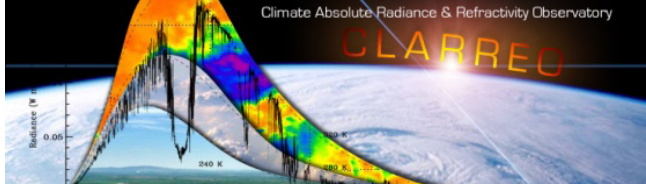

Assessment of Aqua MODIS and S-NPP VIIRS Reflective Solar Calibration

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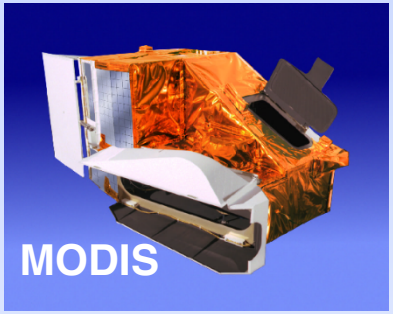
Contributions:

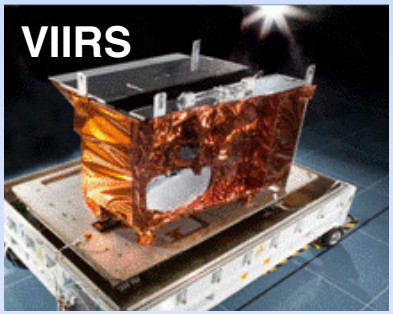
MODIS Characterization Support Team (MCST), NASA GSFC
VIIRS Characterization Support Team (VCST), NASA GSFC

Outline

- **Background**
- **MODIS and VIIRS Reflective Solar (RS) Calibration**
  - Methodologies
  - Activities
- **Performance Assessment**
  - Radiometric
  - Spectral and Spatial
  - Calibration Inter-comparison
- **Challenging Issues and Future Work**

Background





- Aqua MODIS launched on 05/04/2002
- 36 spectral bands with λ from 0.41 to 14.4 μm
- Spatial resolutions of 250 m (B1-2), 500 m (B3-7), and 1000 m (B8-36)
- On-board SD, SDSM, BB, SRCA, SV
- Well calibrated sensor; widely used for cross-sensor calibration and inter-comparisons; accepted by the GSICS community as the reference sensor for the RS calibration

- S-NPP VIIRS launched on 10/28/2011
- 22 spectral bands with λ from 0.41 to 12.4 μm
- Spatial resolutions of 375 m for I bands and 750 m for M bands
- On-board SD, SDSM, BB, SV
- Built with strong MODIS heritage and applied similar calibration approaches and strategies

Long-term data records since 2000
A broad range of applications

Aqua preceded by Terra (launched in Dec 1999)
S-NPP to be followed by JPSS (J1: L-2017; J2: L-2020; and J3/J4)

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

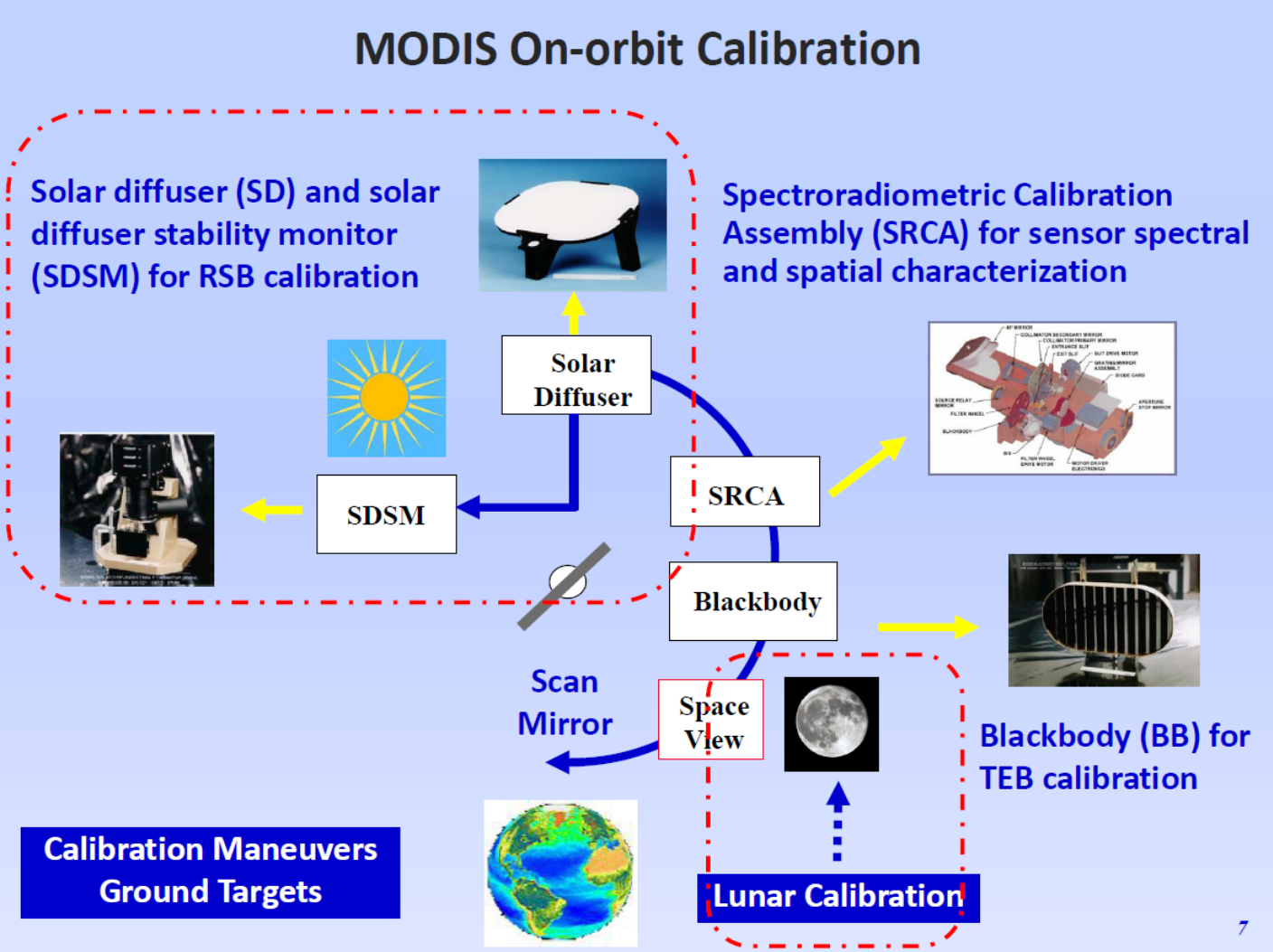
1 DNB

14 RSB
(0.4-2.3 μm)

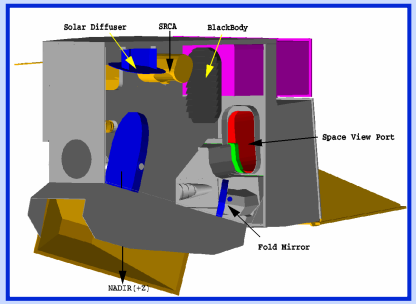
Dual Gain Bands:
M1-M5, M7, M13

7 TEB

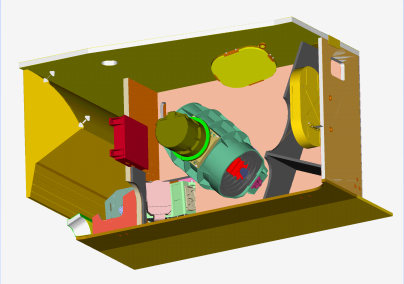
MODIS and VIIRS Reflective Solar Calibration



MODIS



VIIRS

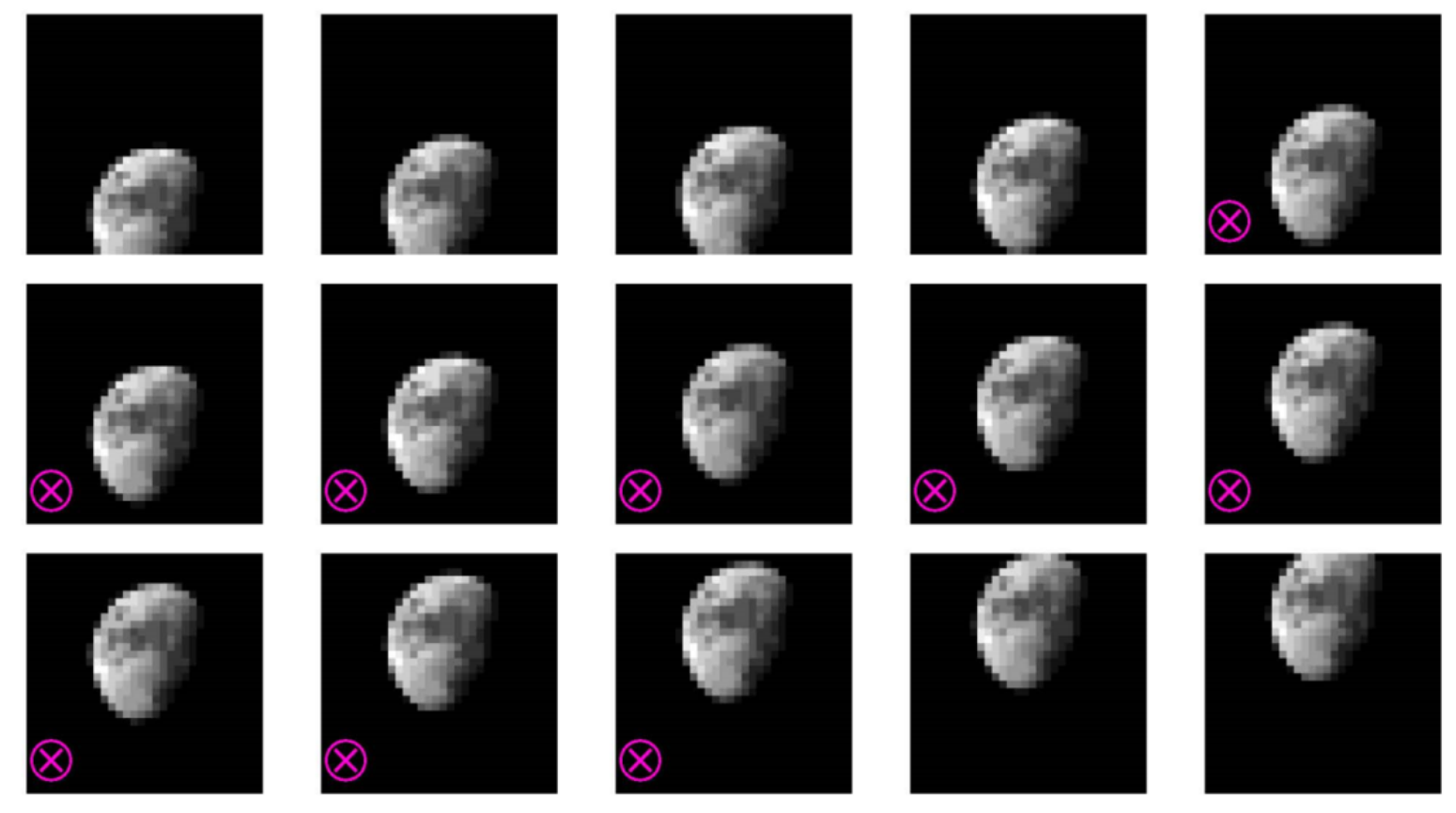


Similar Operation and Calibration Strategies Applied to both MODIS and VIIRS

Aqua MODIS and S-NPP VIIRS Calibration Activities

- **Solar Calibration – Traceability and Accuracy**
  - SD calibration scheduled regularly for MODIS with an optional attenuation screen (SD door closed if there is no calibration)
  - SD calibration performed each orbit for VIIRS through a fixed attenuation screen (no SD door)
  - SD degradation tracked by the on-board SDSM at gradually reduced frequencies: currently 3 per week for VIIRS and once every 3 weeks for Aqua MODIS
- **Lunar Calibration – Stability and Consistency**
  - Lunar observations regularly scheduled at the "same" phase angles: -55° for Aqua MODIS and -51° (initially at -55°) for VIIRS, viewed through Space View (SV) port, and performed via spacecraft roll maneuvers and data sector rotation
  - Calibration referenced to the USGS ROLO model
  - 30 lunar observations scheduled for S-NPP VIIRS and 122 for Aqua MODIS

