Update of MODIS and VIIRS Calibration and Validation Activities

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S-NPP and JPSS VIIRS SDR Calibration Team, NOAA

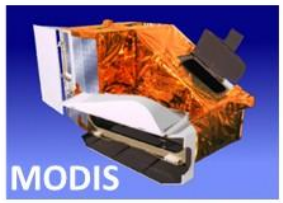
CEOS WGCV IVOS-28, Beijing, China (July 18-21, 2016)

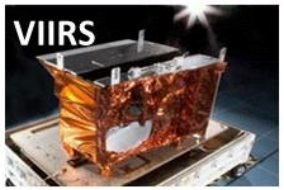
Outline

- MODIS and VIIRS Instruments
- Calibration Methodologies and Activities
- Instrument On-orbit Performance
- Challenging Issues and Future Work

MODIS and VIIRS Instruments

- **MODIS on EOS Terra and Aqua Missions**
  - Terra: Dec. 18, 1999 – Present
  - Aqua: May 04, 2002 – Present
- **VIIRS on S-NPP and JPSS Missions**
  - S-NPP: Oct. 28, 2011 – Present
  - JPSS-1: Launch in early 2017; currently in SC testing phase
  - JPSS-2: Launch in 2021; currently in ambient testing phase





MODIS and VIIRS Instruments

MODIS

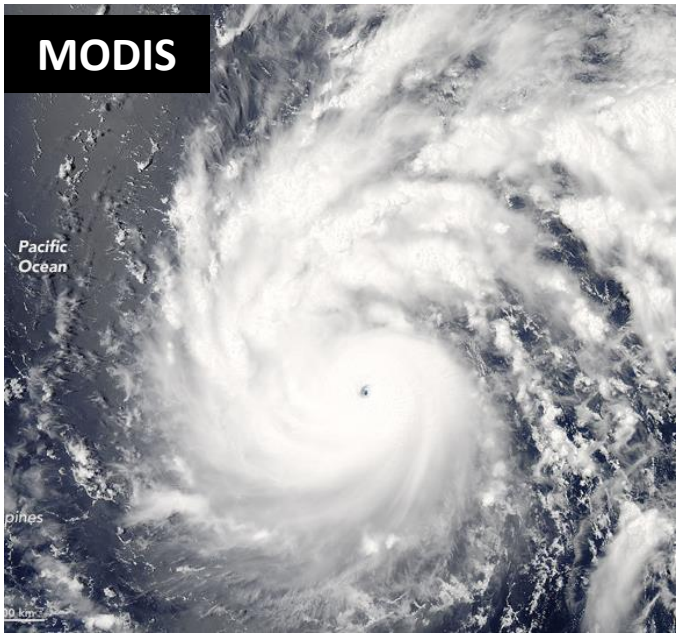
- Purpose: Global observations of land, ocean, & atmosphere parameters at high temporal resolution (< 2 days)
- 2-sided scan mirror
- Spectral range: 36 bands between 0.4 µm and 14.5 µm
  - 20 RSB and 16 thermal emissive bands (TEB)
- Focal plane assemblies (FPA): VIS, NIR, SMIR, and LWIR
- Spatial resolution: 250, 500, 1000 m
- Swath Width: 2330 km
- On-board Calibrators: SD, SDSM, BB, SV, and SRCA
- SD aperture door

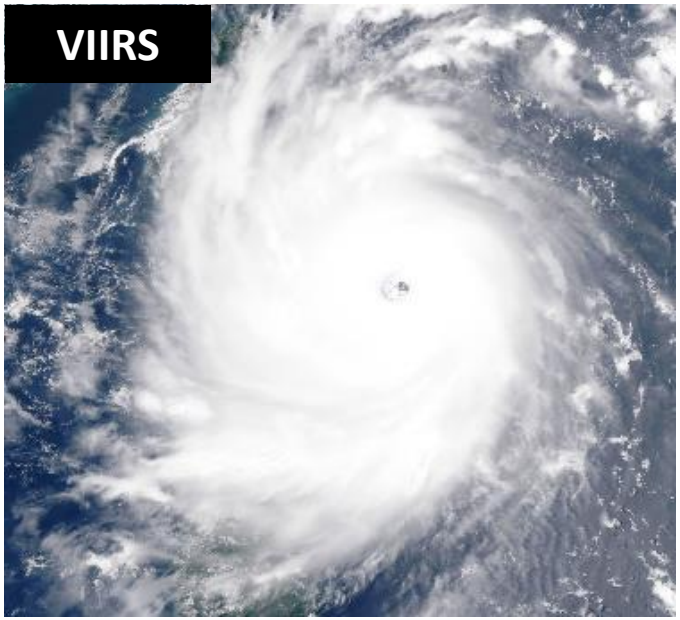
VIIRS

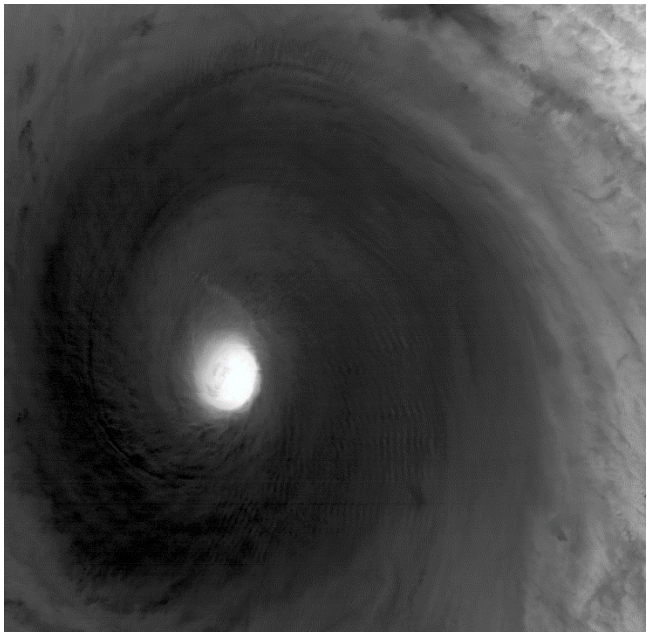
- Purpose: Global observations of land, ocean, & atmosphere parameters at high temporal resolution (daily)
- Rotating telescope plus HAM
- Spectral range: 22 bands between 0.4 µm and 12.5 µm
  - 14 RSB, 7 TEB, and 1 Day Night Band (DNB)
- Focal plane assemblies (FPA): VIS/NIR, SMIR, and LWIR
- Spatial resolution: 375 and 750 m
- Swath Width: 3000 km
- On-board Calibrators: SD, SDSM, BB, and SV
- Pixel aggregations and bowtie deletion

Nearly 40 science data products from MODIS and 22 EDRs from VIIRS

Super Typhoon Nepartake over Taiwan (early July 2016)



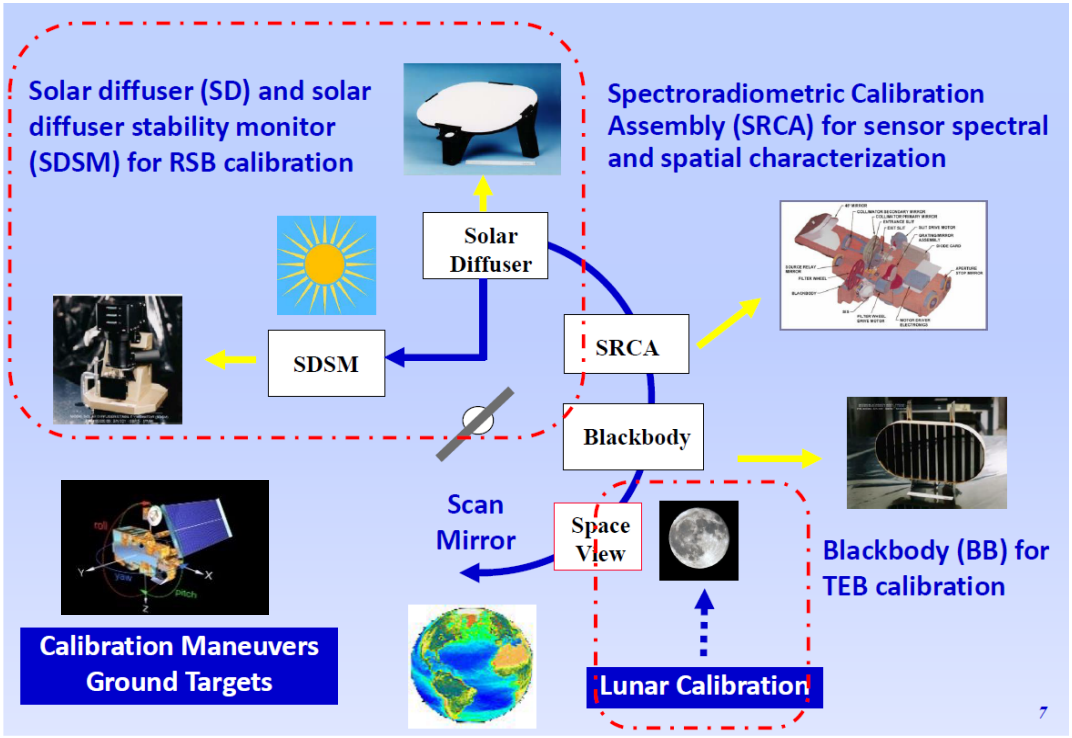




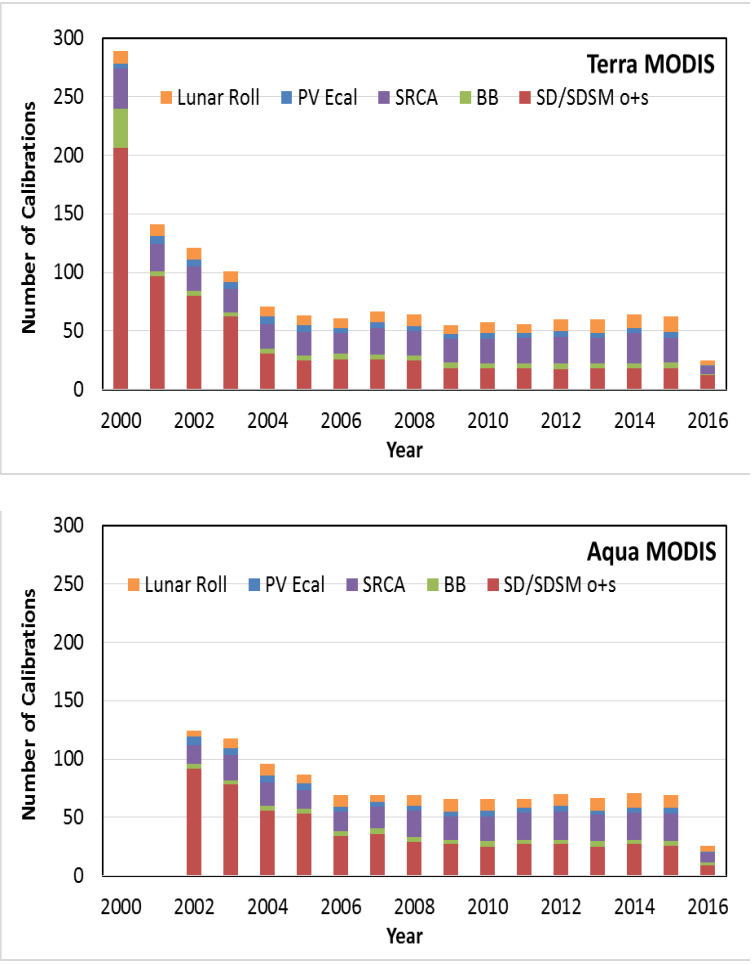
Eye of the Super Typhoon Nepartake (VIIRS band I5)

