



# MODIS and VIIRS Lunar Observations

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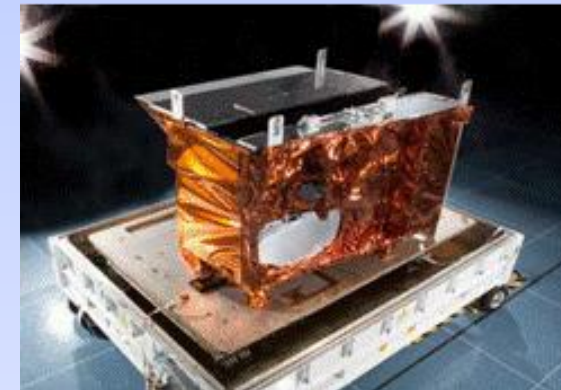
# Outline

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- **Background**
  - MODIS and VIIRS
  - On-board Calibrators
- **MODIS and VIIRS Lunar Observations**
- **Applications**
- **Results and Discussion**
- **Concluding Remarks**

# Background

- **Moderate Resolution Imaging Spectroradiometer (MODIS)**
  - Key instruments for NASA EOS Terra (launched in 1999) and Aqua (launched in 2002)
  - Spectral bands: 20 reflective solar bands (RSB) and 16 thermal emissive bands (TEB)
  - Spectral wavelengths: 0.4-14.5  $\mu\text{m}$
  - Spatial resolutions: 250 m (2 bands), 500 m (5 bands), and 1 km (29 bands)
- **Visible/Infrared Imager Radiometer Suite (VIIRS)**
  - Key instruments for S-NPP (launched in 2011) and JPSS (launch in 2017)
  - Spectral bands: 15 reflective solar bands (RSB), including a day and night band (DNB); 7 thermal emissive bands (TEB)
  - Spectral wavelengths: 0.4-12.4  $\mu\text{m}$
  - Spatial resolutions: 375 m for I bands; 750 m for M bands and DNB
  - Special features: dual gains, aggregation, bow-tie deletion

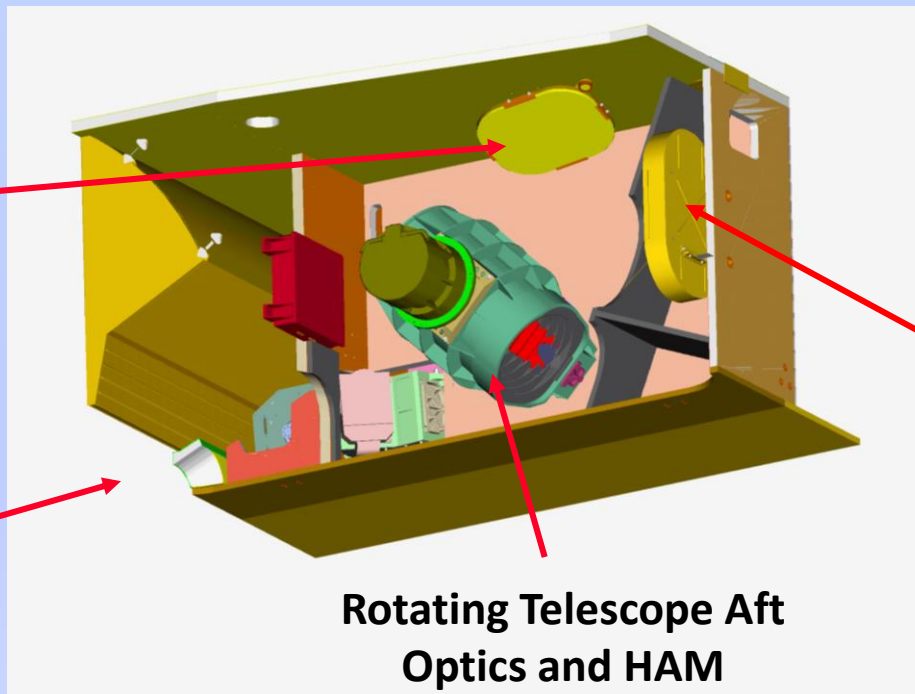
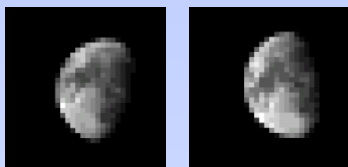


# MODIS and VIIRS On-board Calibrators (OBC)



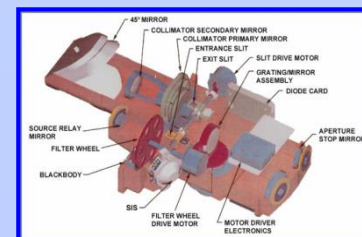
Solar Diffuser

SV Port



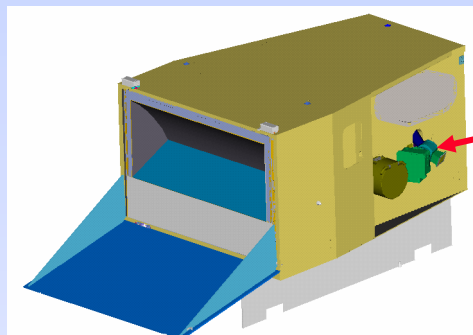
Rotating Telescope Aft Optics and HAM

## SRCA (MODIS only)



Blackbody

MODIS uses a two-sided scan mirror



Solar Diffuser Stability Monitor

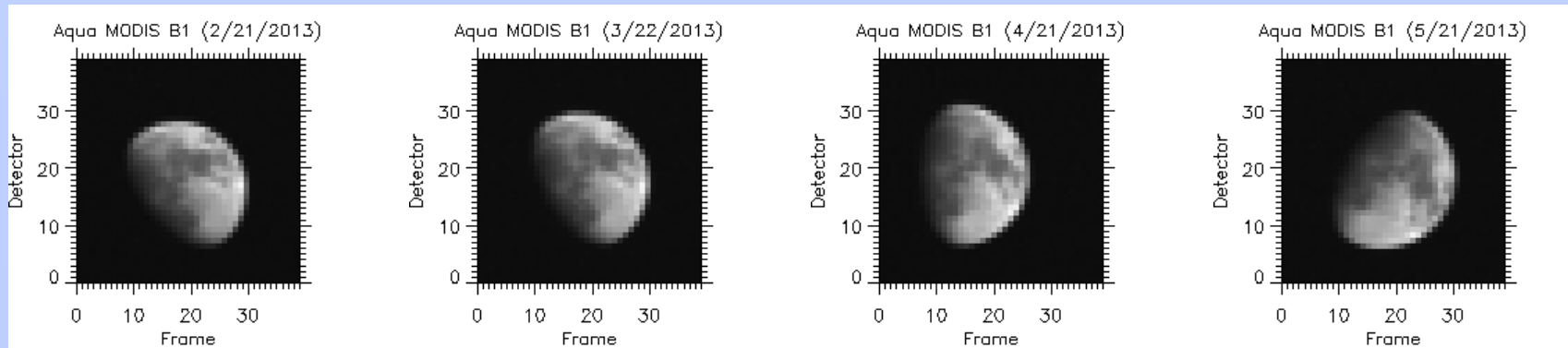
# MODIS and VIIRS Lunar Observations

- **Regularly Scheduled at the “same” Phase Angle**
  - Terra/Aqua MODIS:  $55^{\circ}$  to  $56^{\circ}$  (waning) /  $-55^{\circ}$  to  $-56^{\circ}$  (waxing)
  - SNPP VIIRS:  $-51.5^{\circ}$  to  $-50.5^{\circ}$
- **Viewed through Space View (SV)**
  - A sector rotation implemented so more data samples are collected
- **Performed via Spacecraft Roll Maneuvers**
  - Terra/Aqua MODIS:  $0^{\circ}$  to  $-20^{\circ}$
  - SNPP VIIRS:  $0^{\circ}$  to  $-14^{\circ}$
- **Calibration Referenced to the ROLO Model**
  - Integrated lunar irradiance for each spectral band
  - Oversampling factor when using data from all scans

