phase 1&2 completed
    - Sensor TVAC testing in July, 2014
- **Strong MODIS heritage**
  - Spectral band selection
  - On-board calibrators
  - Operation and calibration
    - Strategies for planning/scheduling
    - Data analysis methodologies / tools

S-NPP VIIRS provides linkage btw EOS (MODIS) and future JPSS (VIIRS) and extends long-term data records for studies for the Earth's land, oceans, and atmosphere

VIIRS On-board Calibrators (MODIS Heritage)

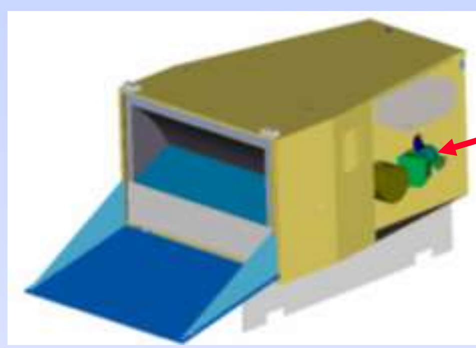
Solar Diffuser



Blackbody

Extended SV Port (Lunar Observations)

Rotating Telescope Aft Optics and HAM



Solar Diffuser Stability Monitor

VIIRS RSB On-orbit Calibration

On-orbit Calibration Methodologies:

- **Solar Calibration (RSB)**
  - Quadratic calibration algorithm
  - Linear calibration coefficients derived/updated from SD observations
  - SD degradation tracked by SDSM
- **Lunar Calibration (RSB)**
  - Regularly scheduled at the "same" phase angles
  - Observed through instrument SV port with a data sector rotation
  - Implemented via S/C roll maneuvers (some constraints)
  - Referenced to the ROLO model (USGS)

Calibration Improvements and Discussions

- New SD and SDSM screen transmission (or VF)
- Correction for the solar vector error
- Impact assessment due to modulated RSR and mitigation strategy
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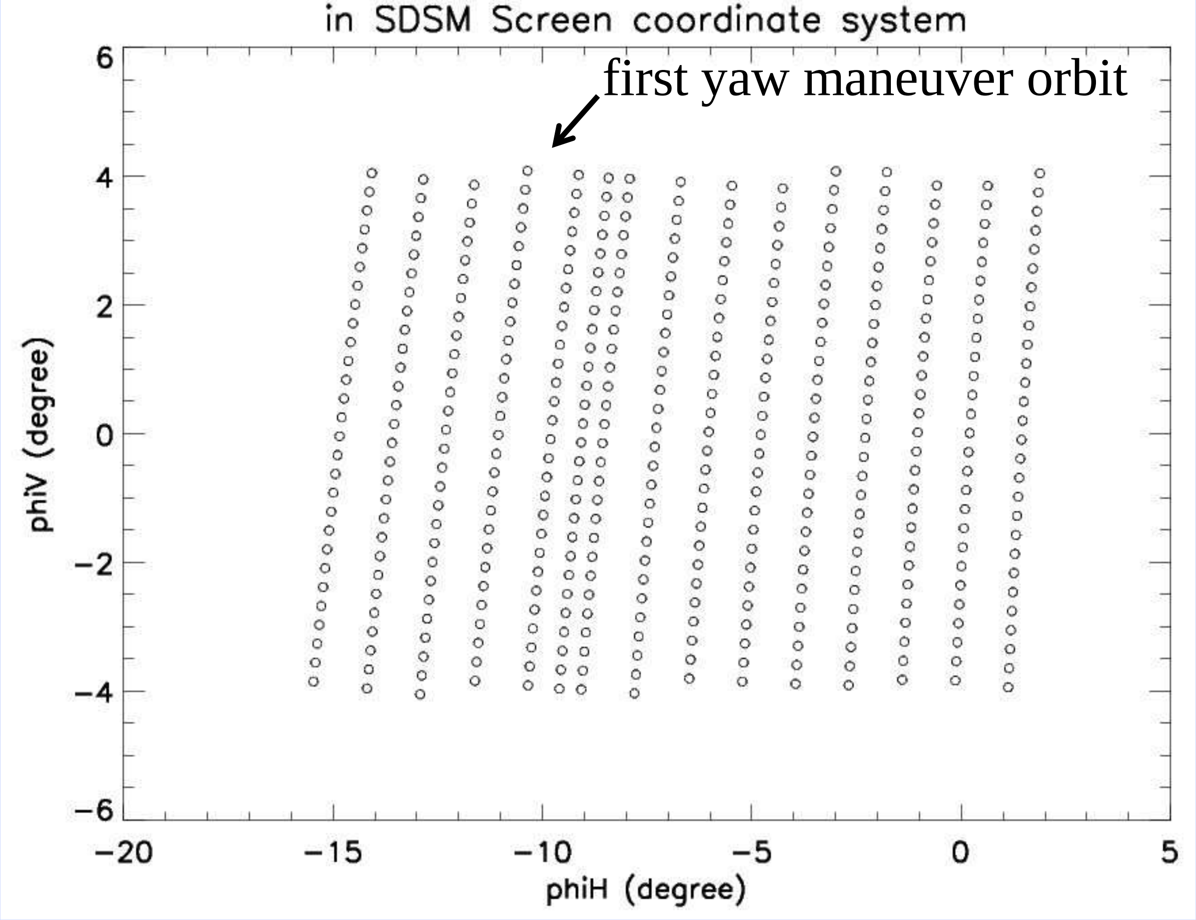
New SD and SDSM Transmission Screens

Yaw maneuver solar angles (SDSM screen coord.)

