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

Thomas C. Stone
U. S. Geological Survey, Flagstaff, AZ

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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:

\[
E_{\text{meas}} = \frac{\Omega_p}{\eta} \sum_{i}^{N} L_i
\]

\(\Omega_p\) = pixel IFOV (solid angle)
\(\eta\) = oversampling factor
\(L_i\) = pixel radiance
\(N\) = # 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)
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)

USGS results: 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)
USGS Results for VIIRS Lunar Calibration

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

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

Analysis approach:
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:

\[ E'_{\text{ref}} = E_{\text{ref}} (1 + c_0 \phi + c_1 \theta) \]

\( \phi \) = sub-observer longitude
\( \theta \) = sub-observer latitude

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

\[ \star \text{A correction to the ROLO model must specify a property of the Moon, and thus be valid for all observations by all instruments} \]
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

29 November 2017

29 December 2017

27 January 2018

26 February 2018

27 March 2018

25 April 2018

23 June 2018

25 May 2018

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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!