MODIS Calibration Methodologies and Activities

Calibration Methodologies



Calibration Activities

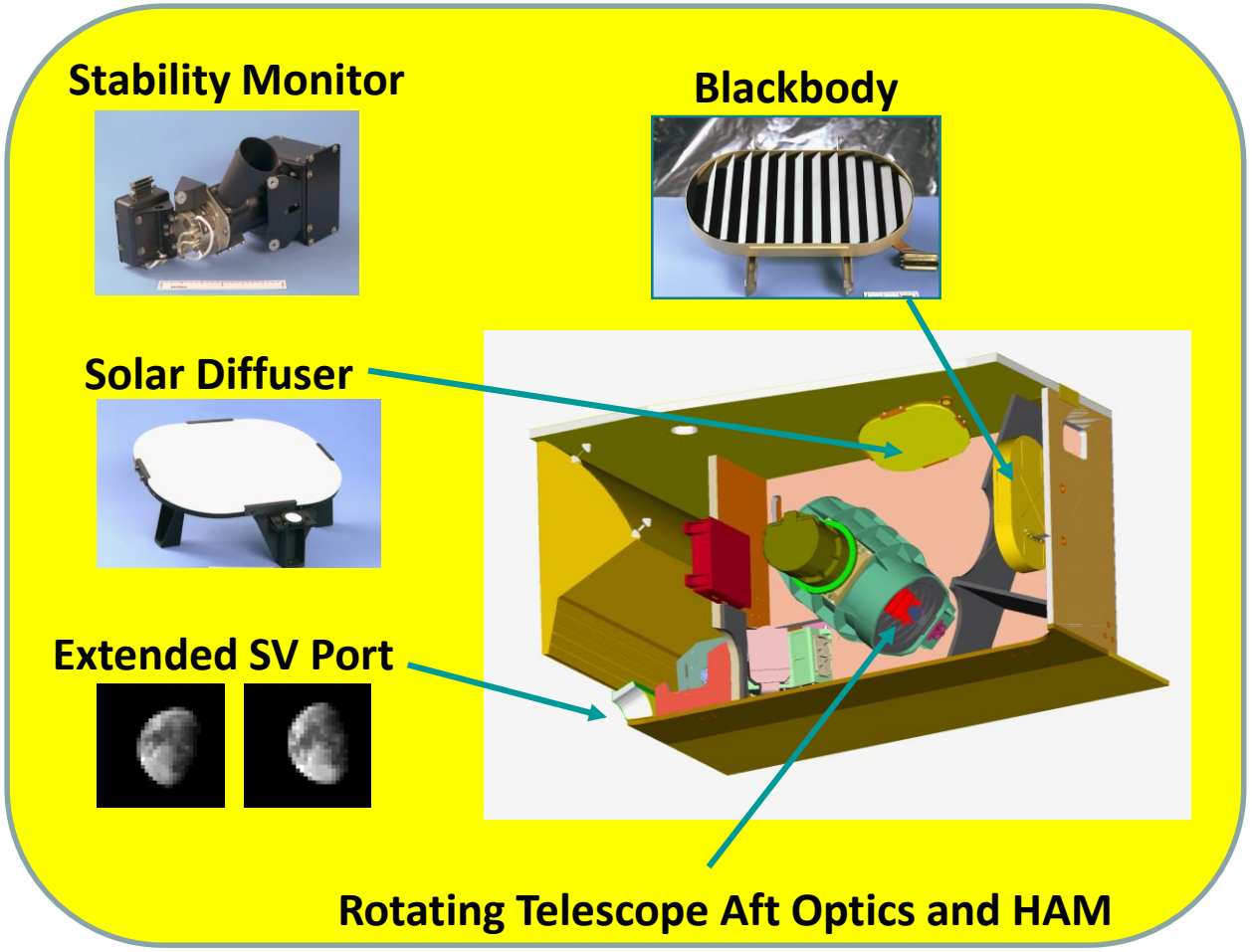


	Terra	Aqua
Lunar Roll:	162	136
PV Ecal:	92	71
SRCA:	433	315
BB:	99	61
SD/SDSM:	715	571

SRCA calibration includes rad/spec/spat
SD/SDSM calibration includes SD screen up/down

VIIRS Calibration Methodologies and Activities

Strong MODIS Heritage: Calibrators and Approaches



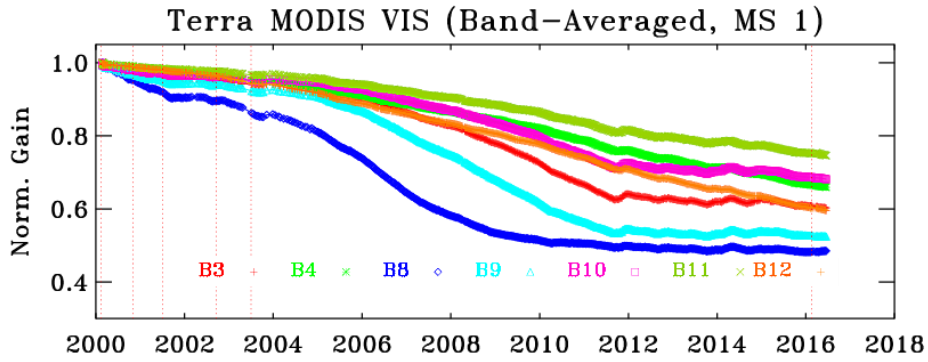
- SD calibration: each orbit
- SDSM: 3 times/week (more at mission beginning)
- BB WUCD: quaterly (18 since launch)
- DNB: monthly VROP operation
- Lunar observations: near-monthly (42 since launch); not all lunar CAL need roll maneuvers

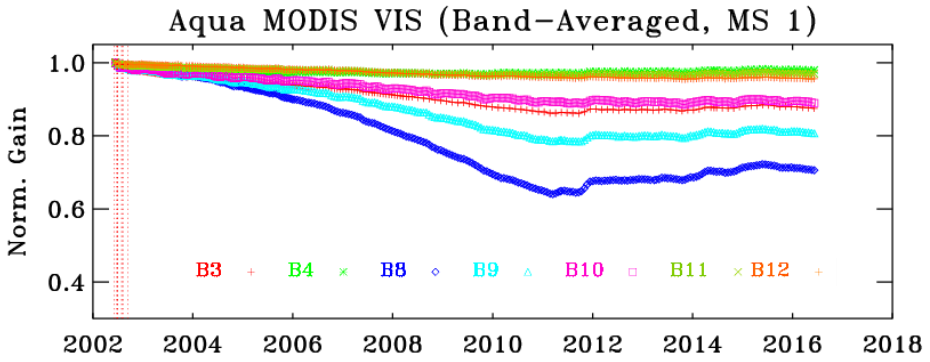
On-orbit Instrument Performance (MODIS)

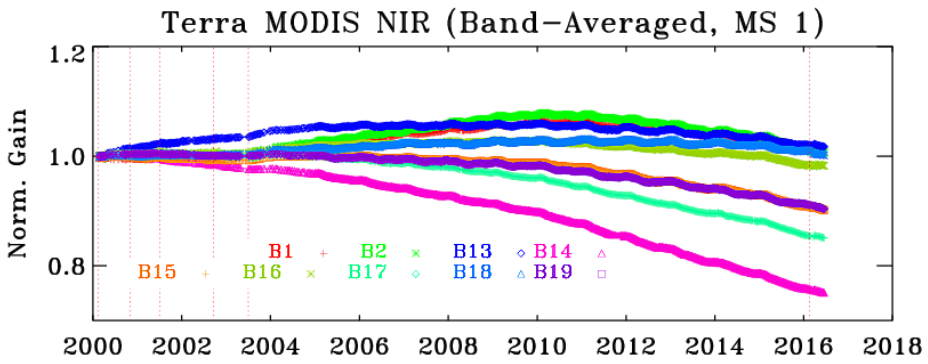
- **Instrument and On-board Calibrators (OBC)**
  - **Terra MODIS** instrument, VIS/NIR FPA temperature increase: < 3.5 K; CFPA temperatures: very stable; BB temperature increase: < 30 mK; SD degradation: faster at shorter wavelengths
  - **Aqua MODIS** instrument, VIS/NIR FPA temperature increase: < 2.0 K; CFPA temperatures: improved control; BB temperatures: very stable; SD degradation: slower than Terra MODIS
- **Radiometric, Spatial, Spectral, and Geometric**
  - Spectral band responses: large at VIS and NIR; small at SWIR, MWIR, LWIR
  - Band-to-band registration (BBR): continue to be stable
  - Center wavelengths: changes are within 0.5 nm for most VIS/NIR bands; relatively large changes for bands with broad bandwidths (bands 1, 18, 19)
  - Geolocation accuracy: satisfactory

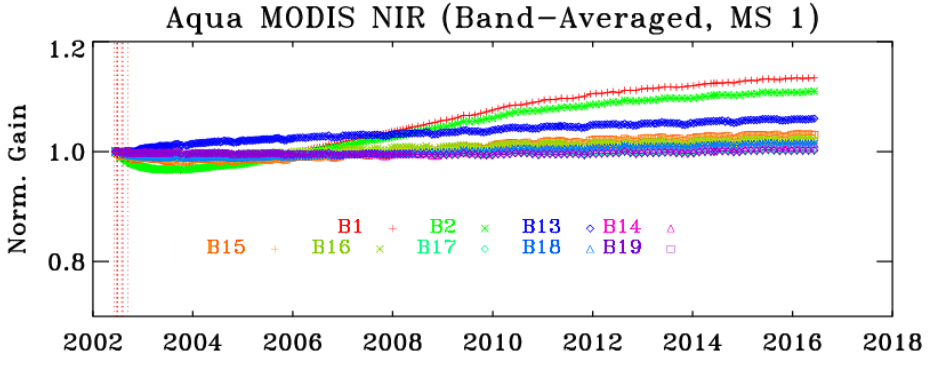
VIS/NIR/SWIR Spectral Band Responses (Gains)

