MODIS and VIIRS Reflective Solar Calibration Update

X. Xiong[1], C. Cao[2], A. Angal[3], S. Blonski[4], N. Lei[3], W. Wang[4], Z. Wang[3], and A. Wu[3]

[1]NASA GSFC, MD 20771, USA; [2]NOAA NESDIS, MD 20740, USA

[3]SSAI, MD 20706, USA; [4]ERT, MD 20707, USA

<u>Contributions:</u>

MODIS/VIIRS Characterization Support Team (MCST/VCST), NASA
S-NPP and JPSS VIIRS SDR Calibration Team, NOAA

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Outline

- **MODIS and VIIRS RS Calibration Approaches and Activities**
- **Instrument On-orbit Performance**
- **Challenging Issues**
- **Future Work**

More details in recent updates of MODIS and VIIRS calibration and performance:

Xiong and Angal, et al, “Terra and Aqua MODIS Instrument Performance,” IGARSS 2016

Xiong and Cao, et al, “S-NPP VIIRS Calibration and Performance Update,” IGARSS 2016

Presentations of this JPSS STM Session 3: VIIRS SDR (Tuesday)

MODIS and VIIRS

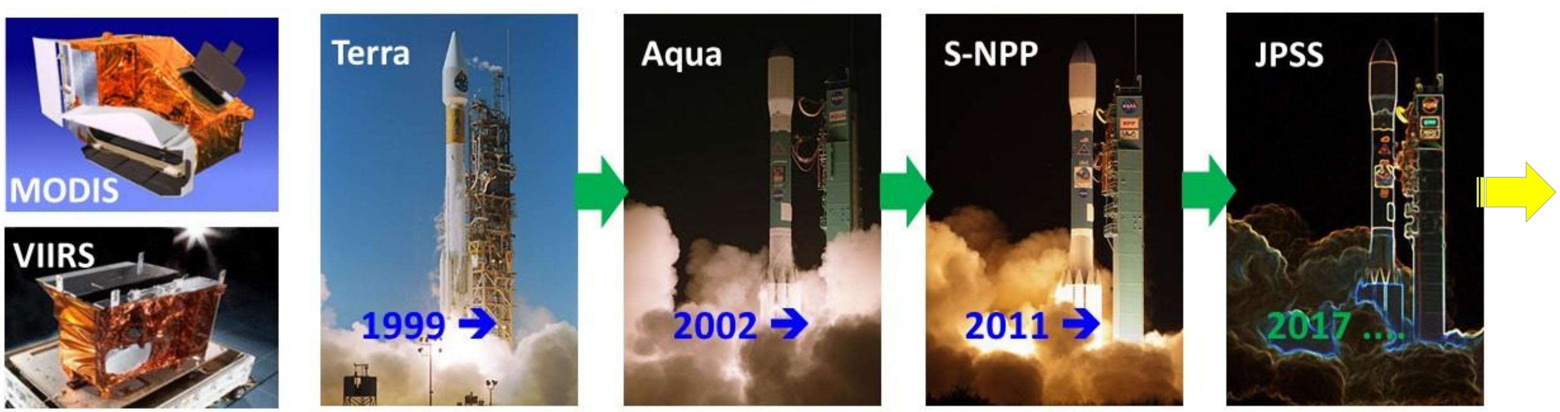
Missions

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

Applications

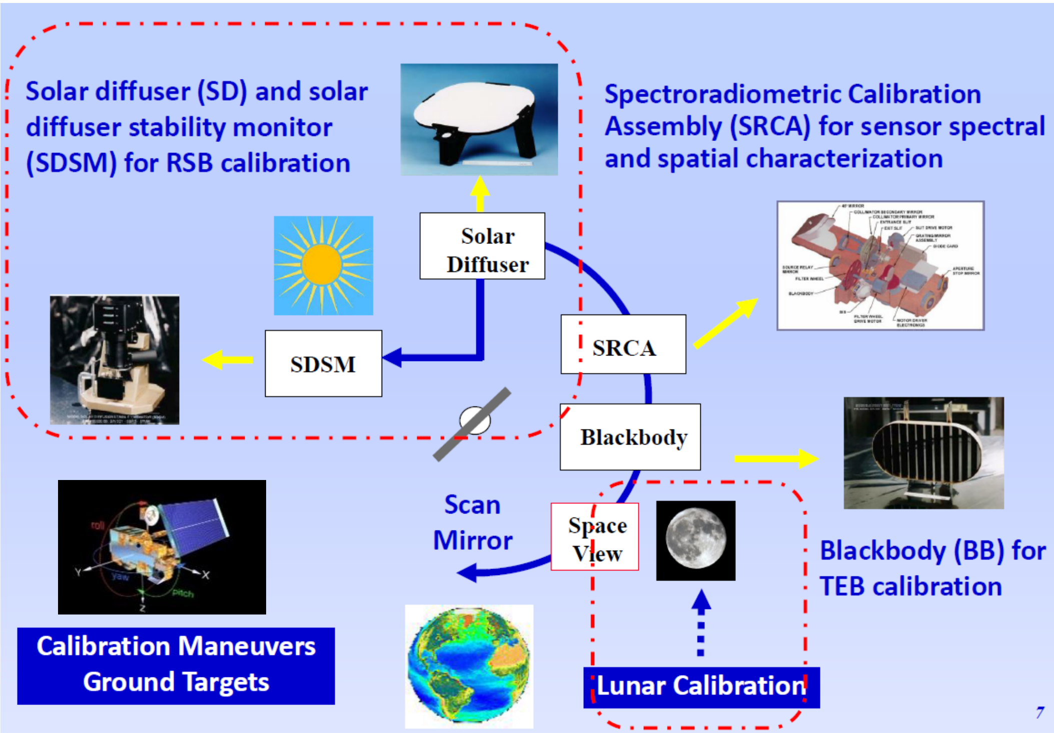
Nearly 40 data products from MODIS

22 environmental data products (EDRs) from VIIRS

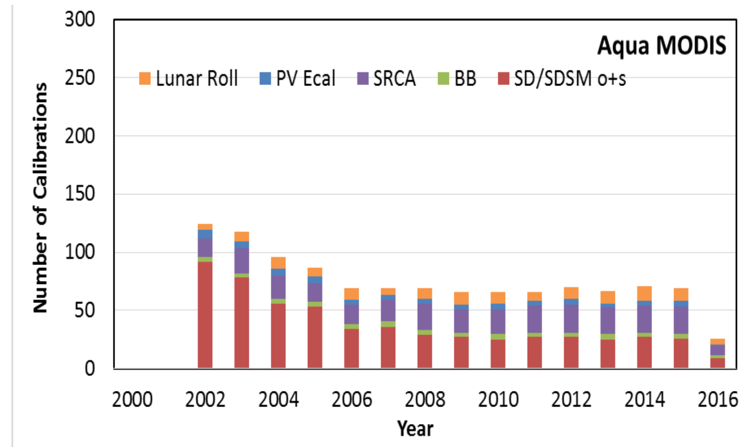


MODIS Calibration Methodologies and Activities

Calibration Methodologies



Calibration Activities



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

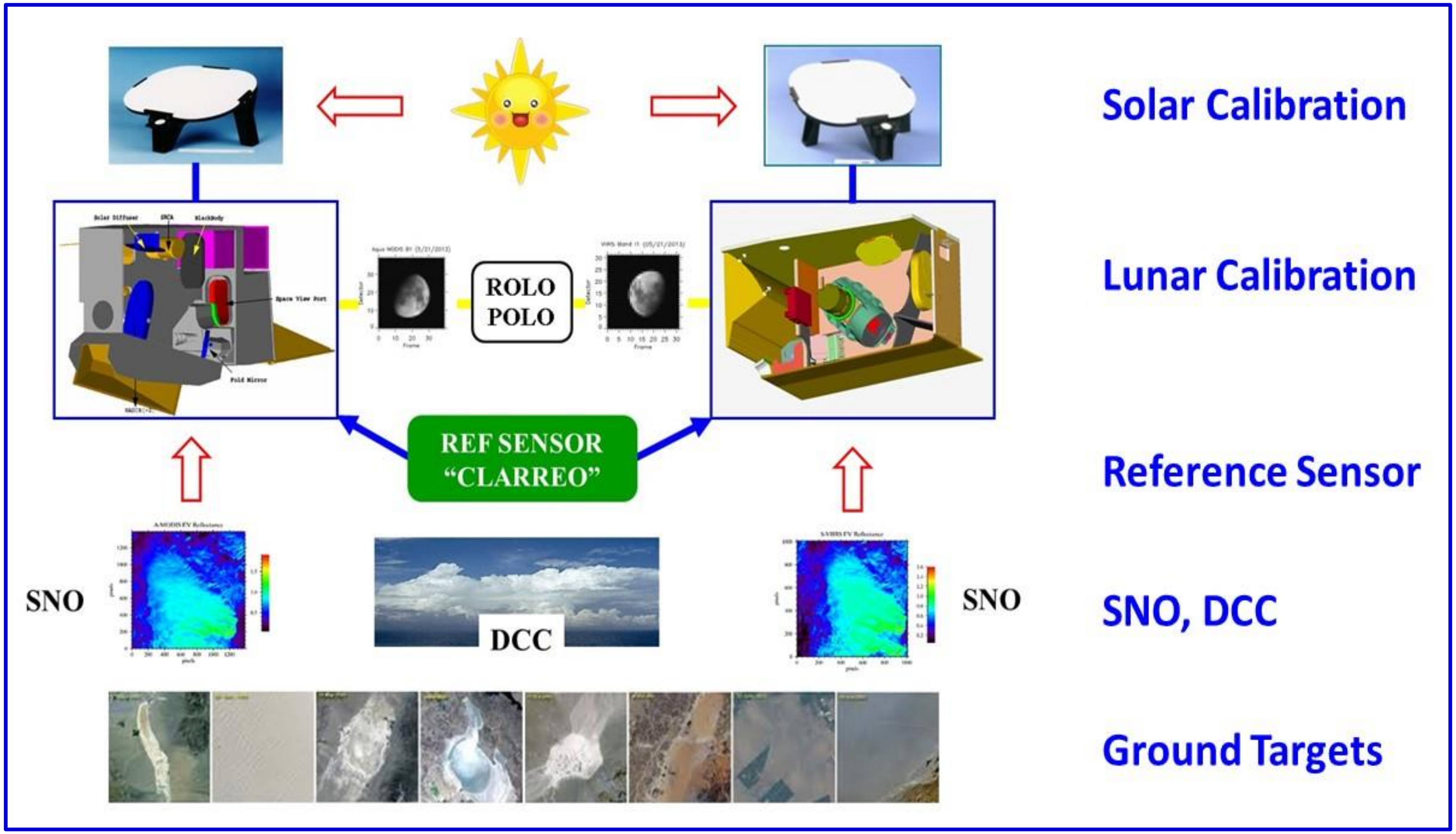
VIIRS Operation and Calibration - MODIS Heritage

- SD calibration: each orbit
- SDSM: 3 times/week (more at mission beginning)
- BB WUCD: quarterly (18 since launch)
- DNB: monthly VROP operation
- Lunar observations: near-monthly (42 since launch)

DNB CAL for VIIRS

SRCA CAL for MODIS

Performance Assessments and Calibration Inter-comparisons



Many efforts and progresses have been made by different groups, including GSICS community

