Lunar Observations for MODIS and VIIRS On-Orbit Calibration

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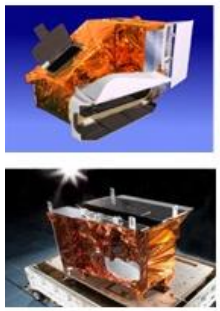
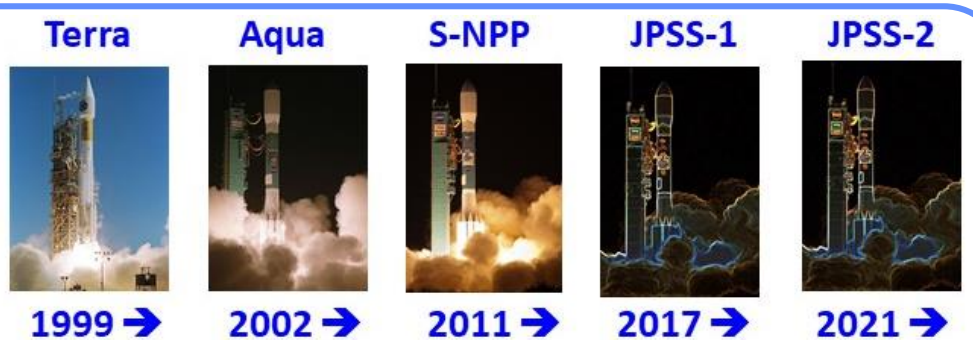
Outline

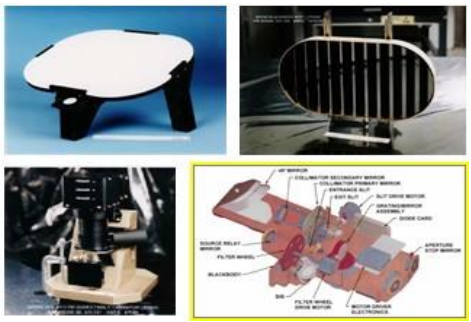
- MODIS and VIIRS Lunar Observations and Applications
- Using Lunar Observations for MODIS and VIIRS On-orbit Calibration
- Lessons and Future Work

MODIS and VIIRS

- **Moderate Resolution Imaging Spectroradiometer (MODIS)**
  - Key instruments for NASA EOS Terra and Aqua missions
  - 20 reflective solar bands (RSB) and 16 thermal emissive bands (TEB)
  - Spectral wavelengths: 0.4-14.5 μm
  - Spatial resolutions: 250 m (2 bands), 500 m (5 bands), and 1 km (29 bands)
- **Visible/Infrared Imager Radiometer Suite (VIIRS)**
  - Key instruments for NASA/NOAA SNPP and NOAA JPSS missions
  - 14 RSB, 7 TEB, and 1 DNB (day and night band)
  - Spectral wavelengths: 0.4-12.4 μm
  - Spatial resolutions: 375 m for I bands; 750 m for M bands and DNB
  - Special features: dual gains, aggregation, bow-tie deletion, no on-board SRCA





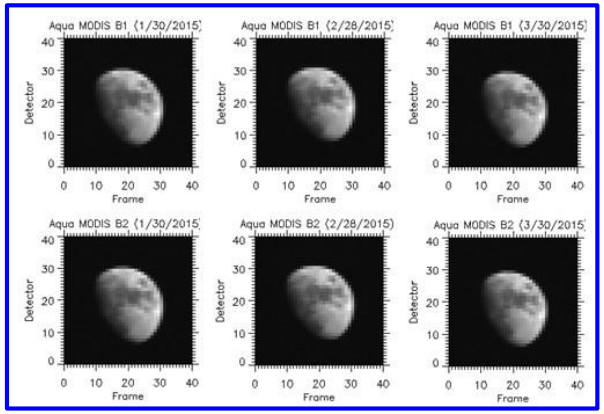


Research and operational applications: 40+ data products from MODIS and 22 EDRs from VIIRS