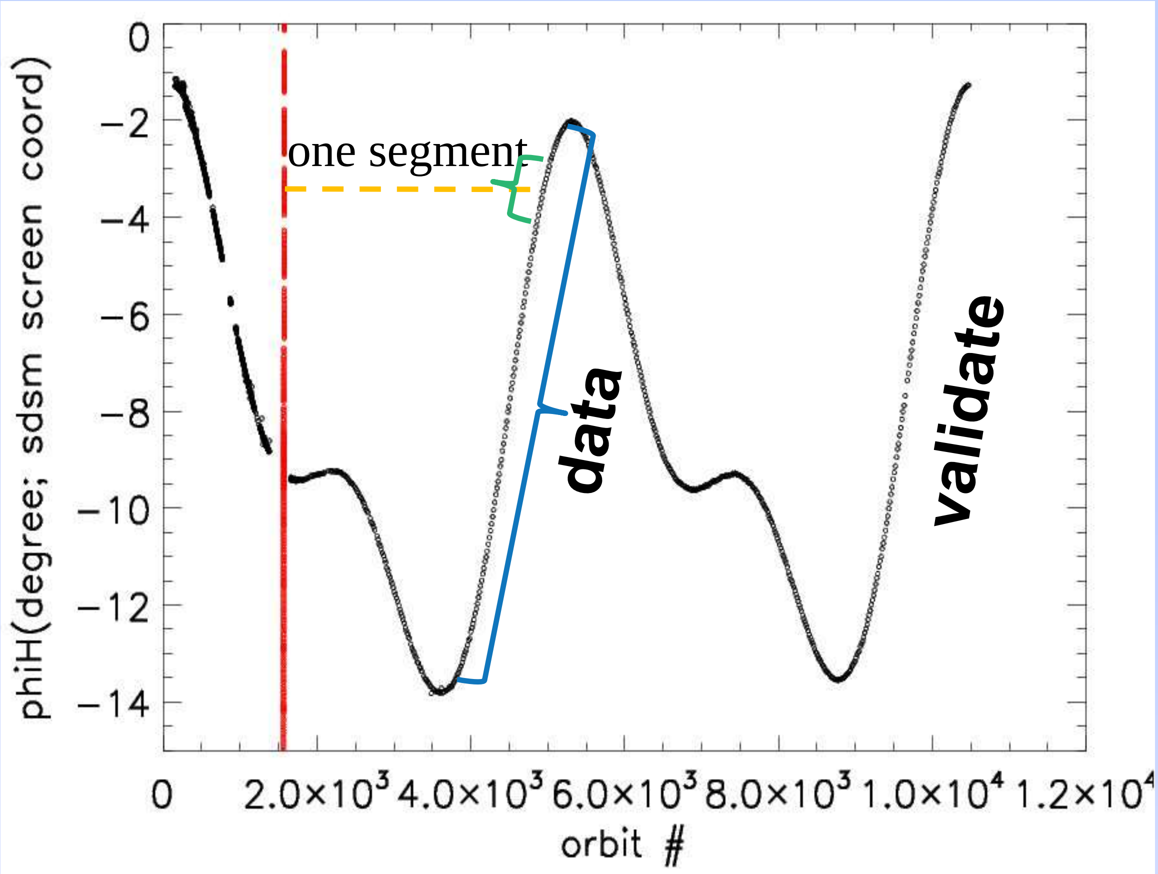


(when the SDSM sees the sun)

Large step size in phiH

Unable to resolve the screen transmittance in detail, resulting in large undulation in the H-factor

Regular on-orbit data



Very fine step size in phiH -> resolve the transmittance in detail

Procedure

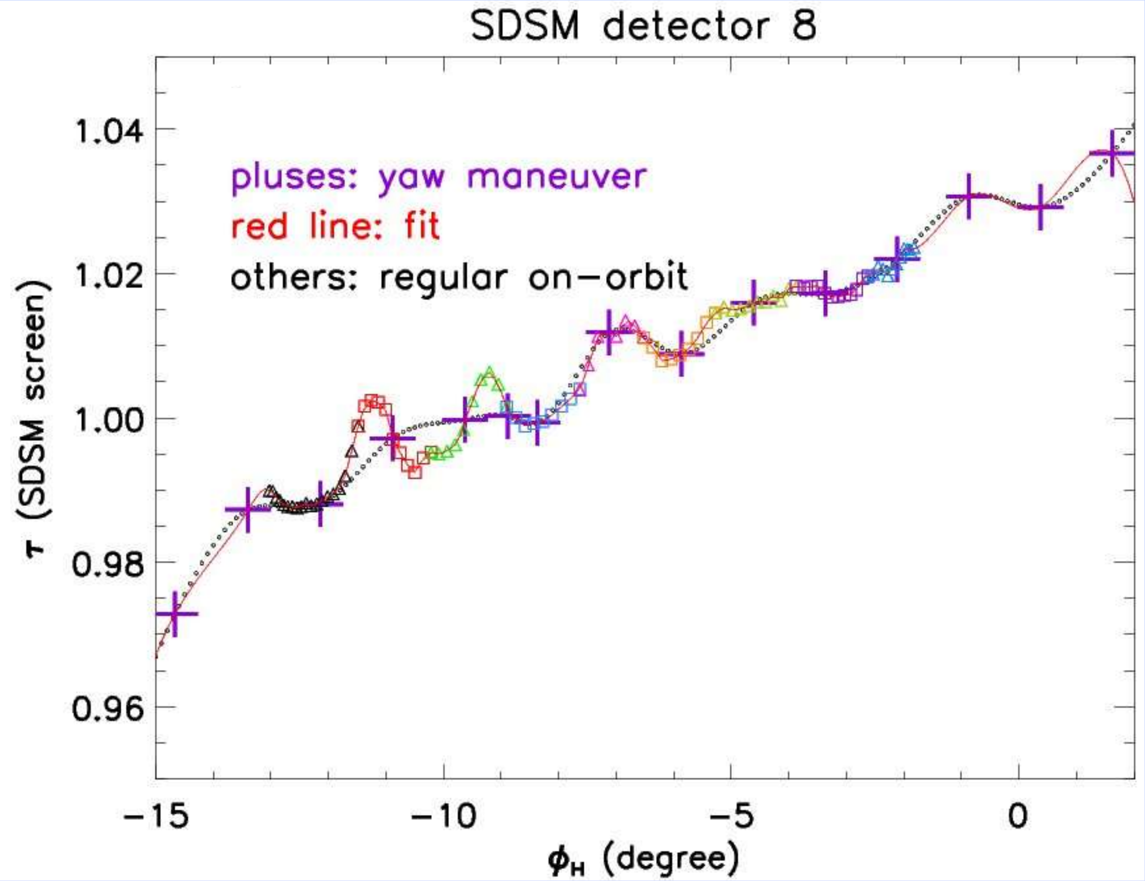
(1) Divide the regular on-orbit data (~3-month) into segments with each covers **one yaw maneuver orbit in solar angles**

(2) Compute transmittance for each segment and interpolate the transmittance at the yaw maneuver solar angles

(3) Tau(yaw) and Tau(non-yaw) differ by a scale factor due to drifts in solar power and the SDSM detector gain, find the scale factor through a least-square fit**; multiply Tau(non-yaw) by the scale factor.**

(4) Combine tau (non-yaw) with linear adjustments.