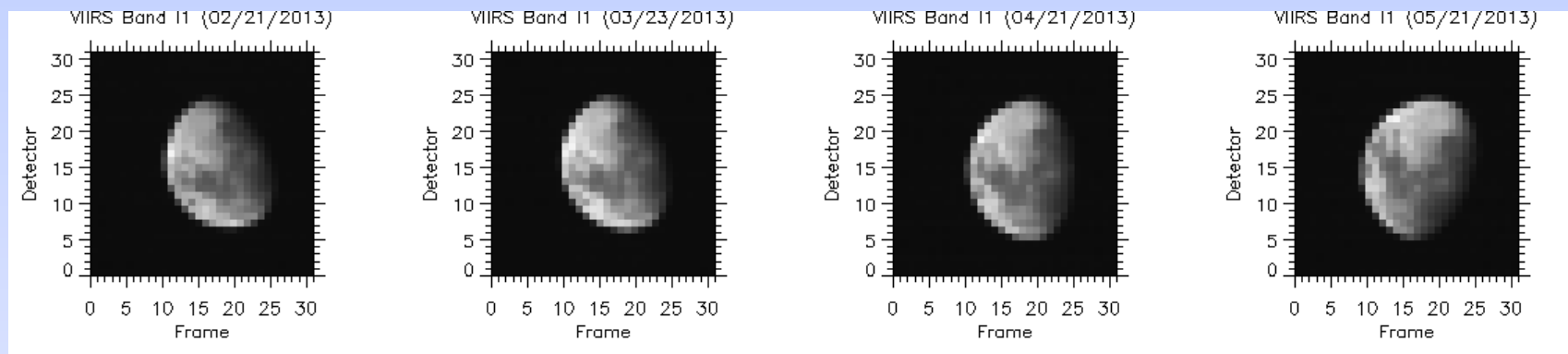
Lunar Observations Made as of March 20, 2014 (T/A MODIS: 136/110; SNPP VIIRS: 19)

# MODIS and VIIRS Lunar Images

**Aqua MODIS B1 lunar observations: 2/21/13, 3/22/13, 4/21/13, 5/21/13)**



**S-NPP VIIRS I1 lunar observations: 2/21/13, 3/23/13, 4/21/13, 5/21/13)**



# Applications

- **Radiometric Calibration Stability**
  - RSB
  - TEB
  - DNB (VIIRS only)
- **Spatial Characterization**
  - BBR (along-scan and along-track)
  - MTF (along-track)
- **Calibration Inter-comparison**
  - Inter-comparison of MODIS and VIIRS
  - Inter-comparison of Terra MODIS, MISR, SeaWiFS, and VIRS
- **Others**
  - Optical Leak Characterization
  - Electronic Crosstalk Assessment

Methodologies and results documented in journal papers or SPIE proceedings

# Results and Discussion

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- **Radiometric Calibration Stability**
  - Reflective solar bands (RSB)
- **Spatial Characterization**
  - BBR and MTF
- **Calibration Inter-comparison**
  - MODIS and VIIRS

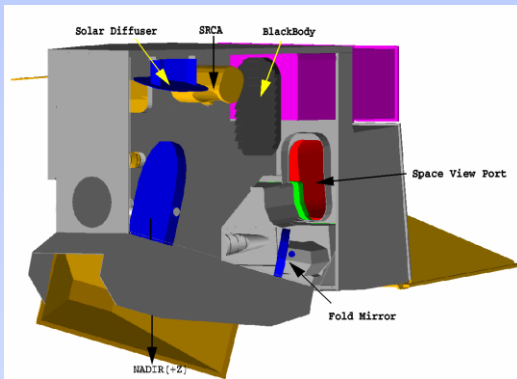


# Radiometric Calibration Stability (RSB)



$$m_1 = \frac{BRF_{SD} \cdot \cos(\theta_{SD})}{\langle dn_{SD}^* \rangle \cdot d_{Earth-Sun}^2} \cdot \Gamma_{SD} \cdot \Delta_{SD}$$

gain  $\propto 1/m_1$



$$m_1 = \frac{f(\text{view\_geometry})}{\langle dn_{Moon}^* \rangle}$$

Geometric Factors

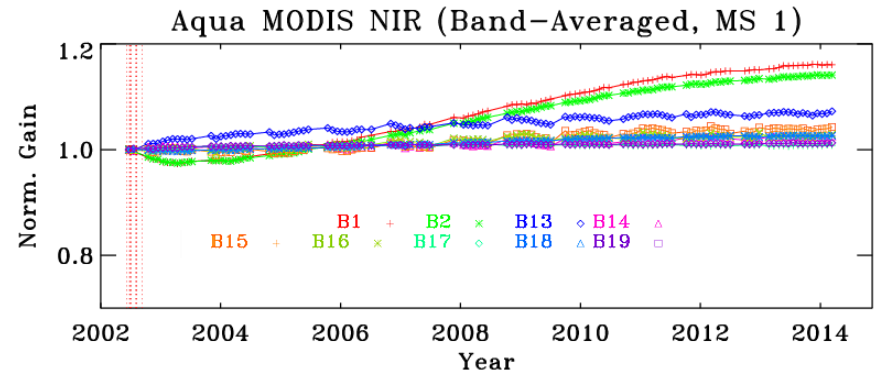
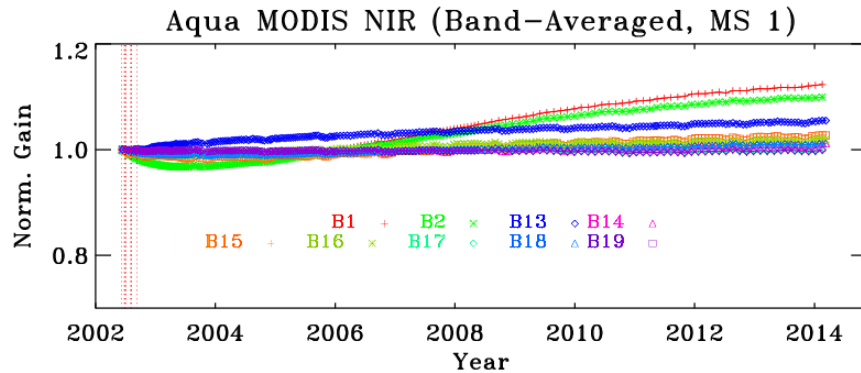
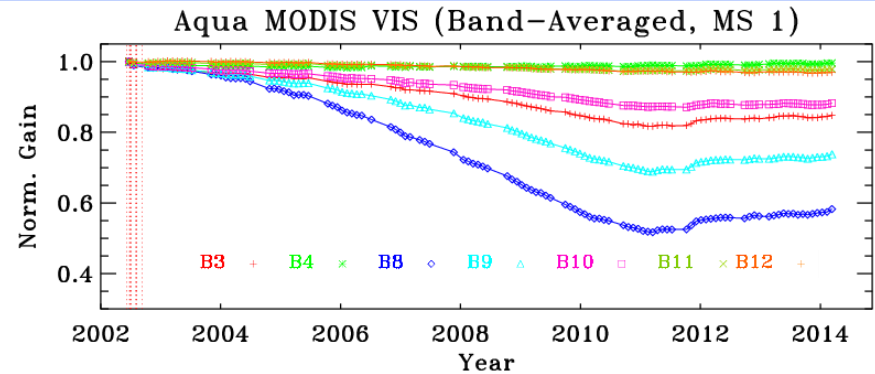
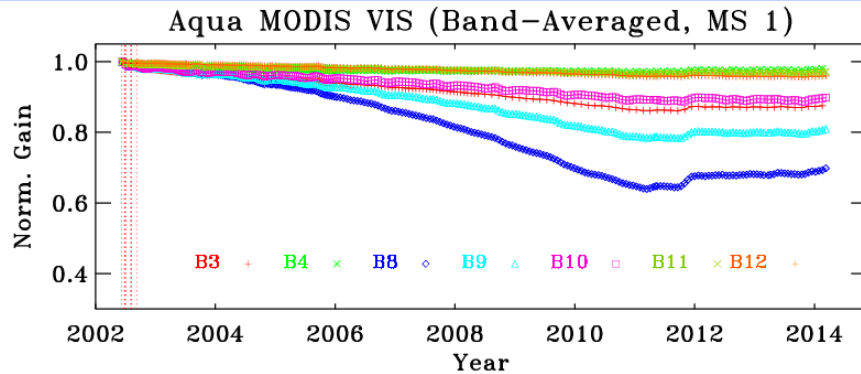


$$f = \frac{f_{\text{phase-angle}} \cdot f_{\text{libration}} \cdot f_{\text{over-sampling}}}{d_{Sun-Moon}^2 \cdot d_{Modis-Moon}^2}$$