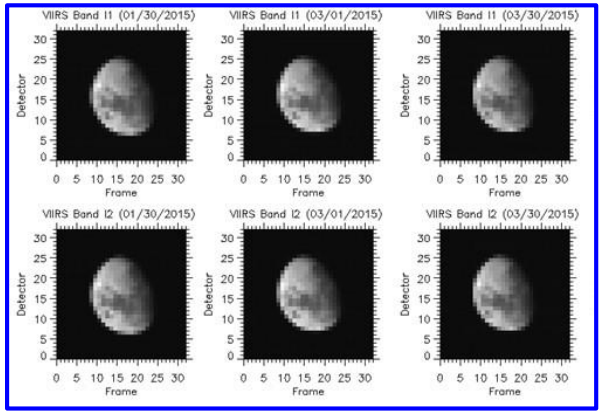
MODIS and VIIRS Lunar Observations

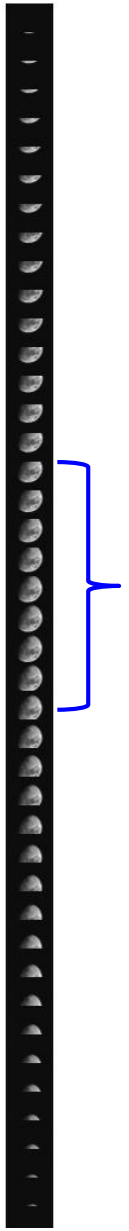
- **Scheduled near-monthly at the "same" lunar phase angles**
  - Terra MODIS: 55° (waning)
  - Aqua MODIS: -55° (waxing)
  - S-NPP VIIRS: -51° (waxing)
- **Performed via spacecraft roll maneuvers**
- **Observed through instrument space view (SV) port with a data sector rotation**
- **Referenced to USGS ROLO model (and GIRO)**

Aqua MODIS B1 and B2 Lunar Images (1/30, 2/28, 3/30/2015)



S-NPP VIIRS I1 and I2 Lunar Images (1/30, 2/28, 3/30/2015)





Regularly scheduled lunar observations (as of Oct 31, 2017):
Terra MODIS: 178; Aqua MODIS: 153; SNPP VIIRS: 51

Applications

Applications made by MCST & VCST using MODIS and VIIRS lunar observations:

- **Radiometric Calibration**
  - RSB (primary application) >> focus of this talk
  - TEB (stability monitoring)
  - DNB (VIIRS only)
- **Spatial Characterization**
  - BBR (along-scan and along-track)
  - MTF (along-track)
- **Calibration Inter-comparison**
  - Instrument-to-instrument >> talk on Wed
  - Band-to-band, detector-to-detector
- **Optical Leak and Electronic Crosstalk Characterization**
  - Optical leak characterization (Terra MODIS) >> talk on Thu
  - Electronic crosstalk assessment (MODIS) >> talk on Thu

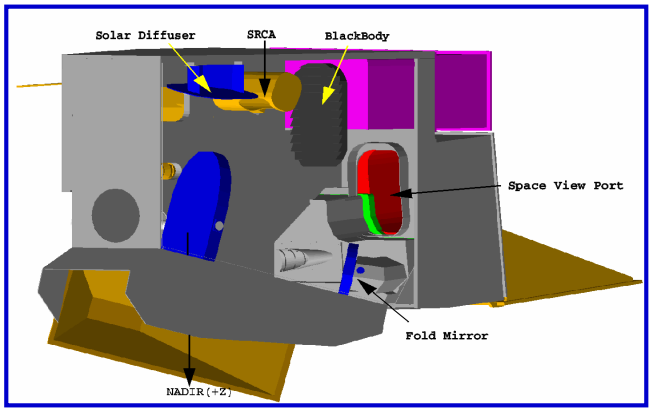
General References:

