



Status of VIIRS Reflective Solar Bands On-orbit Calibration and Performance

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Outline

- **Background**
 - Instrument and On-board Calibrators
- **Reflective Solar Bands On-orbit Calibration**
 - Solar Calibration
 - Lunar Calibration
- **On-orbit Performance**
- **Way Forward**

Background

- **Visible/Infrared Imager Radiometer Suite (VIIRS)**
 - Key instruments for SNPP (L: 2011) and JPSS (J1 L: 2017) missions
 - 14 reflective solar bands (RSB), 7 thermal emissive bands (TEB), and 1 day night band (DNB)
 - Spectral wavelengths: 0.4-12.4 μm
 - Spatial resolution: 375 m for DNB and I bands and 750 m for M bands
 - Sensor Data Records (SDR): equivalent of MODIS L1B
 - 22 Environmental Data Records (EDR): equivalent of MODIS science data products
 - Strong MODIS design heritage (lessons and improvements)
 - Spectral bands
 - On-board calibrators (OBC)

VIIRS Spectral Bands and Data Products

VIIRS 22 Bands (16 M-Band, 5 I-Band and 1 DNB)

VIIRS Band	Spectral Range (um)	Nadir HSR (m)	MODIS Band(s)	Range	HSR
DNB	0.500 - 0.900				
● M1	0.402 - 0.422	750	8	0.405 - 0.420	1000
● M2	0.436 - 0.454	750	9	0.438 - 0.448	1000
● M3	0.478 - 0.498	750	3 10	0.459 - 0.479 0.483 - 0.493	500 1000
● M4	0.545 - 0.565	750	4 or 12	0.545 - 0.565 0.546 - 0.556	500 1000
I1	0.600 - 0.680	375	1	0.620 - 0.670	250
● M5	0.662 - 0.682	750	13 or 14	0.662 - 0.672 0.673 - 0.683	1000 1000
M6	0.739 - 0.754	750	15	0.743 - 0.753	1000
I2	0.846 - 0.885	375	2	0.841 - 0.876	250
● M7	0.846 - 0.885	750	16 or 2	0.862 - 0.877 0.841 - 0.876	1000 250
M8	1.230 - 1.250	750	5	SAME	500
M9	1.371 - 1.386	750	26	1.360 - 1.390	1000
I3	1.580 - 1.640	375	6	1.628 - 1.652	500
M10	1.580 - 1.640	750	6	1.628 - 1.652	500
M11	2.225 - 2.275	750	7	2.105 - 2.155	500
I4	3.550 - 3.930	375	20	3.660 - 3.840	1000
M12	3.660 - 3.840	750	20	SAME	1000
● M13	3.973 - 4.128	750	21 or 22	3.929 - 3.989 3.929 - 3.989	1000 1000
M14	8.400 - 8.700	750	29	SAME	1000
M15	10.263 - 11.263	750	31	10.780 - 11.280	1000
I5	10.500 - 12.400	375	31 or 32	10.780 - 11.280 11.770 - 12.270	1000 1000
M16	11.538 - 12.488	750	32	11.770 - 12.270	1000

VIIRS 20 EDRs (Land, Ocean, Cloud, Snow)

Name of Product	Group	Type
Imagery *	Imagery	EDR
Precipitable Water	Atmosphere	EDR
Suspended Matter	Atmosphere	EDR
Aerosol Optical Thickness	Aerosol	EDR
Aerosol Particle Size	Aerosol	EDR
Cloud Base Height	Cloud	EDR
Cloud Cover/Layers	Cloud	EDR
Cloud Effective Particle Size	Cloud	EDR
Cloud Optical Thickness/Transmittance	Cloud	EDR
Cloud Top Height	Cloud	EDR
Cloud Top Pressure	Cloud	EDR
Cloud Top Temperature	Cloud	EDR
Active Fires	Land	Application
Albedo (Surface)	Land	EDR
Land Surface Temperature	Land	EDR
Soil Moisture	Land	EDR
Surface Type	Land	EDR
Vegetation Index	Land	EDR
Sea Surface Temperature *	Ocean	EDR
Ocean Color and Chlorophyll	Ocean	EDR
Net Heat Flux	Ocean	EDR
Sea Ice Characterization	Snow and Ice	EDR
Ice Surface Temperature	Snow and Ice	EDR
Snow Cover and Depth	Snow and Ice	EDR