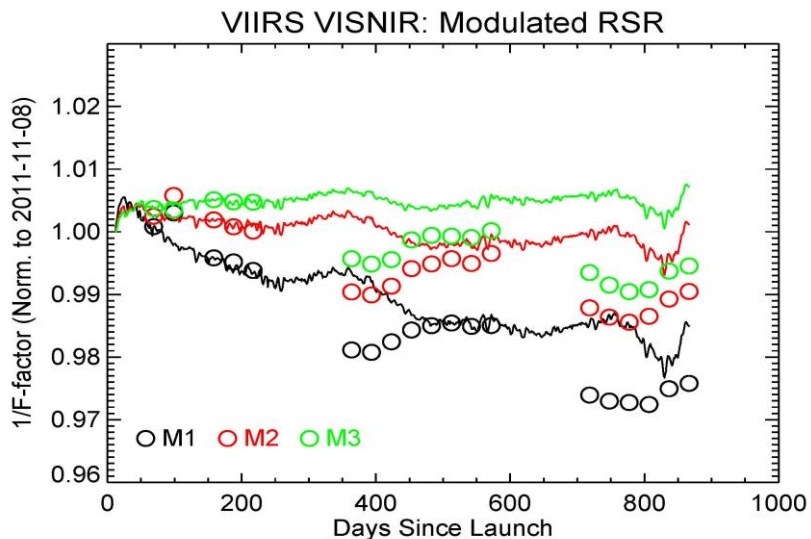
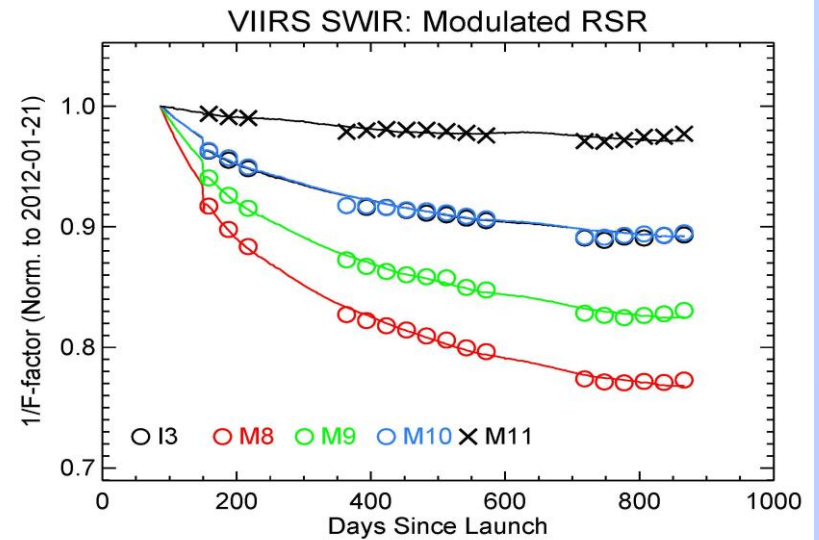
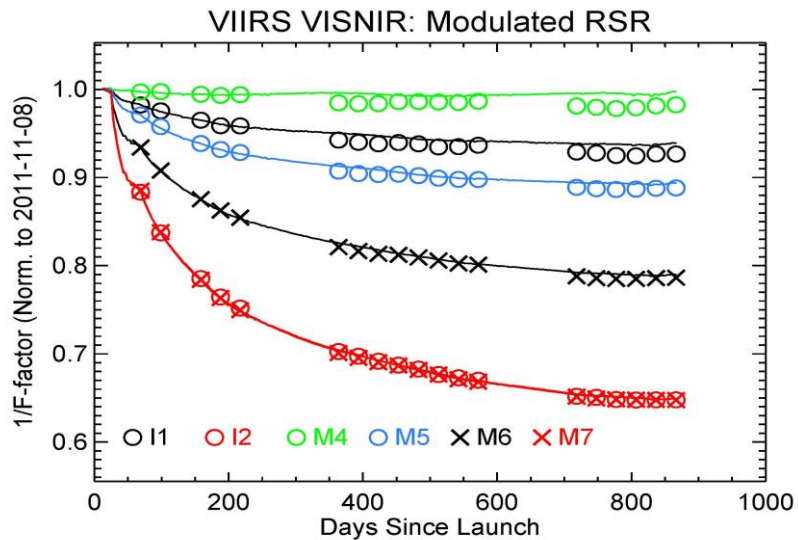
MODIS lunar observations are made at different scan angles

# Radiometric Calibration Stability: MODIS

Lunar and SD CAL used to track changes in sensor response versus scan-angle (RVS)