X. Xiong, J. Sun, A. Angal, K. Chiang, and W. Barnes, "Applications and Results of MODIS Lunar Observations," SPIE 2007

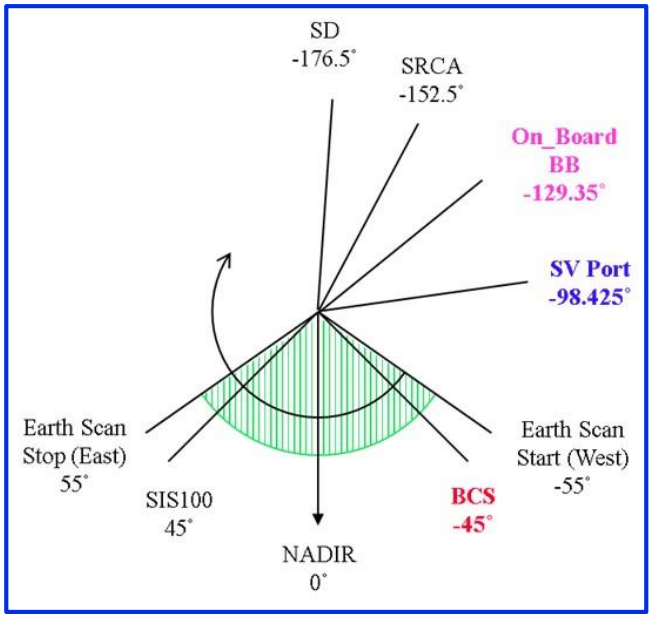
X. Xiong, Z. Wang, J. Sun, A. Angal, J. Fulbright, and J. Butler, "MODIS and VIIRS Lunar Observations and Applications," SPIE 2013

Using Lunar Observations for MODIS RSB Calibration

- **Scanning radiometer**
  - A two-sided scan mirror
  - EV data collected with AOI from 10.5° to 65.5°
  - SD observations at AOI of 50.2°
  - Lunar observations at AOI of 11.2°



- **Response versus scan angle (RVS)**
  - For bands with small changes in responses: RVS derived using SD and lunar observations
  - For bands with large changes in responses: RVS derived using SD, Moon, and select PICS (at multiple AOIs)
  - On-orbit changes in RVS are wavelength (spectral band) and mirror side dependent



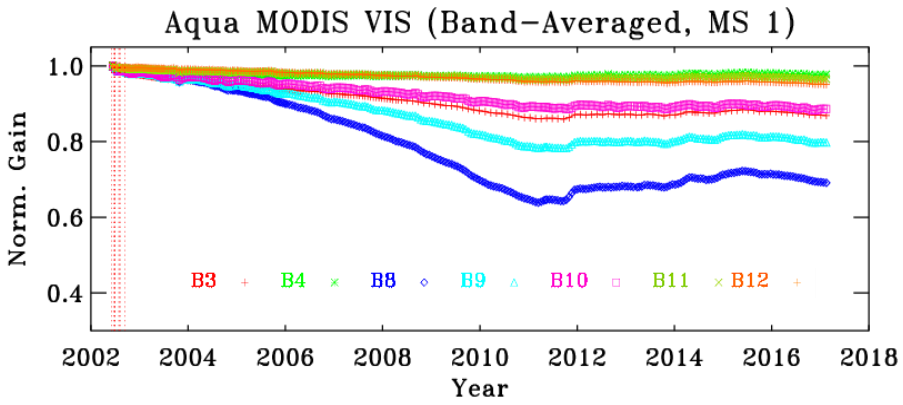
Select References:

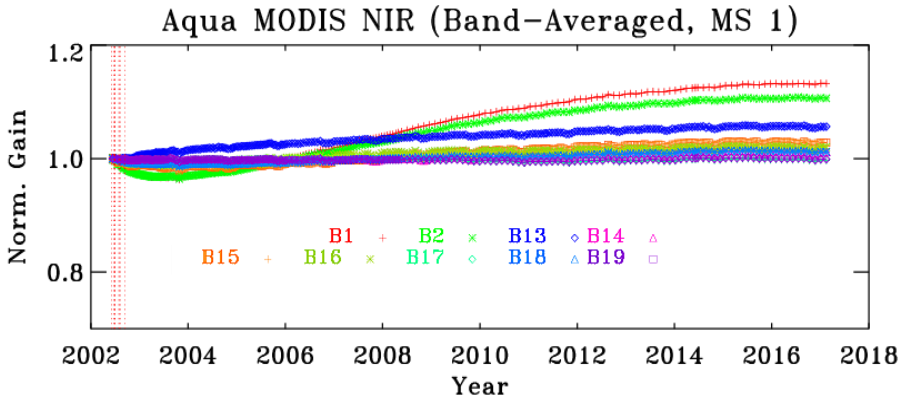
J. Sun, X. Xiong, A. Angal, H. Chen, A. Wu, and X. Geng, "Time-Dependent Response Versus Scan Angle for MODIS Reflective Solar Bands," IEEE TGRS, 2014