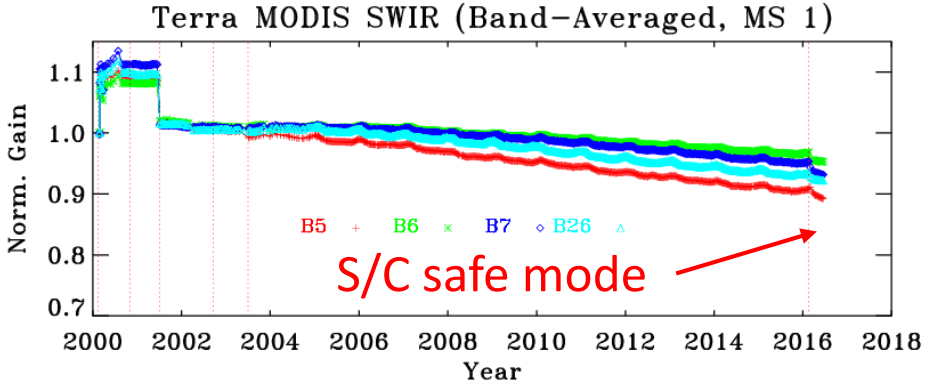
Spectral band responses: large in VIS and NIR; small in SWIR, MWIR, LWIR

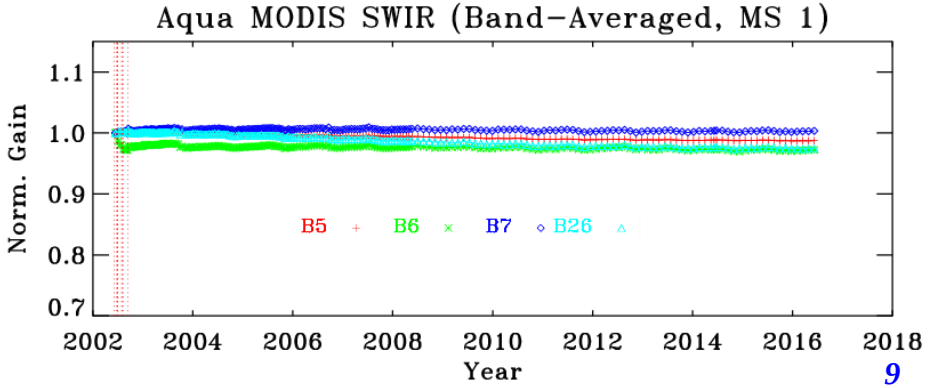




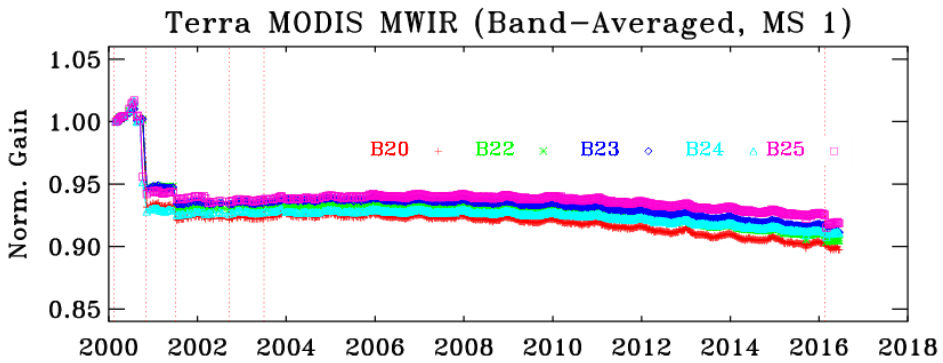


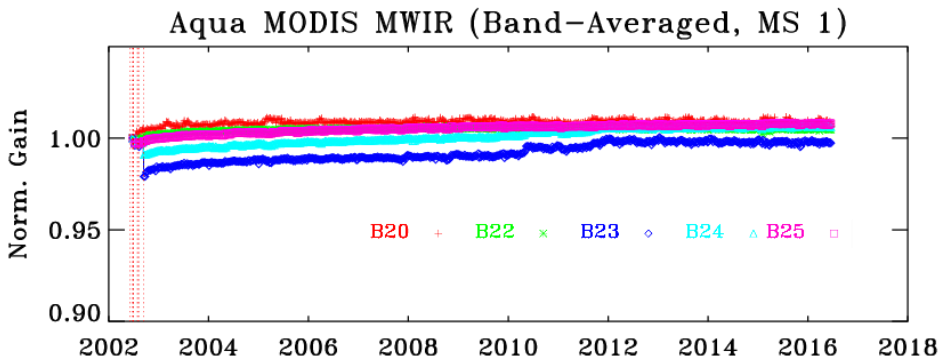


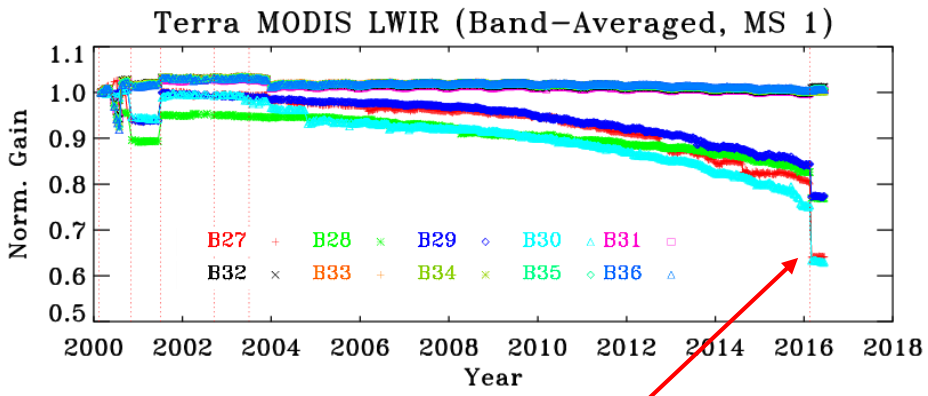


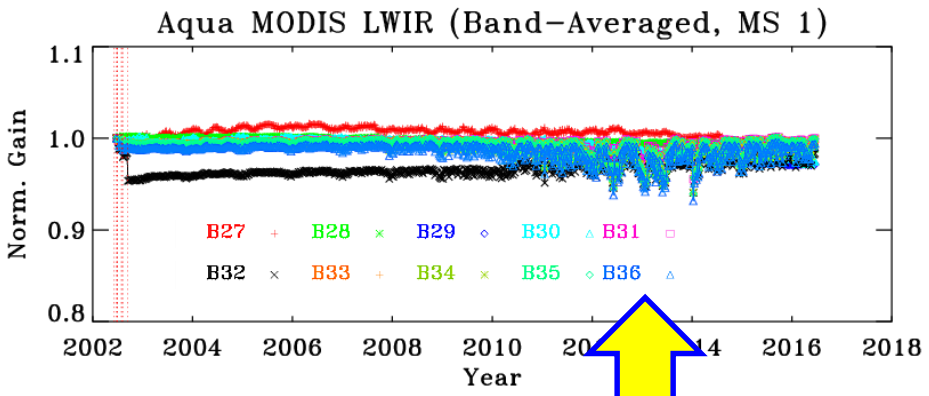


MWIR/LWIR Spectral Band Responses (Gains)



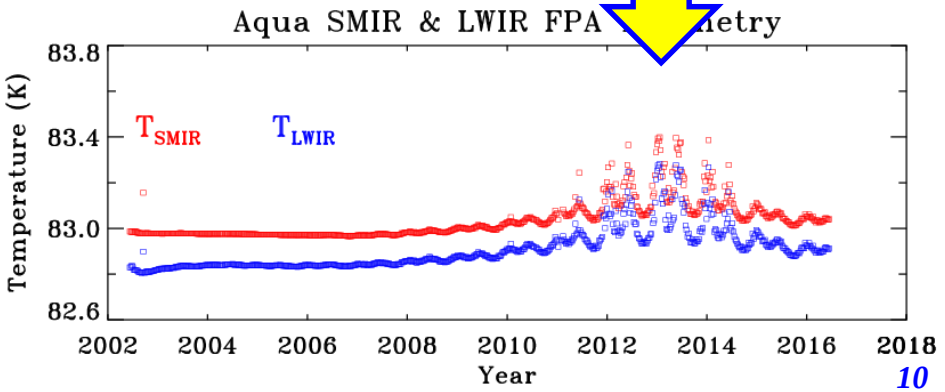






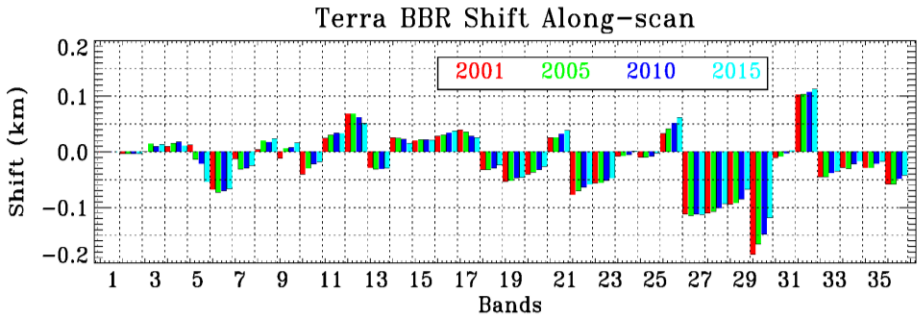
S/C safe mode

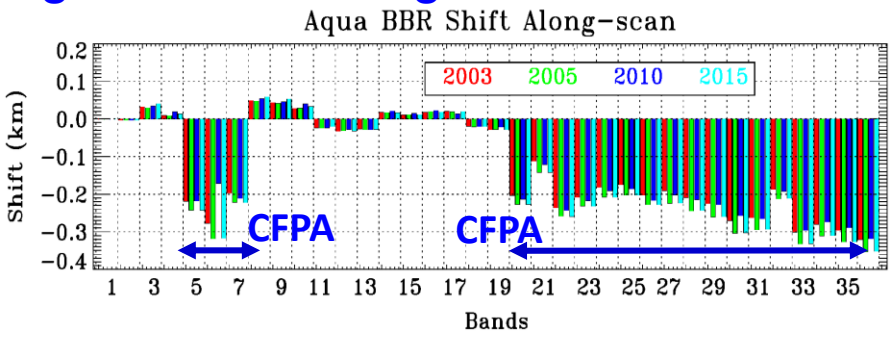
Fluctuations in CFPA temp. led to small variations in LWIR detector responses