● Dual gain band

Similar MODIS bands

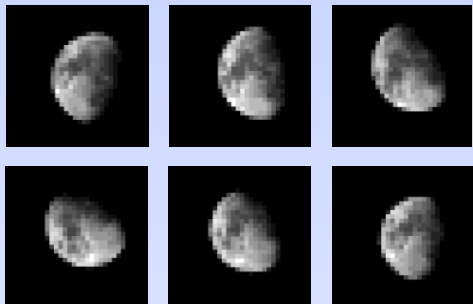
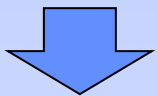
* Product is a Key Performance Parameter (KPP)

VIIRS On-board Calibrators (MODIS Heritage)

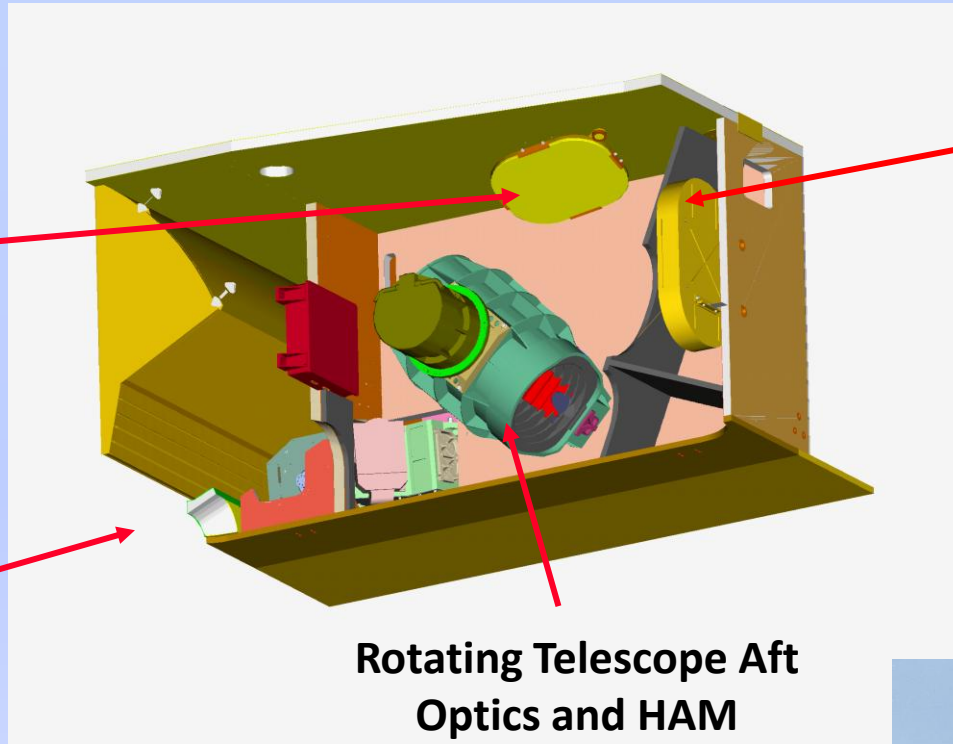


Solar Diffuser with Fixed Screen

Extended SV Port



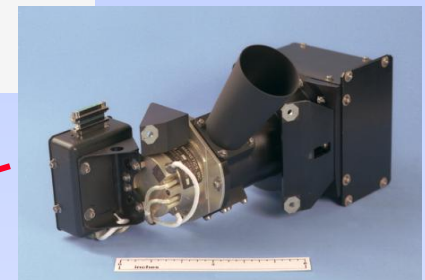
S-NPP VIIRS I1 Lunar Images



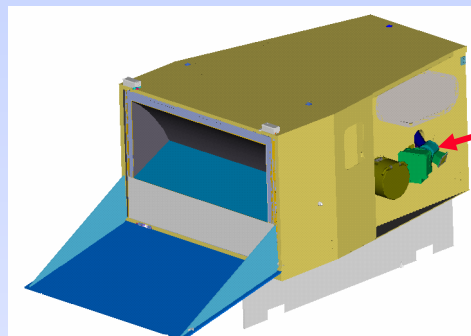
Rotating Telescope Aft Optics and HAM



Blackbody



Solar Diffuser Stability Monitor



MODIS: scan mirror, SRCA

Reflective Solar Bands On-orbit Calibration

- **Solar Calibration**

- SD calibration performed each orbit (no SD door)
- SDSM operated on a daily basis
 - More frequently at mission beginning
- **Yaw maneuvers**
 - **Completed at mission beginning**