A. Angal, X. Xiong, A. Wu, X. Geng, and H. Chen, "Improvements in the On-orbit Response Versus Scan Angle Characterization of the Aqua MODIS Reflective Solar Bands," accepted for publication, IEEE TGRS, 2017

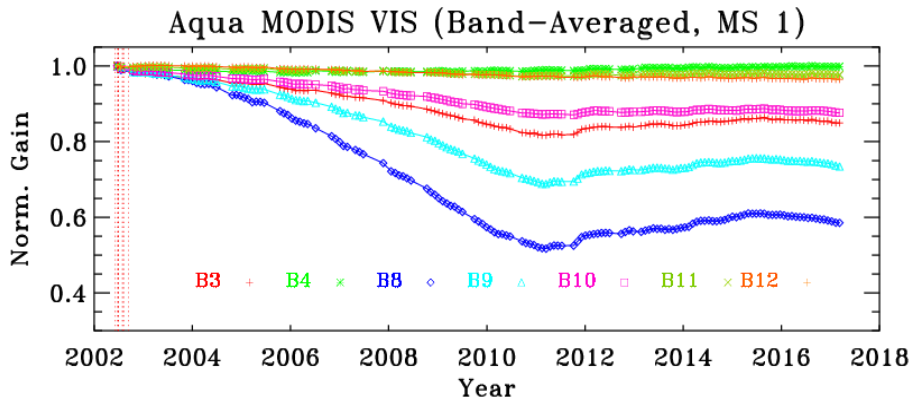
MODIS RSB Responses from SD and Lunar Observations