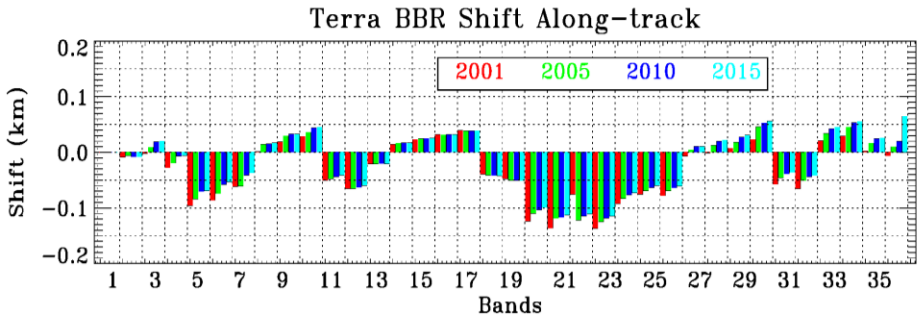


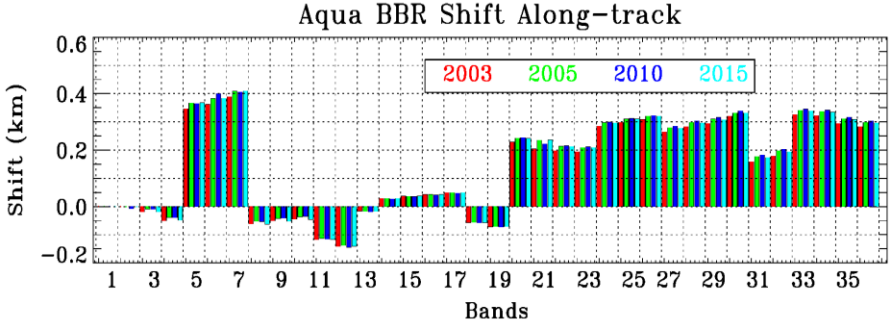
Spatial and Spectral Performance

Band-to-Band Registration (BBR) in Along-scan and Along-track Direction

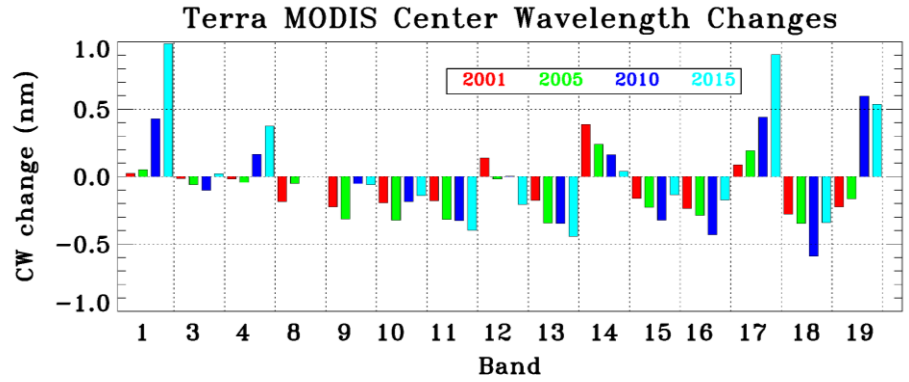


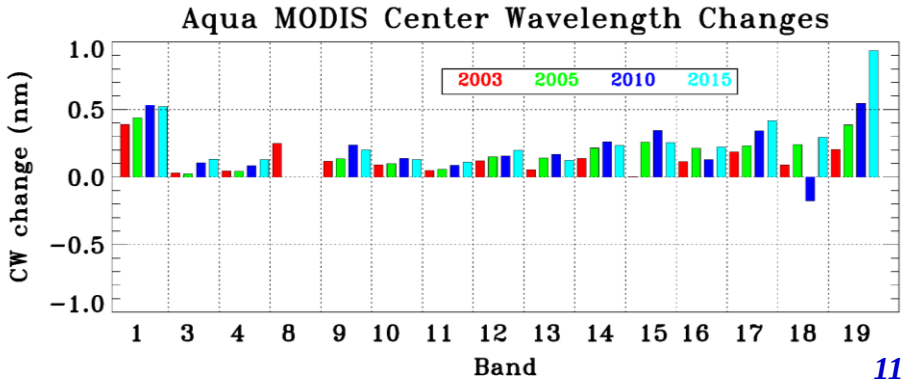






Changes in Spectral Band Center Wavelengths (CW)

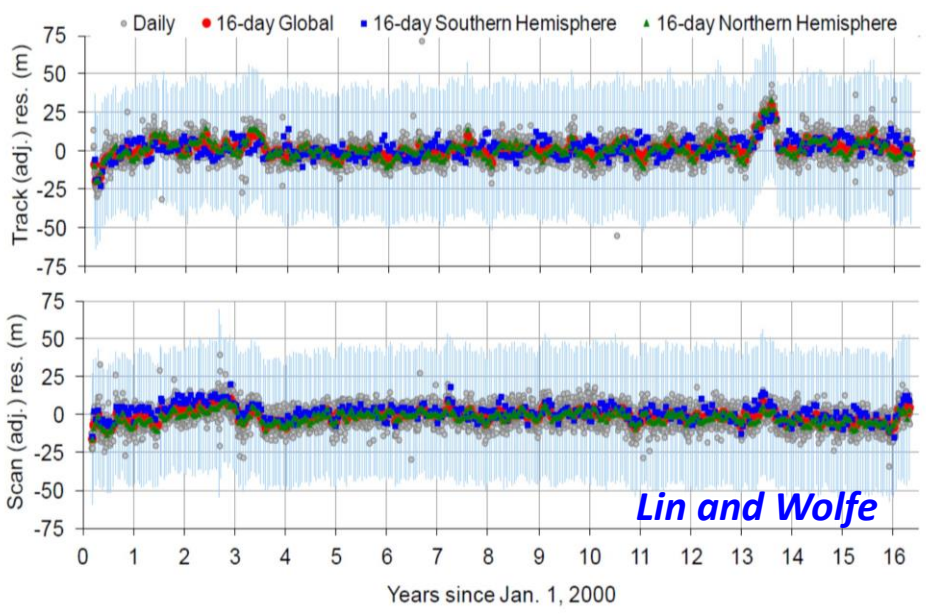




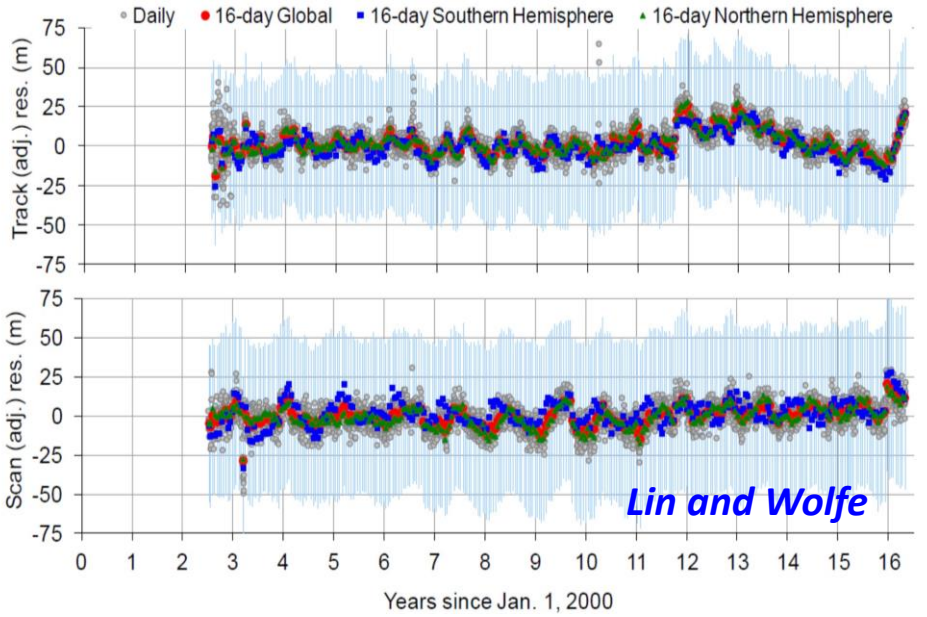
Geolocation Performance

Terra and Aqua MODIS Geolocation Performance Remains Satisfactory

Terra MODIS RMSE (C6)
Track: 43 m Scan: 44 m



Aqua MODIS RMSE (C6)
Track: 46 m Scan: 53 m



Daily 16-day Global 16-day Southern Hemisphere 16-day Northern Hemisphere

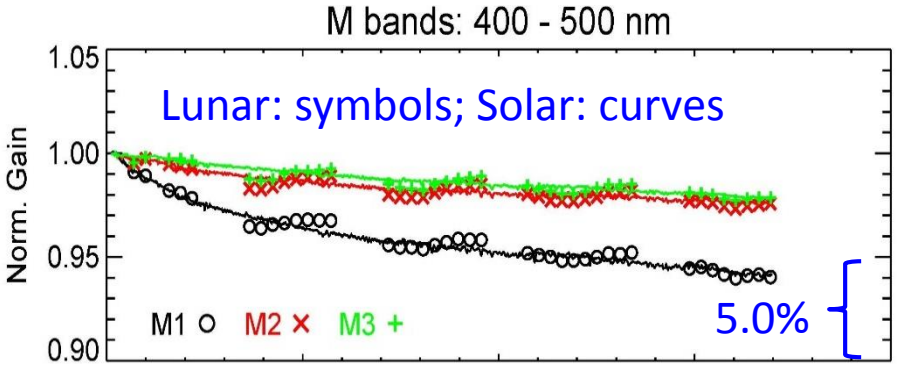
Terra track direction jump - due to a delayed implementation/update of Geo LUTs (from 01/01/2013 to 08/10/2013).