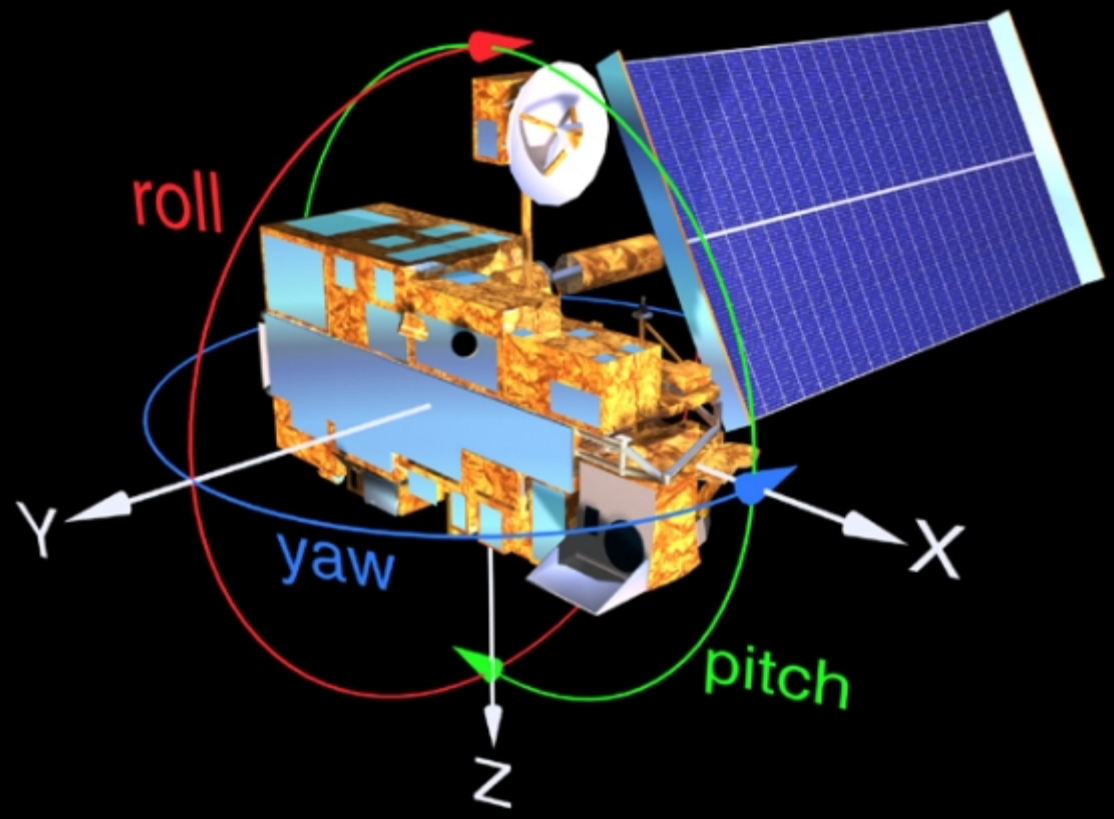
Example of S-NPP VIIRS Lunar Images



S-NPP VIIRS band I1 lunar images from Feb 10, 2014-02 lunar calibration (marked scans are the ones used in spectral irradiance calculation)

Spacecraft Maneuvers

- ✓ Terra
- ✓ Aqua
- ✓ S-NPP
- JPSS-1
- ..



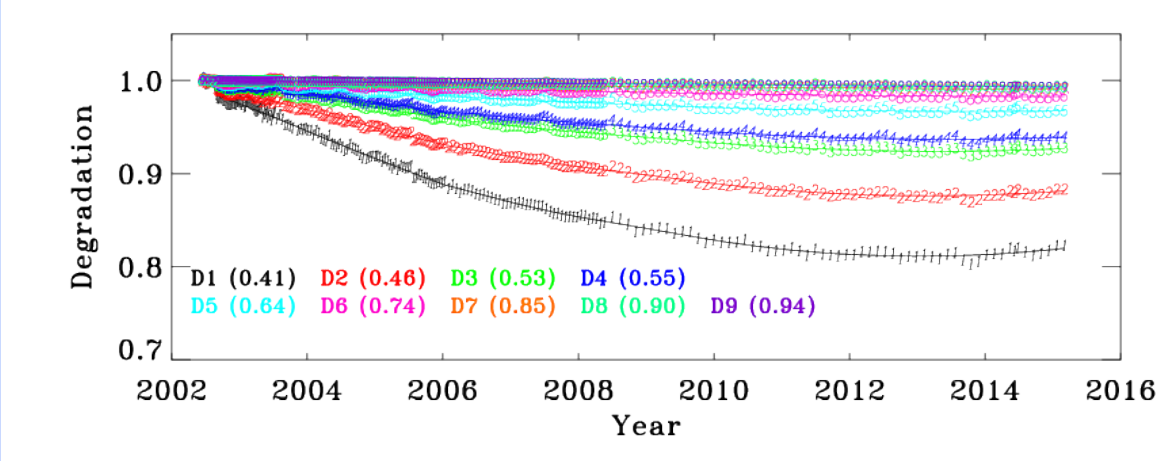
- Yaw maneuvers: SD BRF and SD screen vignetting function
- Roll maneuvers: Lunar observations
- Pitch maneuvers: TEB response versus scan angle (RVS)

Performance Assessments

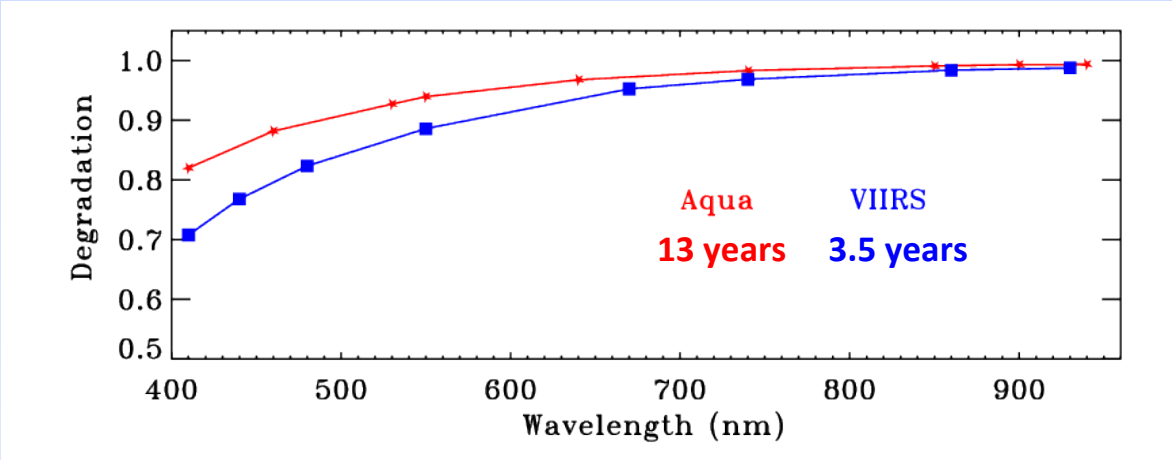
- **Radiometric**
  - Similar SD degradation (large at short wavelengths)
  - Large changes in Aqua MODIS VIS responses
  - Large changes in S-NPP VIIRS NIR/SWIR responses
  - Use of solar and lunar calibration for MODIS and VIIRS
- **Spectral and Spatial**
  - Spectral performance: stable for MODIS; modulated RSR for VIIRS
  - Spatial performance: stable for both MODIS and VIIRS (backup slides)
- **Calibration Inter-comparison**
  - SNO
  - Ground targets
  - Lunar observations

Aqua MODIS and S-NPP VIIRS SD Degradation

Aqua MODIS SD degradation (vs time)



Aqua MODIS and S-NPP VIIRS SD degradation (vs λ)

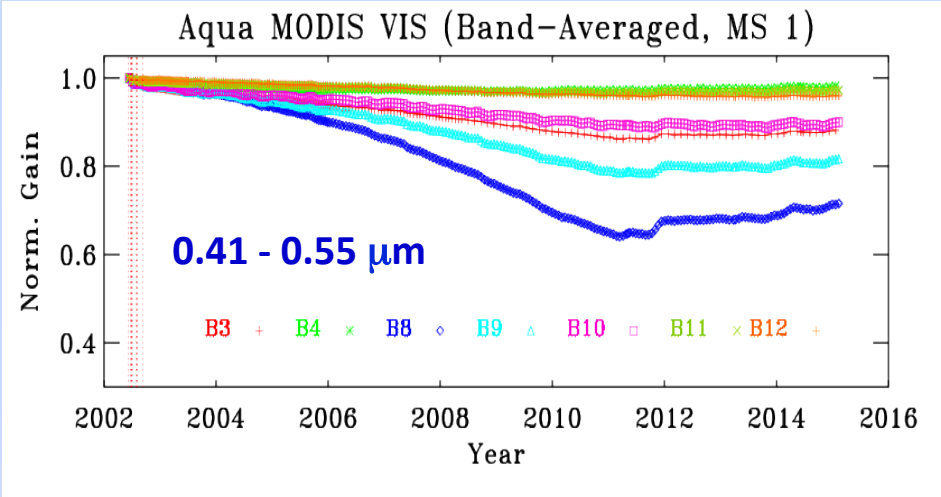


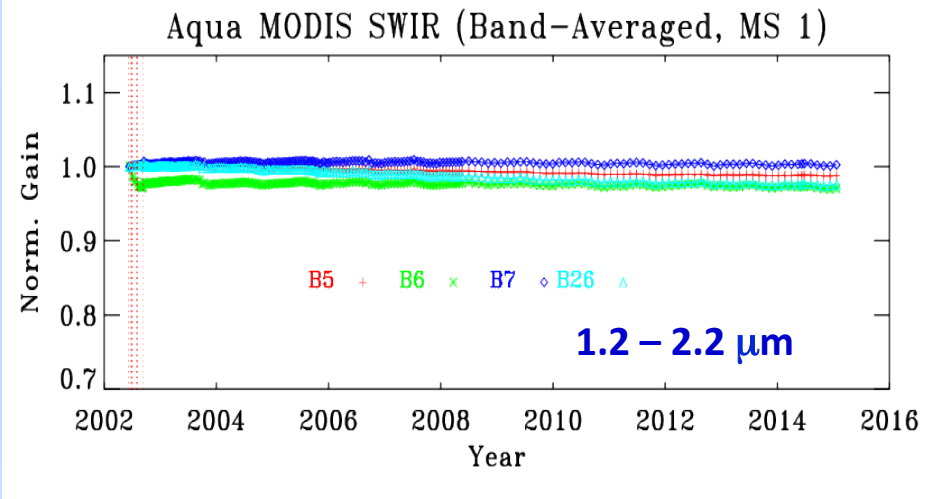
SDSM: alternate Sun view, SD view, and dark view