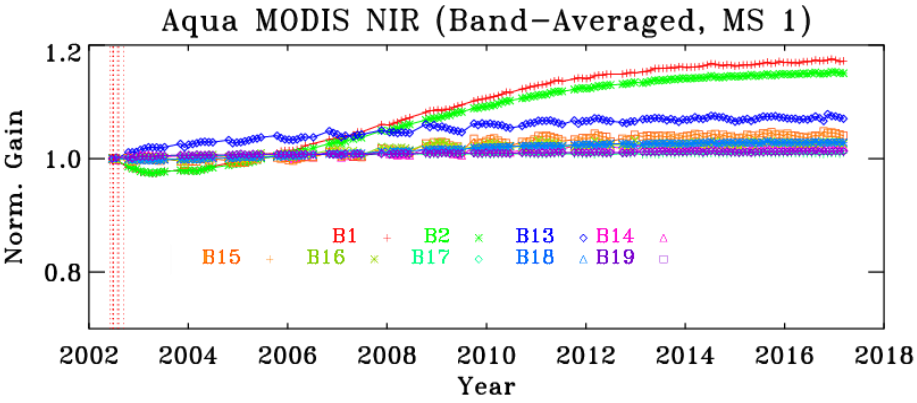
Responses from SD Observations





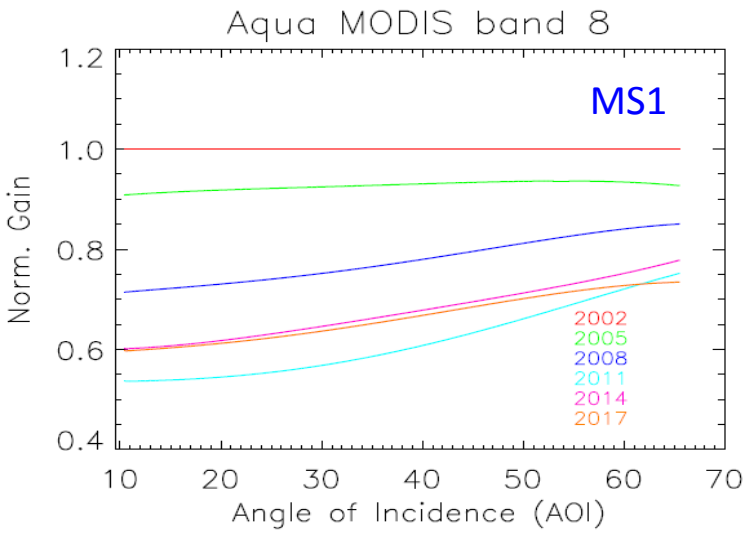
Responses from Lunar Observations

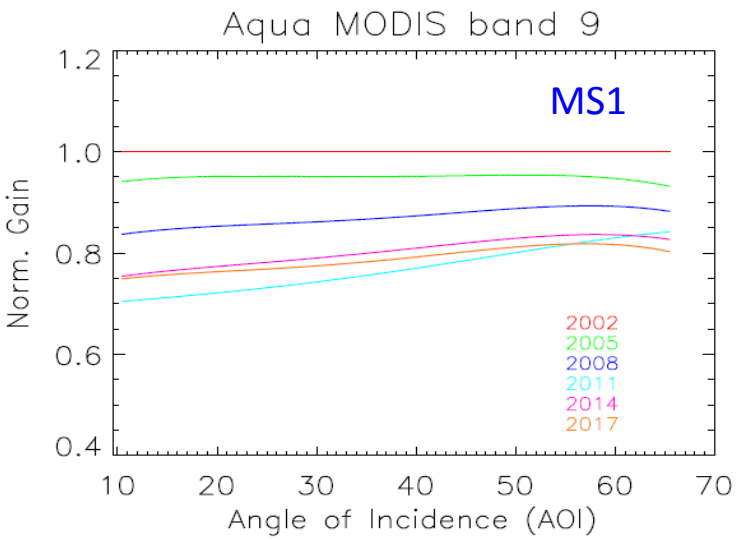


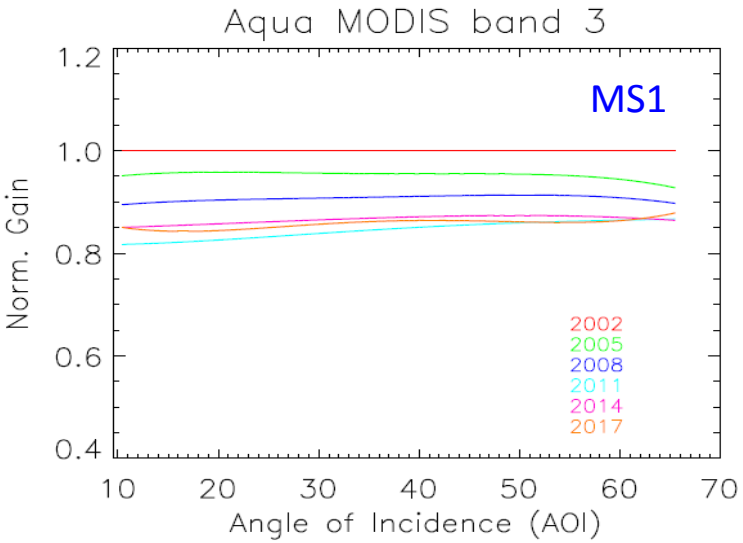


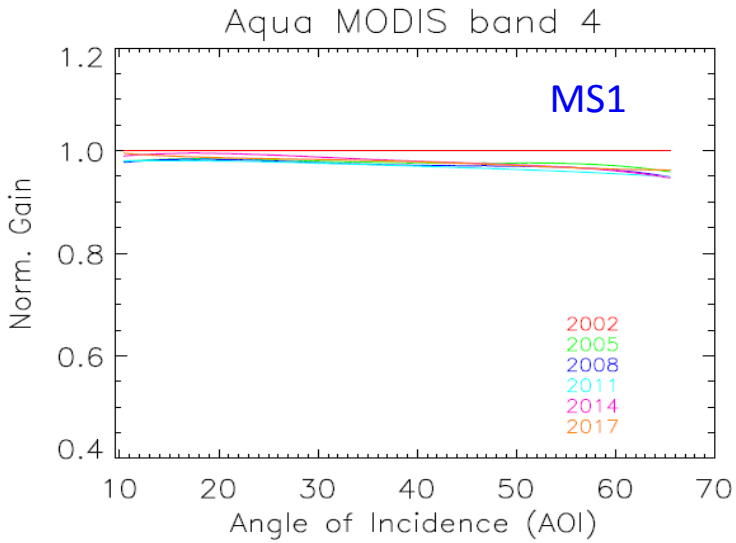
Changes in RSB responses are wavelength, AOI, and mirror-side dependent
More challenges for Terra MODIS due to changes in polarization sensitivity

