VIIRS Lunar Observation and Applications

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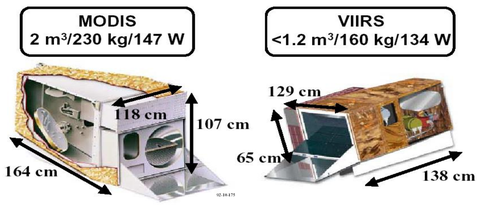
Introduction - VIIRS

- The **V**isible **I**nfrared **I**maging **R**adiometer **S**uite (VIIRS) onboard the Suomi National Polar-orbiting Partnership (S-NPP) spacecraft was launched on October 28, 2011.
- VIIRS consists of 14 Reflective Solar Bands (RSB), 7 Thermal Emissive Bands (TEB) and a Day/Night Band (DNB), covering a spectral range from 0.41 to 12.2 µm.
- The spatial resolutions are 375 m for imagery (I) bands I1-I5 and 750 m for moderate-resolution (M) bands M1-M16.
- VIIRS is calibrated by onboard calibrators – solar diffuser (SD) and SD stability monitor (SDSM) for RSB; blackbody (BB) for TEB.
- The design/operation of VIIRS has strong MODIS heritage:



- The NASA VIIRS Characterization Support Team (VCST) supports VIIRS SDR radiometric / geometric calibration and characterization.

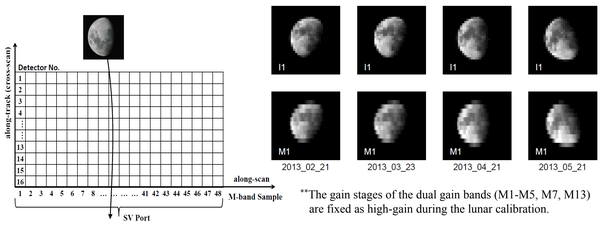
VIIRS Lunar Calibration

- VIIRS lunar observations have been scheduled on a nearly monthly basis since January 2012.
- The lunar phase is within a limited range of [-51.5, -50.5] degrees.

M/D/Y	H:M:S	Roll Angle	Phase Angle	SEaVr Angle	Sector
01/04/2012	08:48:53	-9.490	-55.41	35.9	SV
02/03/2012	04:21:32	-5.445	-56.19	41.3	SV
02/03/2012	06:03:34	-5.279	-55.38	39.6	SV
04/02/2012	23:05:11	-3.989	-51.24	23.0	EV
05/02/2012	10:20:06	-3.228	-50.92	340.2	EV
05/31/2012	14:47:14	-0.081*	-52.97	53.5	EV
10/25/2012	06:58:15	-4.048	-51.02	309.0	EV
11/23/2012	21:18:20	-9.429	-50.74	326.6	EV
12/23/2012	15:00:50	-7.767	-50.90	24.0	EV
01/22/2013	12:13:35	-3.383	-50.81	28.1	EV
02/21/2013	09:31:25	-1.712	-50.71	28.8	EV
03/23/2013	03:29:00	-3.320	-51.15	25.2	EV
04/21/2013	19:47:54	-3.882	-50.82	18.6	EV
05/21/2013	08:43:15	-0.809*	-50.67	335.7	EV
10/14/2013	21:39:19	-1.305	-50.95	305.6	EV
11/13/2013	06:57:41	-7.981	-50.66	314.9	EV
12/12/2013	19:35:46	-9.438	-50.39	334.3	EV
01/11/2014	09:59:45	-6.727	-51.30	25.9	EV
02/10/2014	05:34:12	-3.714	-51.03	29.0	EV
03/12/2014	01:11:43	-3.944	-51.05	28.4	EV
04/10/2014	20:53:17	-4.977	-50.60	22.2	EV

*No roll maneuver performed for small angles.

