SNPP VIIRS Lunar Images and Irradiances — a Correlation Study of Moon Image Orientation

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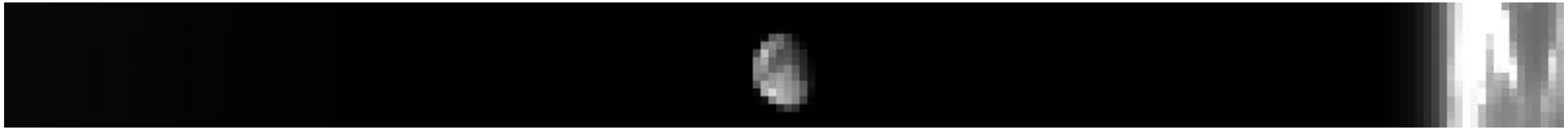
VIIRS Observations of the Moon

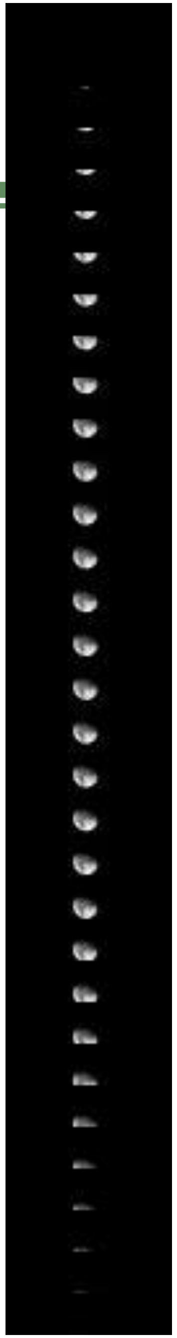
SNPP and NOAA-20 execute roll maneuvers each month to capture the Moon in the Earth-view sector at phase angle ~51° before Full Moon

- when the Moon is observable, typically October through June
- as the spacecraft traverses its orbit, the Moon passes through the field of view
- roll angle specified to center the Moon disk in Earth view:



SNPP VIIRS image d20170604_t1934579, band M7, scan 12

- centering avoids stray light, seen by stretching the display level:



Lunar Calibration

USGS lunar calibration works with lunar irradiances, comparing sensor measurements against reference values generated by the ROLO model.

- Reference irradiances are computed for the Sun-Moon-observer geometry (phase, librations, distances) corresponding to the instrument's Moon observations, transformed to the sensor's band wavelengths

- Irradiance measurements from Moon images involves spatial integration of pixels on the lunar disk:

$$E_{\text{meas}} = \frac{\Omega_{\text{p}}}{\eta} \sum_{i}^{N} L_i$$

$\Omega_{\text{p}} = \text{pixel IFOV (solid angle)}$
$\eta = \text{oversampling factor}$
$L_i = \text{pixel radiance}$
$N = \text{\# of pixels on Moon}$

★ The accuracy of lunar irradiance measurements from images depends on careful evaluation of:

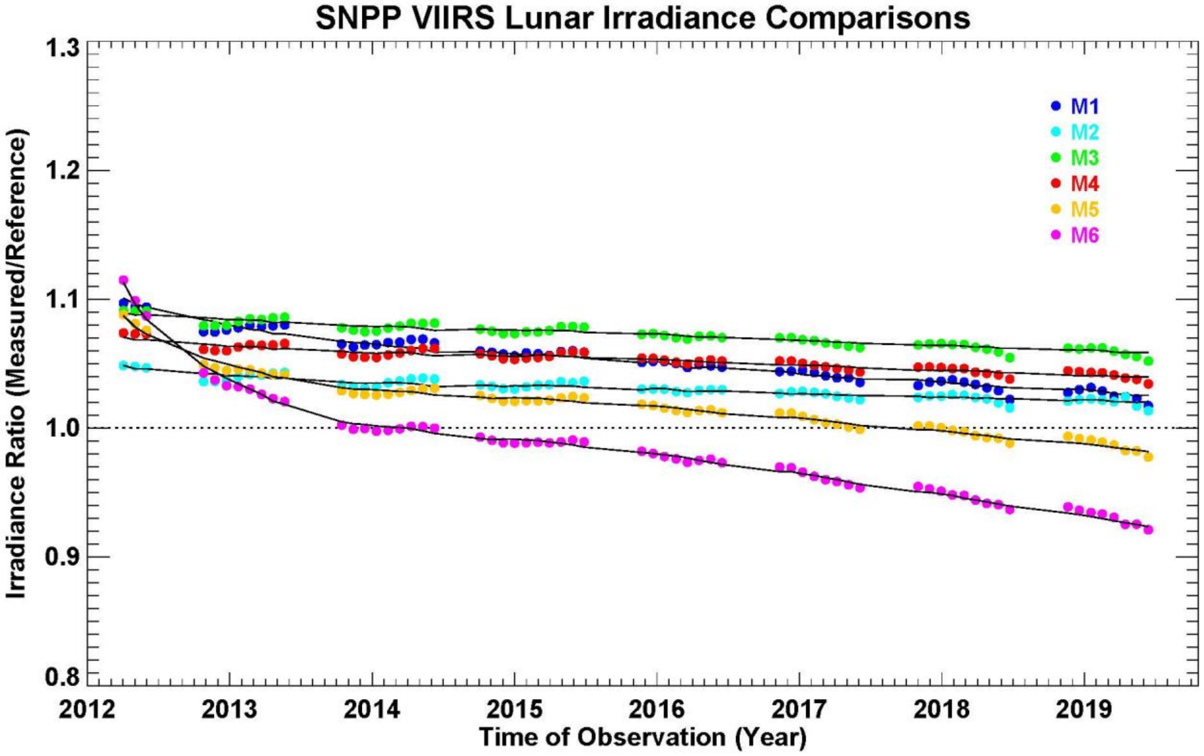
- net radiance: subtraction of the dark background
- actual detector spatial response (IFOV, different from GSD)
- oversampling of the Moon disk (different from slew/sampling)