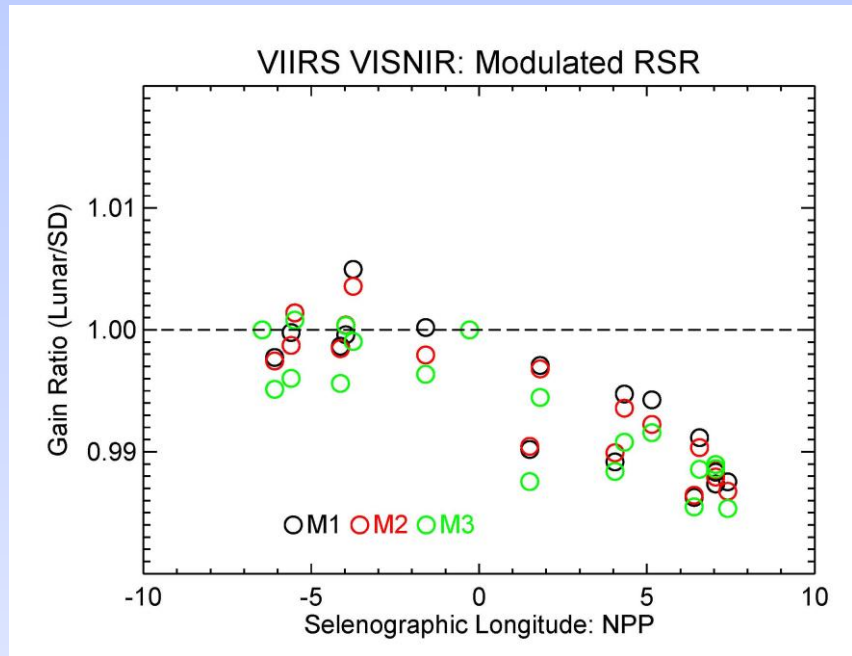
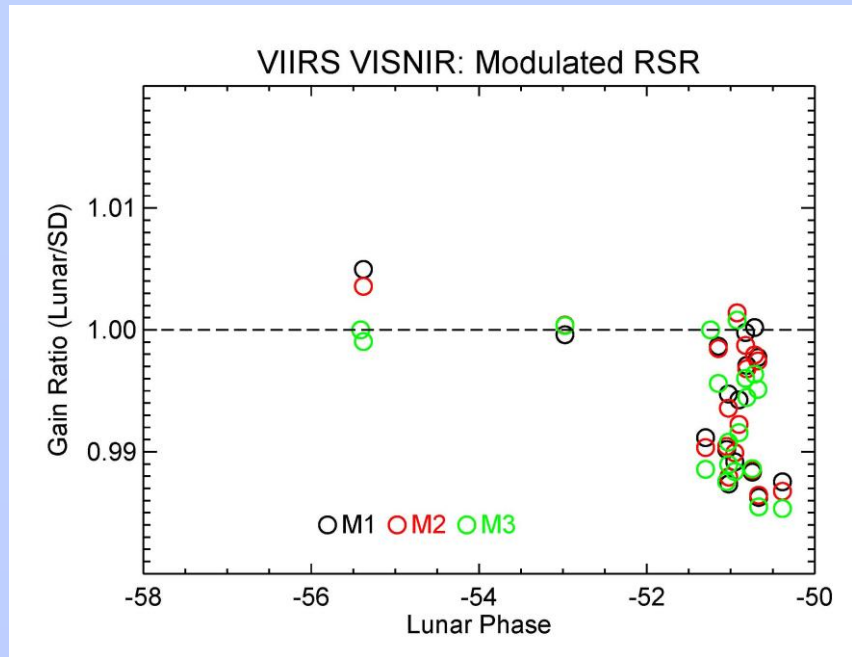
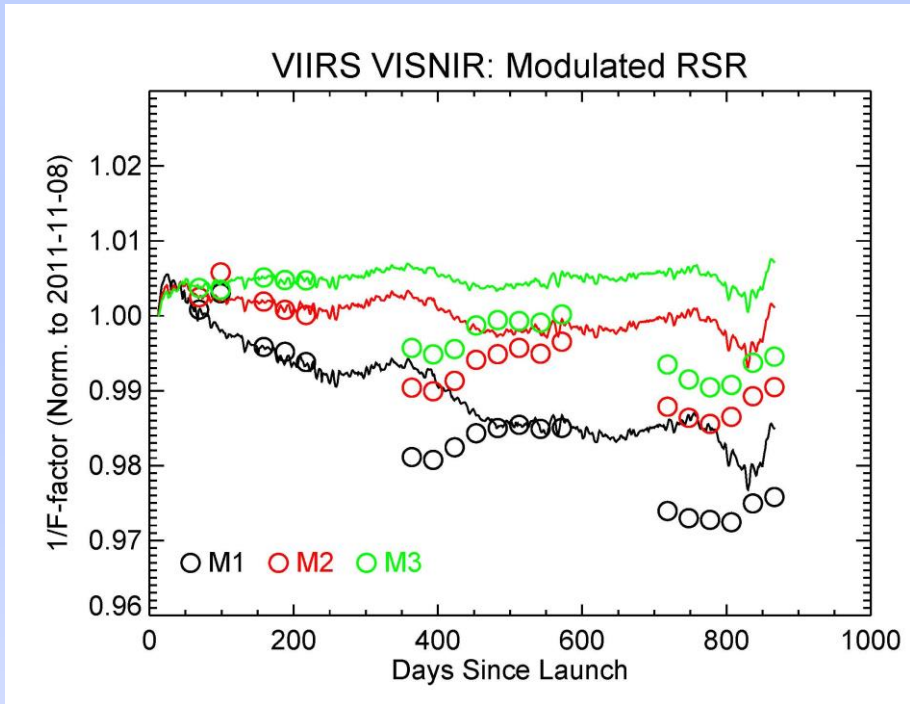
# Radiometric Calibration Stability: VIIRS



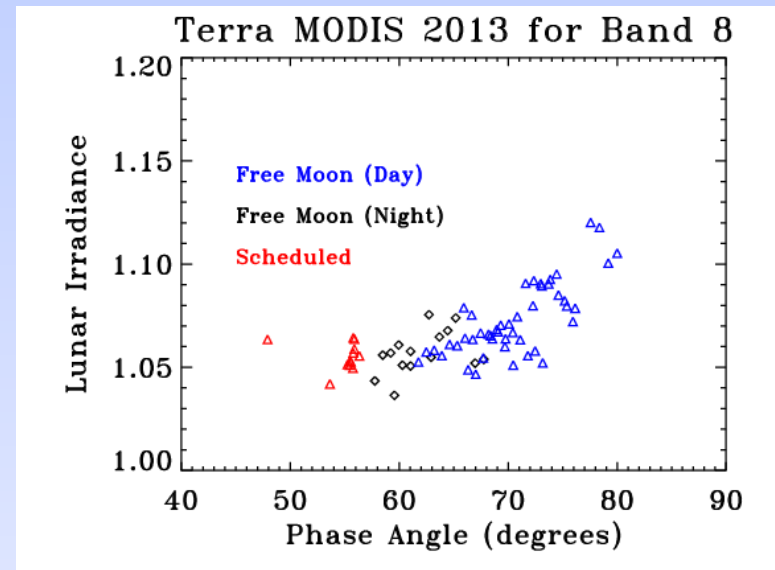
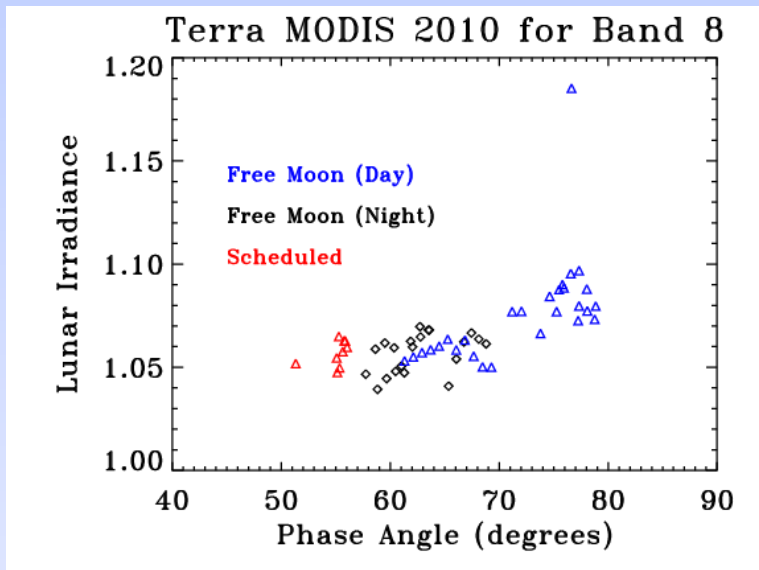
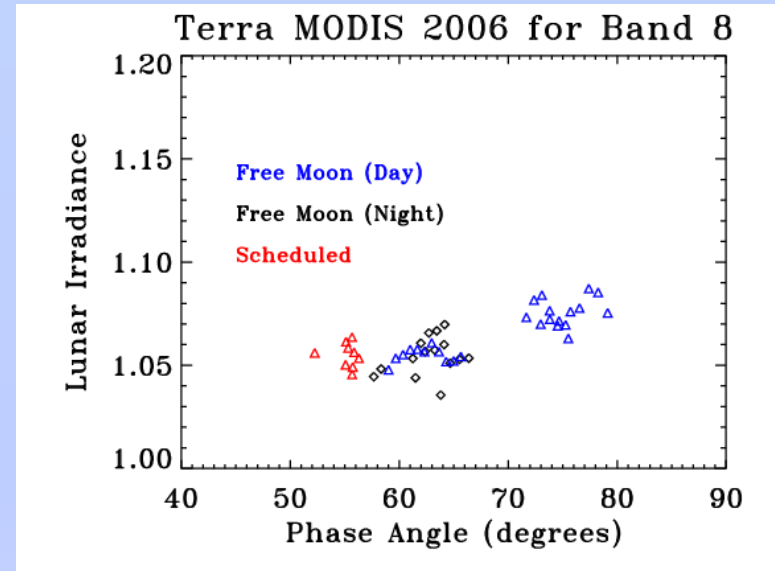
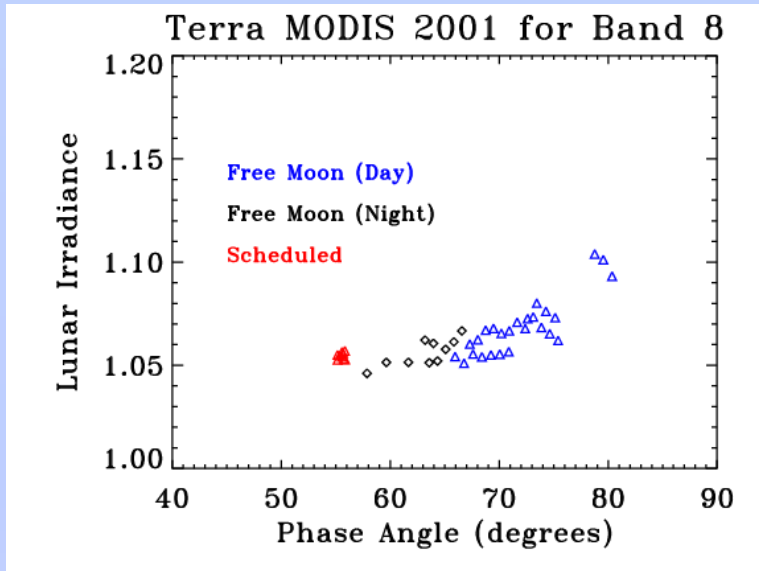
**SD and lunar calibration made at same angle of incidence (AOI)**