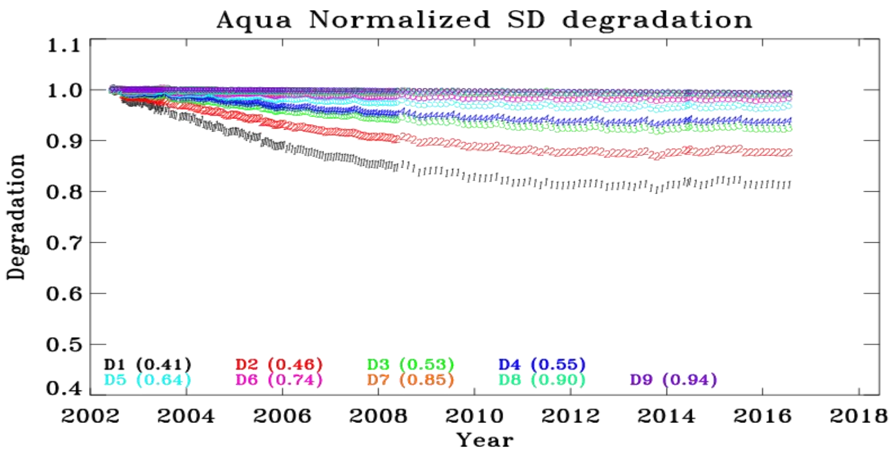
Instrument On-orbit Performance (RSB)

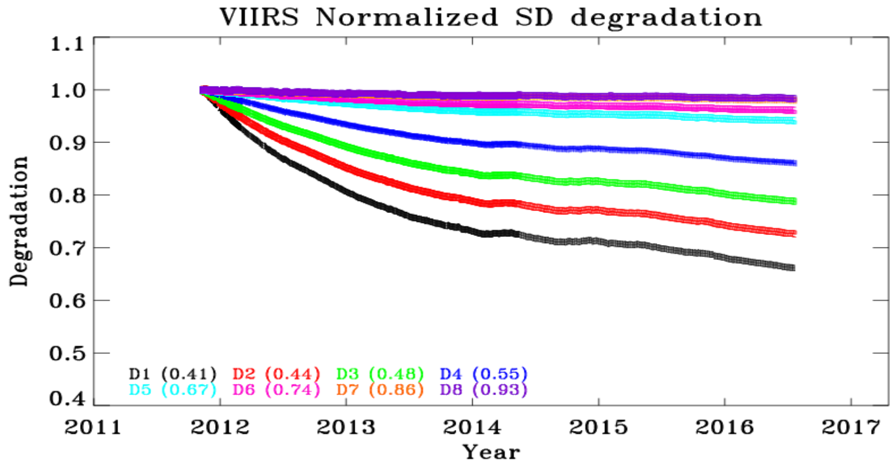
- **Aqua MODIS**
  - Inst. and VIS/NIR FPA temperature: stable (< 2.0 K increase over 14 years)
  - SD degradation: large at short wavelengths; slower than Terra MODIS
  - Spectral band responses: large at VIS and NIR; small at SWIR
  - Band-to-band registration (BBR): stable (tracked using SRCA)
  - Center wavelengths: changes are within 0.5-1.0 nm for most VIS/NIR bands; relatively large changes for bands with broad bandwidths (bands 1, 18, 19)

- **S-NPP VIIRS**
  - Inst. and VIS/NIR FPA temperatures: stable (< 1.0 K increase over 4.5 years)
  - SD degradation: large at short wavelengths; similar to Terra MODIS
  - Spectral band responses: large at NIR and SWIR; small at VIS
  - Band-to-band registration (BBR): stable (tracked using lunar observations)
  - Relative spectral response (RSR): modulated on-orbit (due to wavelength dependent optics degradation); noticeable impact for DNB