On-orbit Changes in MODIS RSB RVS





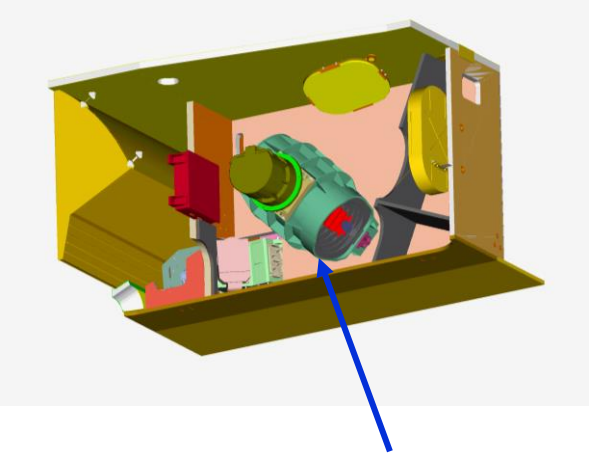




Changes in RSB responses are not linear with AOI – data at multiple AOIs are needed for RVS

Using Lunar Observations for VIIRS RSB Calibration

- **Scanning radiometer**
  - A rotating telescope assembly (RTA) coupled with a half-angle mirror (HAM)
  - EV data collected with AOI from 29° to 56.5°
  - SD observations at AOI of 60.2°
  - Lunar observations at AOI of 60.2°
- **Response versus scan angle (RVS)**
  - Changes in RVS have been very small
  - Special attention needed as mission continues
- **Improved SD on-orbit degradation monitoring**
  - SDSM covers wavelengths from 0.4 to 0.93 μm
  - Large SD degradation in VIS and no SWIR coverage in SWIR



Rotating Telescope Assembly

References:

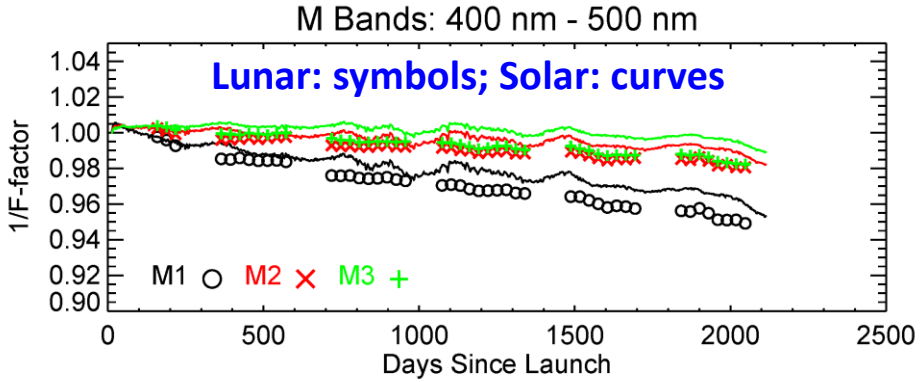
A. Wu, X. Xiong, and C. Cao, "Assessment of Stability of the Response Versus Scan Angle for the S-NPP VIIRS Reflective Solar Bands Using Pseudo-Invariant Desert and Dome C sites," SPIE 2017

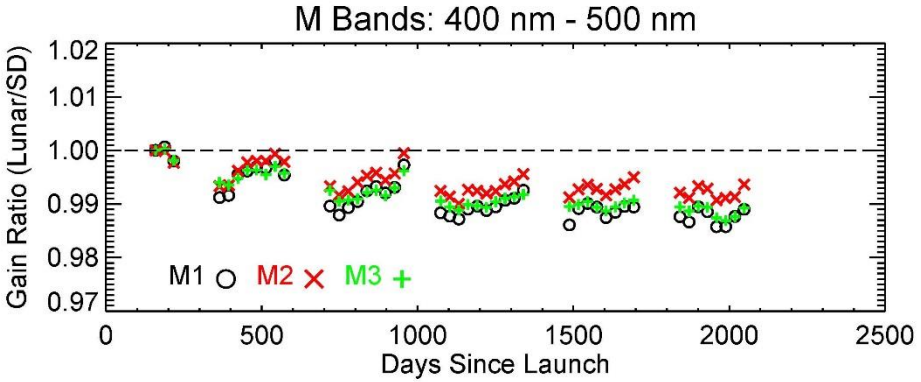
N. Lei and X. Xiong, "Impacts of the Angular Dependence of the Solar Diffuser BRDF Degradation Factor on the SNPP VIIRS Reflective Solar Band On-Orbit Radiometric Calibration", IEEE TGRS, 2017