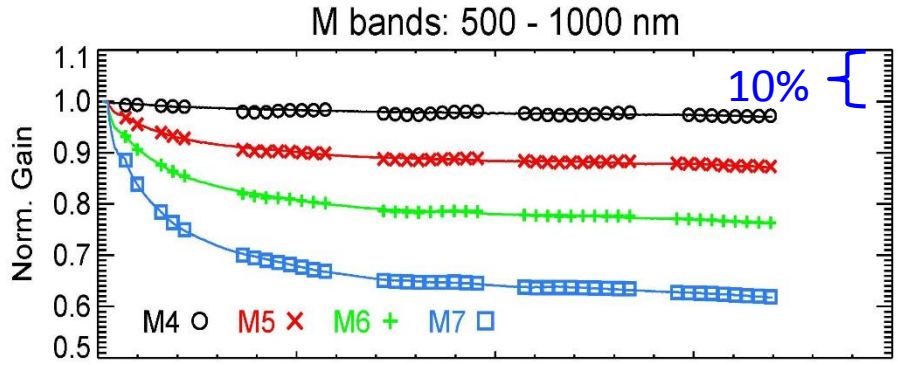
Aqua track direction jump at the end of 2011 (now it's back to "normal") - need to model it and update the LUT.

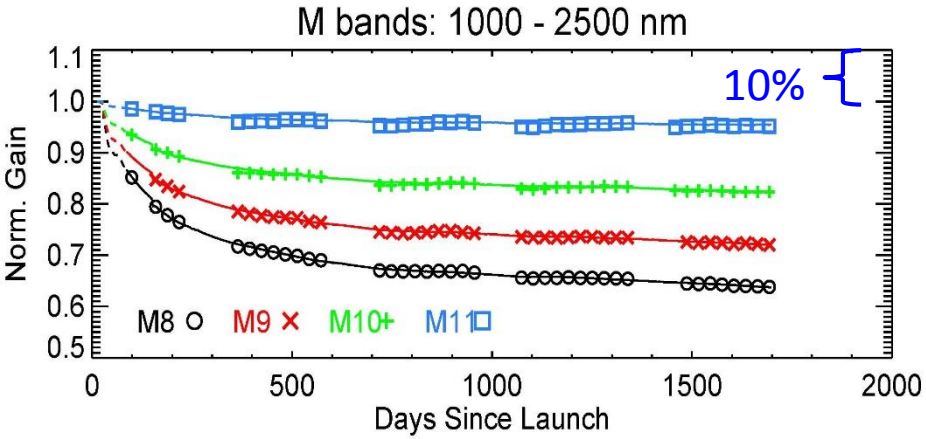
On-orbit Instrument Performance (VIIRS)

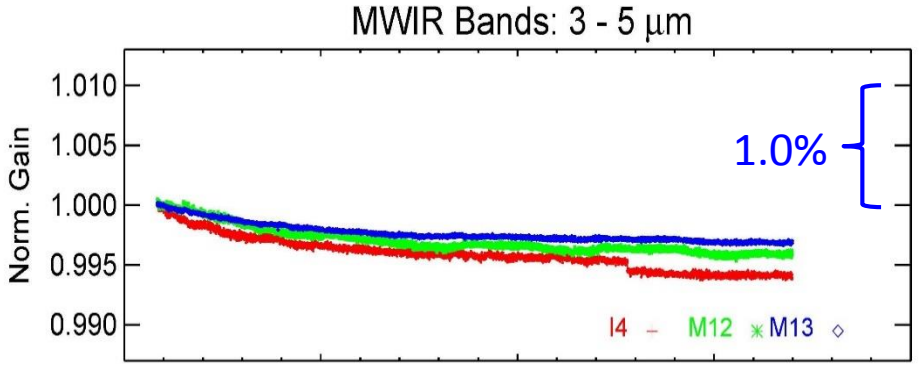
- **Instrument and On-board Calibrators (OBC)**
  - Instrument and FPA temperatures: stable
  - BB stability: extremely stable (similar to Aqua MODIS)
  - SD degradation: large at short wavelengths (similar to Terra MODIS)
- **Radiometric, Spatial, Spectral, and Geometric**
  - Spectral band responses: large at NIR and SWIR; small at VIS, MWIR, LWIR
  - Band-to-band registration (BBR): stable (tracked using lunar observations)
  - Relative spectral response (RSR): modulated on-orbit (due to strong wavelength dependent optics degradation)
    - Noticeable impact for DNB and small effect on M/I bands
  - Geolocation: satisfactory and can be improved further

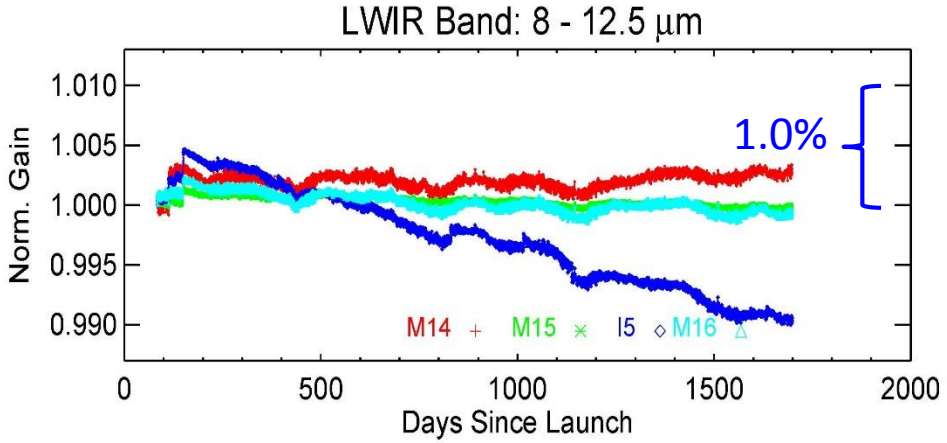
Changes in Spectral Band Responses (Gains)







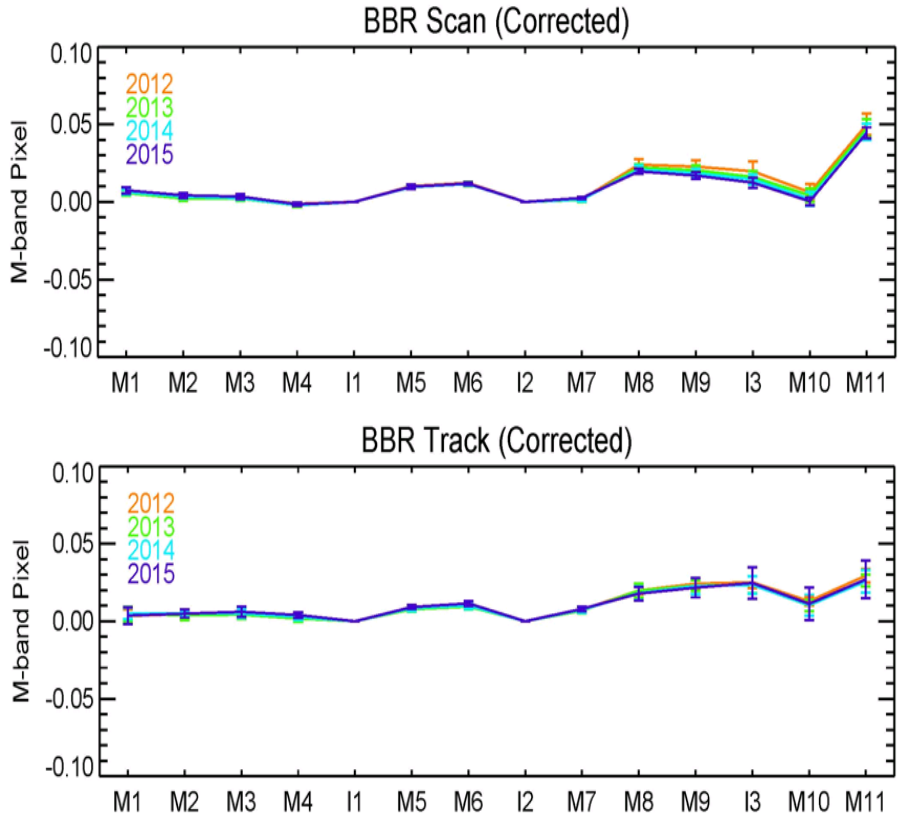




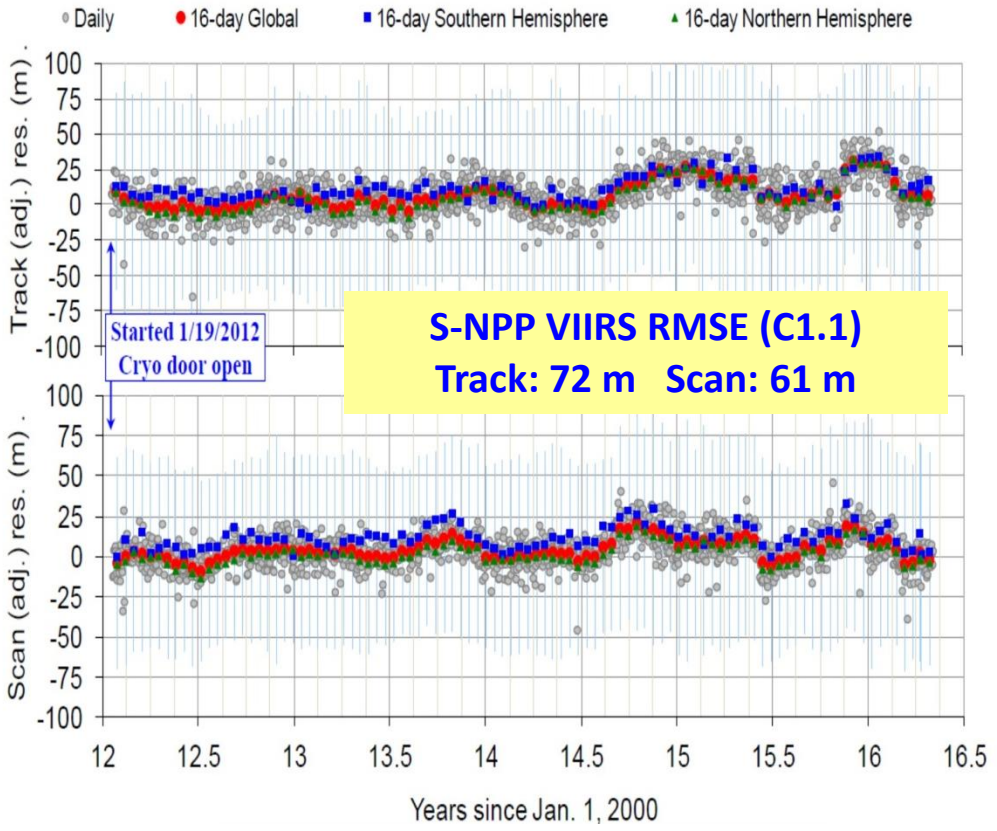
- Large changes in NIR and SWIR (due to mirror contamination)
- Small changes in VIS, MWIR, and LWIR