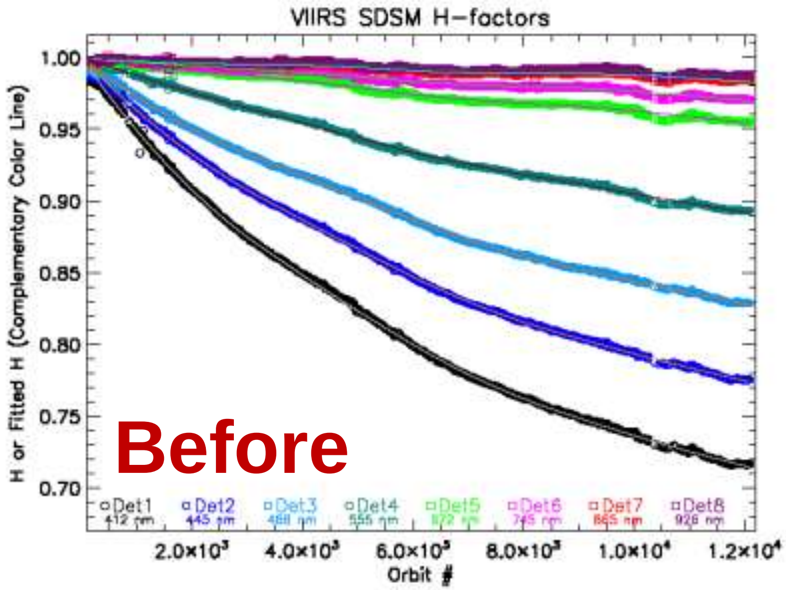
Results

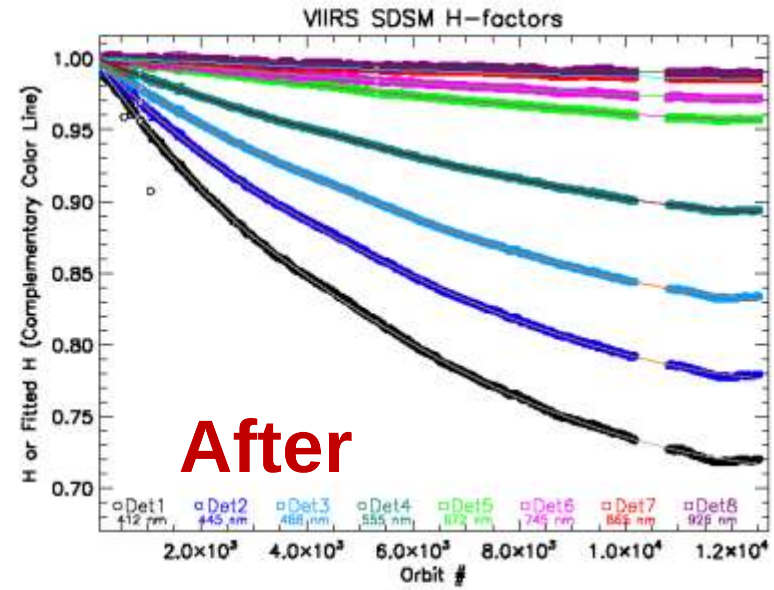


At phiV=0

Very fine details of transmittance revealed

Transmittance indicated by the red line is used to compute the H-factor


VIIRS SDSM H-factors
H or Fitted H (Complementary Color Line)
Orbit #
Before
Det1 412 nm
Det2 445 nm
Det3 488 nm
Det4 555 nm
Det5 672 nm
Det6 745 nm
Det7 865 nm
Det8 926 nm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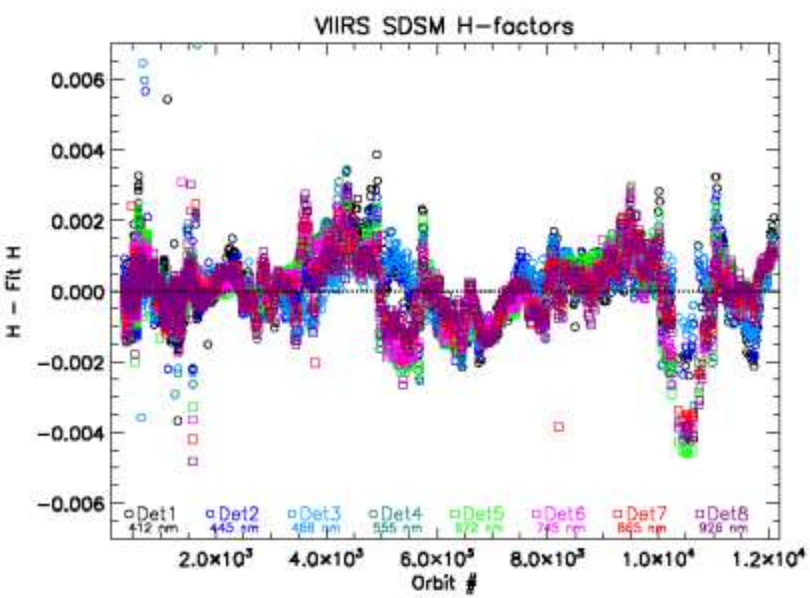
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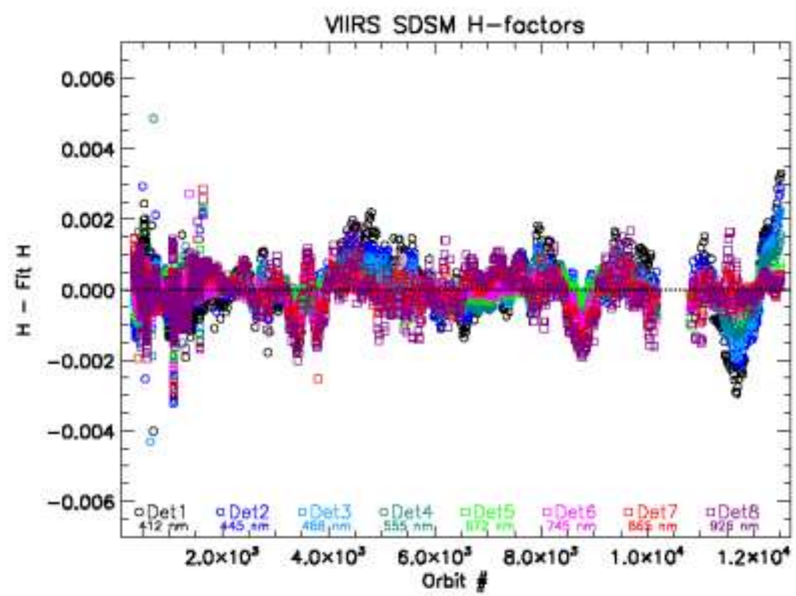
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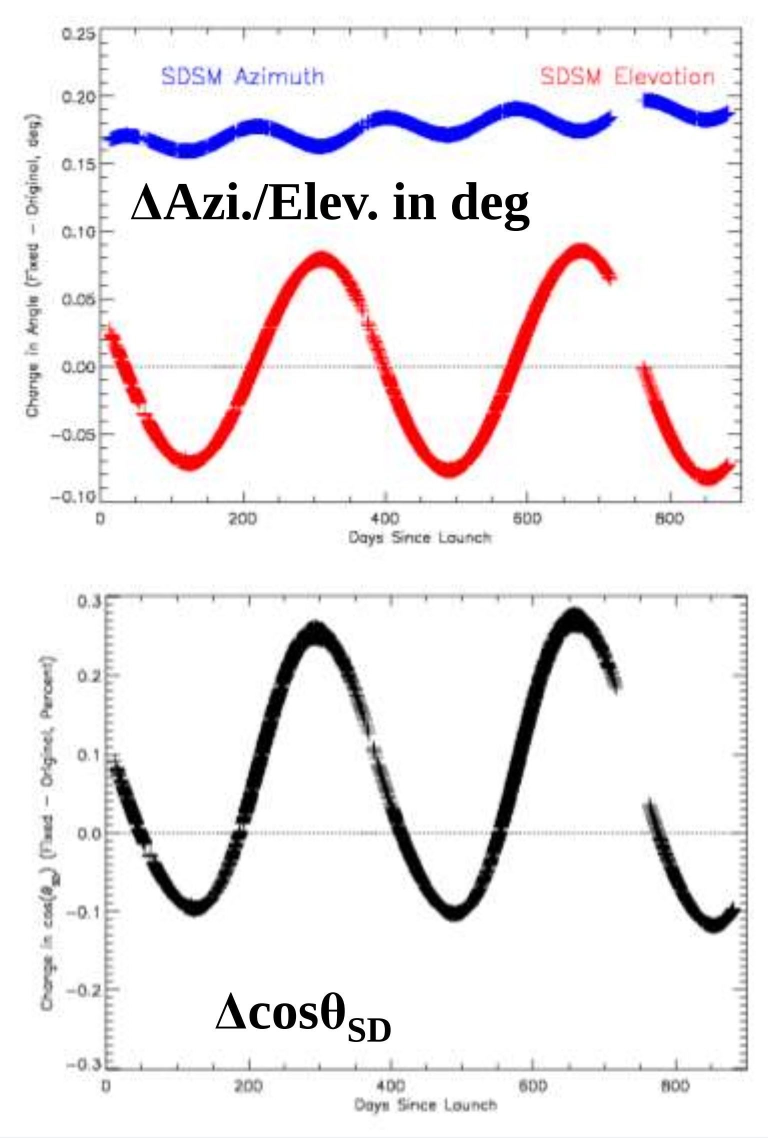
Correction for the Solar Vector Error