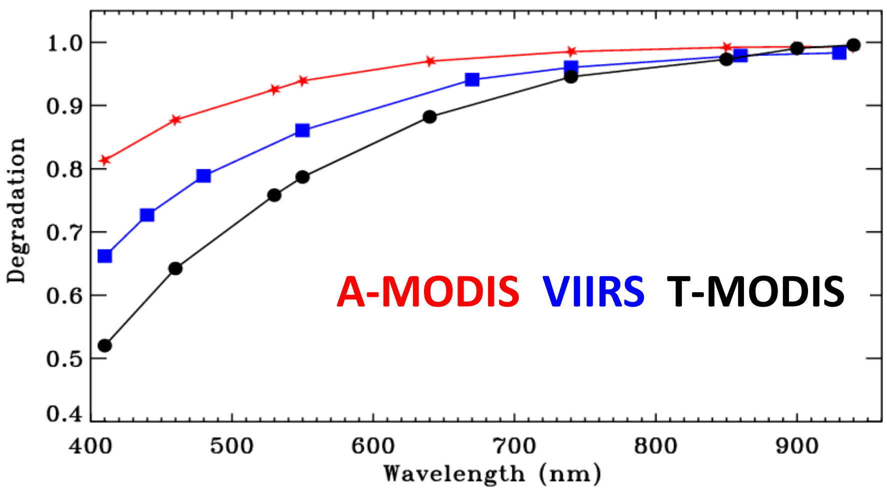
MODIS and VIIRS SD Degradation

SD on-orbit degradation trending: faster at shorter wavelengths



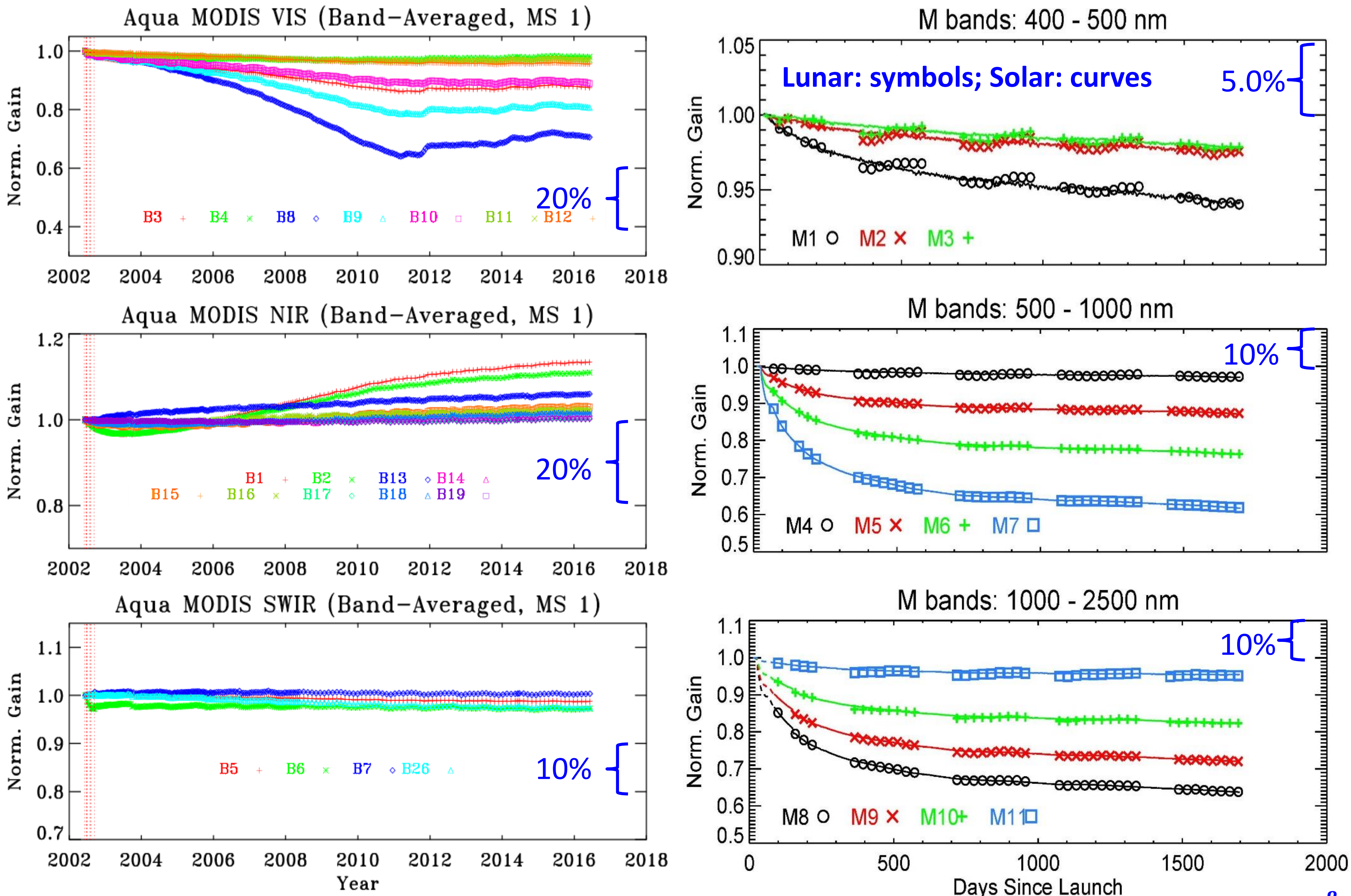


SD degradation vs wavelength

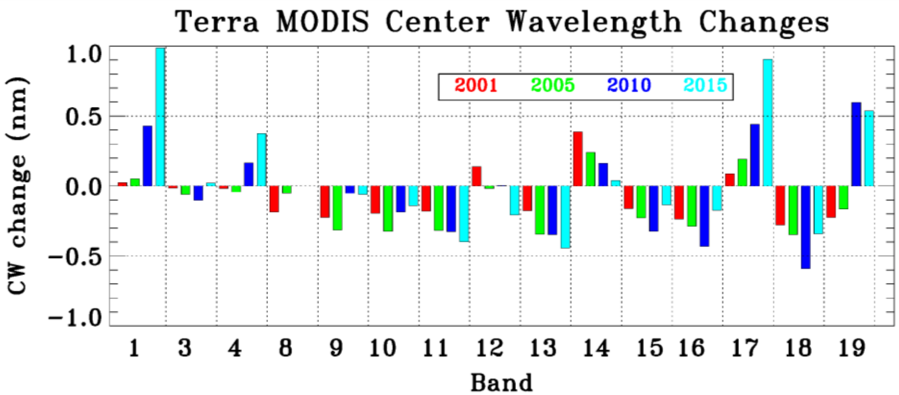


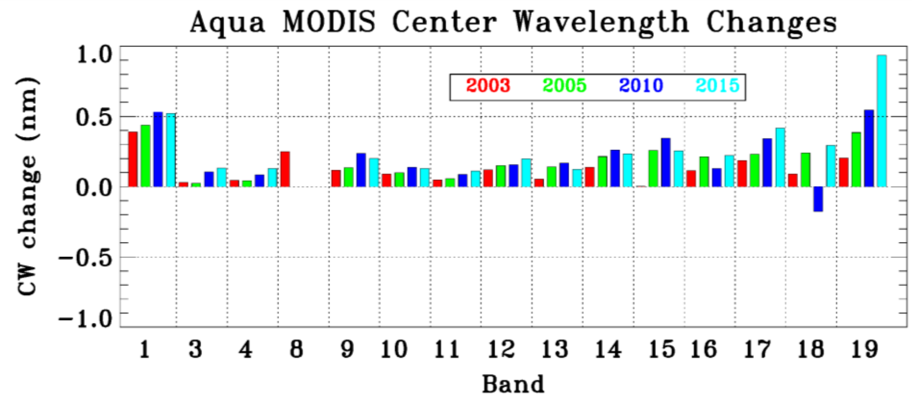
- Large SD degradation at short wavelength
- Increased SD degradation in Terra MODIS after its SD door fixed at "Open"
- VIIRS has no SD door

VIS/NIR/SWIR Spectral Band Responses (Gains)