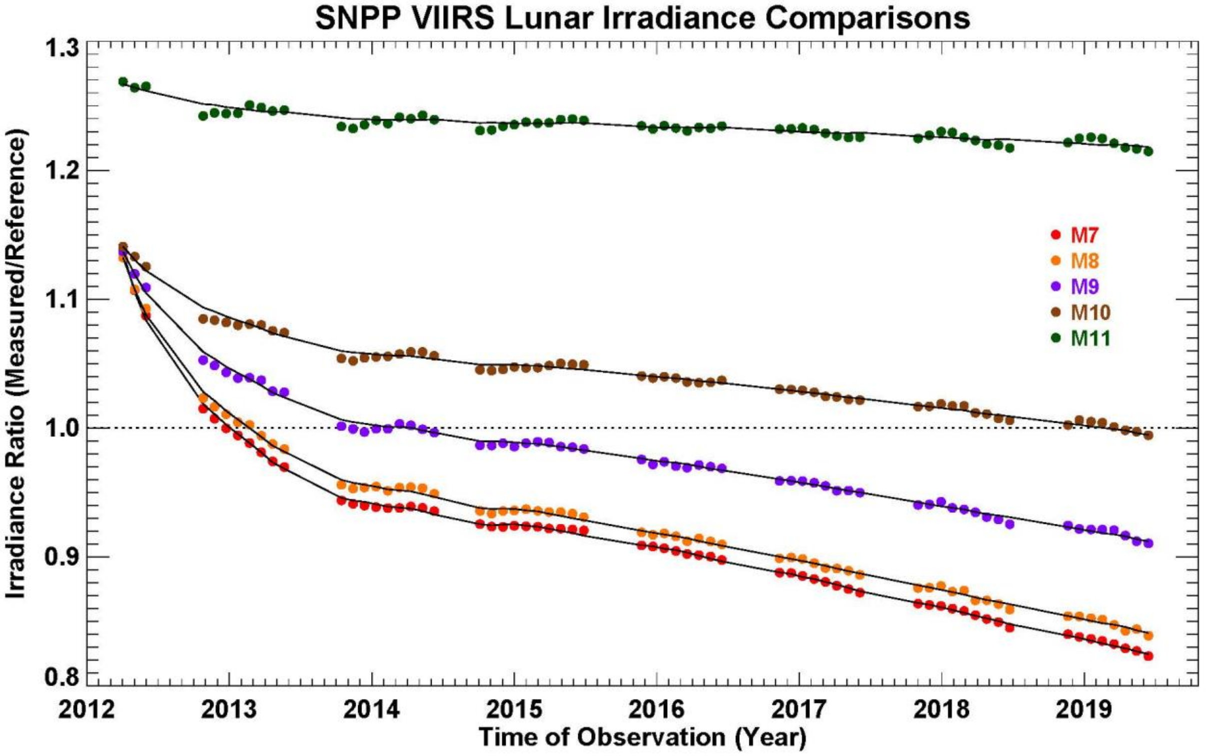
USGS

Lunar Calibration

Typical usage: tracking sensor response changes on orbit

- time series of measurement/model ratios reveal sensor response trends





VIIRS Lunar Image Analysis at USGS

Moon image processing to irradiance, independent of VCST and OBPG

- RDRs obtained from NOAA CLASS
- SDR software system installed on USGS compute cluster: ADL 4.2.8
  - code modifications to remove time-dependent calibration components; all granules processed identically
- VIIRS moon image spatial integration routines developed at USGS
  - detector dark level evaluation from deep space regions around the Moon disk
  - radiance conversion using SDR base calibration factors, extracted from SDR files
  - pixel solid angle derived from Horizontal Sampling Interval (from geolocation ATBD)
- temporal response trends corrected using daily-average SD f-factors for days of Moon observations (thanks to VCST)

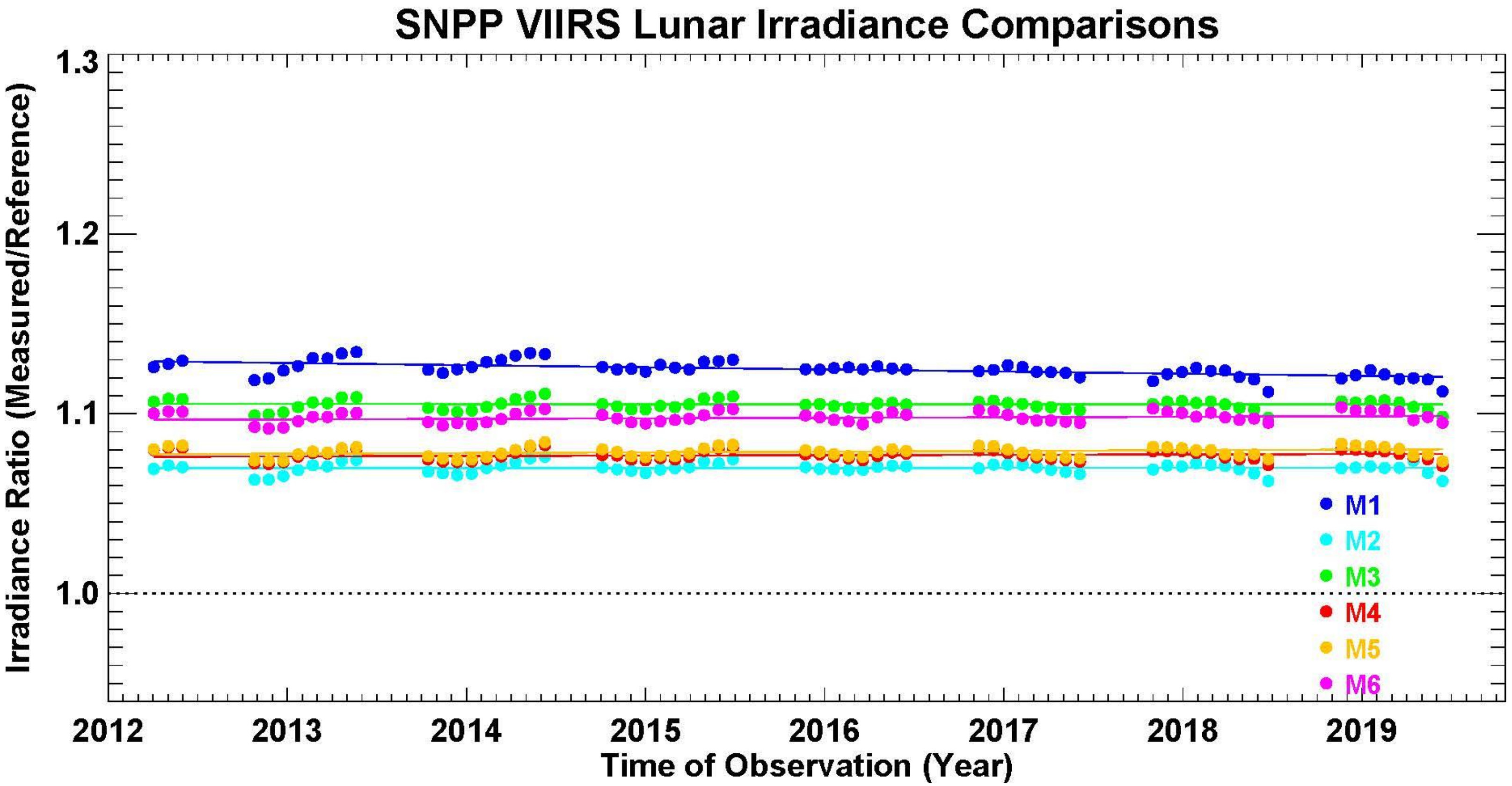
<u>USGS results</u>: time series of measurement/ROLO ratios, **not normalized**