- **Lunar Calibration**

- Regularly scheduled at nearly the same phase angle
 - SC roll maneuvers
- Observed through SV port
 - Sector rotation (data in EV sector – more frames than SV sector)

VIIRS Lunar Observations (Scheduled)

Lunar Cal #	Date	DOY	Orbit	Phase Angle (degree)	Note
1	1/4/2012	2012-004	964	55.41	Lunar data in SV sector
2	2/3/2012	2012-034	1387 1388	56.19 55.38	Lunar data in SV sector; two orbits
3	4/2/2012	2012-093	2235	51.24	Lunar data in EV sector
4	5/2/2012	2012-123	2654	50.92	Lunar data in EV sector
5	5/31/2012	2012-152	3068	52.97	Lunar data in EV sector; no roll
6	10/25/2012	2012-299	5149	51.02	Lunar data in EV sector
7	11/23/2012	2012-328	5569	50.74	Lunar data in EV sector
8	12/23/2012	2012-358	5990	50.9	Lunar data in EV sector
9	1/22/2013	2013-022	6414	50.81	Lunar data in EV sector
10	2/21/2013	2013-052	6838	50.71	Lunar data in EV sector

Missed 3/3/2012 lunar calibration due to an error in predicated maneuver time

RSB On-orbit Calibration (SD/SDSM)

RSB Calibration: F and H Factors

$$L_{EV} = F \cdot \mu_0 + c_1 \cdot dn_{EV} + c_2 \cdot dn_{EV}^2$$

$$L_{SD_Meas} = F \cdot \mu_0 + c_1 \cdot dn_{SD} + c_2 \cdot dn_{SD}^2$$

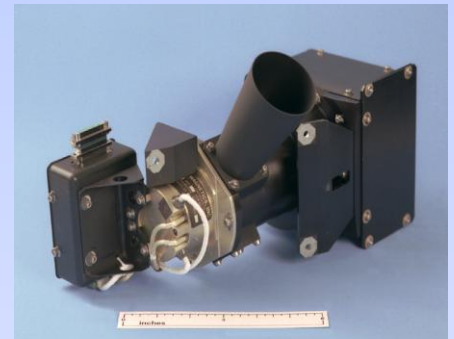
$$L_{SD_Comp} \propto E_{SUN} \cdot BRDF_{SD}(t) \cdot \tau_{SDS}$$

$$F = \frac{L_{SD_Comp}}{L_{SD_Meas}}$$

$$BRDF_{SD}(t) = H_{SD}(t) \cdot BRDF_{SD}(t_0)$$

$$H_{SD}(\mu) = H(\mu) \cdot H(\mu_0)$$

$$H(\mu) \propto \frac{dc_{SD} \cdot \tau_{SDSMS}}{dc_{SUN} \cdot \tau_{SDS}}$$



The dn and dc are VIIRS and SDSM detector “corrected” responses

RSB Calibration (Moon)

- Integrated lunar irradiance (or radiance) from sensor observations

$$J(B, M, G) = \sum_{s,d} [c_0(B, M, G) + c_1(B, M, G)dn(s, d) + c_2(B, M, G)dn(s, d)^2]$$

- B : Band; M : HAM side; G : Gain stage; d : Detector; s : Sub-frame;
- dn : Background subtracted response
- c_0 , c_1 , and c_2 : calibration coefficients

- Relative lunar F-factor



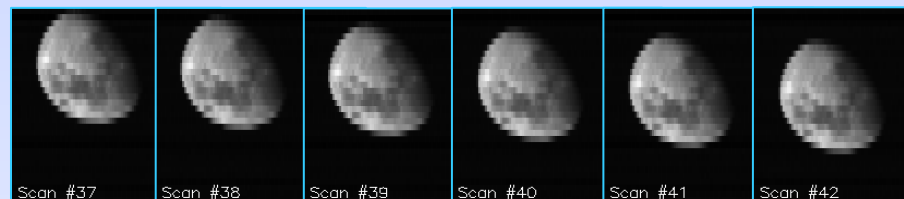
$$F(B, M, G) = J_{Model}(B) / J(B, M, G)$$

- $J_{Model}(B)$ from USGS ROLO model

SD F-factor

$$F = \frac{L_{SD_Comp}}{L_{SD_Meas}}$$

Examples of band I1 lunar images (Jan 4, 2012)