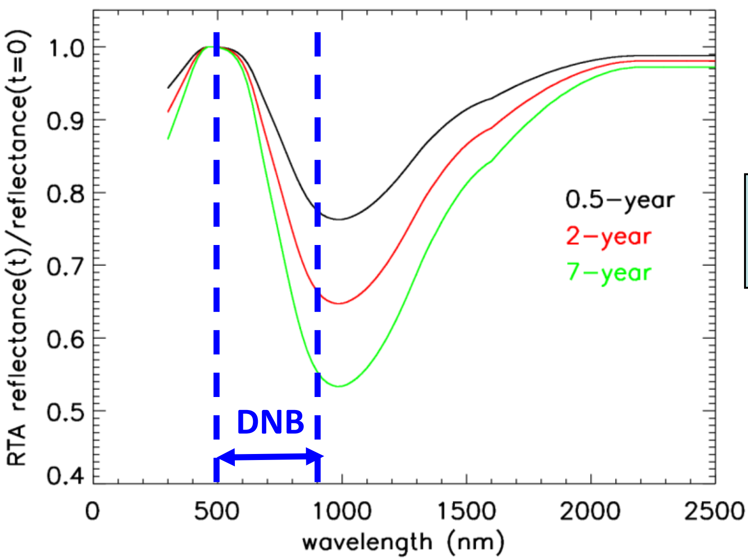
Spectral Characterization Performance



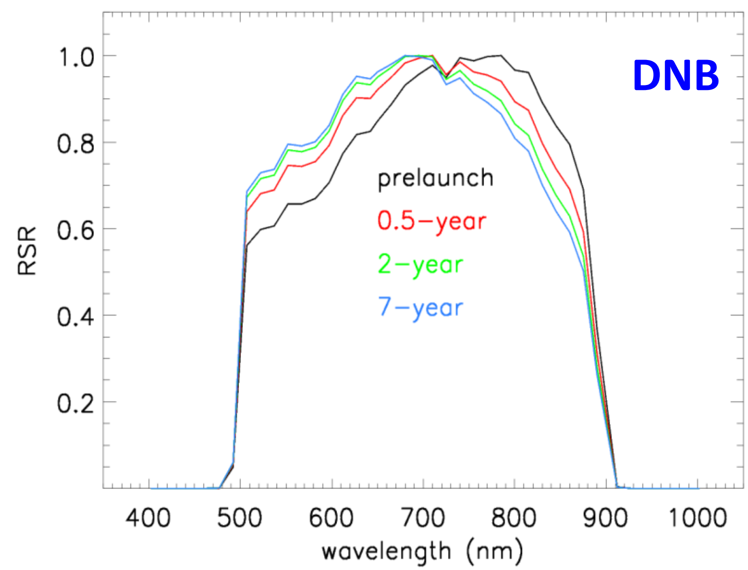


Characterized by the on-board SRCA

λ dependent optics degradation



On-orbit modulated RSR



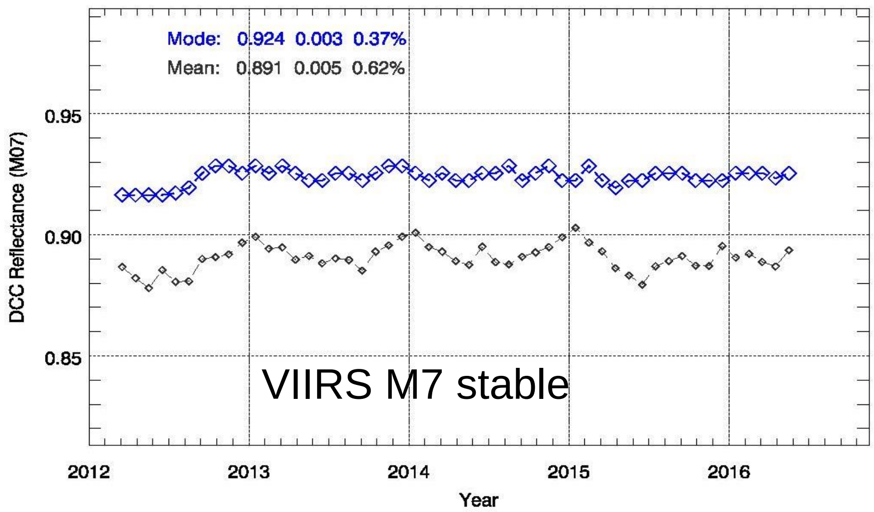
Small impact on M/I bands

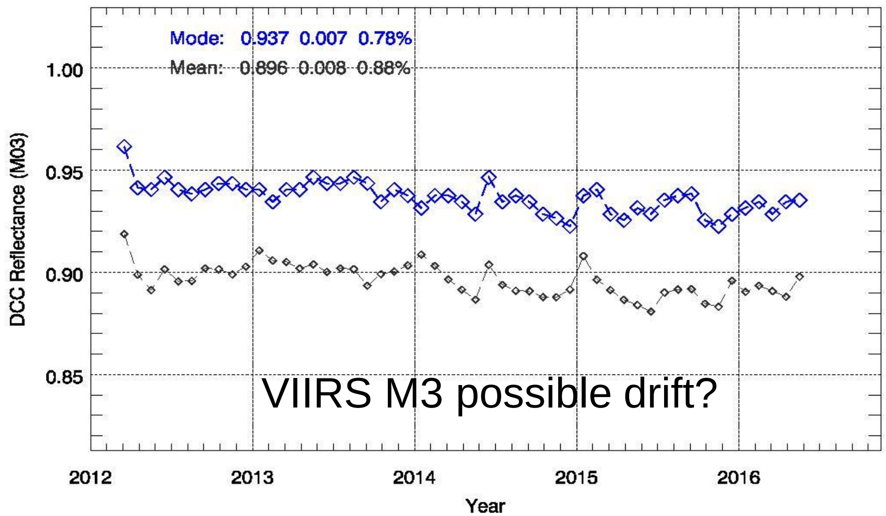
Determined via an optics degradation model

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

(VIIRS data from IDPS SDR)