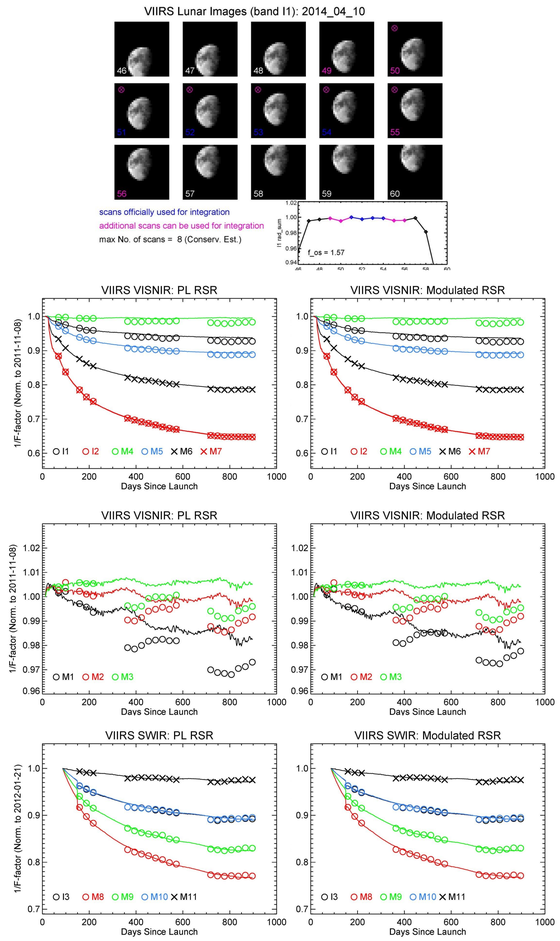
- Multiple scans of lunar images are captured during each calibration.



**The gain stages of the dual gain bands (M1-M5, M7, M13) are fixed as high-gain during the lunar calibration.

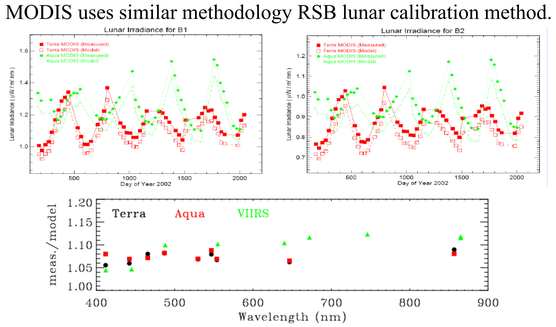
RSB Radiometric Calibration

- The VIIRS lunar spectral irradiance $I_{moon,PL}$ is calculated by integrating lunar images using the pre-launch gain coefficient.
- The actual lunar irradiance I_{ROLO} is predicted by ROLO model.
- The lunar calibration F-factor is the ratio of I_{ROLO} and $I_{moon,PL}$.
- The lunar F-factor and SD F-factor trending should agree.



Inter-comparison with MODIS

- MODIS uses similar methodology RSB lunar calibration method.



RSB Spatial Characterization

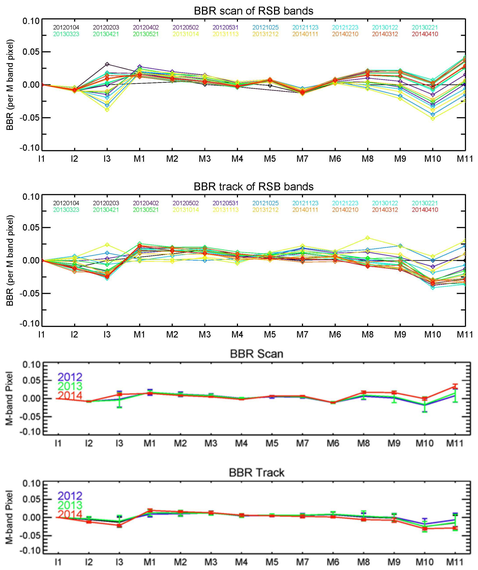
Band-to-Band Registration (BBR)

- The BBR is quantized by the offset Δ between the matching detectors of the two bands.
- The lunar *dn* is background subtracted and corrected with the detector gain difference.
- The centroid of the 2-D lunar image is

$$f_{B,D} = \frac{\sum_f \left(\sum_s dn^*_{B,D} \right) \cdot f}{\sum_f \sum_s dn^*_{B,D}} \qquad s_{B,D} = \frac{\sum_s \left(\sum_f dn^*_{B,D} \right) \cdot s}{\sum_s \sum_f dn^*_{B,D}}$$