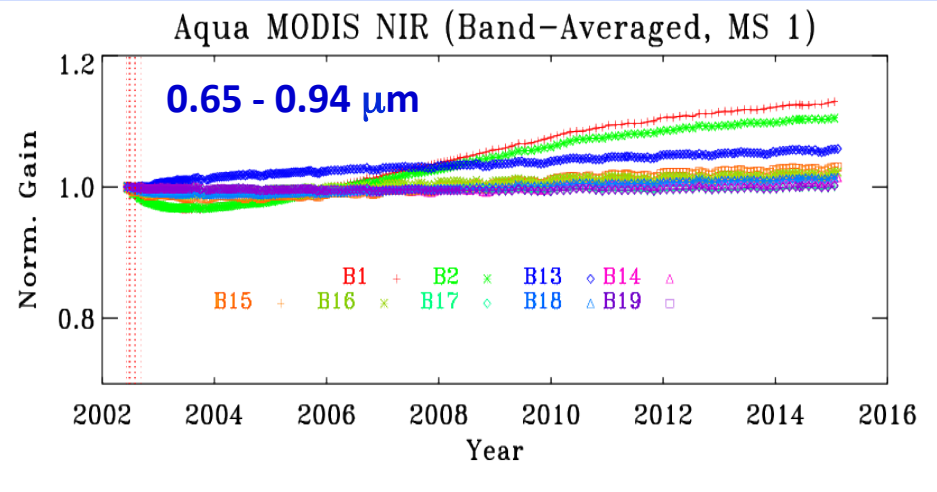
Lager degradation at shorter wavelengths

Radiometric Gains of Aqua MODIS VIS/NIR/SWIR Bands

Large changes in VIS and NIR responses; small changes in SWIR responses







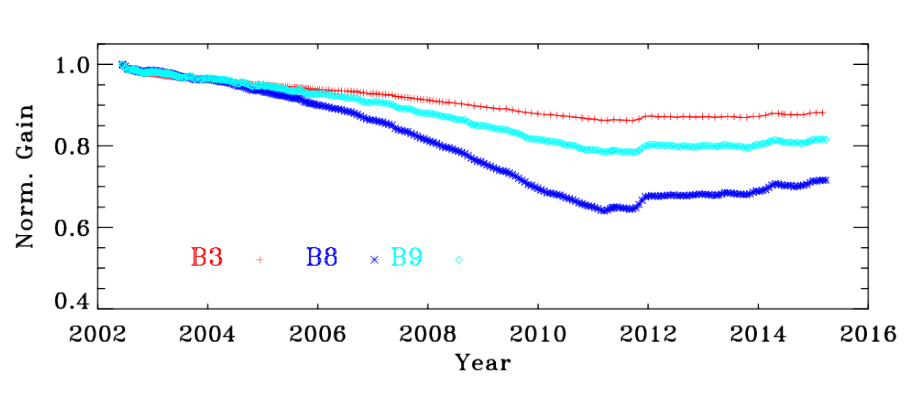
Changes are wavelength, AOI, and mirror-side dependent

Spectral bands are on 3 different focal plane assemblies (FPA)

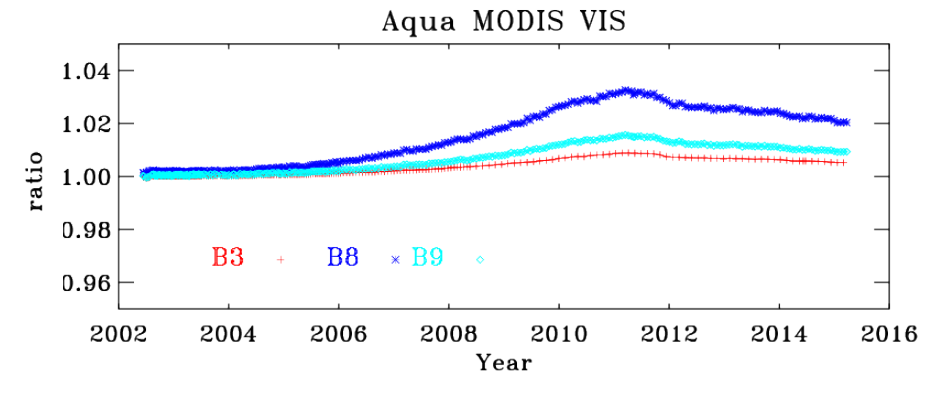
Radiometric Gains of Aqua MODIS Bands 8, 9, and 3

Changes are wavelength, AOI, and mirror-side dependent

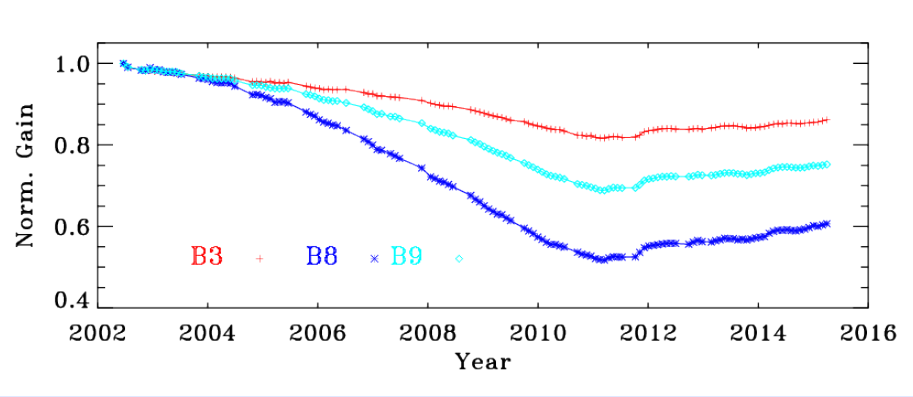
Normalized Gains (Solar CAL at AOI=50°)



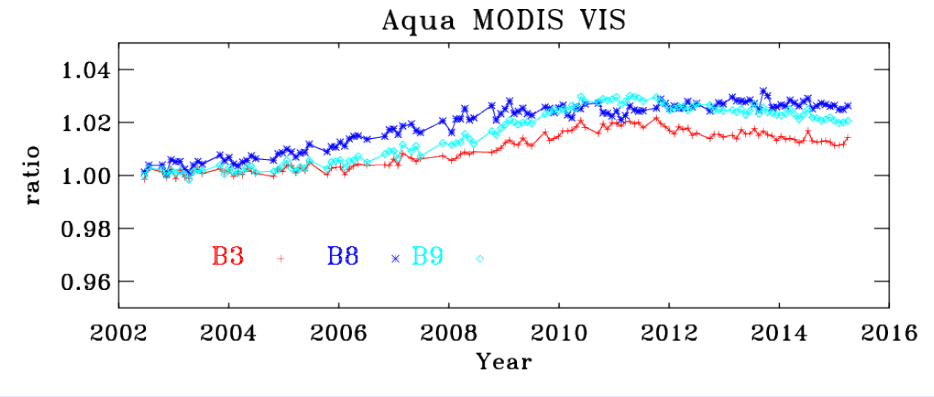
Gain ratio (Solar CAL MS1/MS2)



Normalized Gains (Lunar CAL at AOI=11°)

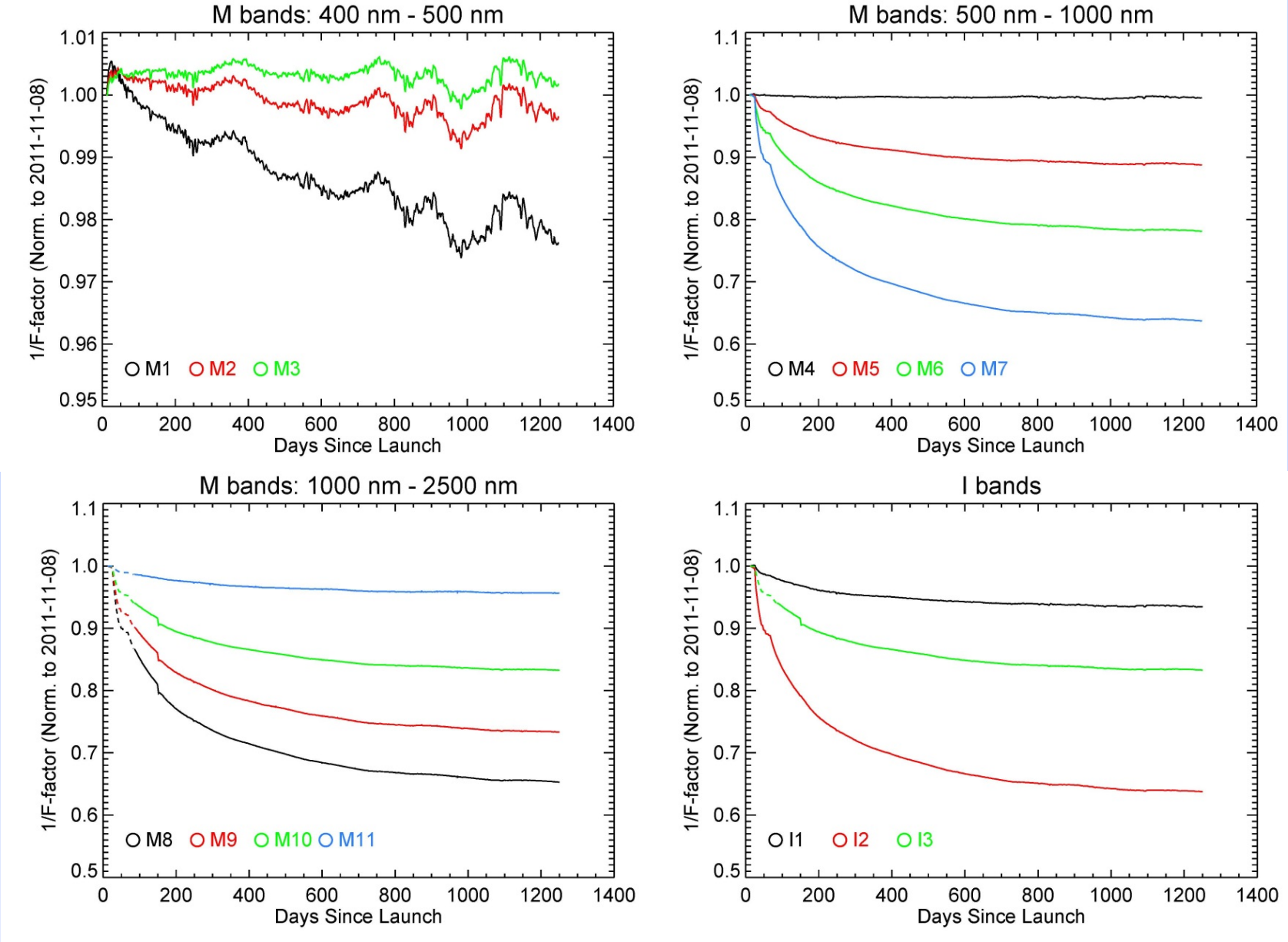


Gain ratio (Lunar CAL MS1/MS2)