**Lines - SD Cal; Symbols - Lunar Cal**

# Issues to be studied

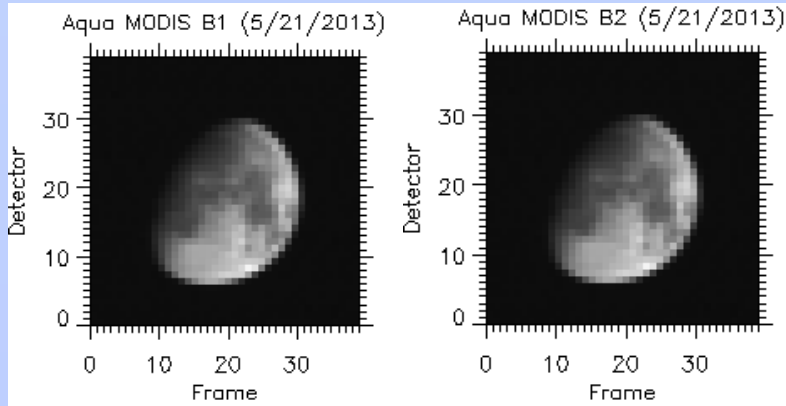


# Issues to be studied

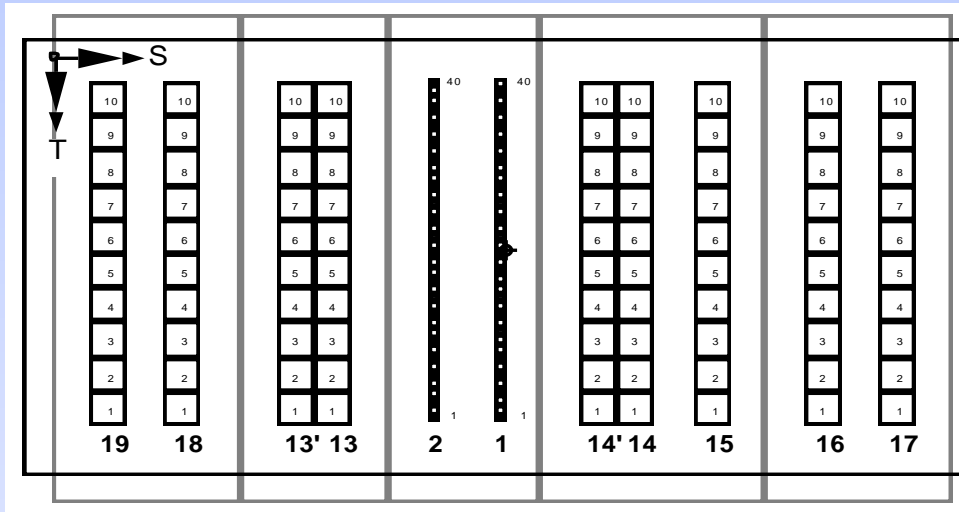
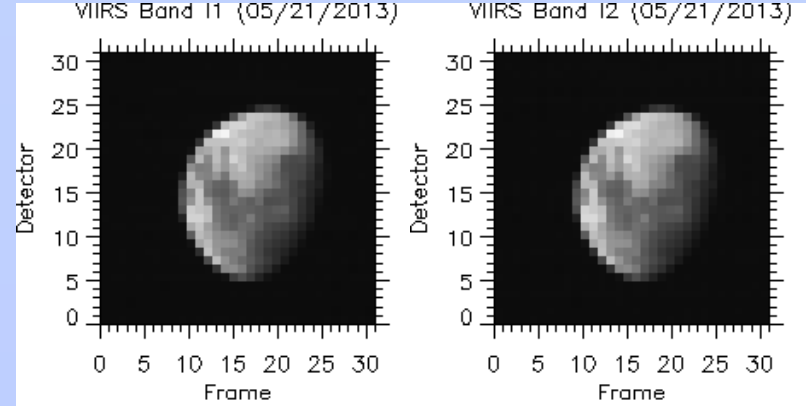