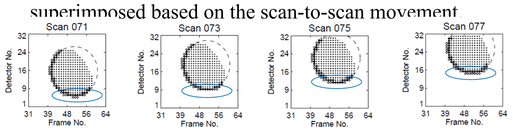
- The BBR offset is calculated by

$$\Delta_{scan} = \overline{f_{B1,D}} - \overline{f_{B2,D}} \qquad \Delta_{track} = \frac{\overline{s_{B1,D}} - \overline{s_{B2,D}}}{\beta}$$

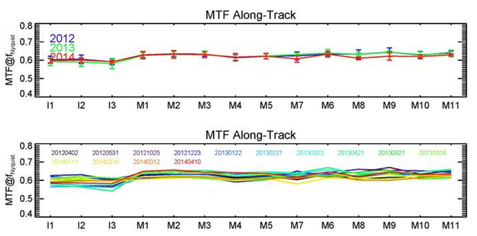


Modulation Transfer Function (MTF)

- MTF is the spatial frequency response of the instrument.
- The edge of the Moon can be used to derive the VIIRS MTF in both along-scan and along-track directions.
- Images of multiple scans need to be aligned and superimposed based on the scan-to-scan movement.

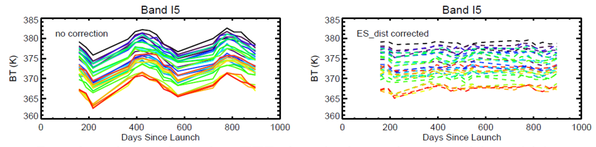


- Along-track MTF is constantly monitored.

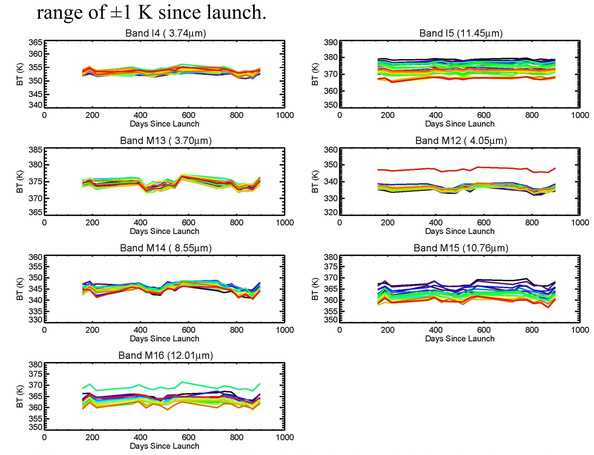


TEB Calibration Stability Trending

- TEB is calibrated by an on-board blackbody on a scan basis.
- The Brightness Temperature (BT) of the lunar surface can be retrieved with the calibrated gain coefficient.
- The thermal properties of lunar surface is stable, so the surface BT trending can be used to assess the calibration stability.
- Seasonal oscillation of the BT trending is reduced, mostly by considering the Earth/Moon-Sun distance variation.



- Results show that the TEB bands have been stable within a range of ±1 K since launch.



- The accuracy of the trending is limited mainly by the facts of
  1) surface temperature varies considerably across the Moon;
  2) the lunar images of all TEB detectors are partially saturated;
  3) the trended pixels among events are not perfectly registered.

Summary

- Calibration/characterization of some VIIRS on-orbit radiometric and spatial parameters can be performed through the scheduled lunar observation, including
  1) determining the RSB radiometric calibration coefficient;
  2) calibration inter-comparison with MODIS and other sensors;
  3) characterizing the spatial parameters BBR and MTF;
  4) tracking the stability of the TEB radiometric calibration.
- These parameters will be continuously monitored throughout VIIRS lifetime.
- Most of these parameters can also be derived from un-scheduled lunar observations.
- The methodologies/algorithms are mainly developed for MODIS lunar calibration and have been successfully extended to VIIRS.
- More lunar calibration applications are under study.

2014 NOAA STAR JPSS Annual Science Team Meeting, May 12-16, College Park, MD, U.S.A.