USGS Results for VIIRS Lunar Calibration

Lunar irradiance ratios (VIIRS/ROLO) — de-trended —

Notable features:

- discrepancies (offsets) 7-16% for M1 to M6
- **band-correlated oscillation pattern**



- lines show linear fits to time series
  - slopes reveal residual temporal drifts (small)

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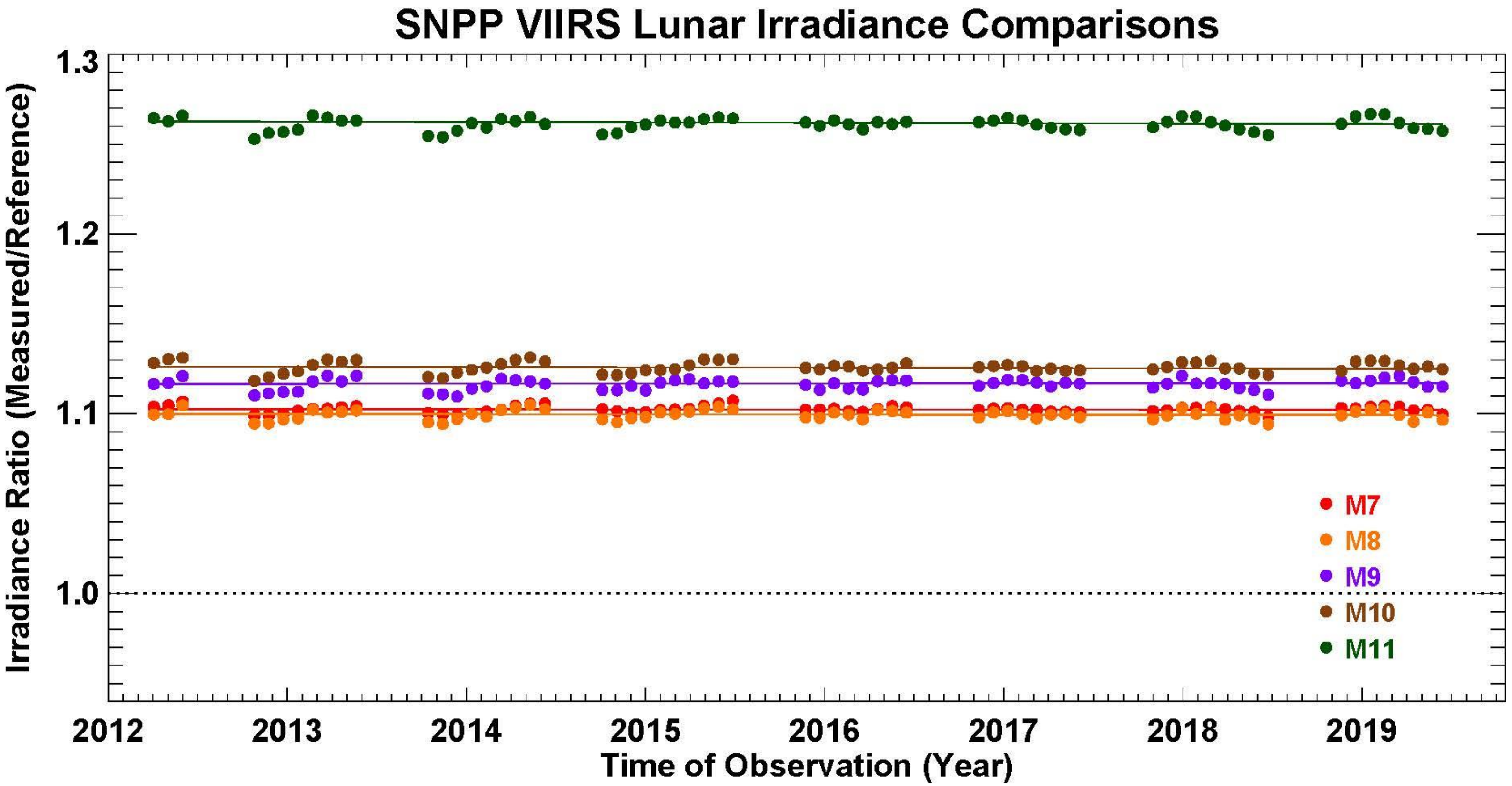