Spatial and Geometric Characterization

Band-to-band registration (BBR)



Geolocation



- Improved methodology (originally developed for MODIS BBR using lunar observations and validated using on-board SRCA)
- On-orbit BBR is very stable in both scan and track directions

Comparison with Terra and Aqua MODIS

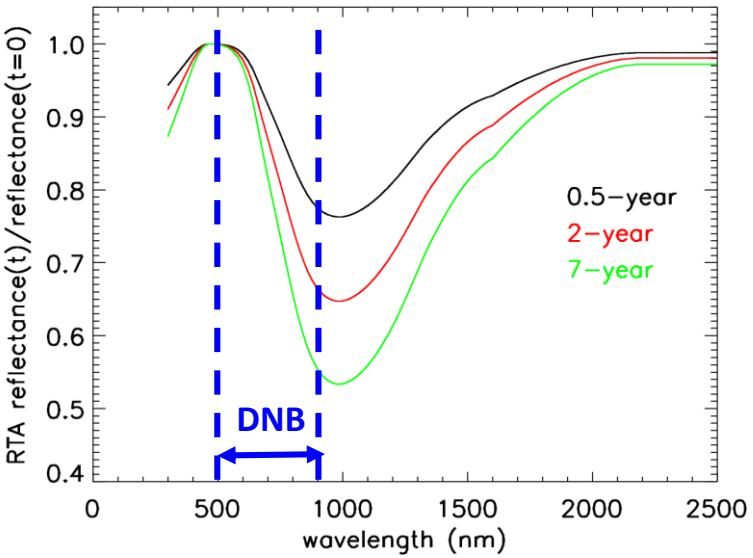
Terra MODIS RMSE (C6)
Track: 43 m; Scan: 44 m

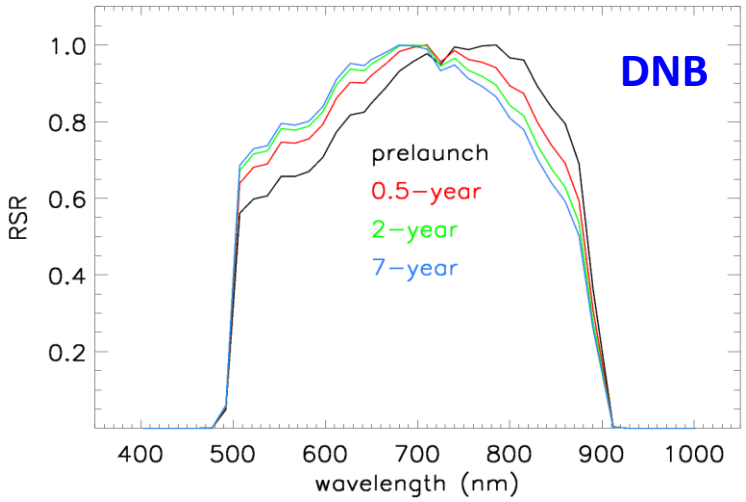
Aqua MODIS RMSE (C6)
Track: 46 m; Scan: 53 m

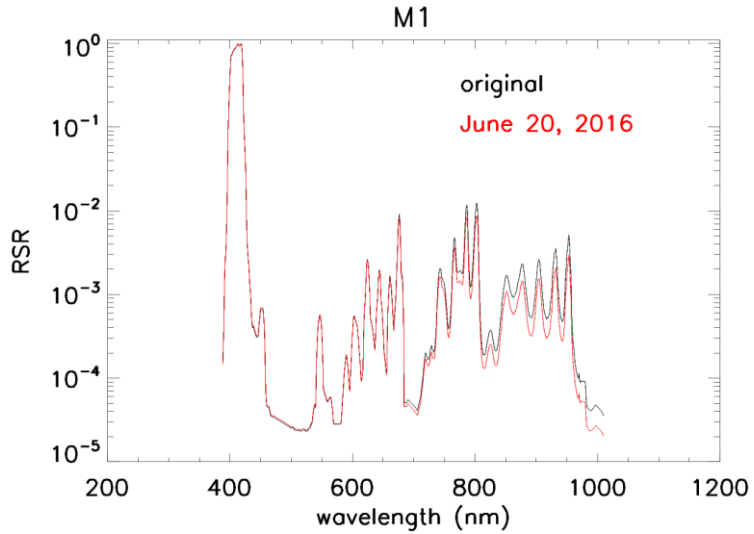
(Geometric Cal: Lin and Wolfe)

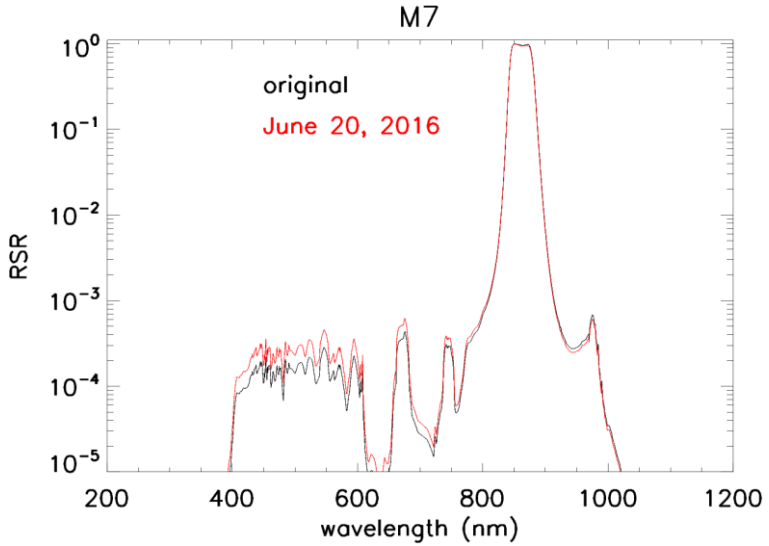
On-orbit Modulated Relative Spectral Response (RSR)

λ dependent optics degradation





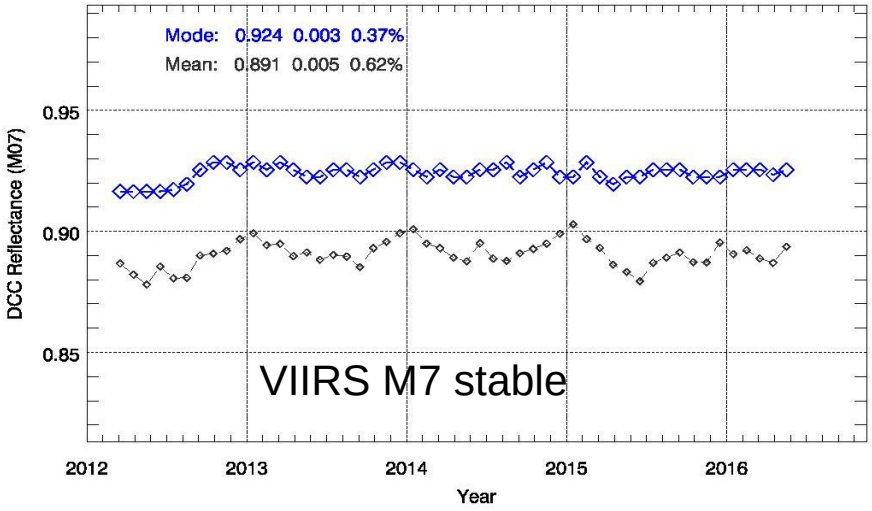


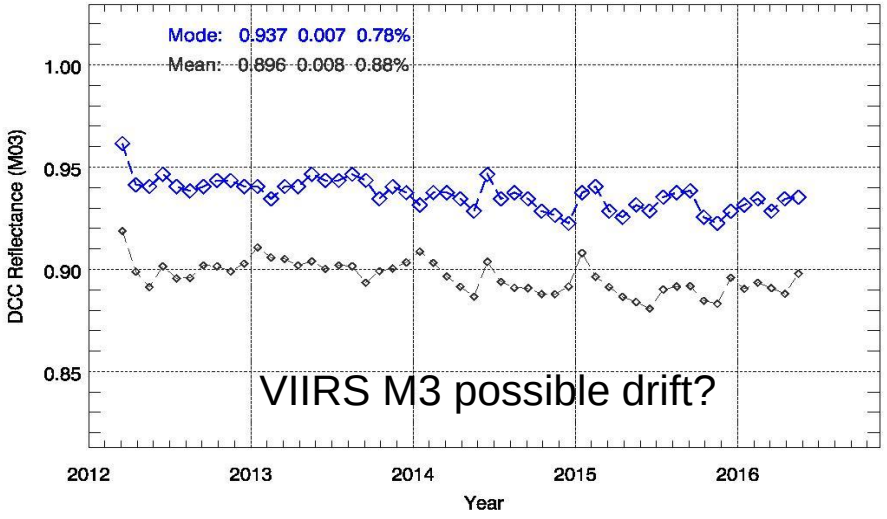


Impact of modulated RSR depends on spectral band location, bandwidth, and OOB response

Deep Convective Clouds (DCC) for Stability Assessments

- The reflectance of deep convective clouds (DCC) are known to be statistically stable over time
- Detecting VIIRS calibration drifts < 0.5% in selected bands over several years has been demonstrated
- A large number of data points can help reduce uncertainties
- Additional effort is required to use DCC for calibration inter-comparisons