# Spatial Characterization (BBR)

## Aqua MODIS B1 and B2 (5/21/2013)

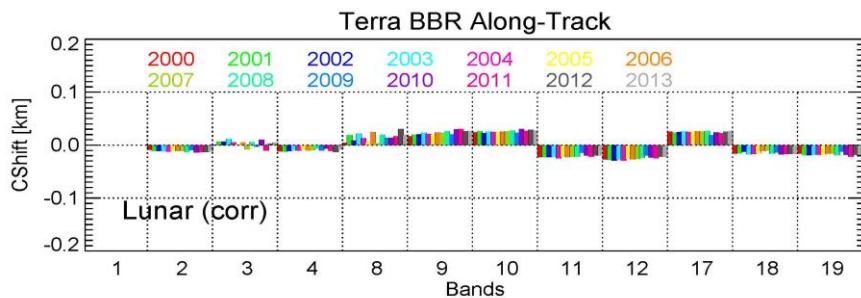
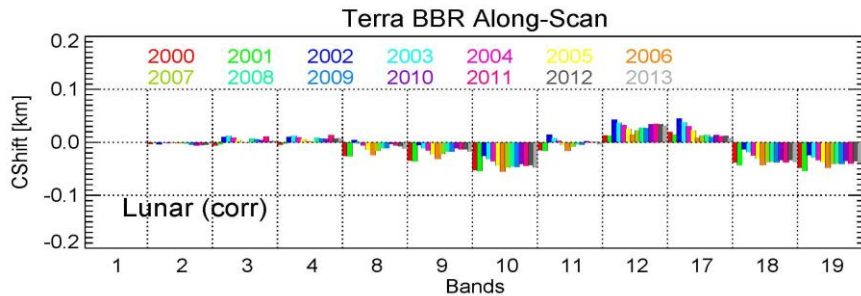
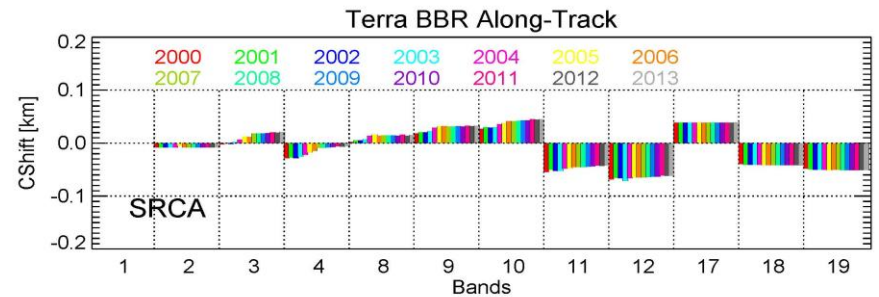
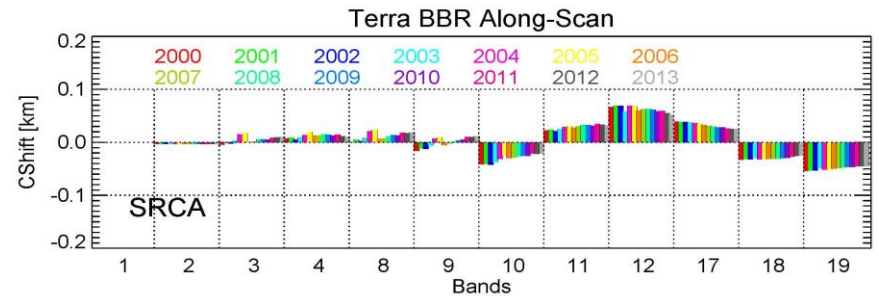
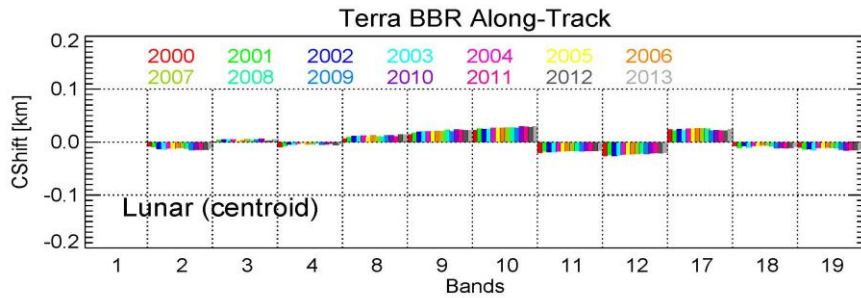
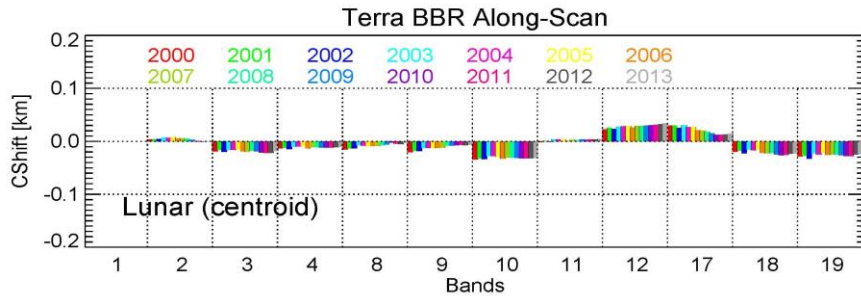


## S-NPP VIIRS I1 and I2 (5/21/2013)



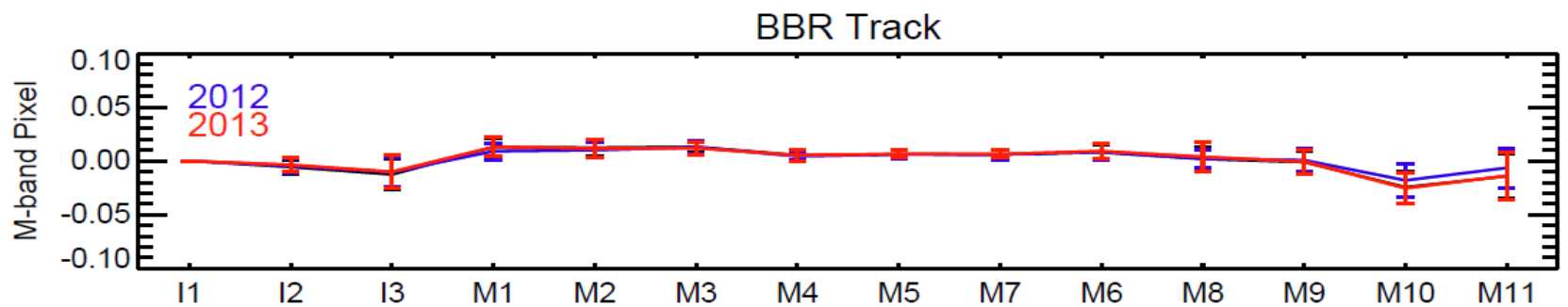
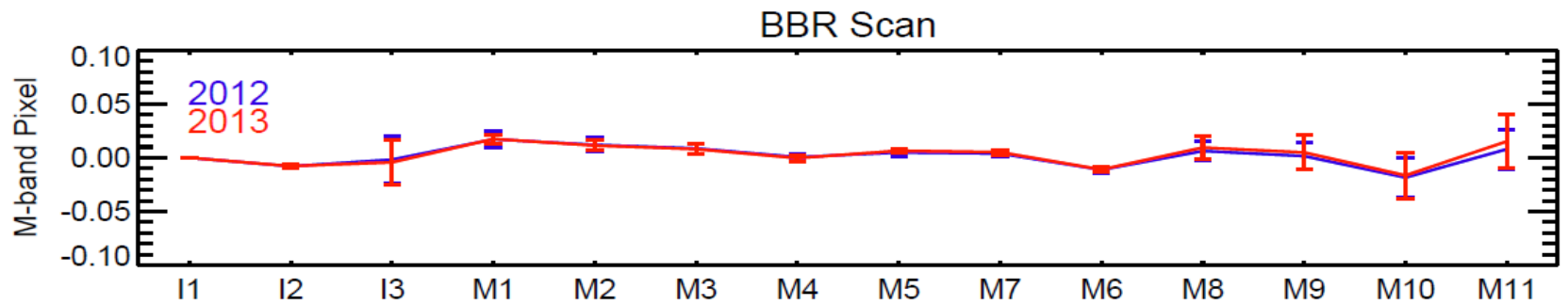
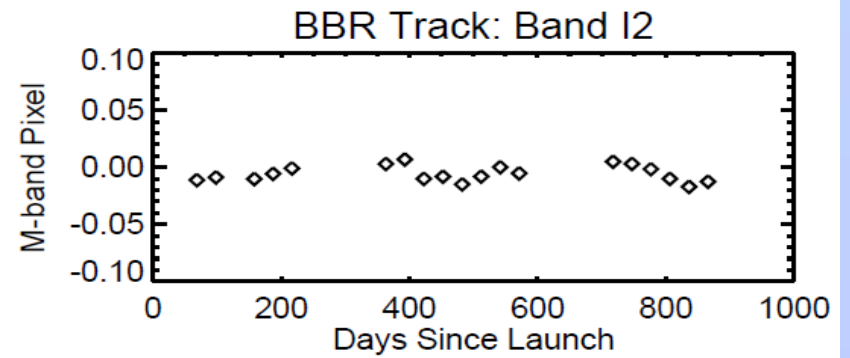
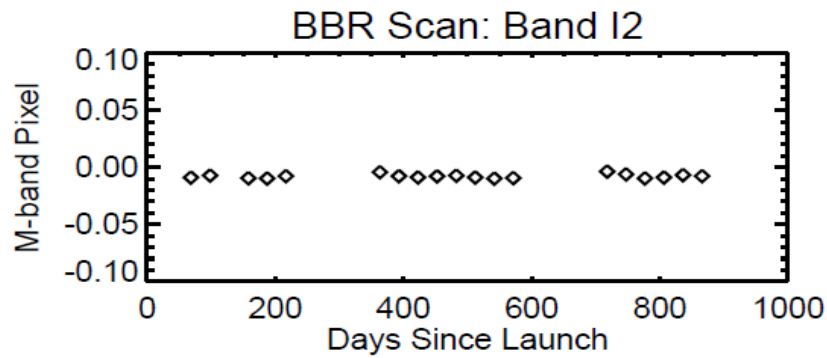
## MODIS NIR Focal Plane Assembly