Notable features:

- discrepancies (offsets)
  9-14% for M7 to M10
  ~26% for M11
- **band-correlated oscillation pattern**

- lines show linear fits to time series
  - slopes reveal residual temporal drifts (small)

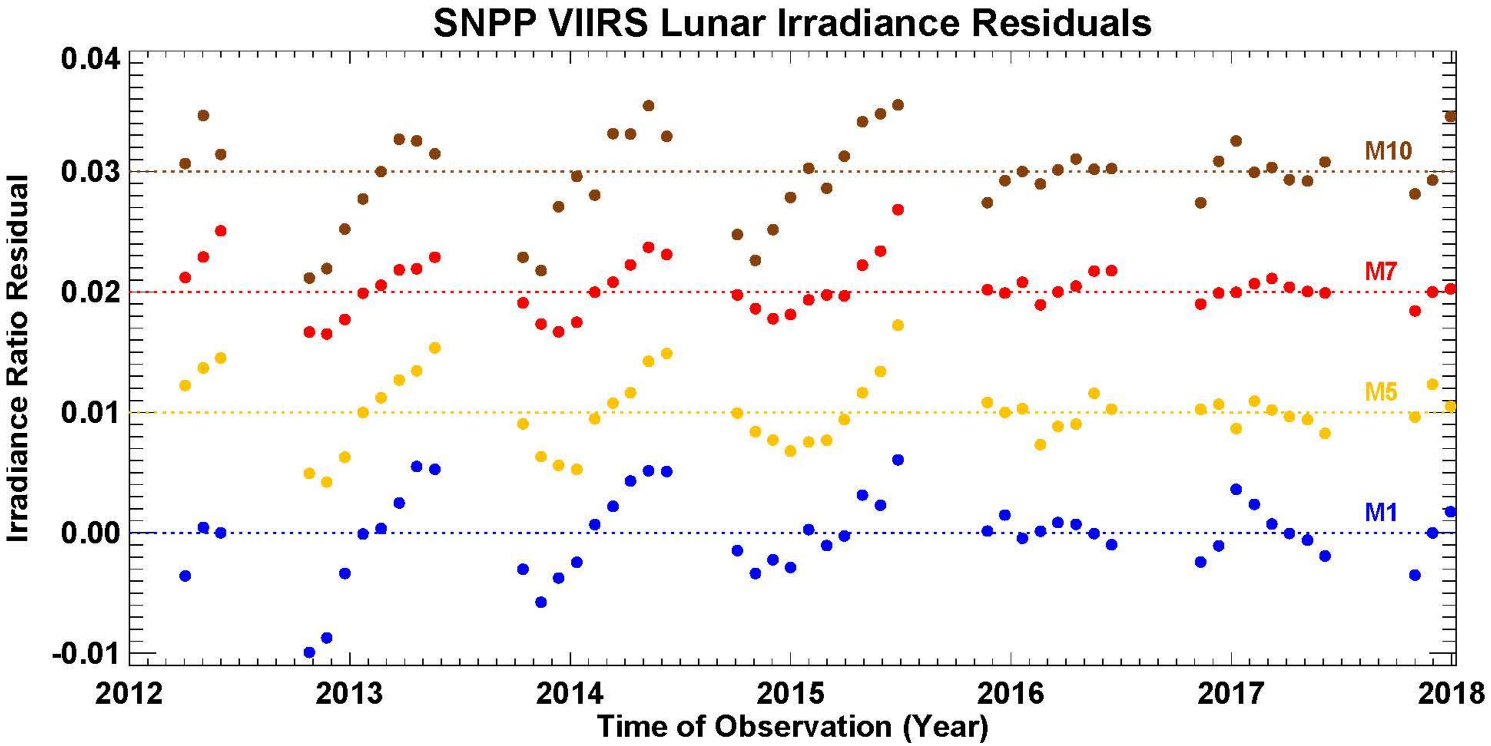
Investigating the Oscillation Patterns

The cross-band correlation suggests an origin in the ROLO lunar model.

- for a given sensor band, the model results are governed by only the phase angle and lunar librations