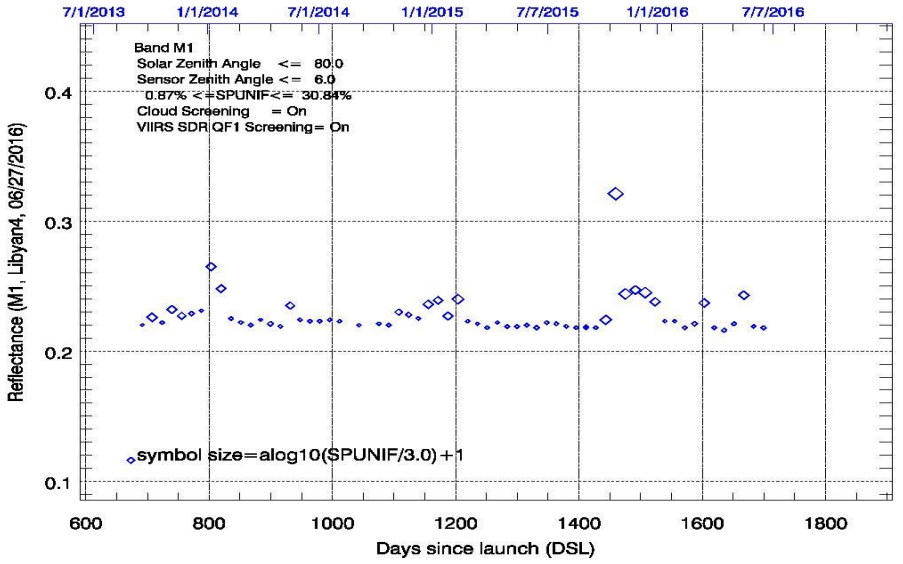


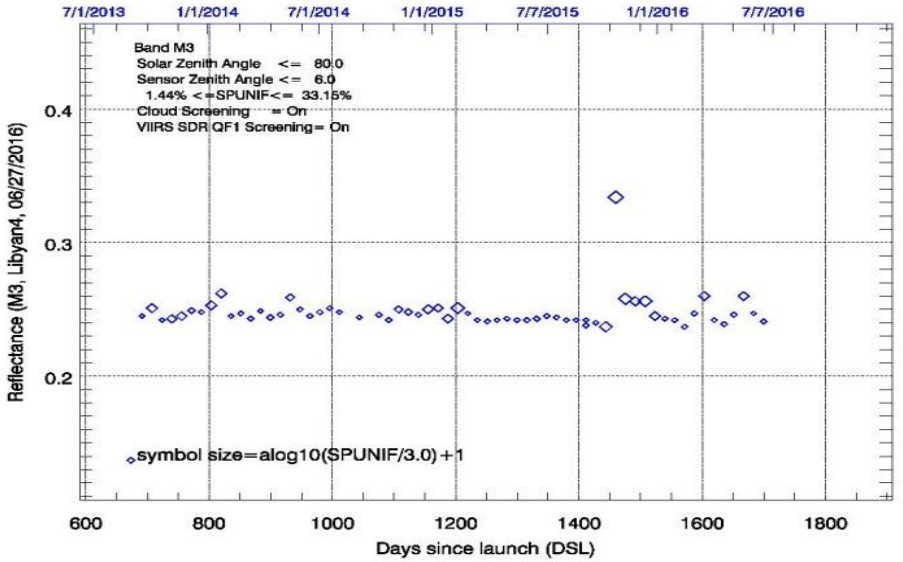


Wang & Cao, Remote Sensing 2016

Desert Sites for Stability Assessments

- CEOS Working Group on Cal/Val (WGCV) has identified and endorsed several pseudo invariant desert sites for calibration stability monitoring, such as Libya4
- Caveats: sky is not always clear in the desert which reduces the number of useful data points; bi-directional reflection introduces uncertainties
- Desert observations have helped MODIS in correcting long-term drift

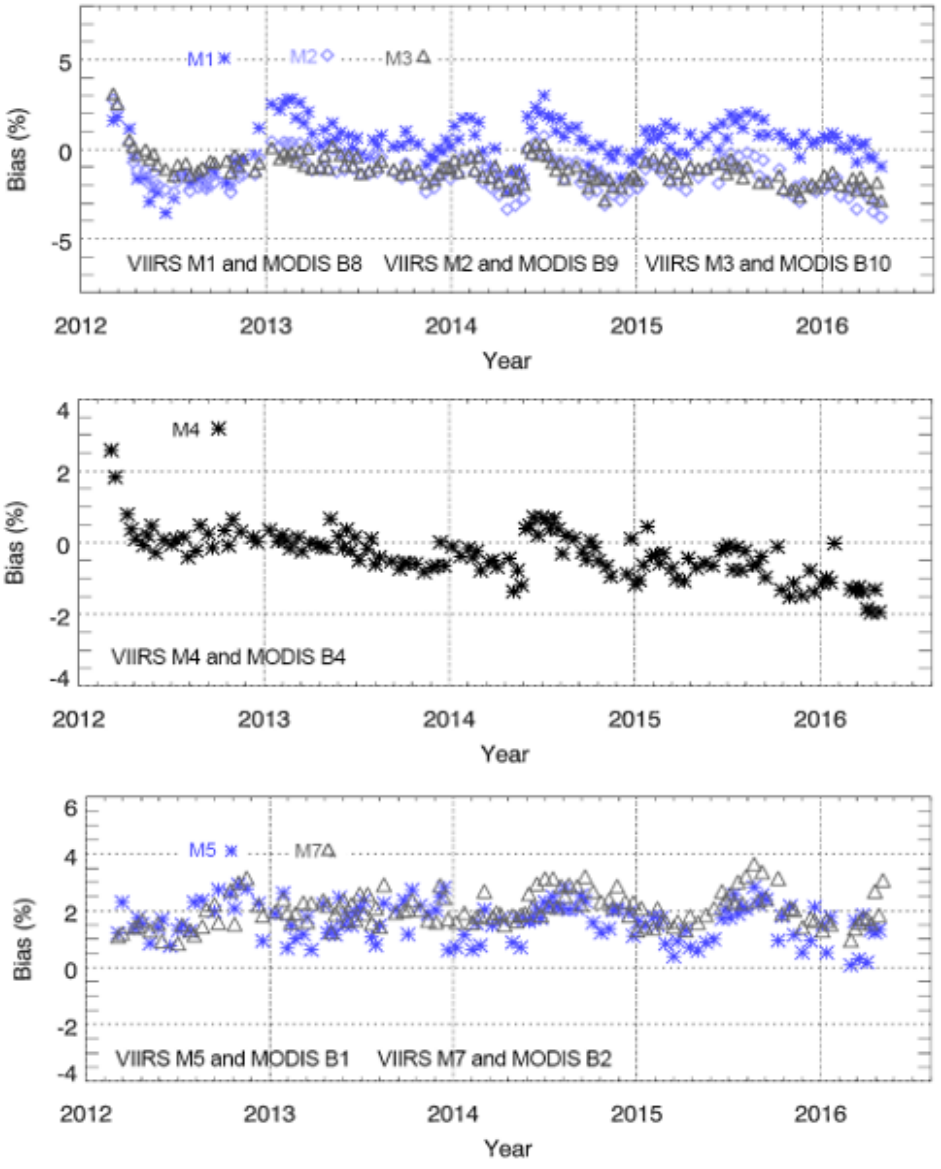




Desert trend doesn't necessarily agree with the DCC trend

SNOs for Sensor Calibration Inter-comparisons

- Comparisons between VIIRS and MODIS have been routinely performed at the Simultaneous Nadir Overpass (SNOs)
- Caveats: this approach only provides relative bias between VIIRS and MODIS, using MODIS as the reference (14 years in orbit)
- Need to extend the inter-comparisons with other satellite instruments at SNOs
- GSICS will help facilitate the comparisons



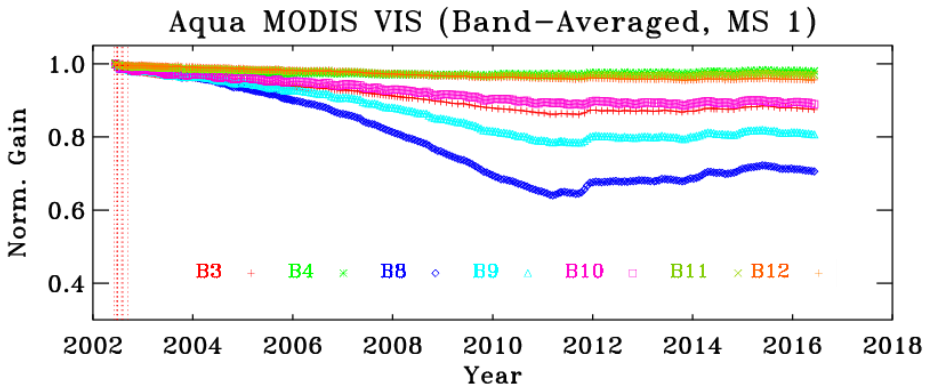
Uprety & Cao, RSE 2015

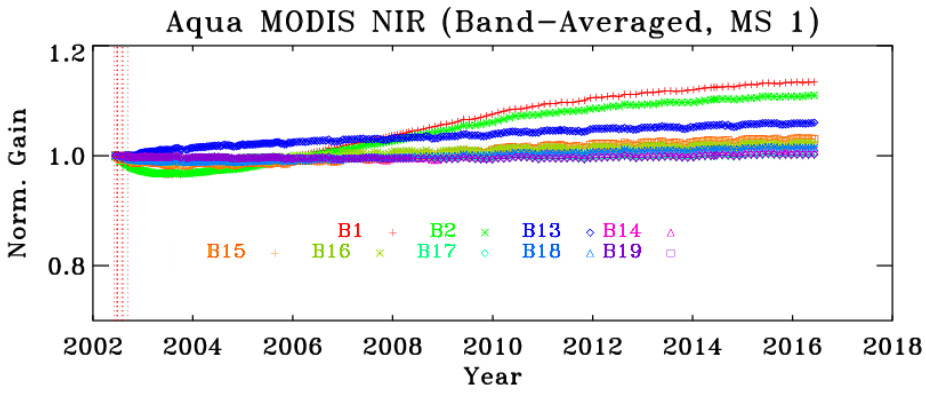
Challenging Issues and Future Work

- **Future work to address existing and new challenging issues and to continue improving sensor on-orbit calibration**
  - Changes in MODIS VIS/NIR response versus scan-angle (RVS) – continuing effort
  - Changes in Terra MODIS polarization sensitivity and impact on sensor's earth view response trending – progress has been made in recent years
  - Uncertainty due to large SD degradation and no SD degradation monitoring for SWIR bands – further improvement
  - Terra LWIR PV Xtalk impact – correction algorithm testing and implementation
  - Special calibration and validation effort in support of VIIRS data reprocessing – effort by both NASA and NOAA
  - Improved use of VIIRS SD and lunar calibration parameters – impact of RSR
  - Tracking potential changes in VIIRS RVS – lessons from MODIS
- **MODIS and VIIRS calibration consistency and impact on science products**
  - Extensive calibration and validate effort and science support
  - Community effort and interagency collaboration