# MODIS BBR derived from on-board calibrator and lunar observations





# VIIRS BBR from Lunar Observations



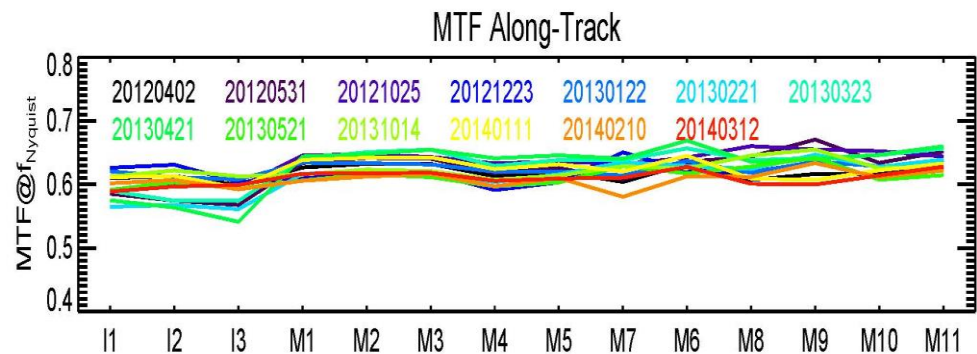
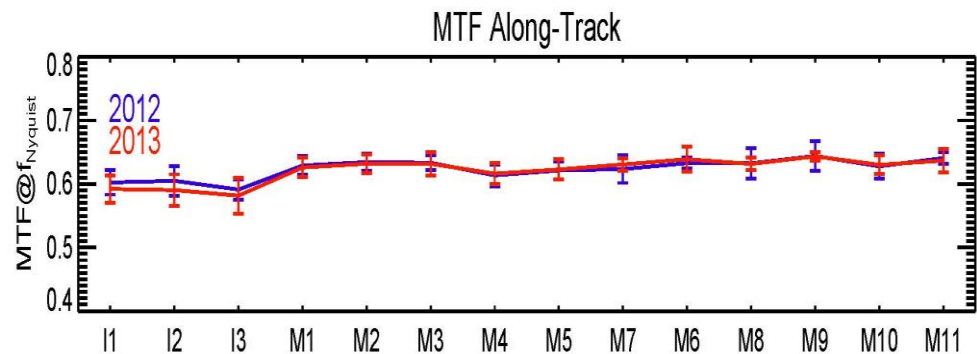
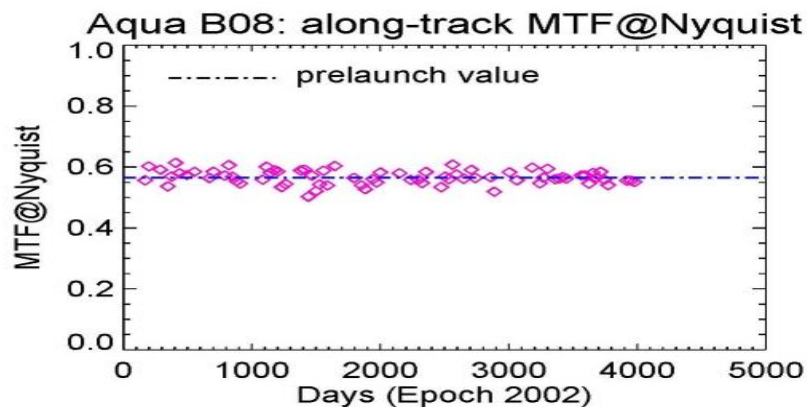
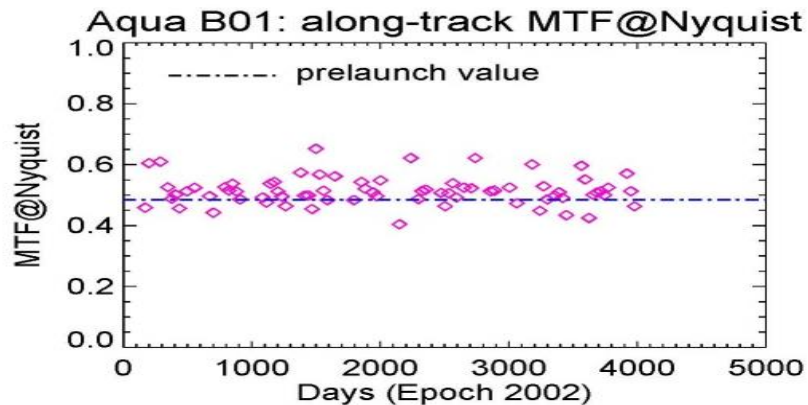


# Spatial Characterization (MTF)

## Edge Response Function in both along-scan and along-track direction

- Good agreement between MODIS lunar and on-board SRCA MTF results
- Approach developed for MODIS also applied to VIIRS
- More challenges for along-scan direction

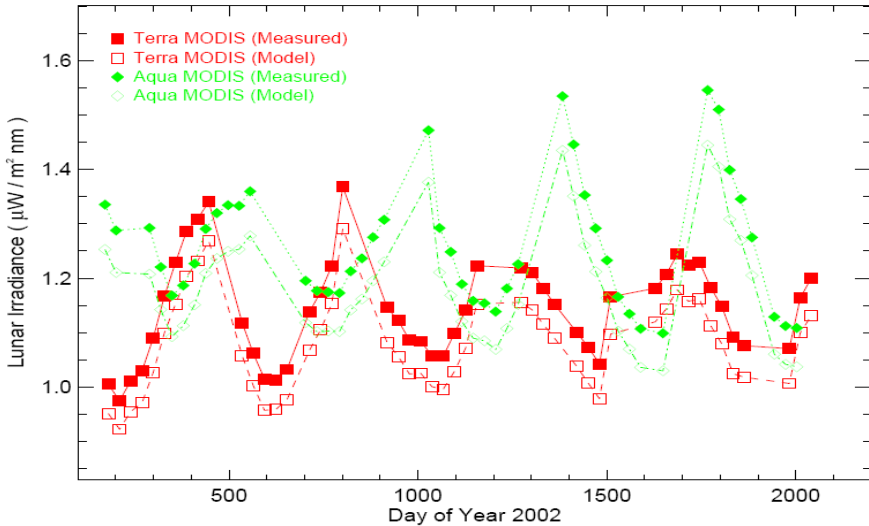
ERF => LSF => MTF



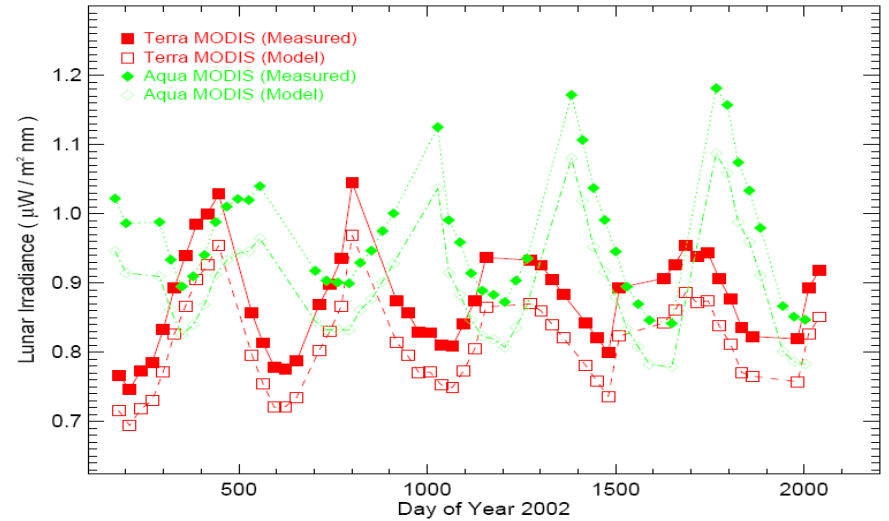
# Calibration Inter-comparison (MODIS B1 and B2)

$$\left( \frac{I_{\text{Meas\_Sensor-A}}}{I_{\text{Model\_Sensor-A}}} \right) / \left( \frac{I_{\text{Meas\_Sensor-B}}}{I_{\text{Model\_Sensor-B}}} \right)$$