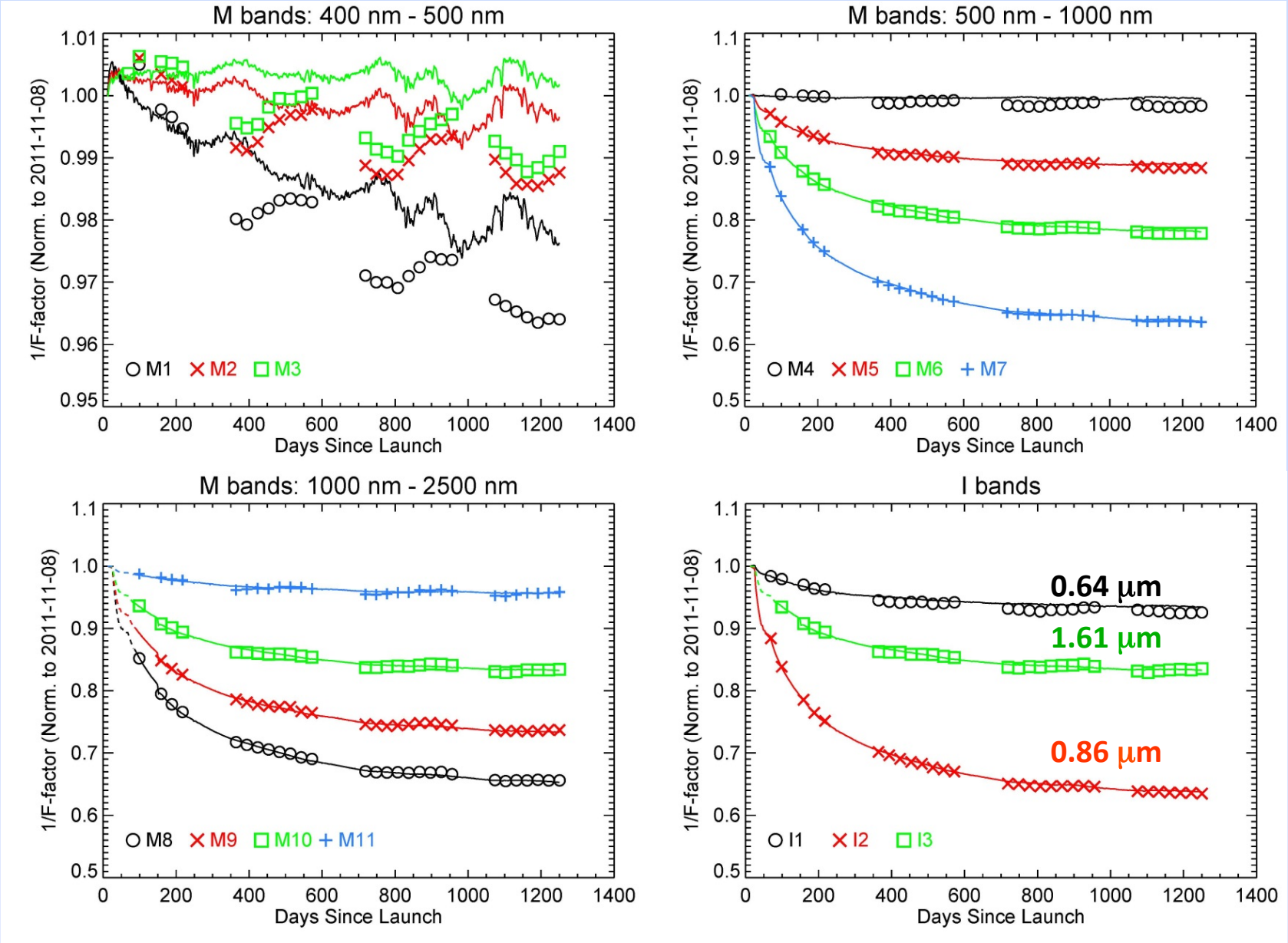


Band 8: 0.41 μm; Band 9: 0.44 μm; Band 3: 0.47 μm

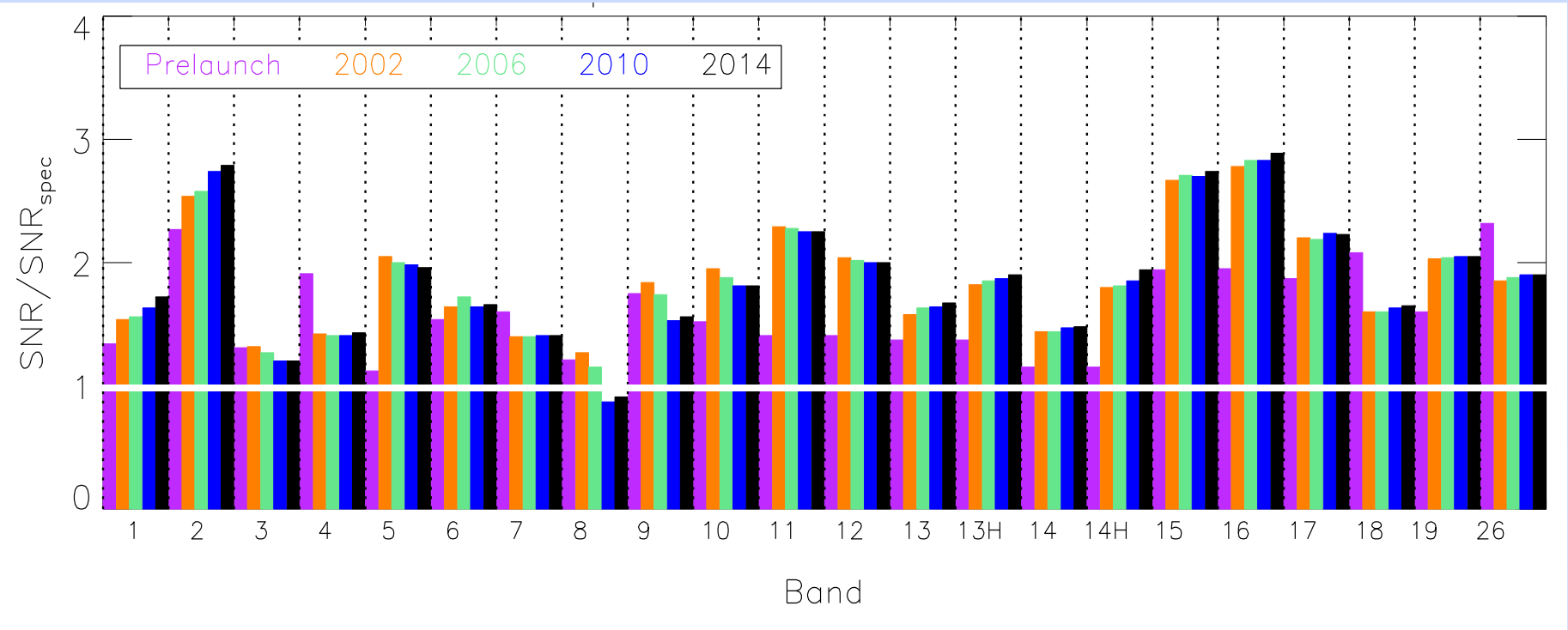
S-NPP VIIRS Radiometric Gains (1/F) from SD Calibration



S-NPP VIIRS Radiometric Gains (1/F)



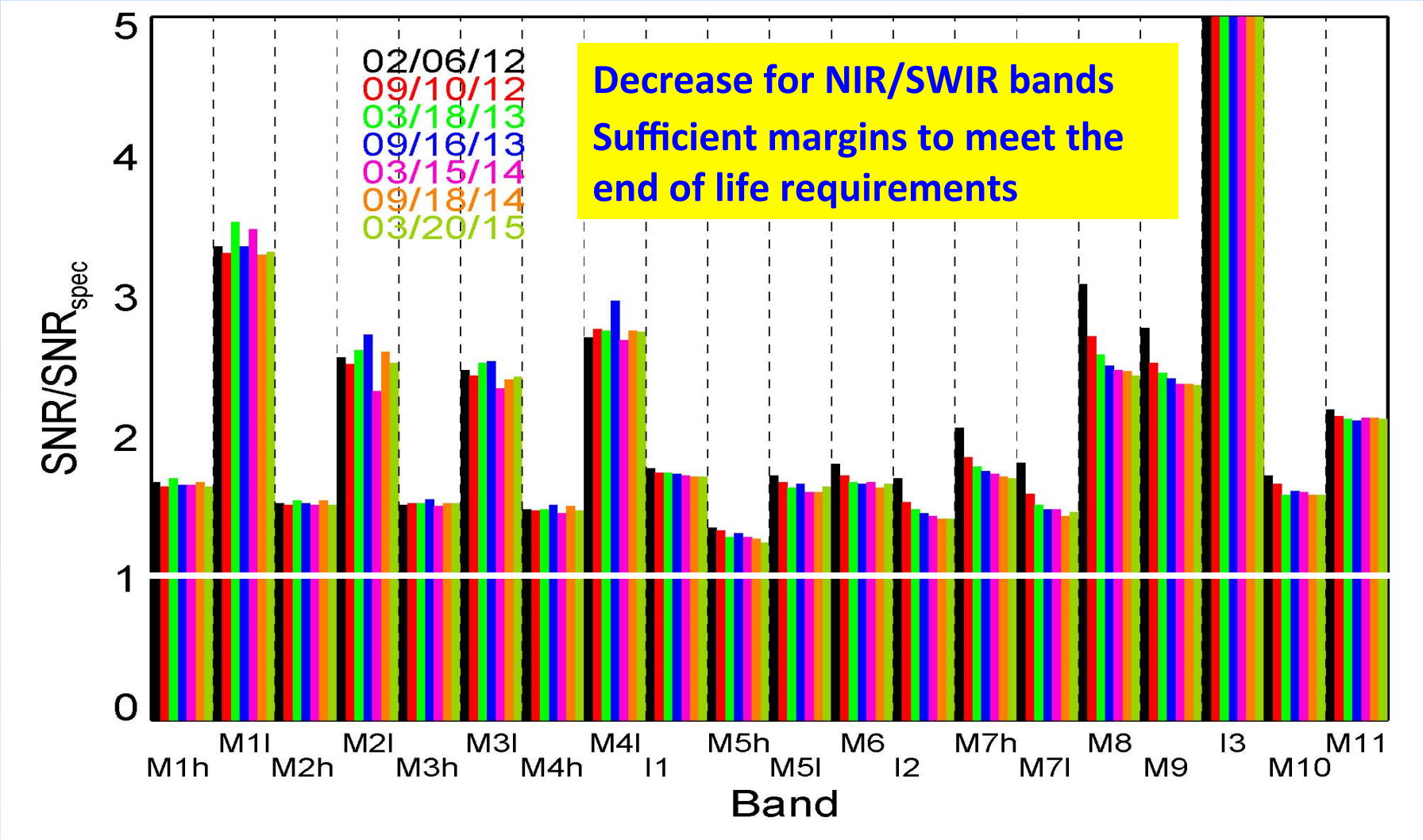
Aqua MODIS RSB Signal-to-Noise Ratios (SNR)



Noticeable increase (bands 1 and 2) and decrease (band 8) of SNR are primarily due to on-orbit changes in sensor (detector) responses

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

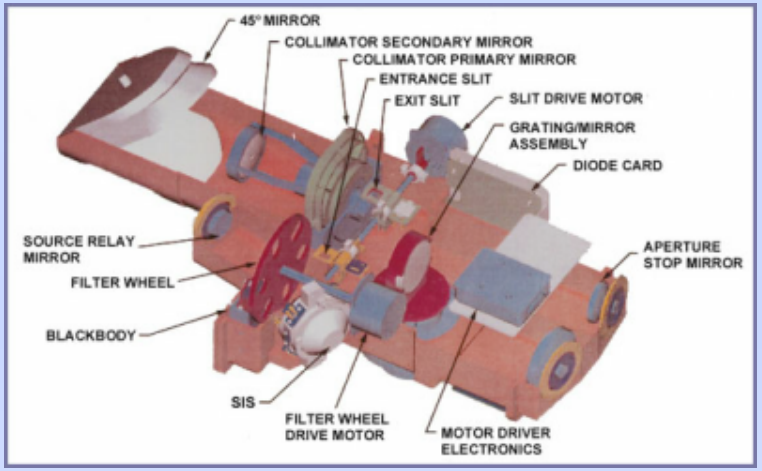
S-NPP VIIRS RSB Signal-to-Noise Ratios (SNR)