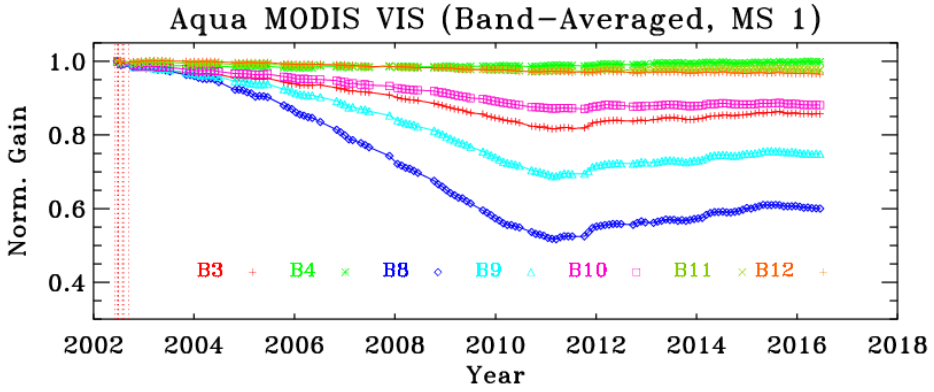
Changes in Response Versus Scan-angle (RVS)

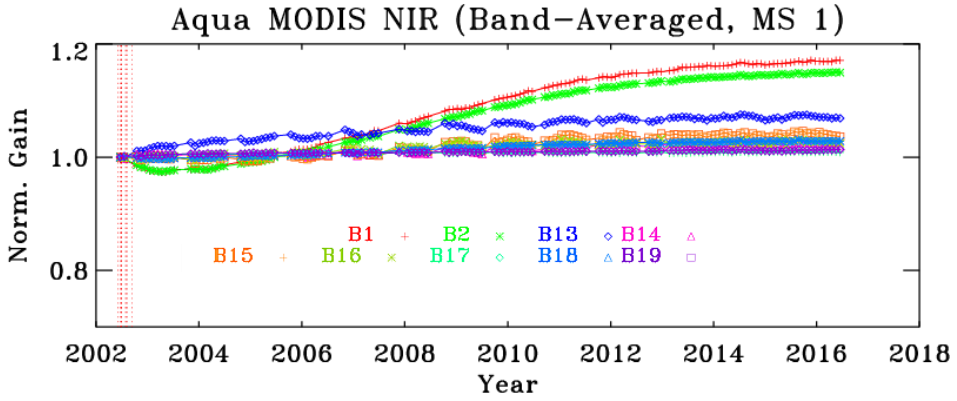
SD Calibration





Lunar Calibration



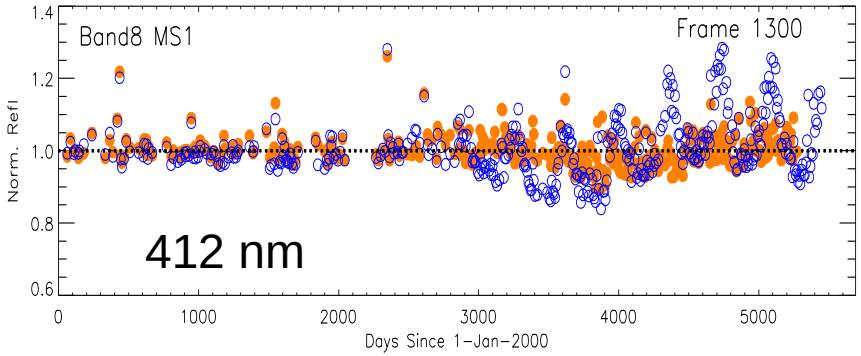


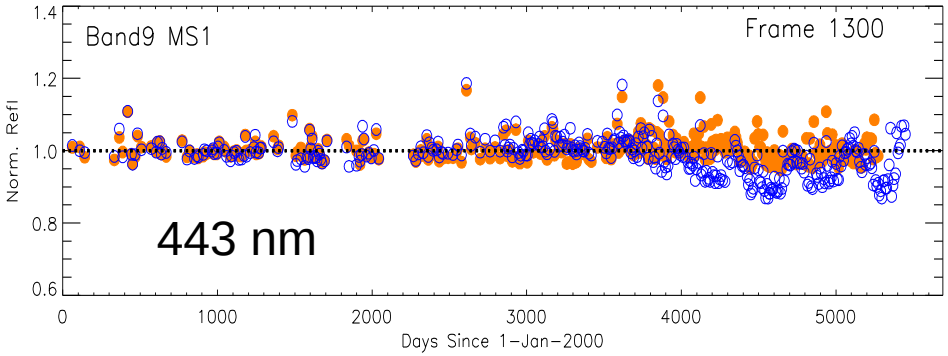
SD and lunar calibrations performed at 2 different angle of incidences (AOIs)

RVS is wavelength, mirror-side, and AOI dependent

On-orbit Changes in Terra MODIS Polarization Sensitivity

- Noticeable on-orbit changes in the polarization sensitivity, especially at short wavelengths (412 nm and 443 nm bands most impacted)
- Previous effort by NASA OBPG developed an approach to decouple the impacts of on-orbit changes in the RVS and polarization using L3 ocean products [*Kwiatkowska et.al, in AO 2009*]
- Current MCST effort provides an independent approach to track the on-orbit polarization sensitivity using L1 reflectance over pseudo-invariant desert sites [*Wu et.al, in SPIE 2015*]
  - On-orbit polarization correction based on the Mueller matrix [similar to OBPG approach]. Linear Stokes vector components modeled from 6SV

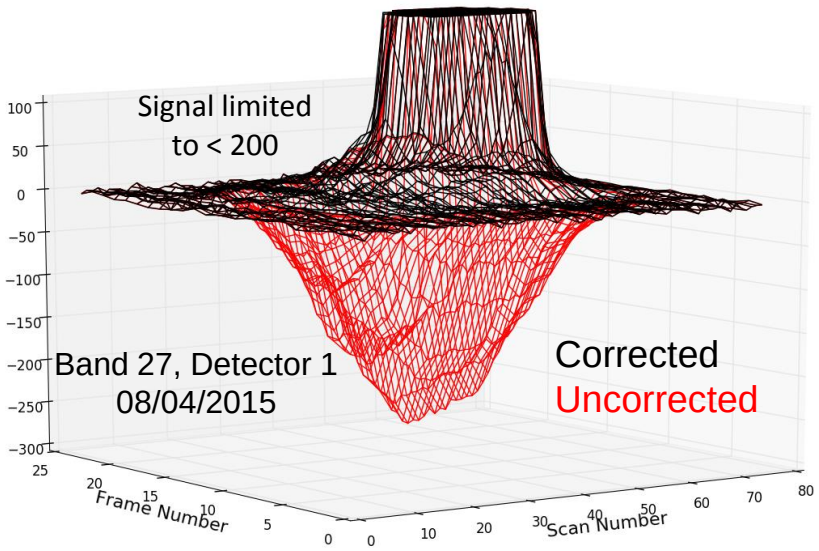




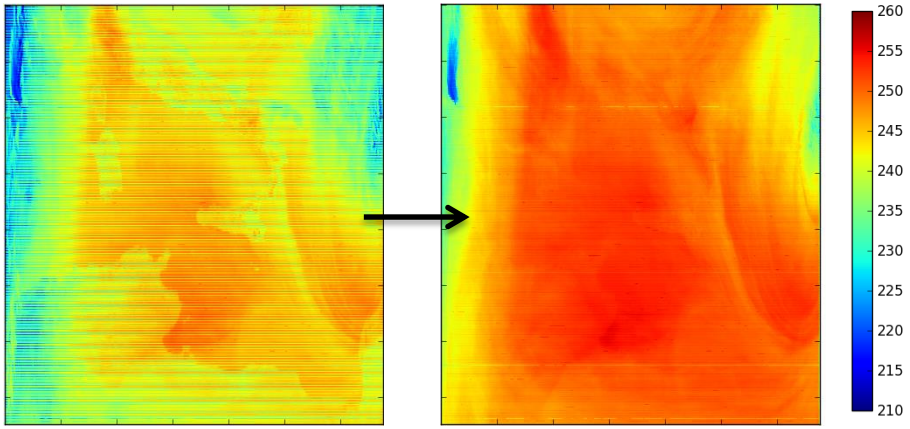
uncorrected reflectance polarization corrected reflectance

Terra MODIS LWIR PV Band Crosstalk Correction

Correcting the Lunar Signal

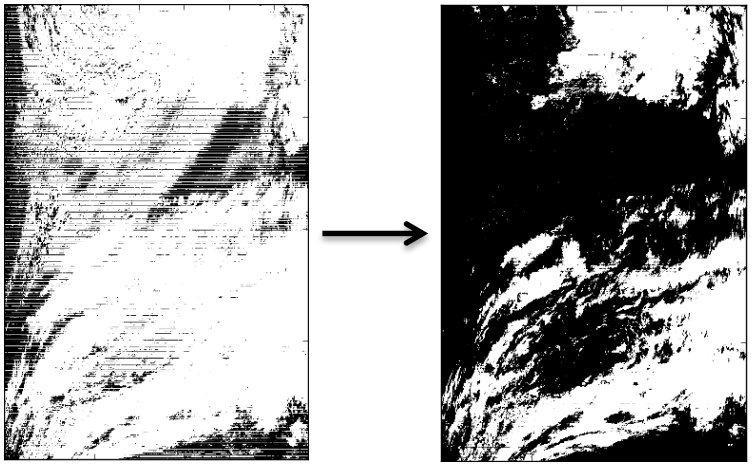


De-striping and Land Feature Removal in Band 27



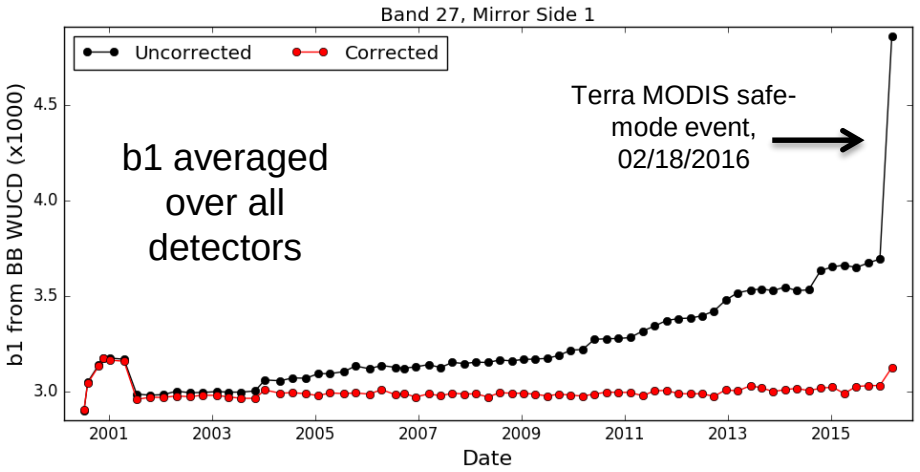
Granule 2015183.1005

Removal of False Clouds from B29 – B31 Cloud Mask



Granule 2015182.1345

Gain Coefficient Drift Correction



Questions?