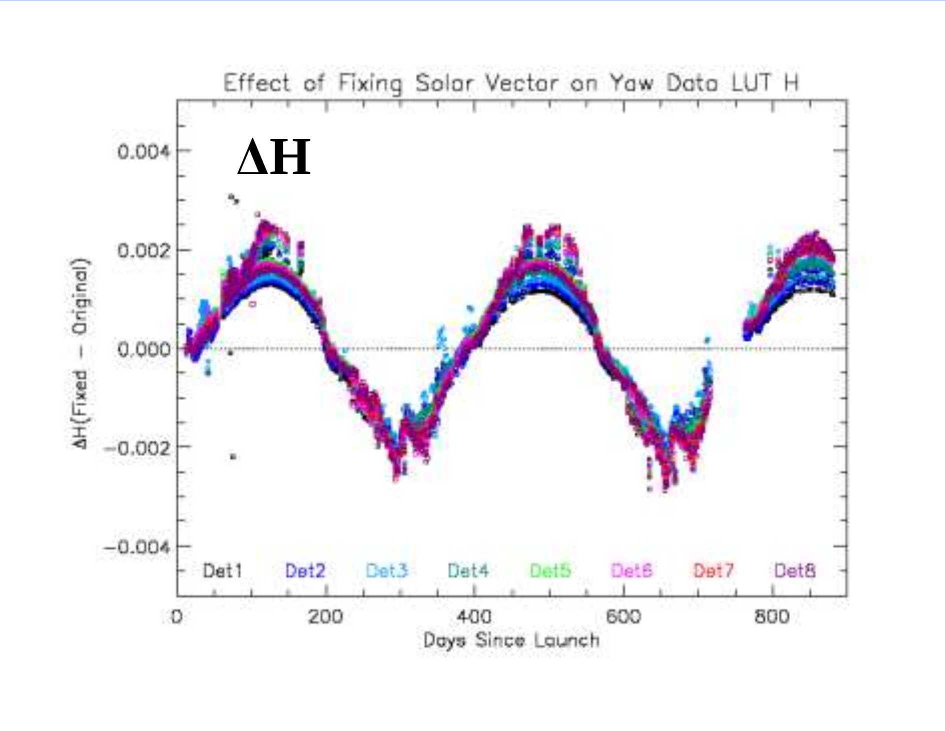
Solar Vector Correction



- A problem in the application of the Common GEO library leads to a slight, but important (~0.2 deg.) error in the solar angles used in the RSB radiometric calibration.

- The problem has been identified (mismatch of ECI frames when computing the transformation to spacecraft coordinates), the CRR has been submitted, and the effects on the radiometric calibration has been evaluated.

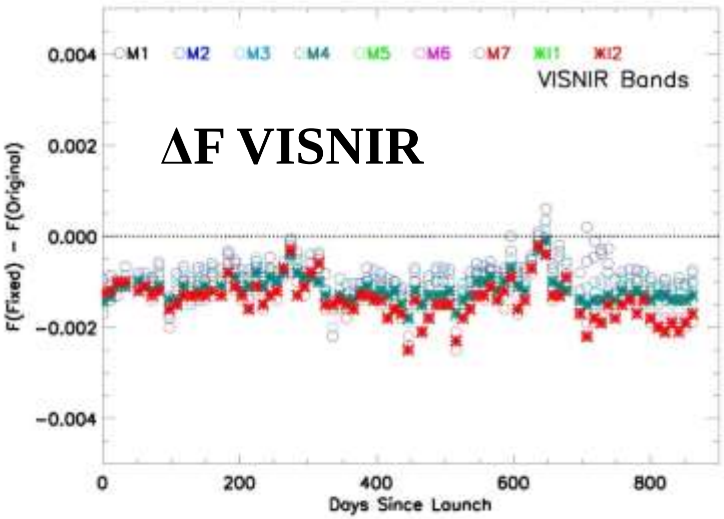
Solar Vector Correction



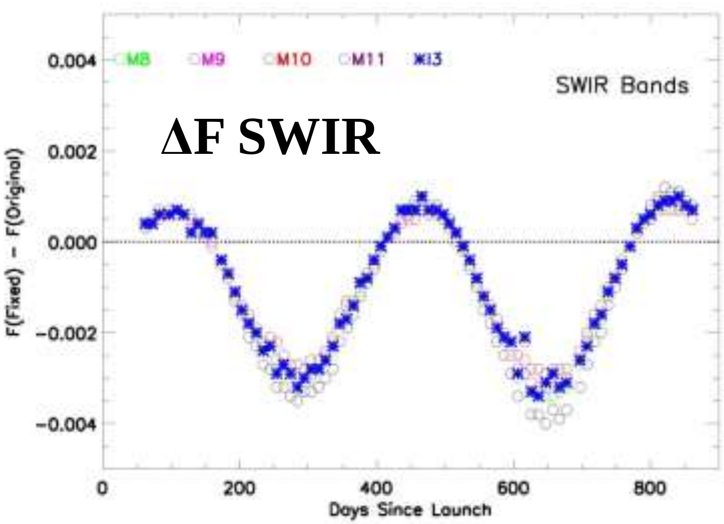
- After the corrected solar vector is used to re-evaluate the entire algorithm (including developing a new screen based on the new solar vectors).

- The change in the H-factors are mainly due to the change of the 1/cos θ_{SD} term in the calculation.