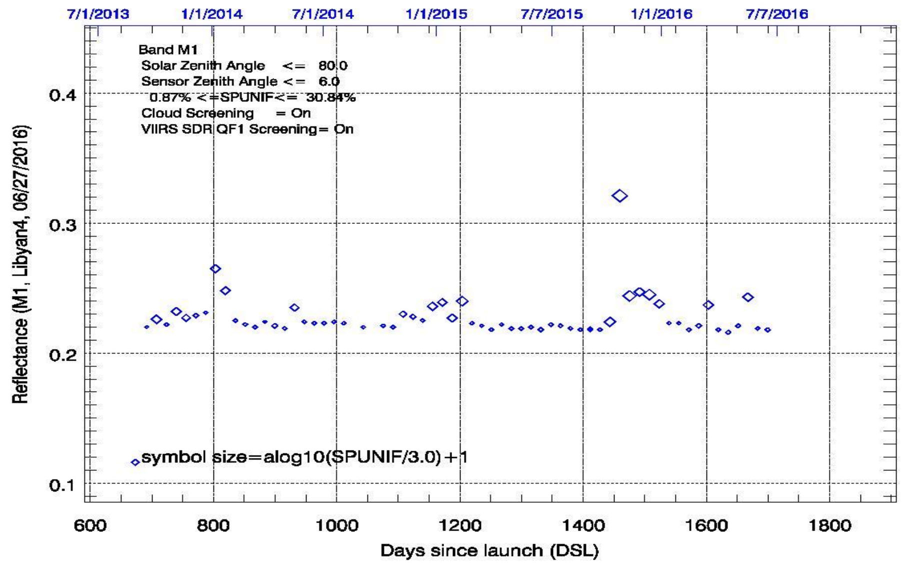


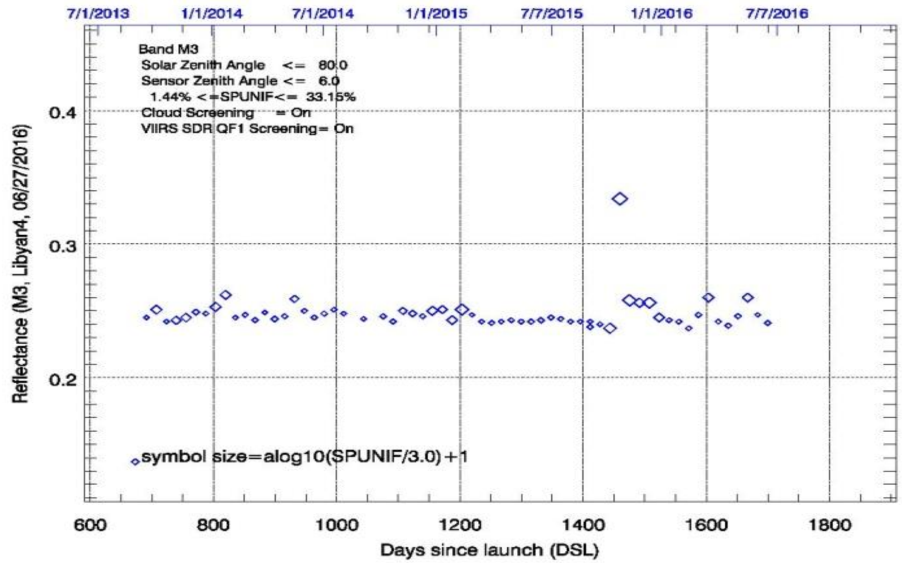
Wang & Cao, Remote Sensing 2016

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

(VIIRS data from IDPS SDR)



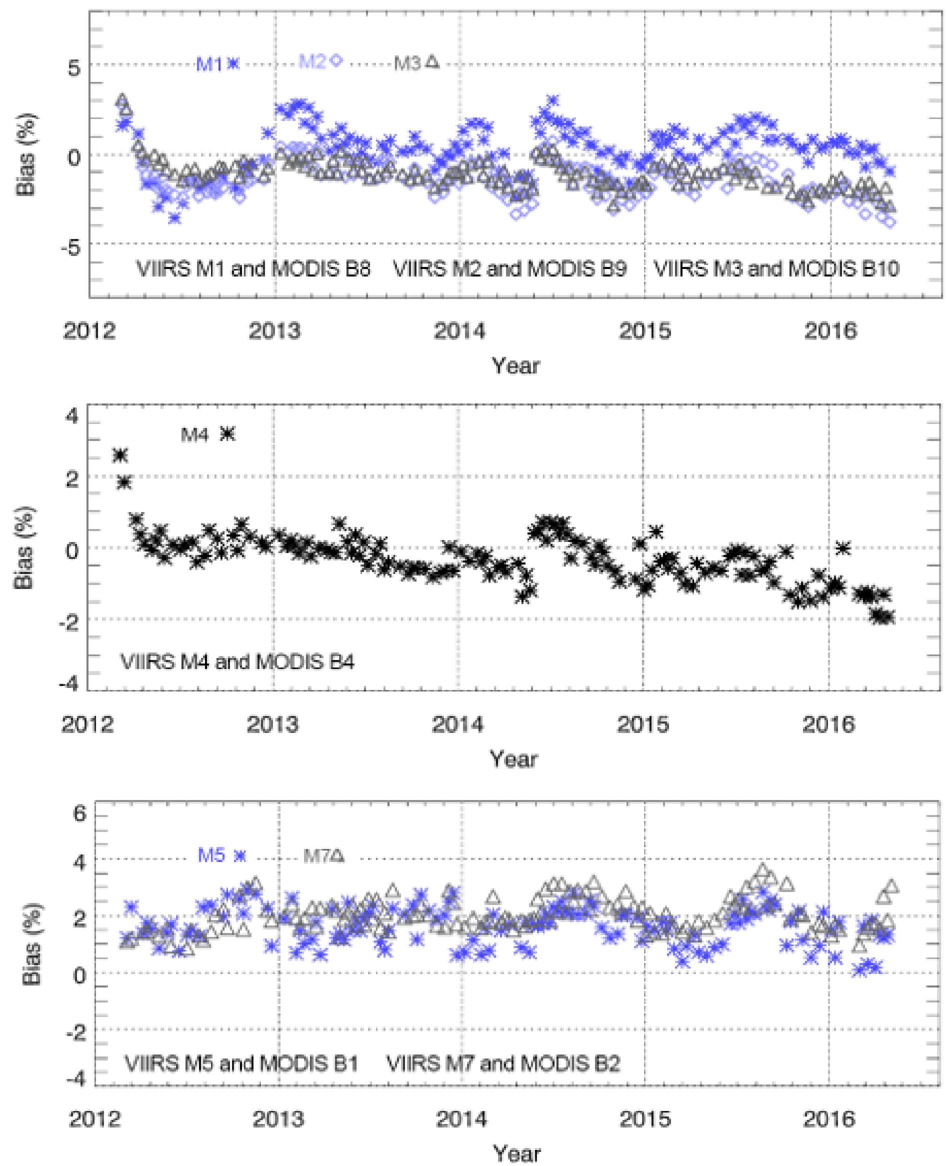


Desert trend doesn't necessarily agree with the DCC trend

SNOs for Sensor Calibration Inter-comparisons

- Comparisons between VIIRS and Aqua 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