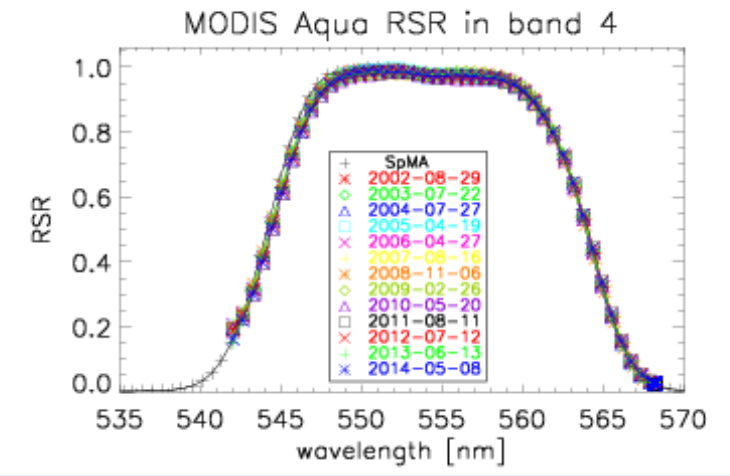


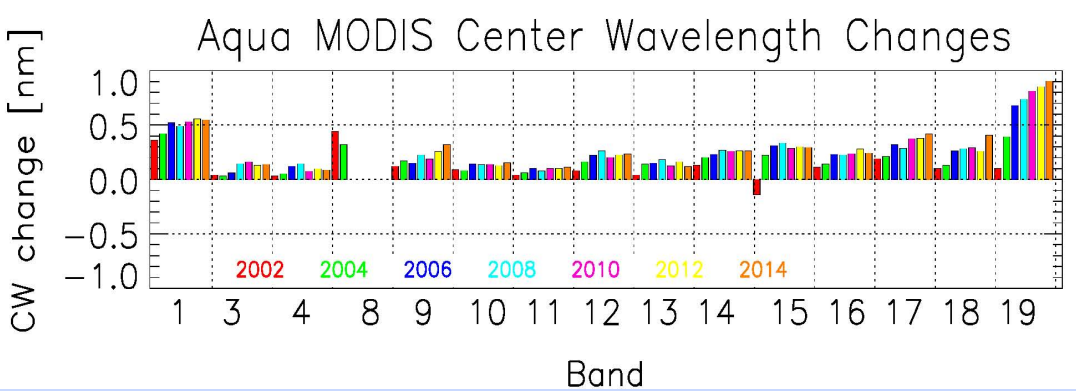
SNR/SNR$_{SPEC}$ > 1: performance better than specified requirements

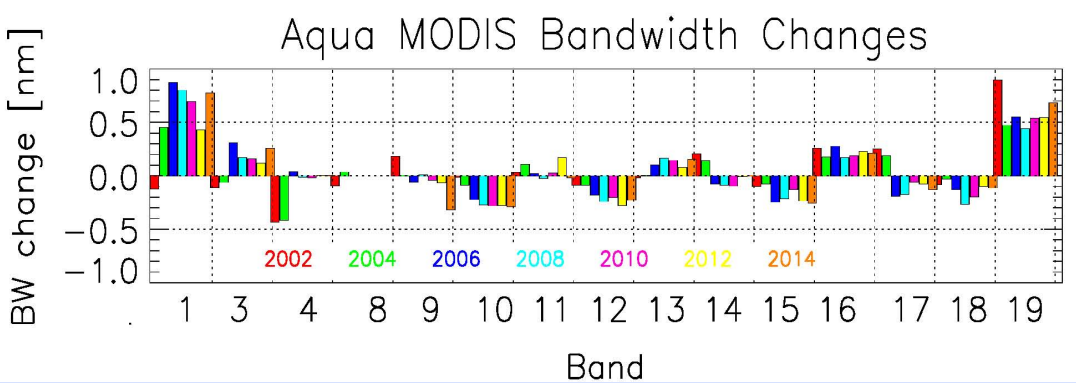
Aqua MODIS Relative Spectral Response (RSR) – Stable

SRCA Modes: (1) Radiometric, (2) Spectral, and (3) Spatial







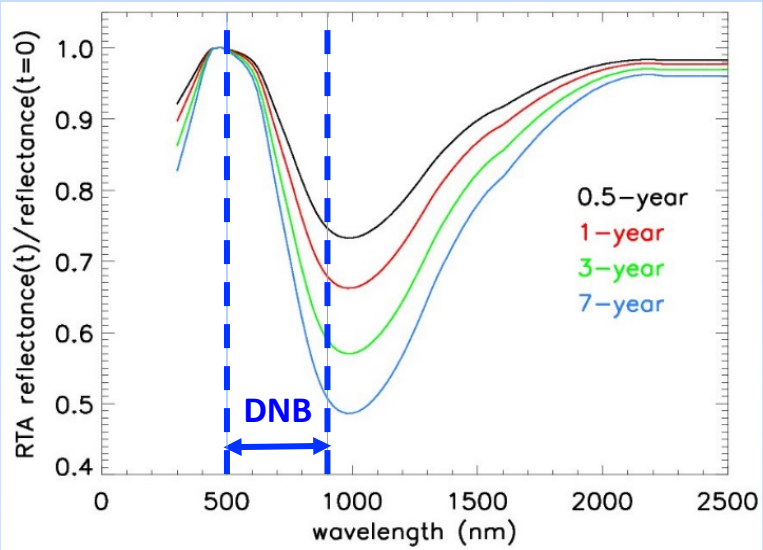


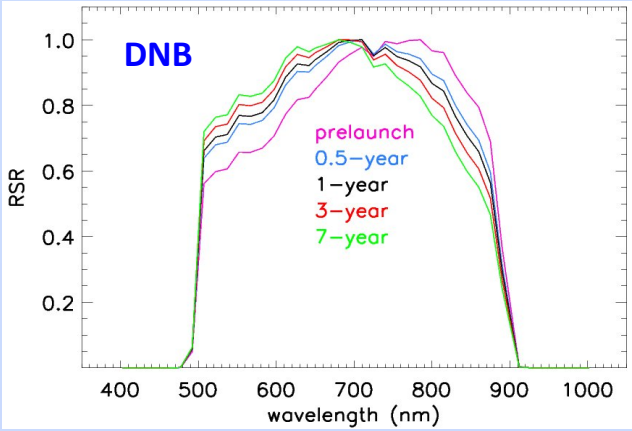
CW and BW changes are within 0.5 nm for most VIS/NIR bands

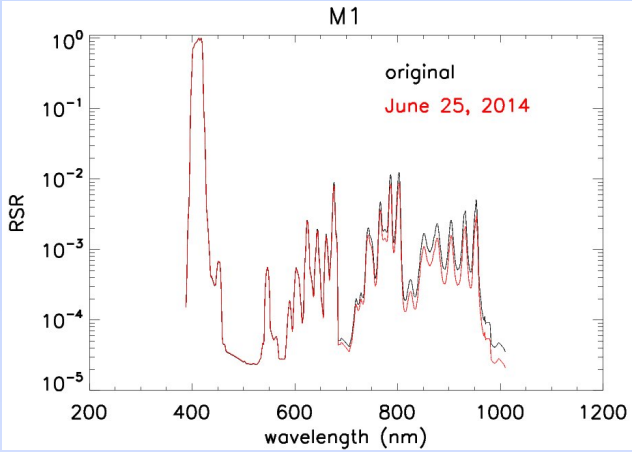
Relatively large changes up to 1.0 nm are observed for bands with broad bandwidths (bands 1, 18, 19)

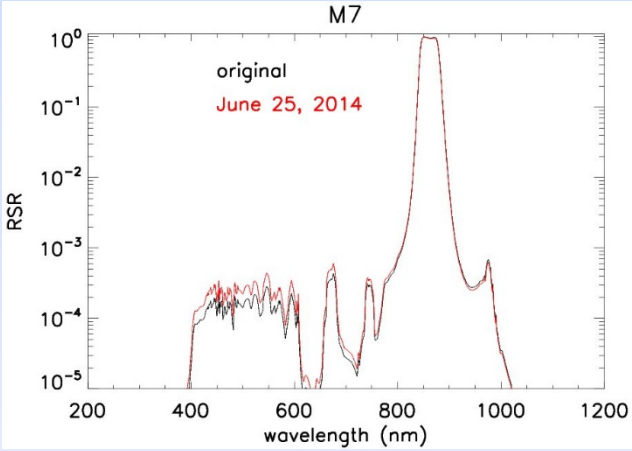
S-NPP VIIRS Modulated RSR

λ dependent optics degradation



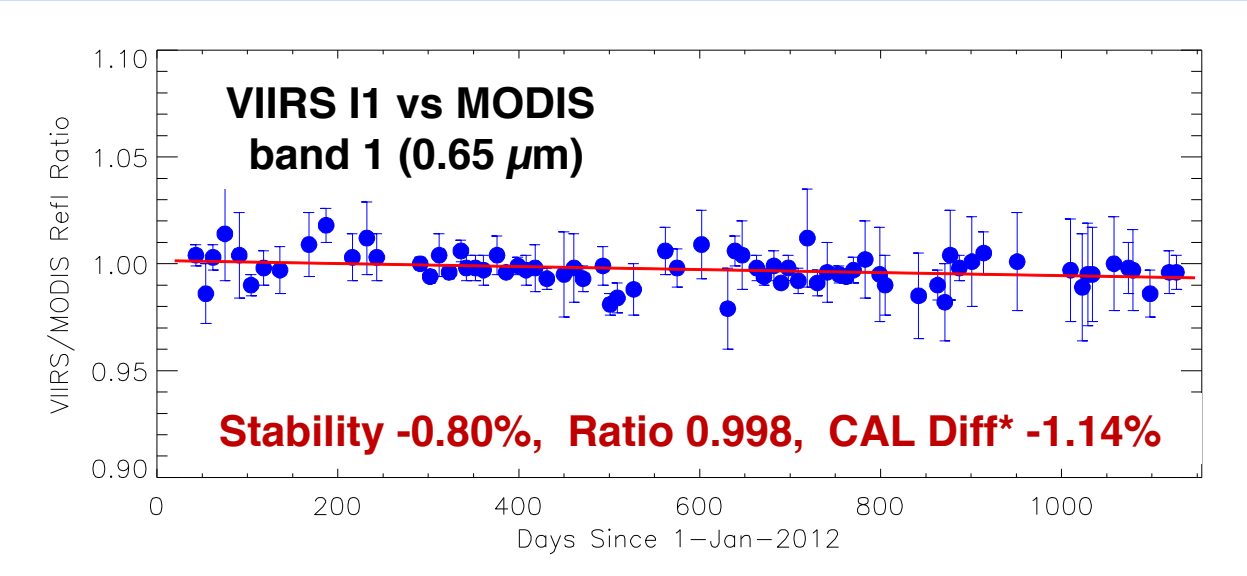




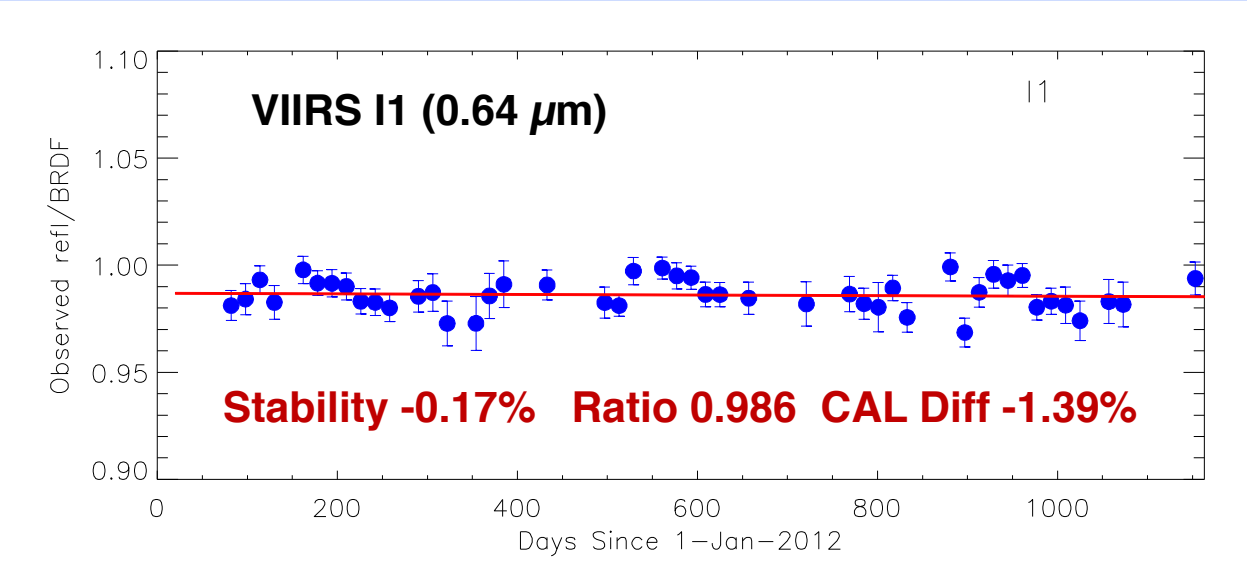


Small impact on bands with narrow bandwidths and small OOB responses; large impact on DNB (broad bandwidth)