  - the only significant correlations were found with the observer (sensor) lunar librations

<u>Analysis approach</u>:

study residuals to the linear trend fits (offset for clarity)



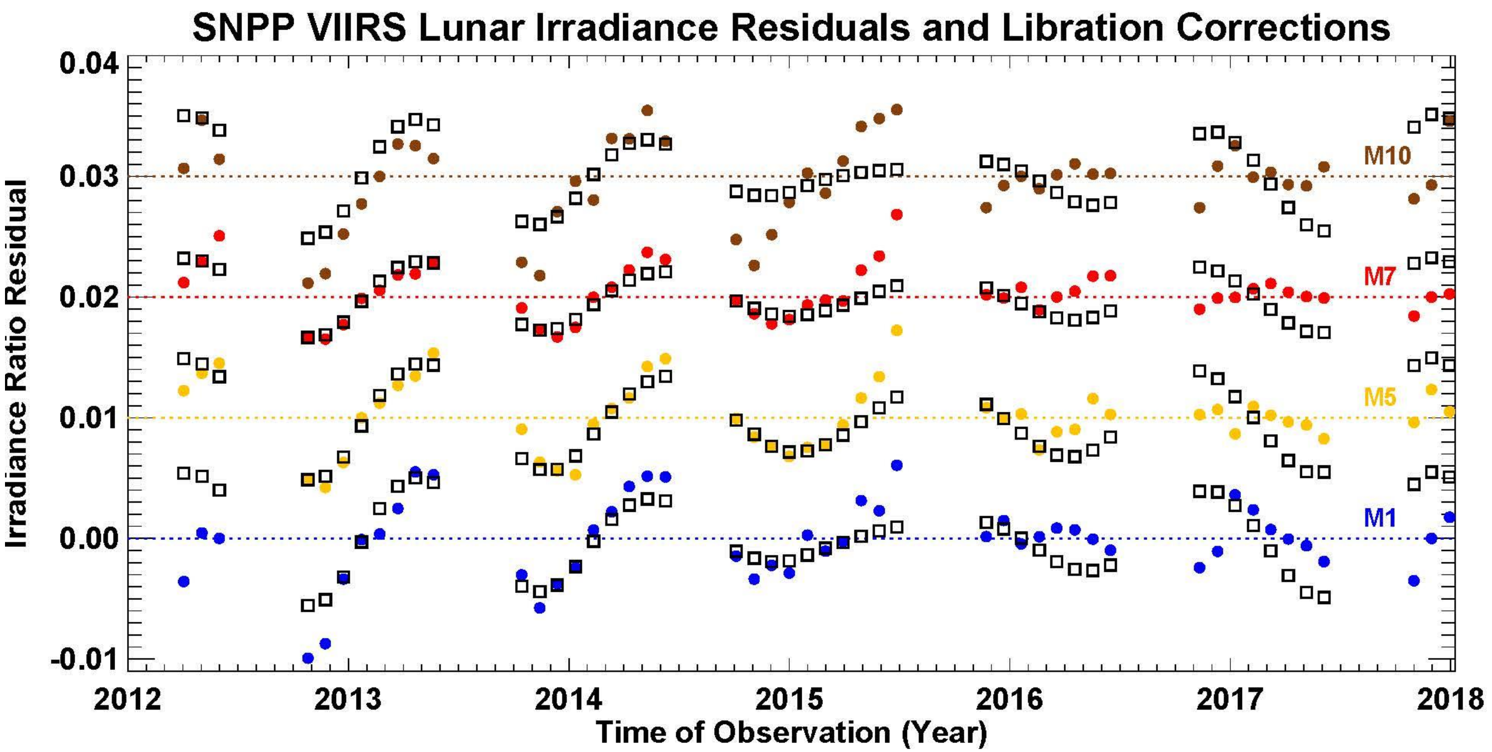
Investigating the Oscillation Patterns

Developed correction to the ROLO model irradiances — a combined linear function of observer libration longitude and latitude:

$$E'_{\text{ref}} = E_{\text{ref}} \; (1 + c_0 \, \phi + c_1 \, \theta)$$

ϕ = sub-observer longitude
θ = sub-observer latitude

- corrections scaled to irradiance residuals ➡
- good correlation for years 2013-2015, then breaks down
- not a valid approach



★ ***A correction to the ROLO model must specify a property of the Moon, and thus be valid for all observations by all instruments***

USGS

Investigating VIIRS Image Integration to Irradiance

VIIRS Moon images are presumed to be neither oversampled nor undersampled.

- if oversampling=1.0 does not strictly hold, then the irradiance measurements should show a dependence on the Moon image orientation in relation to the along-scan direction
  - due to the distribution of radiance across consecutive frames

Image orientations were determined for VIIRS I-band images by selecting high-contrast pixels that define the lunar bright limb.

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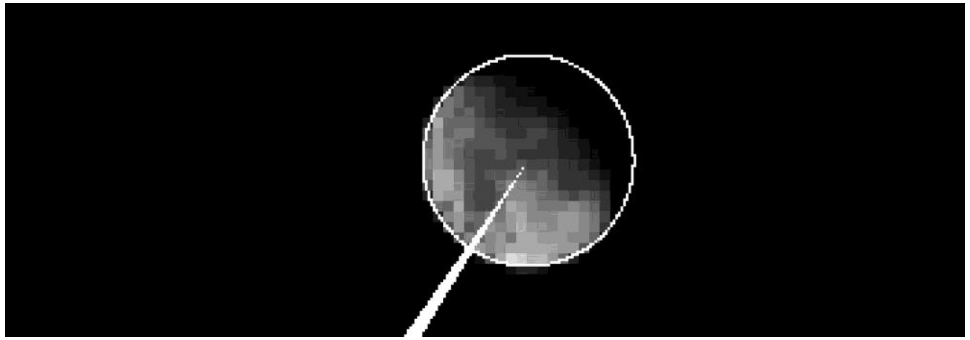