Solar Vector Correction



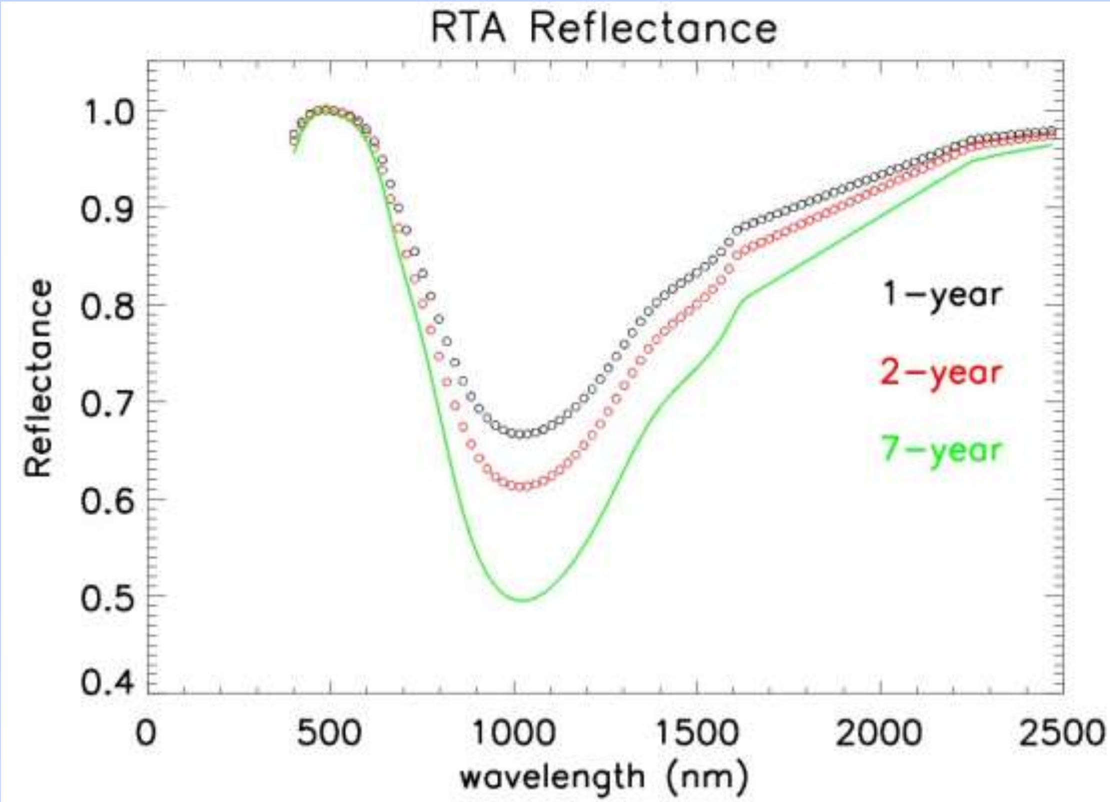
ΔF



- Same end-to-end reanalysis applied for the F-factors, too.
- The VISNIR F-factors have a cos θ_{SD} term which cancels the effect from the H-factors.
- For the SWIR bands, H = 1 by definition, so the cos θ_{SD} term is not cancelled out. This seasonal oscillation of ~0.5% can is in the uncorrected F-factors, but is small compared to the overall change in F.

RSR Modulation Impact Assessment

Modulated RSR



strong wavelength dependent

affect detector relative spectral response

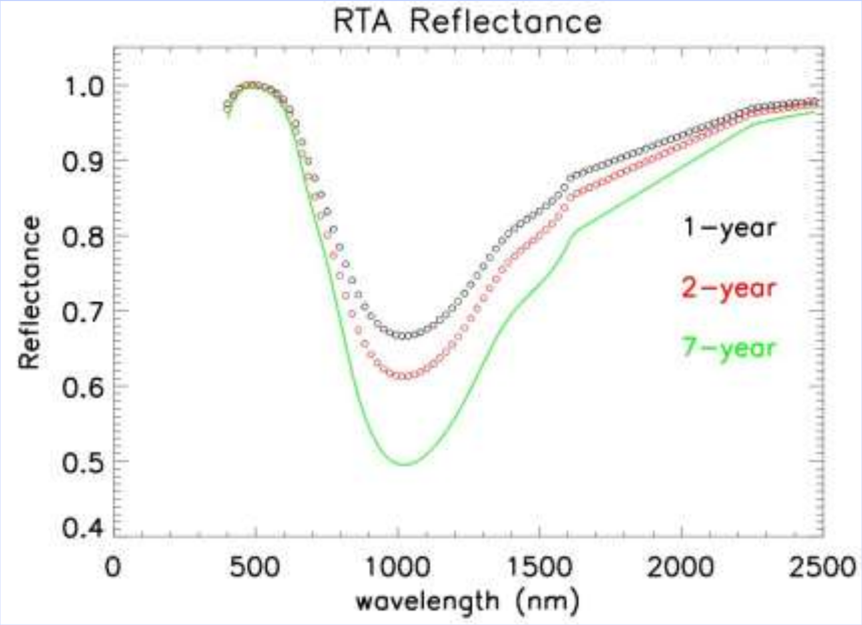
$$RSR_{\text{modulated}}(\lambda,t)=\frac{RSR_{\text{original}}(\lambda)D(\lambda,t)}{\max\left(RSR_{\text{original}}(\lambda)D(\lambda,t)\right)}$$

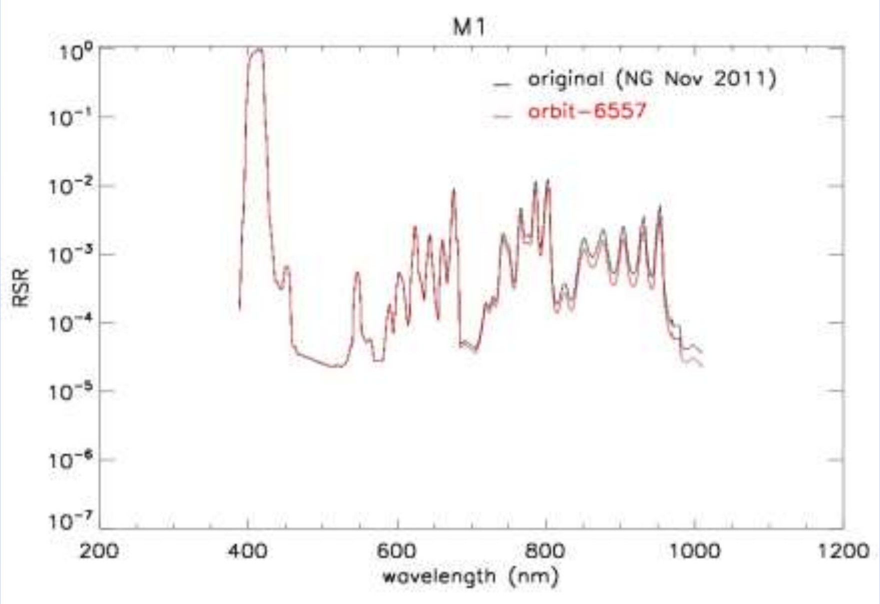
Additional data from VIIRS improves the prediction of end-of-life performance; convergence in prediction indicates greater accuracy.

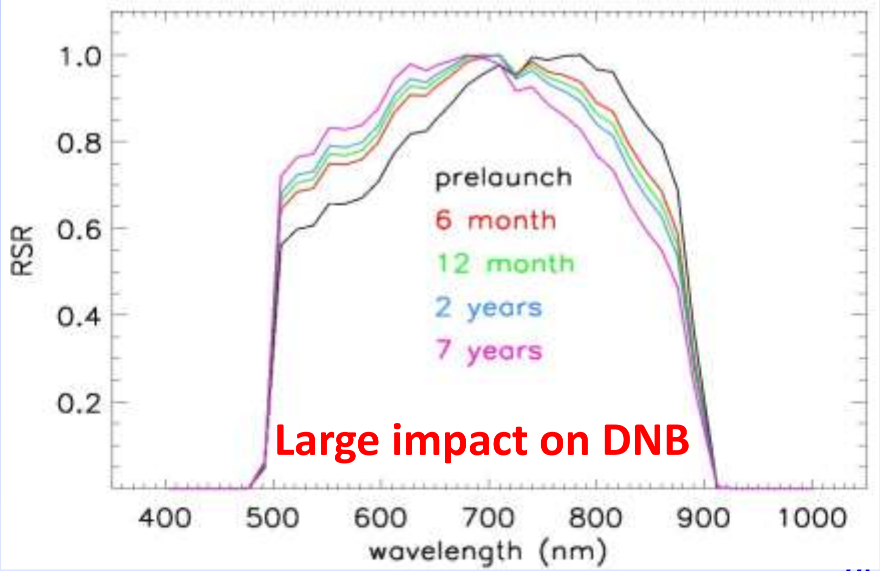
Impact of λ-dependent Changes in Detector Response