Calibration Inter-comparison



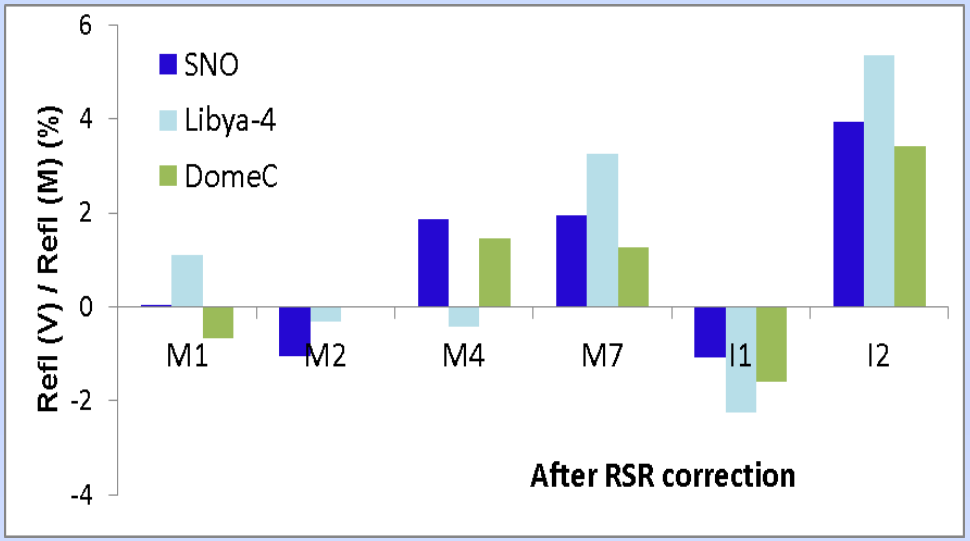
Results from SNO



Results from Libya 4 desert (BRDF from Aqua MODIS)

Calibration Inter-comparison

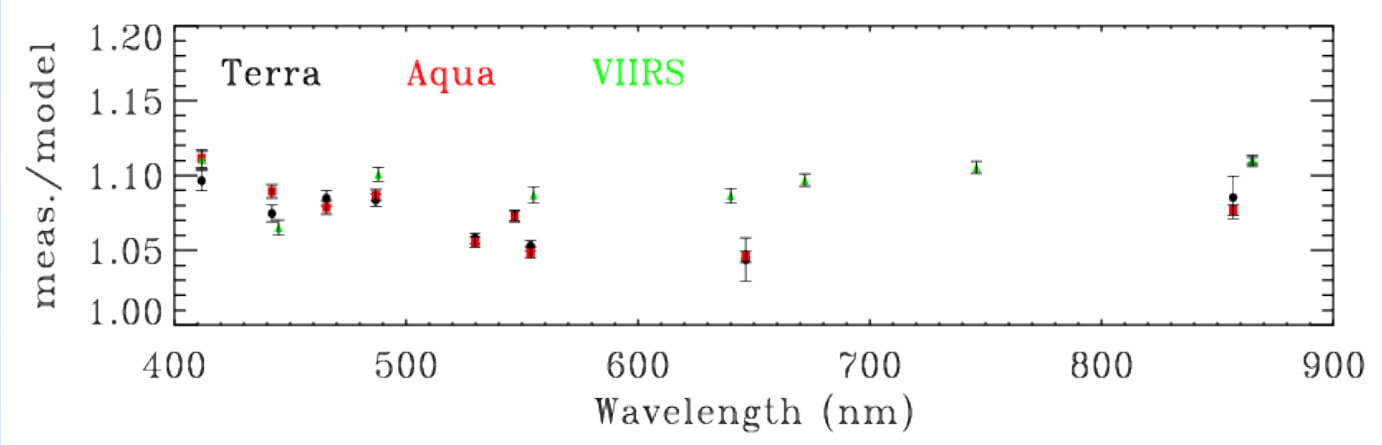
Results (3 yr. avg.) from different approaches



Lunar Calibration

M1	1.002
M2	0.979
M4	1.035
M7	1.032
I1	1.037
I2	1.030

Lunar Irradiance Ratio (Measured/Model)



Challenging Issues and Future Work

- **Aqua MODIS:**
  - On-orbit changes in sensor response versus scan-angle (RVS) for the VIR/NIR bands
    - Large changes in VIS/NIR responses (mirror side, wavelength, and AOI dependent)
    - Use of EV responses to track sensor changes at different AOIs
  - SD degradation
    - Solar illumination angle dependent SD degradation
    - SD degradation correction for SWIR calibration
  - Potential on-orbit changes in sensor polarization sensitivity

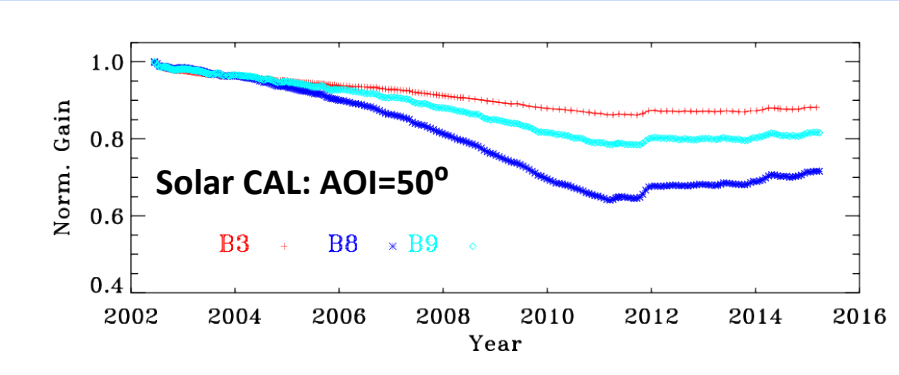
- **S-NPP VIIRS:**
  - Large changes in NIR/SWIR responses: wavelength and time dependent => modulated RSR(t)
  - Large SD degradation (no SD door)

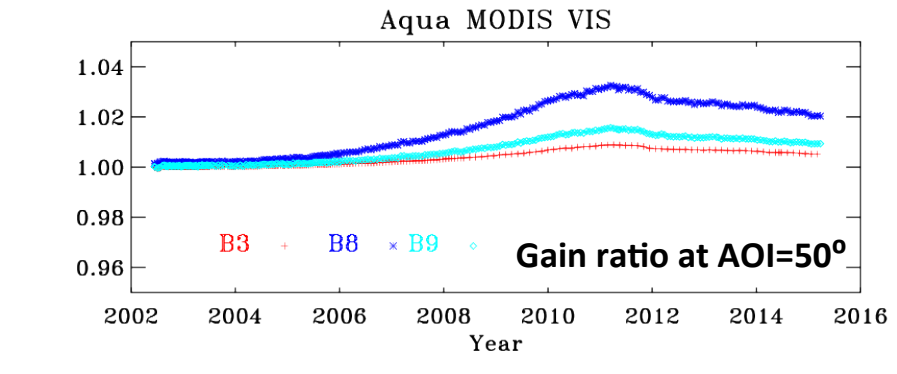
Challenging Issues and Future Work

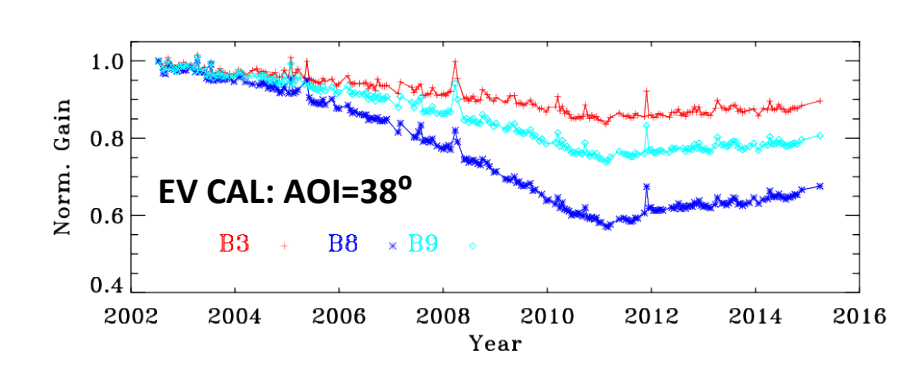
- **Future Work**
  - Continue to improve MODIS RSB RVS characterization, including the use of EV targets at different AOI
  - Develop alternative and independent approaches for SD degradation correction
  - Support VIIRS SDR (L1B) reprocessing via consistent calibration LUTs as a number of improvements have been made since launch
  - Examine S-NPP VIIRS and Aqua MODIS calibration consistency using different approaches and methodologies
  - Evaluate the impact due to modulate RSR for VIIRS calibration
  - Understand and reduce the differences between VIIRS solar and lunar calibration (T. Stone/USGS: ROLO model improvement)

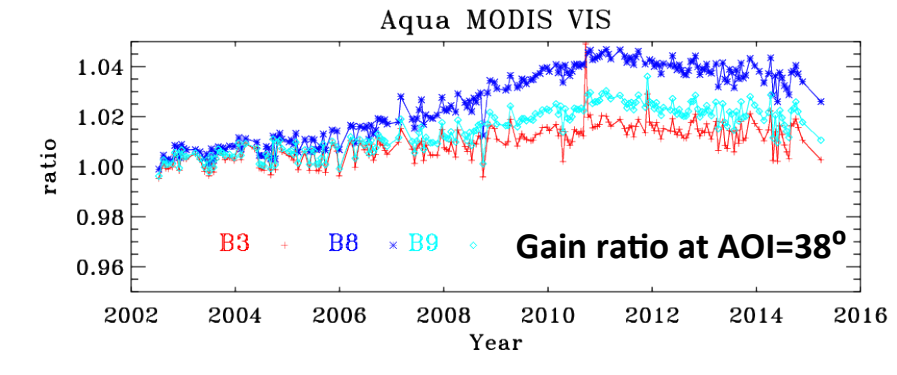
Improvements of MODIS VIR/NIR RVS

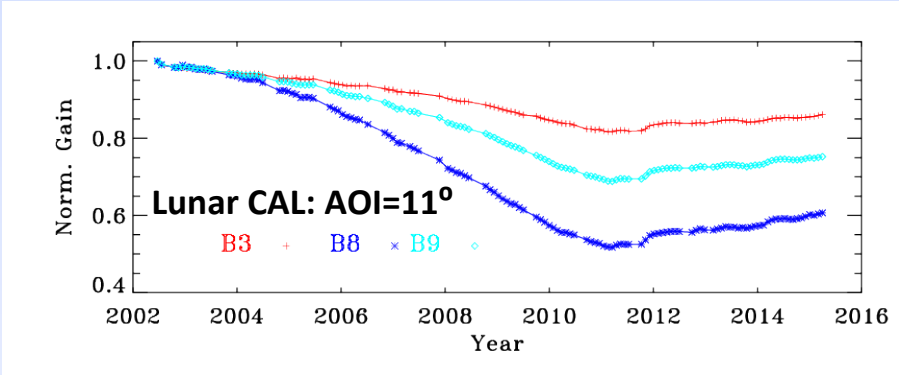
Adequate use of sensor's EV responses at different AOIs