(VIIRS data from IDPS SDR)



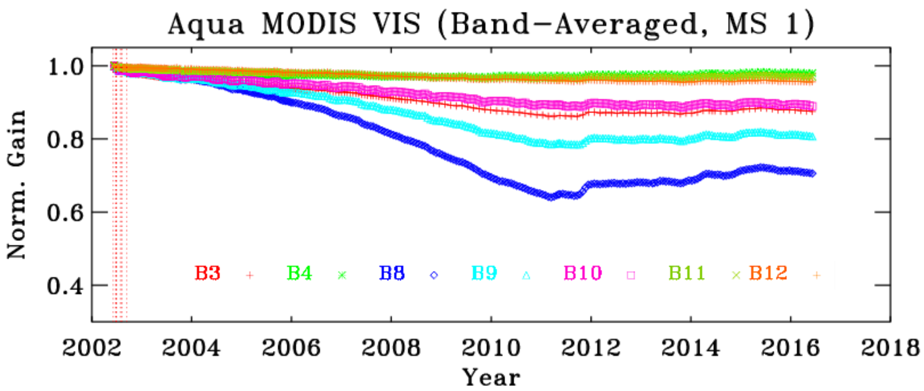
Uprety & Cao, RSE 2015

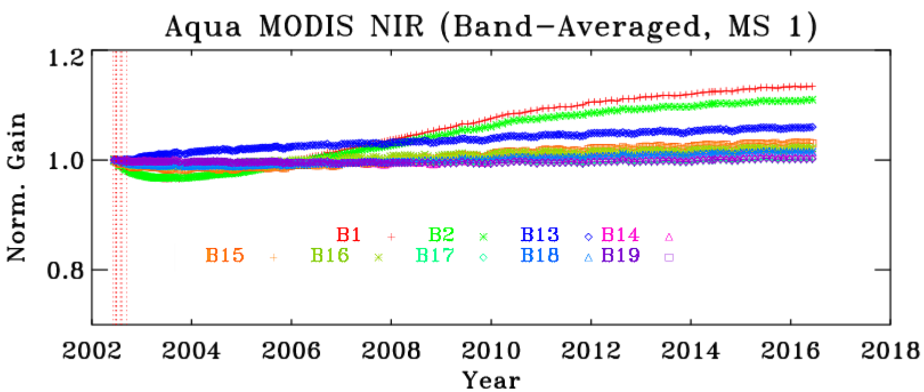
Challenging Issues and Future Work

- **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)
  - Potential changes in Aqua MODIS polarization sensitivity and impact on sensor's earth view response trending (Terra MODIS lessons)
  - Uncertainties due to large SD degradation in VIS bands and no SD degradation monitoring for SWIR bands – various corrections applied by different groups
  - Special calibration and validation effort in support of VIIRS data reprocessing – joint effort by NASA and NOAA teams (groups)
  - Improved use of VIIRS SD and lunar calibration parameters
  - 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

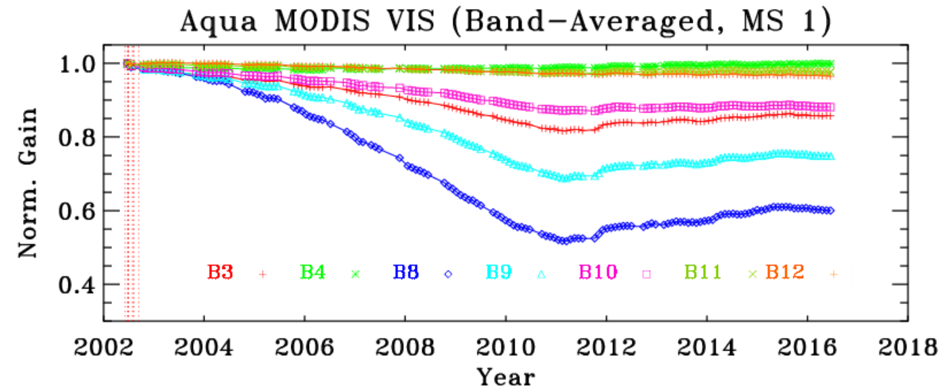
Changes in MODIS VIS/NIR Response Versus Scan-angle (RVS)