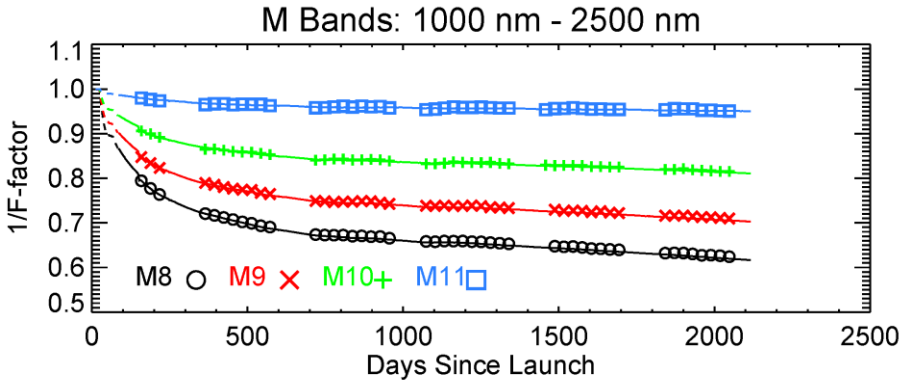
VIIRS RSB Responses from SD and Lunar Observations

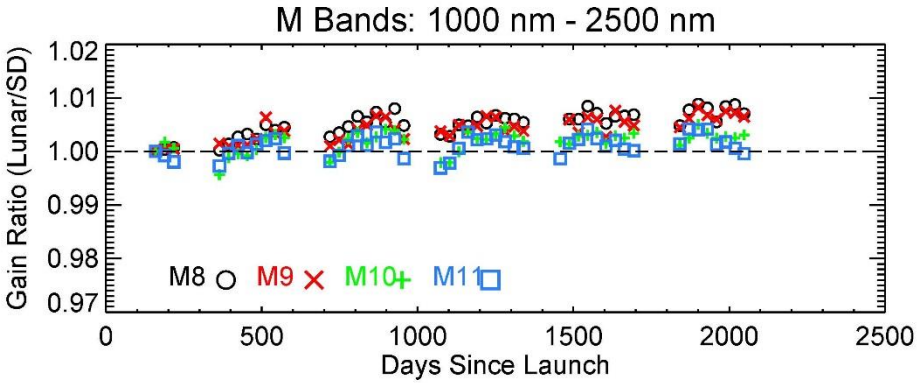
- Small changes in VIS spectral bands; large changes in NIR/SWIR spectral bands
- Small but noticeable differences between SD and lunar responses

Before H Improvement (V1)