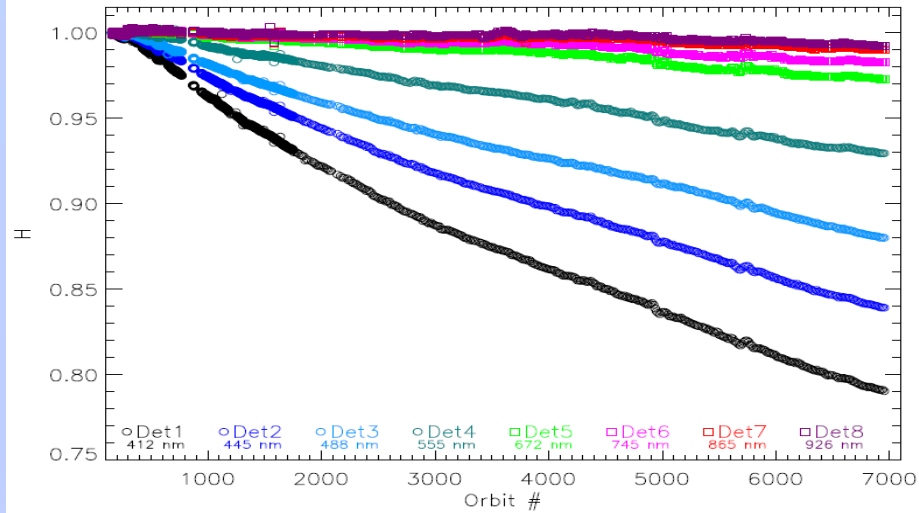
On-orbit Performance

- **SD Degradation**
 - Similar to MODIS with much faster degradation rate
- **Changes in Spectral Band Response**
 - Larger at NIR/SWIR
 - Telescope mirror contamination
- **Changes in Relative Spectral Response (RSR)**
 - Modulated RSR