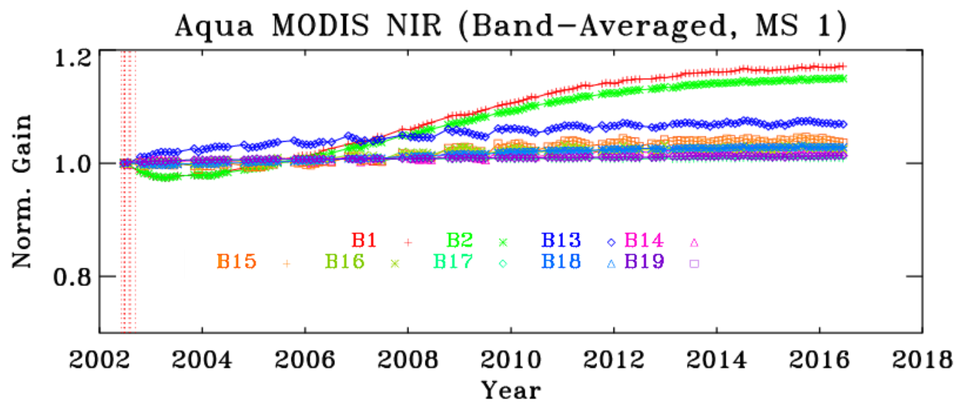
SD Calibration





Lunar Calibration

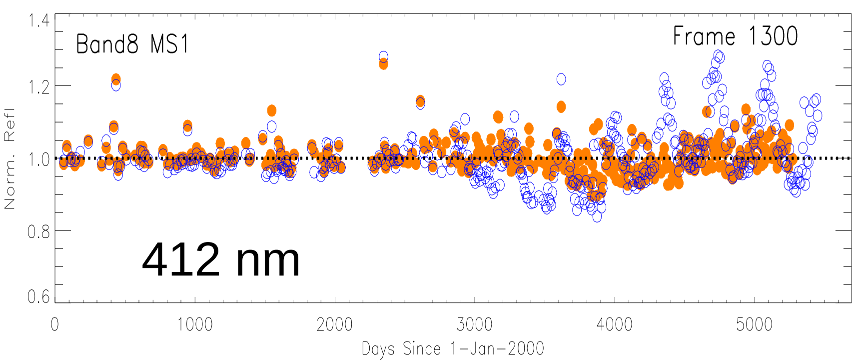


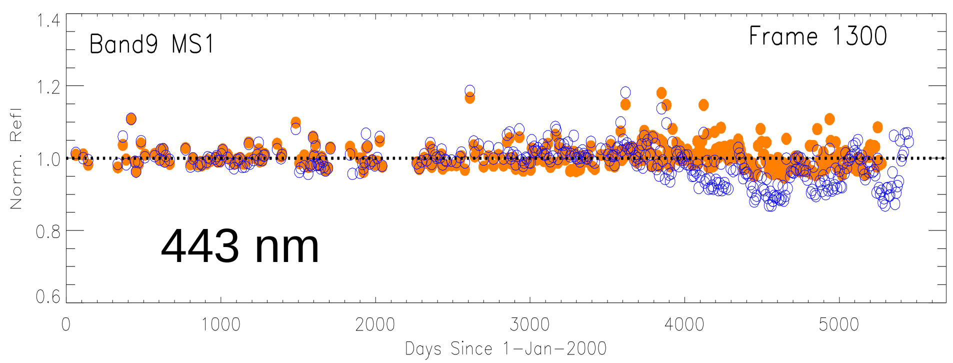


SD and lunar calibrations performed at 2 different angle of incidences (AOIs)
RVS is wavelength, mirror-side, and AOI dependent

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

Aqua MODIS and S-NPP VIIRS Calibration Differences

V/M Band	SNO [1]	SNO [2]	Dome C [1]	Dome C [3,4]	Desert [1]	Desert [3,4]	DCC [5]	Ocean [6]	Ocean [2]
M1/B8	-0.4±1.2	0.8±0.8	-1.3±1.0	-0.2±0.7	0.3±0.9	1.6±0.3	-0.5±1.0	-2.0±1.5	1.2±0.5
M2/B9	-1.0±1.2	-1.7±0.6		-0.5±0.7	-0.3±0.9	0.4±0.3	-0.5±0.8	-4.0±2.0	-1.8±0.5
M3/B10	-0.9±0.8	-1.3±0.4	0.2±0.9	-0.2±0.8		1.3±0.4	-1.0±0.8	-3.5±2.0	-0.1±0.6
M4/B4	1.5±0.8	-1.5±0.3	1.8±1.5	1.6±1.0	-0.8±1.0	-0.2±0.4	2.0±1.0	-1.5±1.5	-0.2±0.9
M5/B1		10.0±0.6		4.8±0.9		9.5±0.5	9.0±0.7	1.5±0.5	
M7/B2	2.6±0.7	4.0±0.5	2.2±1.7	2.8±1.4	3.9±0.6	4.0±0.5	2.5±0.5	4.0±2.0	
M8/B5		3.5±0.4		5.8±4.0		2.8±0.6			
M10/B6						0.5±0.4			
M11/B7						-6.0±1.0			
I1/B1	-0.3±0.7		-0.4±1.5		-0.7±0.8				
I2/B2	2.6±0.7		2.3±1.8		3.4±0.6				

Large RSR difference

Atmospheric impact and MODIS SWIR xtalk

1) Difference computed as 100*(VIIRS-MODIS)/MODIS
2) Non RSR correction applied
3) Numbers shown in the brackets are reference numbers
4) Results are based on MODIS C6 L1B and VIIRS IDPS/Land PEATE SDR

Challenges: help establish and generate long-term consistent science products from MODIS and VIIRS observations

References for Aqua MODIS and S-NPP VIIRS Calibration Differences

1. Wu, A., X. Xiong, C. Cao, and K. Chiang, "Assessment of SNPP VIIRS VIS/NIR radiometric calibration stability using Aqua MODIS and invariant surface targets", IEEE Transactions on Geoscience and Remote Sensing, Vol. 54, No. 5, pp. 2918-2924, 2016.
2. Uprety, S.,C. Cao, X. Xiong, S. Blonski, A. Wu, and X. Shao, "Radiometric Intercomparison between Suomi-NPP VIIRS and Aqua MODIS Reflective Solar Bands Using Simultaneous Nadir Overpass in the Low Latitudes", J. Atmos. Oceanic Technol., 30, 2720–2736. 2013.
3. Uprety, S., C. Cao, S, Blonski, W. Wang, Assessment of VIIRS radiometric performance using vicarious calibration sites, Proc. SPIE 9218, Earth Observing Systems XIX, 92180I, 2014, doi:10.1117/12.2061855.
4. Uprety, S., , C. Cao, Suomi NPP VIIRS reflective solar band on-orbit radiometric stability and accuracy assessment using desert and Antarctica Dome C sites, Remote Sensing of Environment, Vol. 166, pp. 106–115, 2015, doi:10.1016/j.rse.2015.05.021.
5. Wang, W. and C. Cao, "Assessing the VIIRS RSB calibration stability using deep convective clouds", Proc. SPIE, 9264, Earth Observing Missions and Sensors: Development, Implementation, and Characterization III, doi:10.1117/12.2068434, 2014.
6. Pahlevan, N., Z. Lee, R. Arnone, and A. Lawson, Investigating the Consistency between VIIRS and MODIS over the Oceans: The Sensor/Environmental Data Records (SDR/EDR), 2013.

Questions?