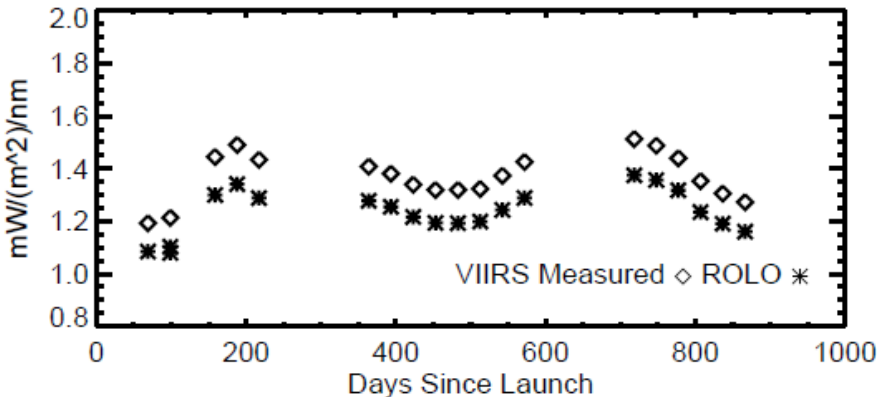
Lunar Irradiance for B1



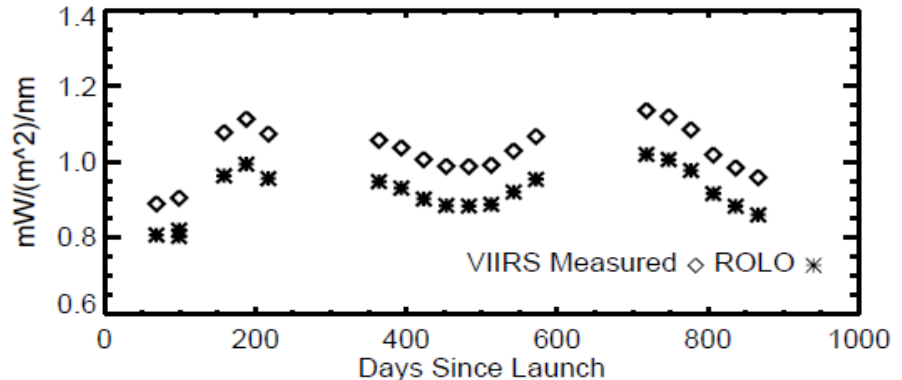
Lunar Irradiance for B2



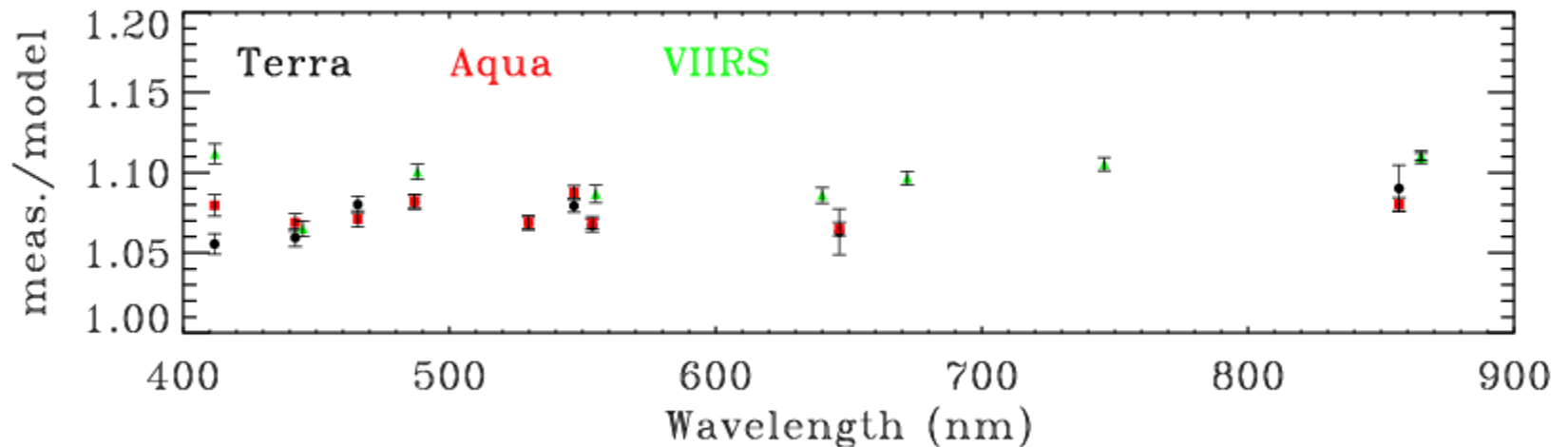
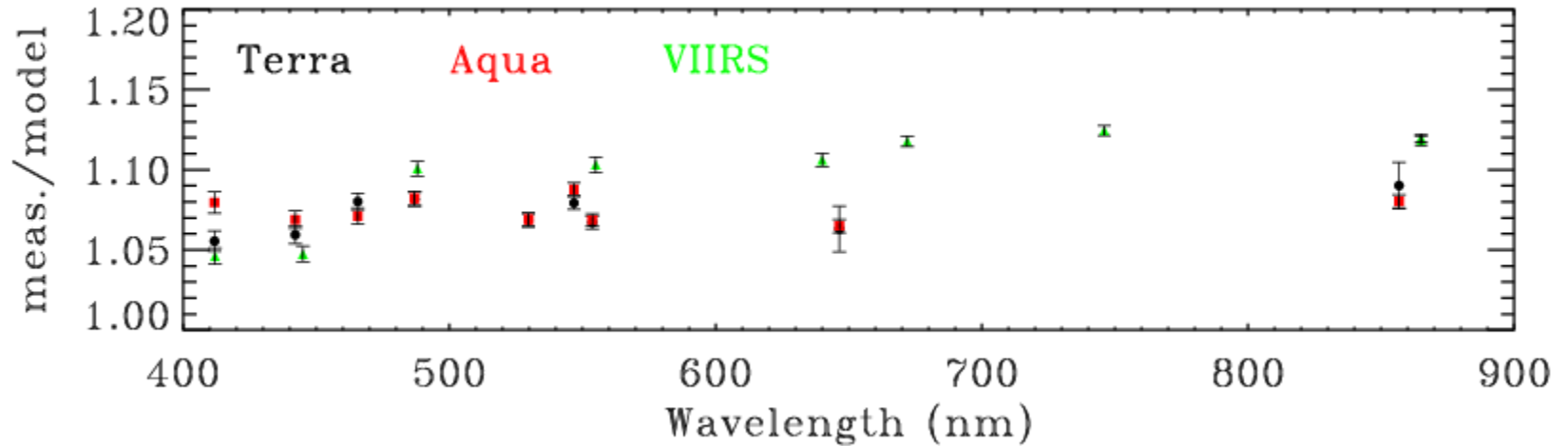
Lunar Irradiance Band: I1



Lunar Irradiance Band: I2



# MODIS and VIIRS Lunar Calibration Comparison



# Concluding Remarks

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- **MODIS and VIIRS lunar observations have been regularly scheduled and successfully used to monitor sensor RSB on-orbit calibration stability**
- **Other applications have been performed using lunar observations**
  - Spatial characterization
  - Optical leak and crosstalk assessment
  - Calibration inter-comparison
- **Future work**
  - Resolve small (0.5-1.0%) difference between VIIRS and SD calibration
  - Study calibration difference between MODIS (T/A) and VIIRS