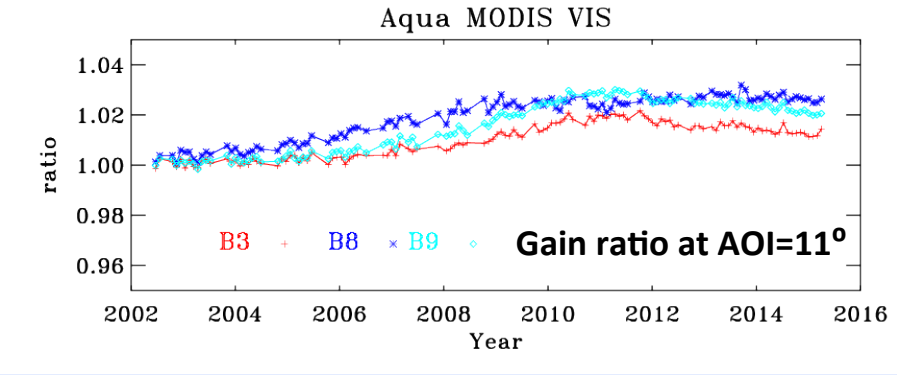








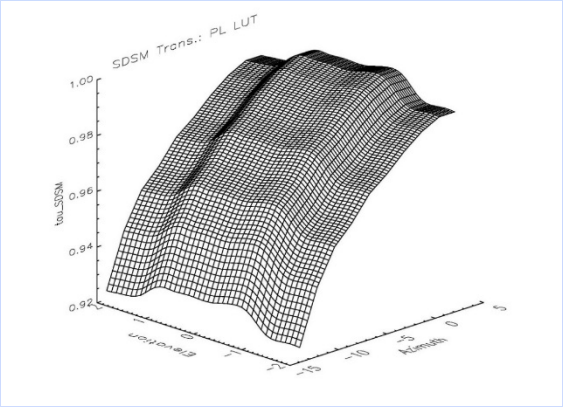




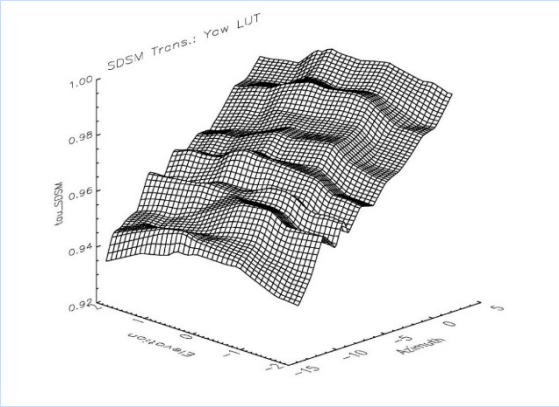
S-NPP VIIRS Consistent Sensor Data Record (SDR)

Many changes and improvements made over time

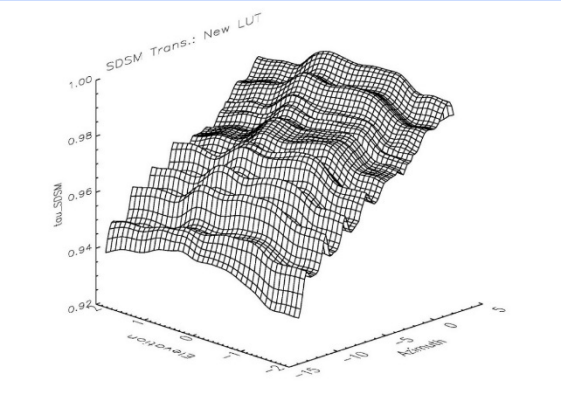
SDSM VF PL LUT

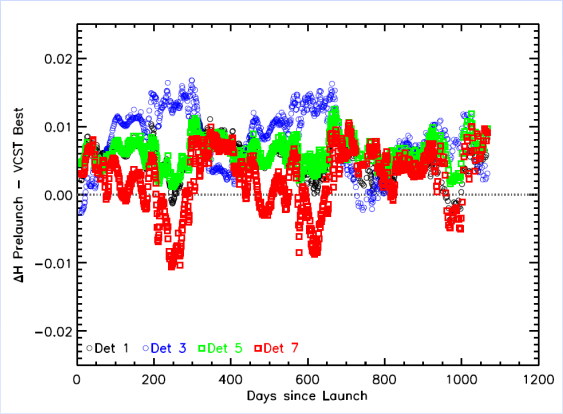


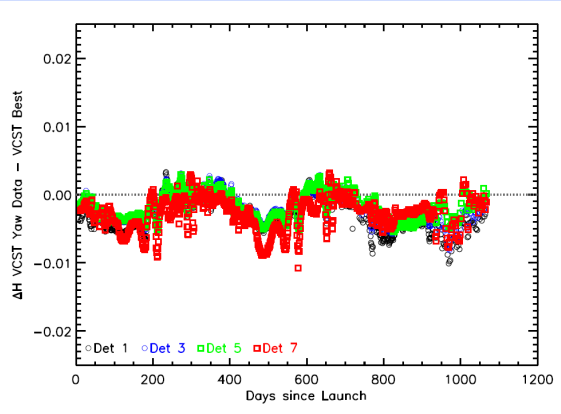
SDSM VF Yaw LUT



SDSM VF "New" LUT

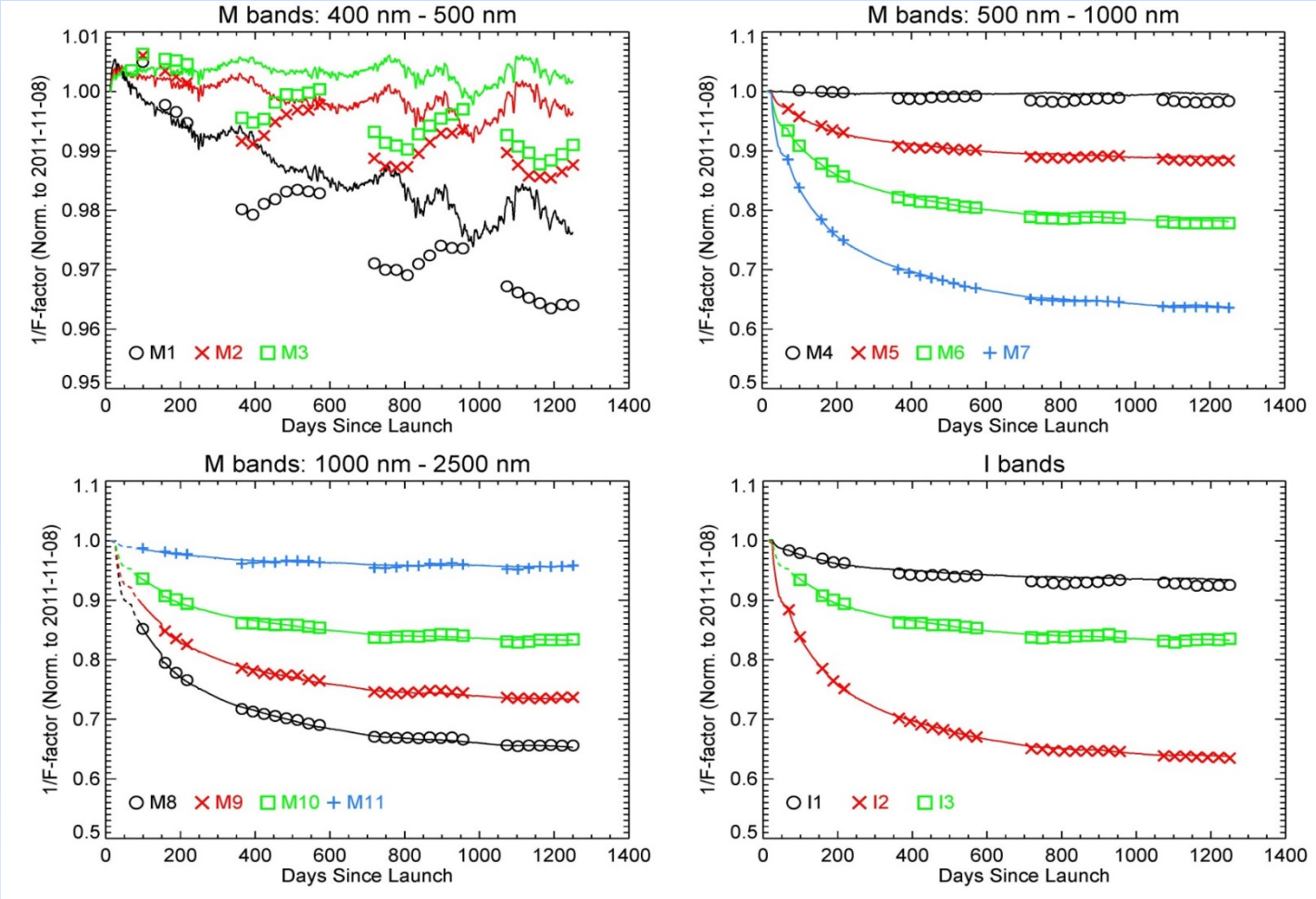






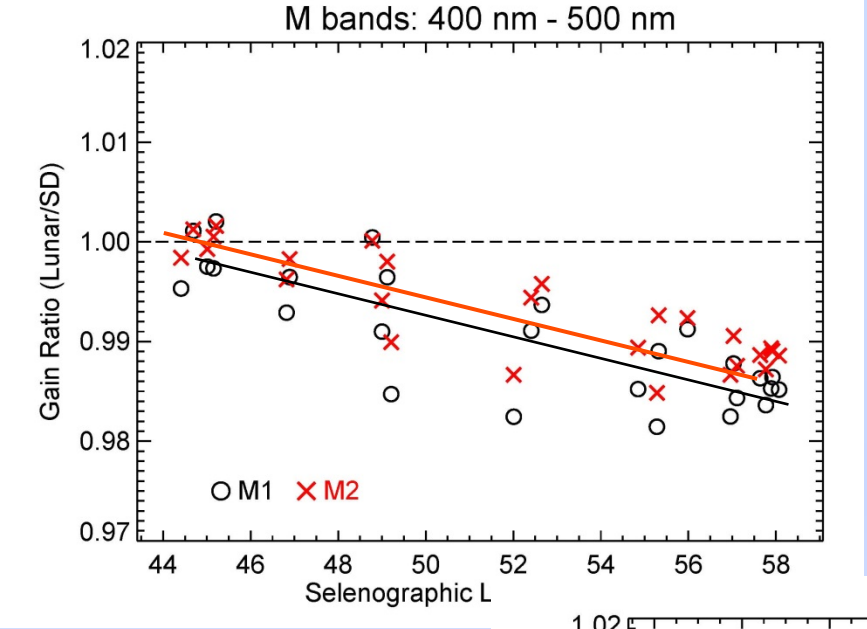
Additional Correction for the Solar Vector Error (discovered in the IDPS SDR Geo library file)