Mirror Degradation Impact on Sensor Relative Spectral Response

λ dependent optics degradation







Large impact on DNB

Modulate RSR has been applied to VIIRS calibration and data production

Lunar Calibration (Trending) Improvements

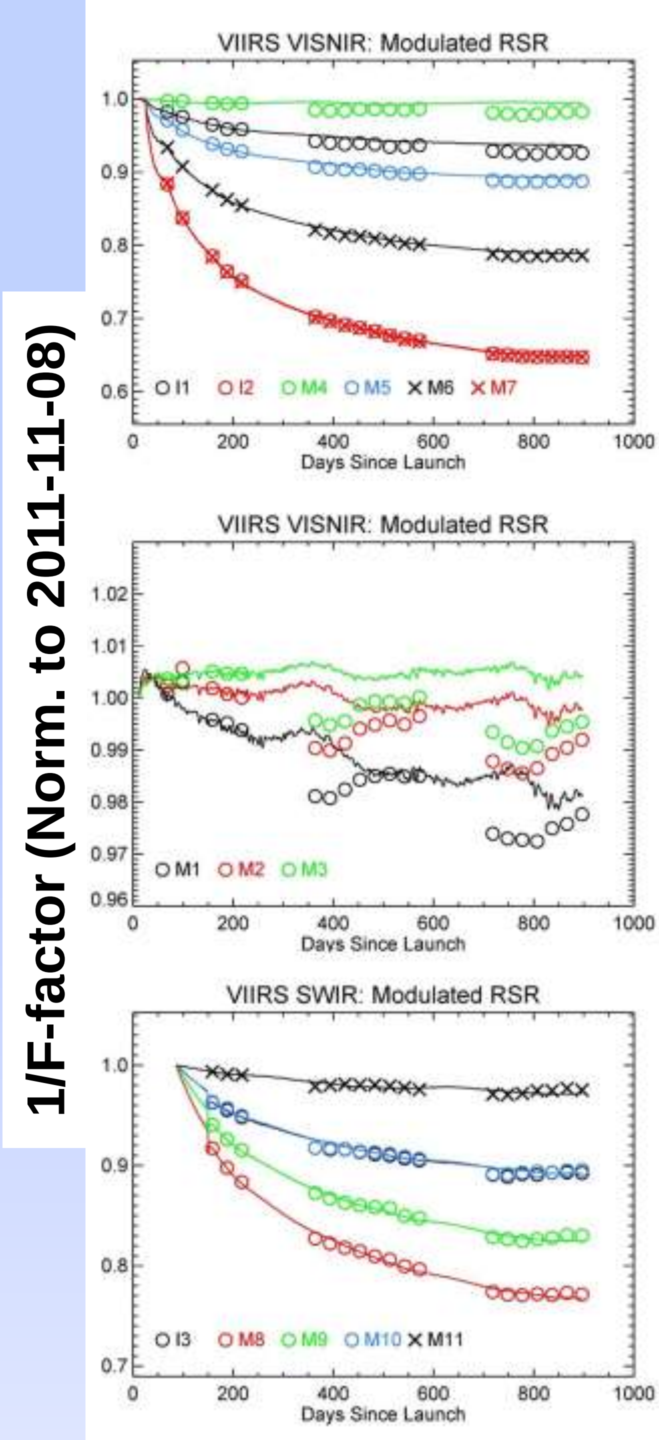
Lunar Trending Improvements

- Lunar observations are not part of the primary calibration of the VIIRS RSB, but they are an important way to verify and improve the RSB calibration.
- There have been 22 scheduled lunar observations that have provided radiometric data (4 Jan 2012 to 10 May 2014).
- Over 70 "unscheduled" serendipitous lunar observations can be analyzed for additional data points.

$$F_{Moon} = \frac{I_{ROLO}}{I_{Pre\_Launch}} = \frac{I_{ROLO}}{\sum\left(c_0 + c_1 dn + c_2 dn^2\right)}$$

where:

- Summation is over all scans, samples, and detectors,
- c_i coefficients are the temperature-corrected pre-launch values,
- I_{ROLO} is the event-specific ROLO model radiance (T. Stone).



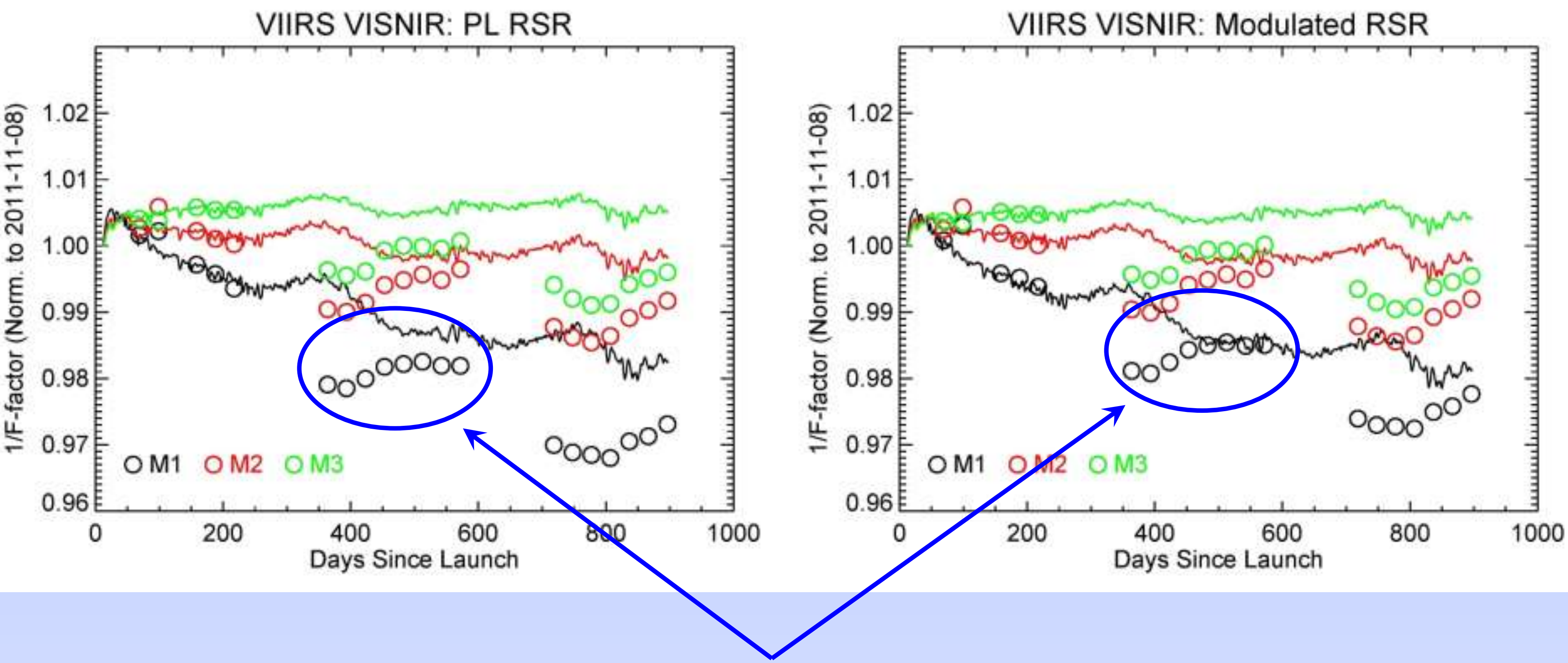
Lunar Trending Improvements

The present comparison shows good general agreement between the SD gain (=1/F; lines) and the lunar gain (symbols).