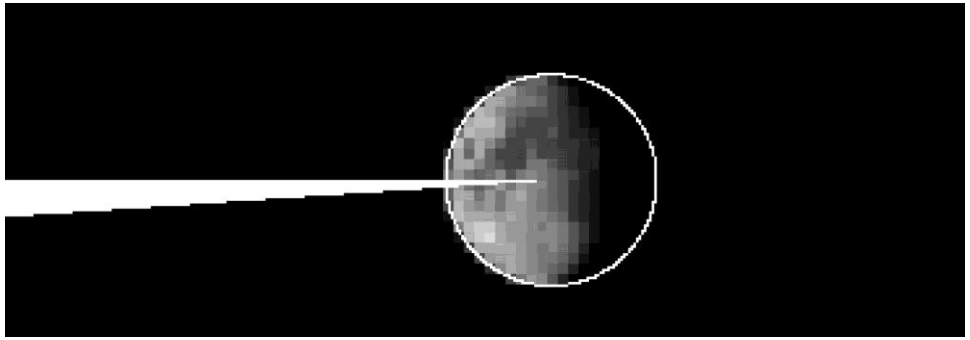
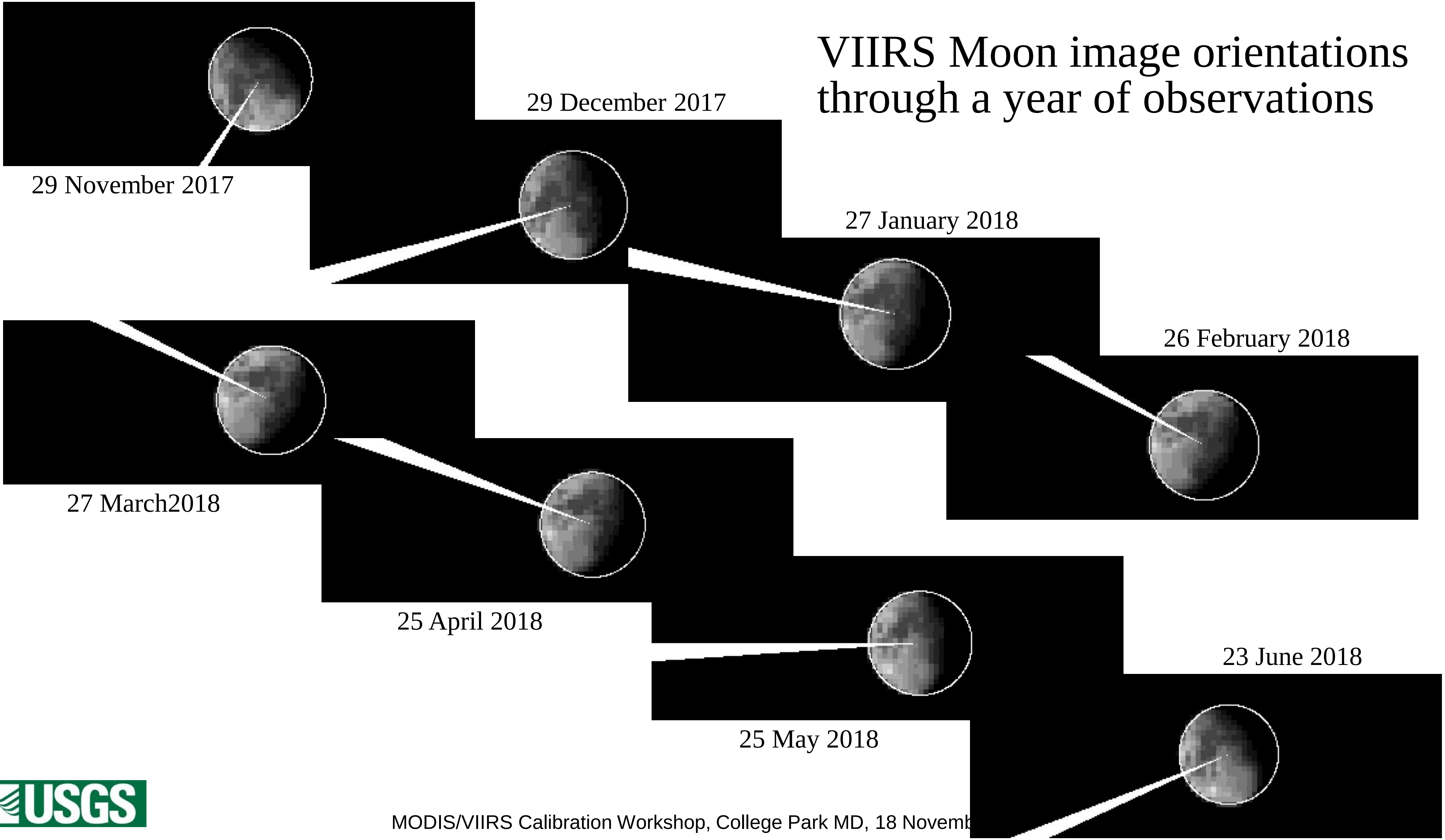


29 November 2017   236.6° ccw from +X



25 May 2018   181.9° ccw from +X

VIIRS Moon image orientations through a year of observations



Study Results and Conclusions

- Examining the complete series of VIIRS Moon observations shows the image orientations have an annual repeat cycle
  - the oscillations seen in the lunar measurement/model residuals have a different periodicity, therefore this effect cannot be attributed to image orientation
  - this negative result does not rule out potential along-scan oversampling errors
  - the cause of the oscillations has not conclusively been determined

- Other aspects of VIIRS lunar image spatial integration to examine:
    - motion of the Moon relative to the line of sight during scans
    - possible effects of pixel aggregation

- The oscillation effect is small, ~1% or less, but coupled across VIIRS bands
  - thus given consideration in the ROLO model redevelopment effort

Thank You!