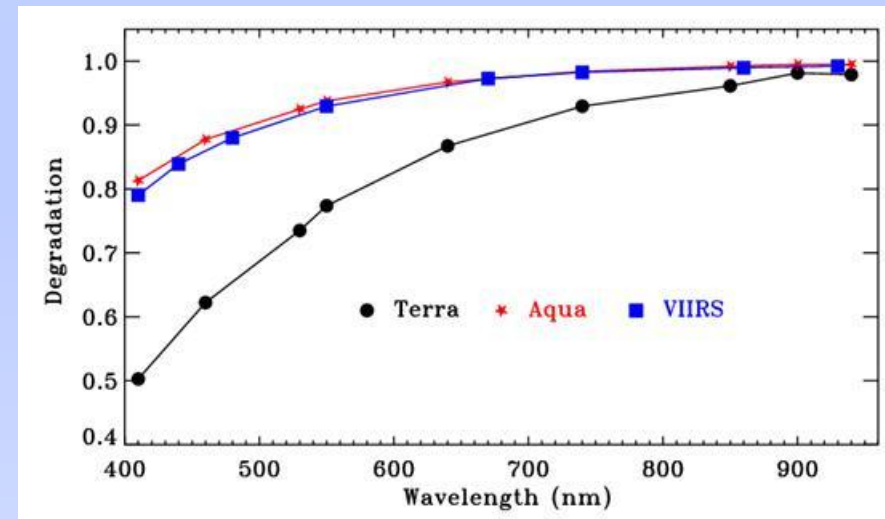
SD Degradation

S-NPP VIIRS

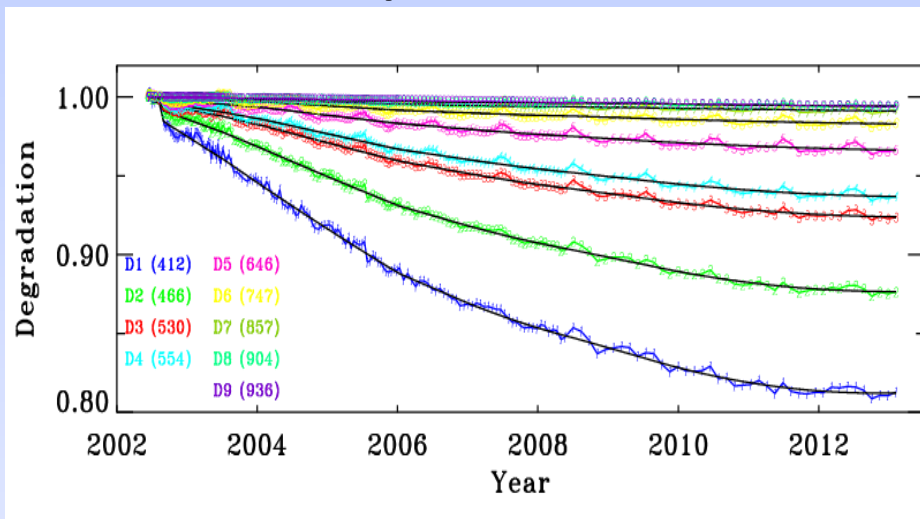
VIIRS SDSM H-factors



SD On-orbit Degradation Tracked by the On-board SDSM