Seasonal variations are apparent, especially in the blue VISNIR bands (M1, M2 and M3). This is NOT corrected by the solar vector fix, but there appear to be (equal? opposite?) seasonal effects in both gains.

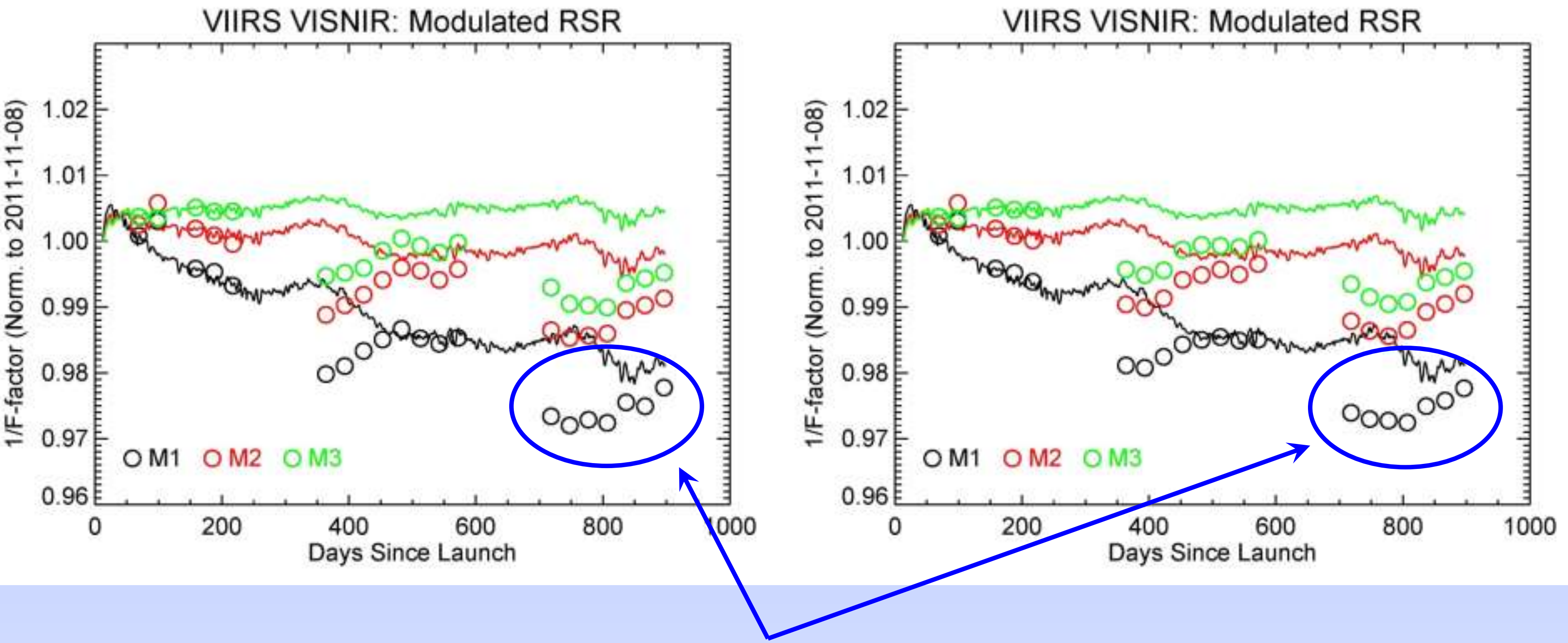
Tom Stone (USGS) and CNES are working together to improve the ROLO model, but it is our job to continually improve the VIIRS calibration using the best science available.

Lunar Trending Improvements



Incorporating modulated RSRs into both the SD and lunar calibration (in the ROLO models) improved the agreement. This supports the use of modulated RSRs in the calibration.

Lunar Trending Improvements



Improvements in the processing of the lunar data (in this case incorporating more scans into the analysis) has improved the internal uncertainties.