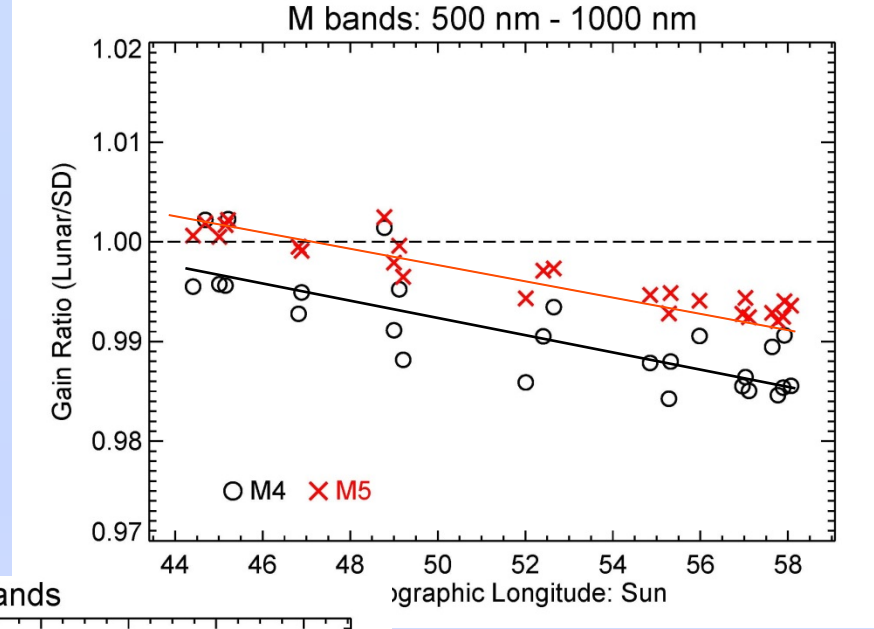
S-NPP VIIRS Radiometric Gains (1/F)

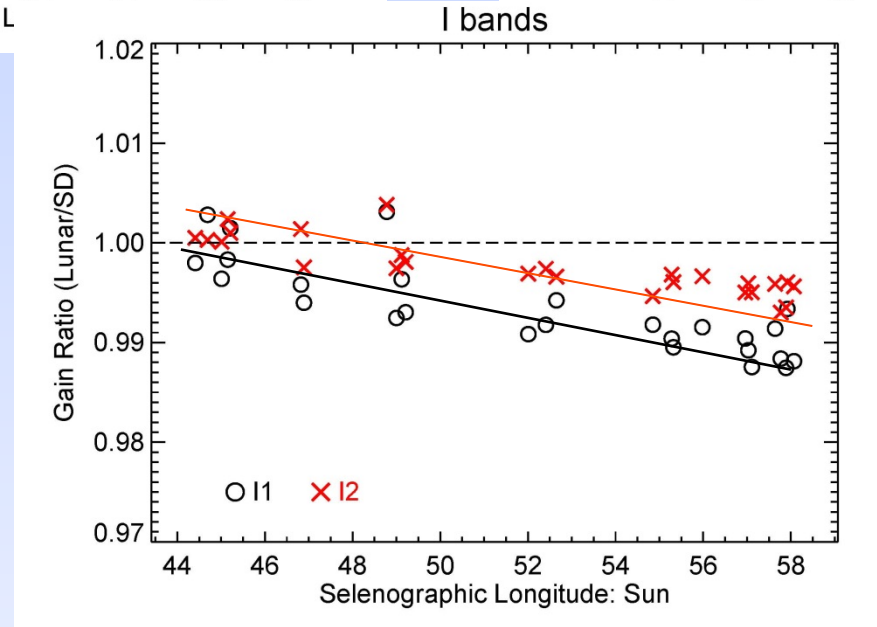


Better understand and reduce the differences between VIIRS solar and lunar calibration

Future Lunar Calibration Improvements



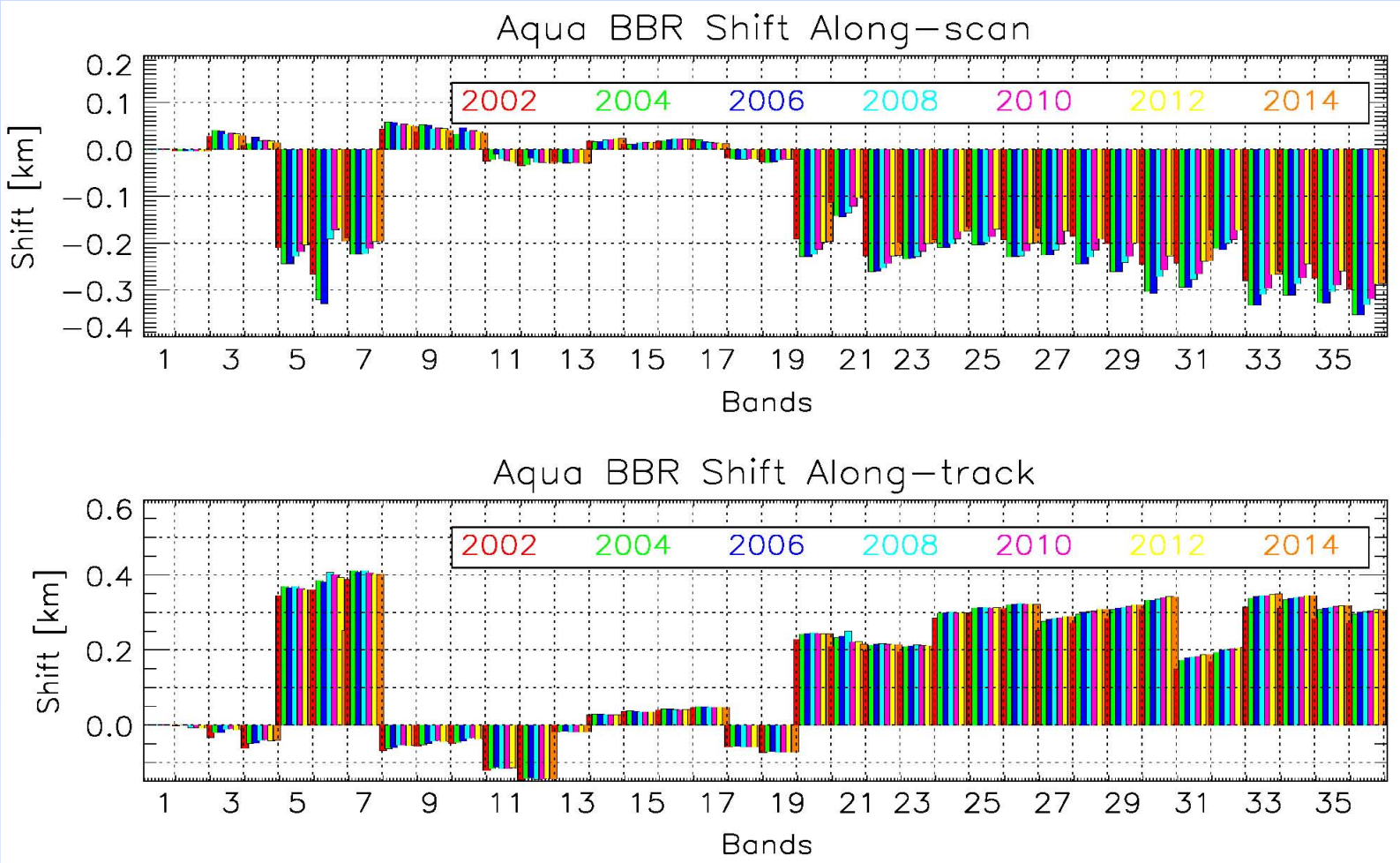




Backup Slides

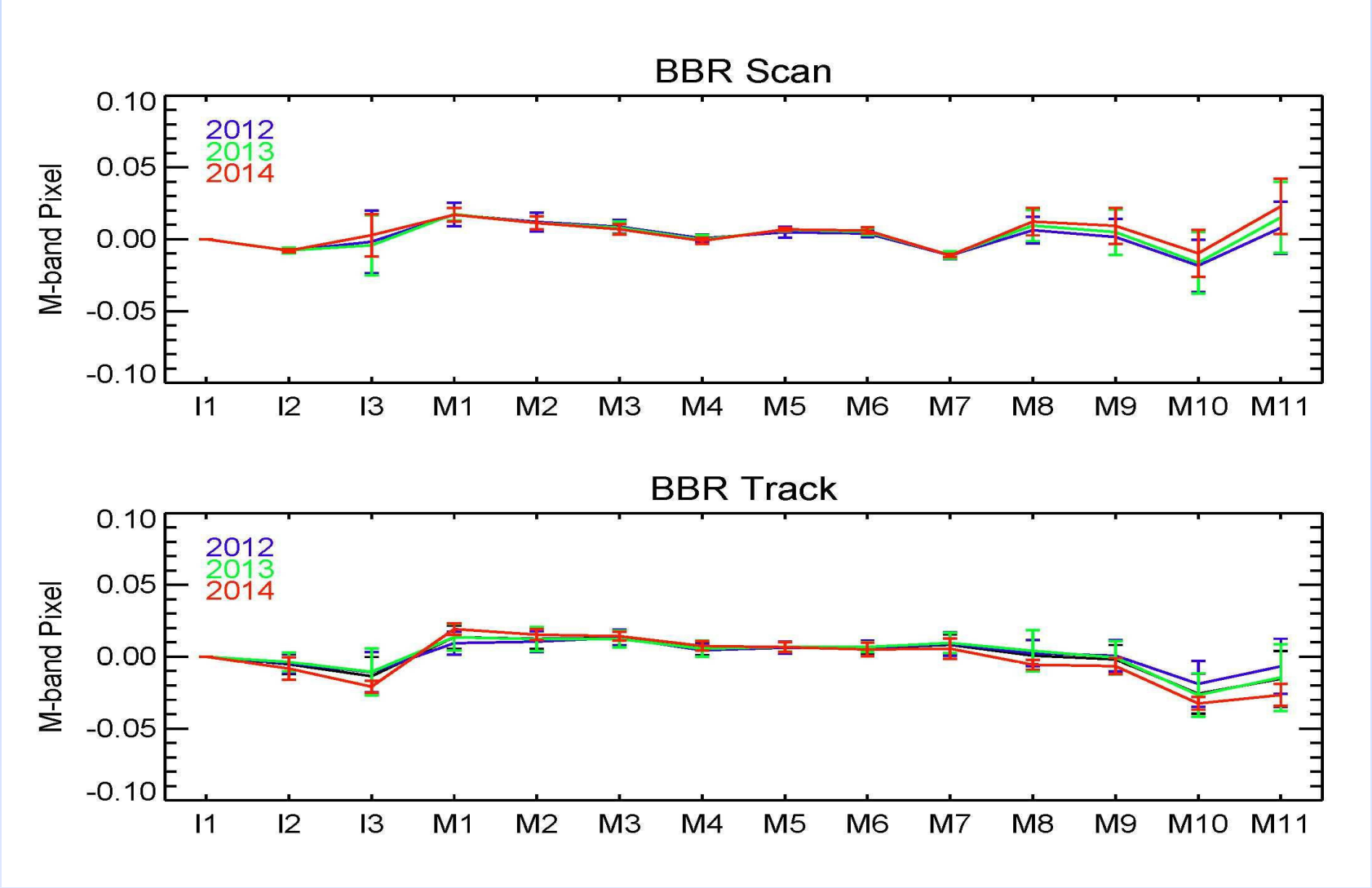
Aqua MODIS Spatial Performance – Stable

Band-to-band registration (BBR) in along-scan and -track direction



Aqua BBR: a known issue since pre-launch but has been stable on-orbit

S-NPP VIIRS Spatial Performance (RSB) – Stable



Derived from on-orbit lunar observations (Wang et al, accepted for TGRS)