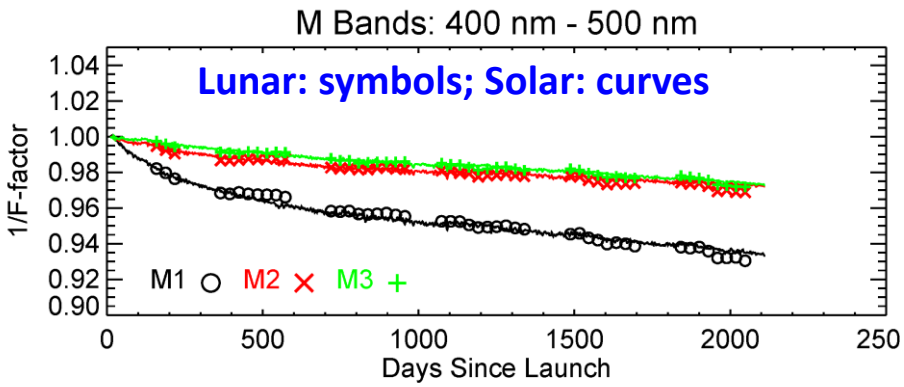


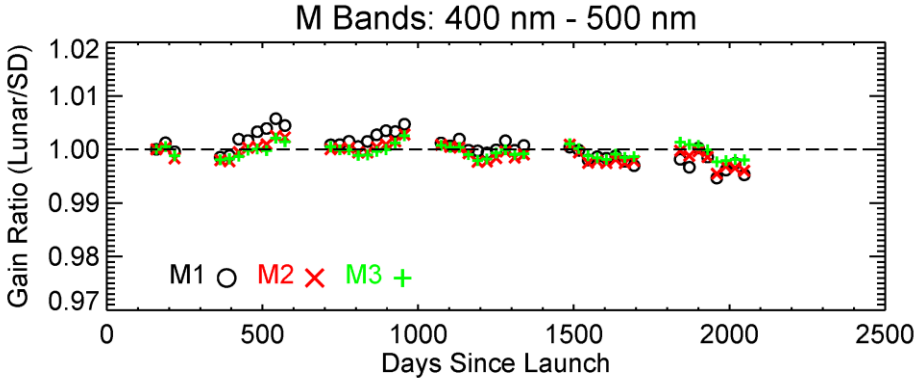


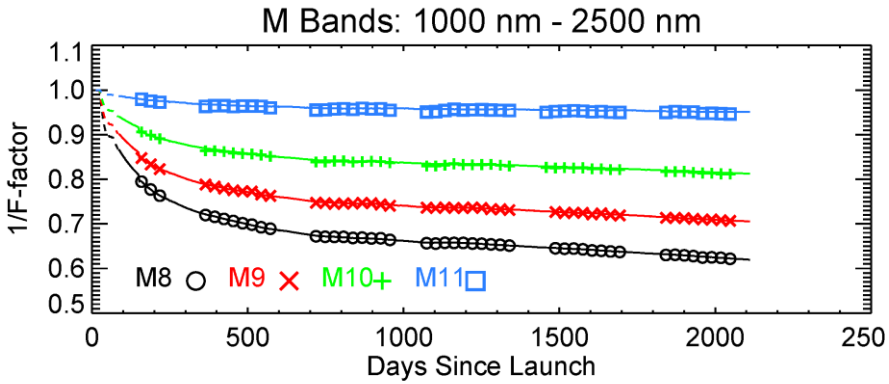
Using Lunar Observations for VIIRS RSB Calibration

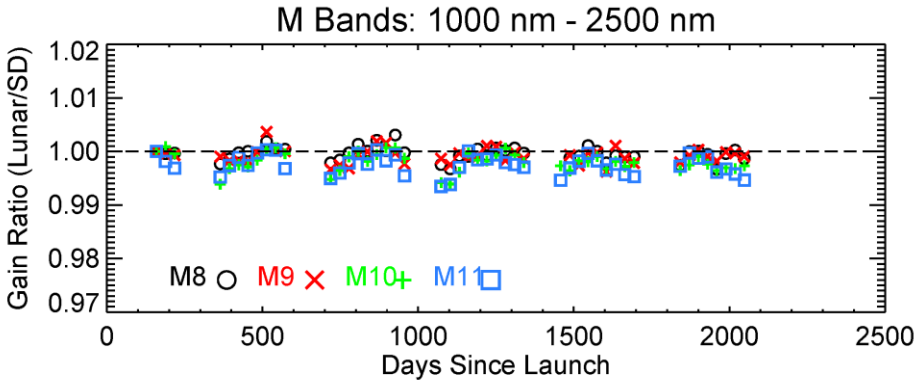
- Differences between SD and lunar responses have been used via a model to correct and improve SD degradation factor (H) derived from SDSM

After H Improvement (V2)









Lessons and Future Work

- **Importance of lunar observations**
  - Support of MODIS and VIIRS on-orbit calibration and characterization, including radiometric, spatial, and other applications for both RSB and TEB
- **Effort and lessons include but not limited to**
  - Pre-launch planning and on-orbit scheduling
  - Coordination with MOT to optimize execution strategies
  - Algorithm development and sensor dependent implementation and applications
  - Data analyses with independent validation
  - Communication and collaboration with other agencies
- **Future activities**
  - MODIS: to improve RVS characterization and calibration transfer from SD to lunar observations (long-term trending)
  - VIIRS: to improve SD degradation monitoring for all RSB wavelengths (from VIS to SWIR)
  - Calibration consistency among different instruments (leverage NIST effort)
  - Future JPSS VIIRS lunar observations will provide more valuable information to improve sensor calibration and calibration inter-comparisons

Acknowledgements

- NASA MODIS and VIIRS Characterization Support Team (MCST/VCST)
- NOAA VIIRS SDR Calibration Team
- Terra, Aqua, and S-NPP Mission Operation Team (MOT)
- MODIS and VIIRS Instrument Vendor (Raytheon)