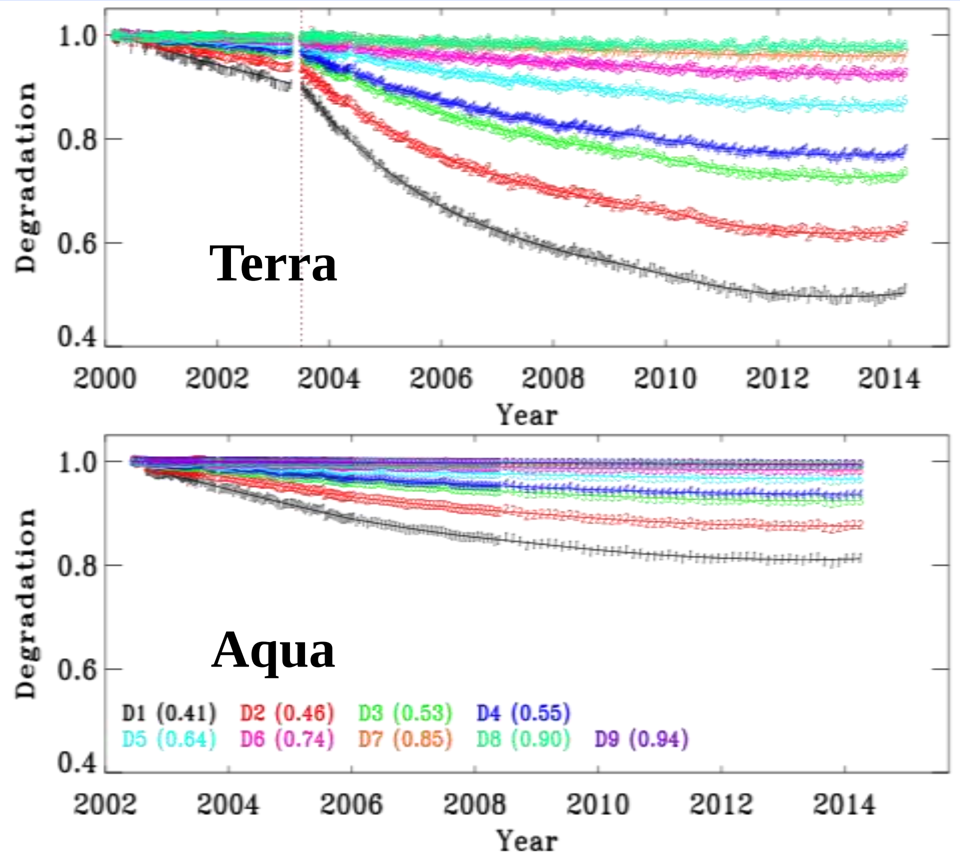
SWIR:
Effects due SD Degradation

SWIR-band SD Degradation

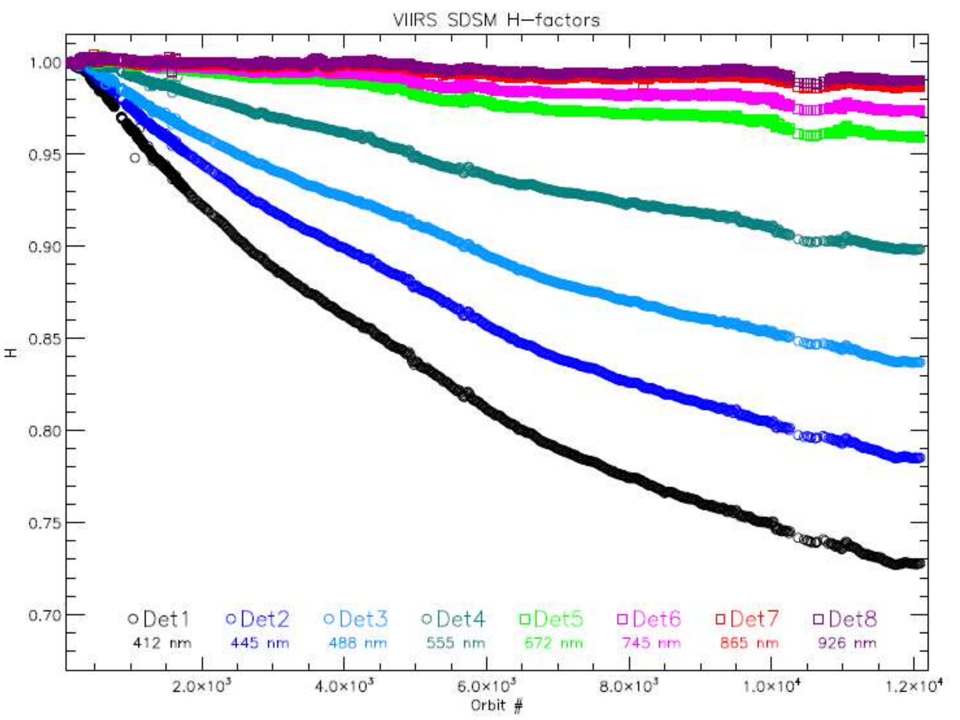
- **Current calibration assumes SD degradation beyond ~926 nm is extremely small and can be ignored (e.g., H = 1).**
  - The measured H-factor at 926 nm is measured to be 0.991, so SD degradation at SWIR wavelength is slowly occurring.
- **MODIS RSB calibration performed using a SD with its degradation monitored using the SDSM (wavelength coverage:412-936 nm)**
  - Terra SDSM D9 (936 nm) change over ~14 years on-orbit is measured to be ~2.3%. Aqua SDSM D9 change over ~12 years is 0.6%.
  - MCST has implemented a correction for Band 5 (1.24 µm) using pseudo-invariant desert targets and find a 1.5% degradation in Band 5 for Terra and a <0.3% degradation for Aqua.
  - Data from Deep Convective Cloud (DCC; data courtesy David Doelling/Raj Bhatt, NASA Langley) backs up the desert site results.
- **If the same trend holds for VIIRS, the H-factor for the M8 band should be around 0.4% or less, but the ground-site trending is not sensitive enough, *yet*. VCST will closely monitor and accurately quantify the correction for M8**

SWIR-band SD Degradation

MODIS Terra and Aqua



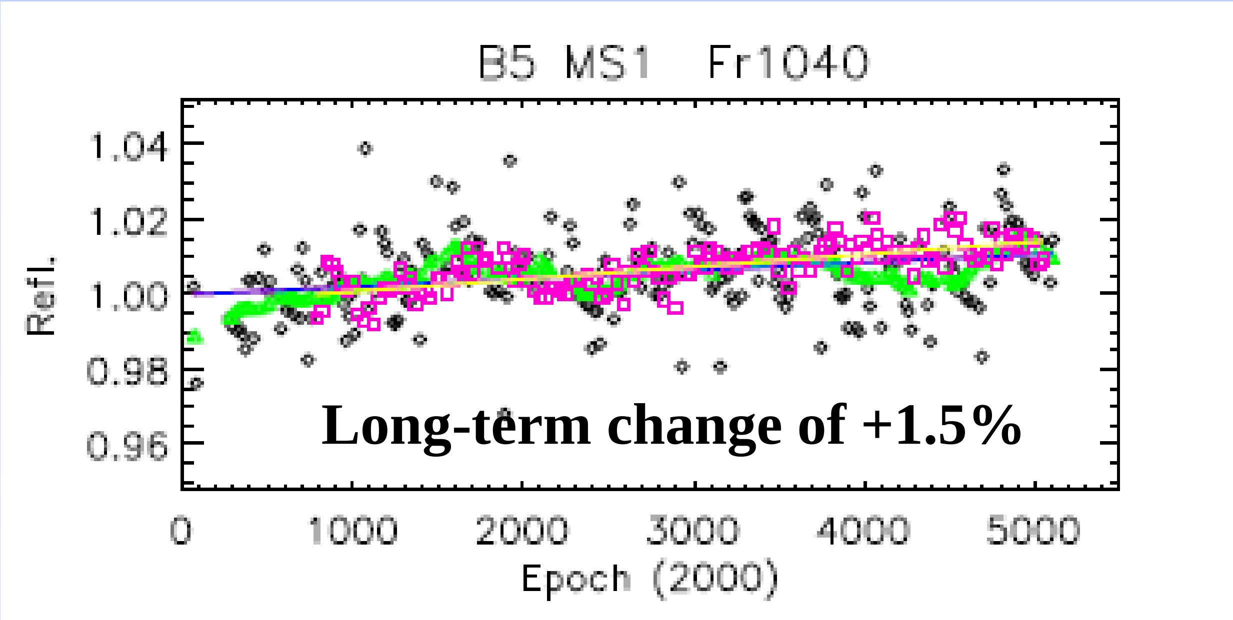
S-NPP VIIRS



D9 Degradation (936 nm):
Terra 2.3%
Aqua 0.6%

D8 Degradation (926 nm):
S-NPP 0.9%

EV-based Evaluation of Terra Band 5 Response



TOA EV reflectance from Libya 4 (BRDF correction applied)

Moving window yearly average of the TOA reflectance trends

DCC trends

Measurements normalized to the first points of the fitted curves

Correction for the upper drift in Terra B5 to be applied in C6

Future Work and Summary

- **Finalize and Implement Solar Vector Correction in RSB Calibration**
  - Further improvements of SD VF for F-factor computation
  - Use in reprocessing mission data
- **Understand and Resolve SD and Lunar Calibration Difference**
- **Monitor and Improve SWIR Calibration (as needed)**
- **Track and Study Potential Changes in RSB RVS (not covered here)**
- **Overall VIIRS RSB Calibration Meet the Design Requirements**
  - Constant improvements
  - Dedicated calibration and monitoring effort
  - Collaboration and independent assessments
  - Interaction with science community and other sensor calibration team, such as MCST