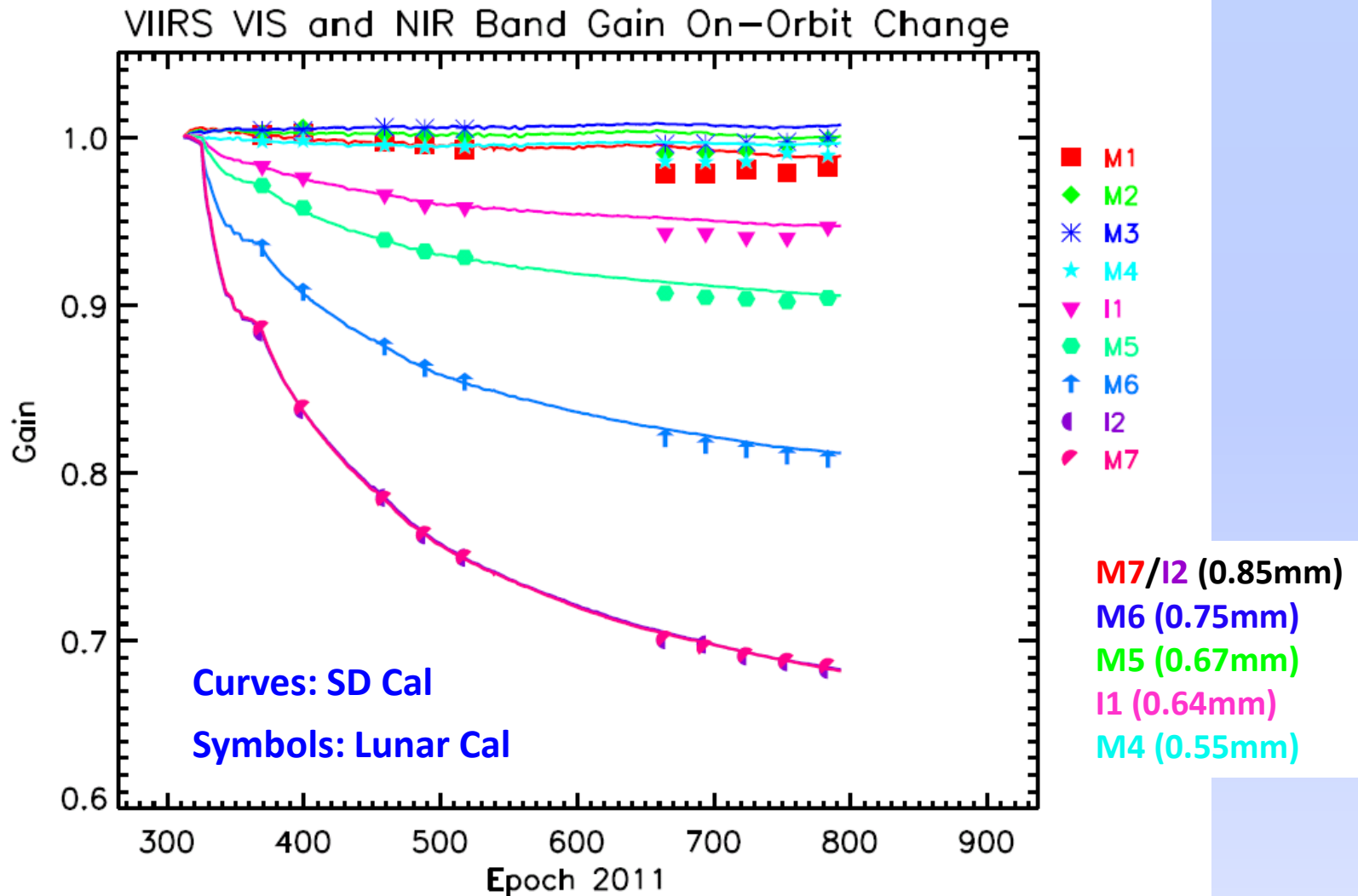
Aqua MODIS



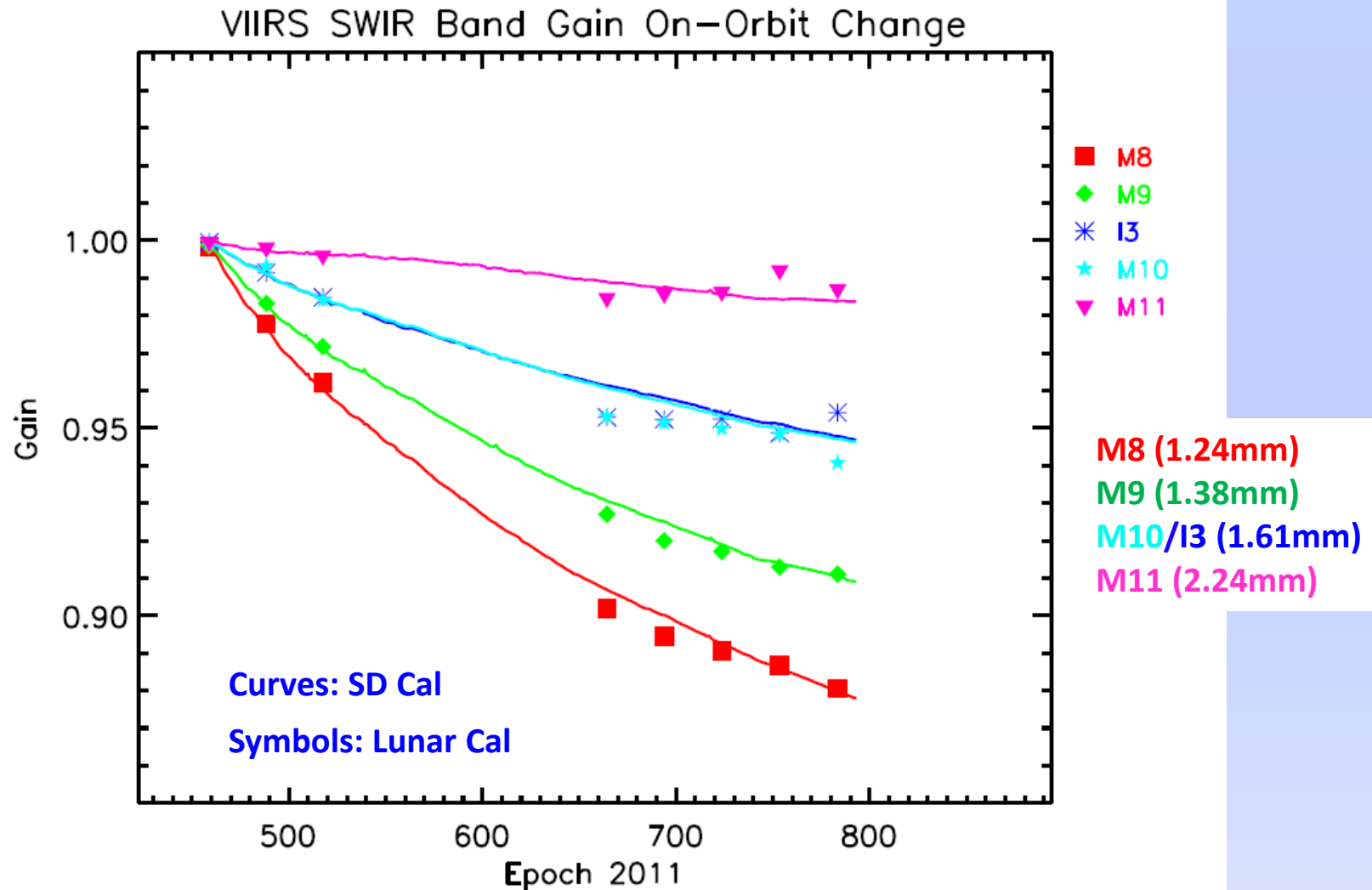
VIIRS has no SD door:

Large degradation in SD BRF

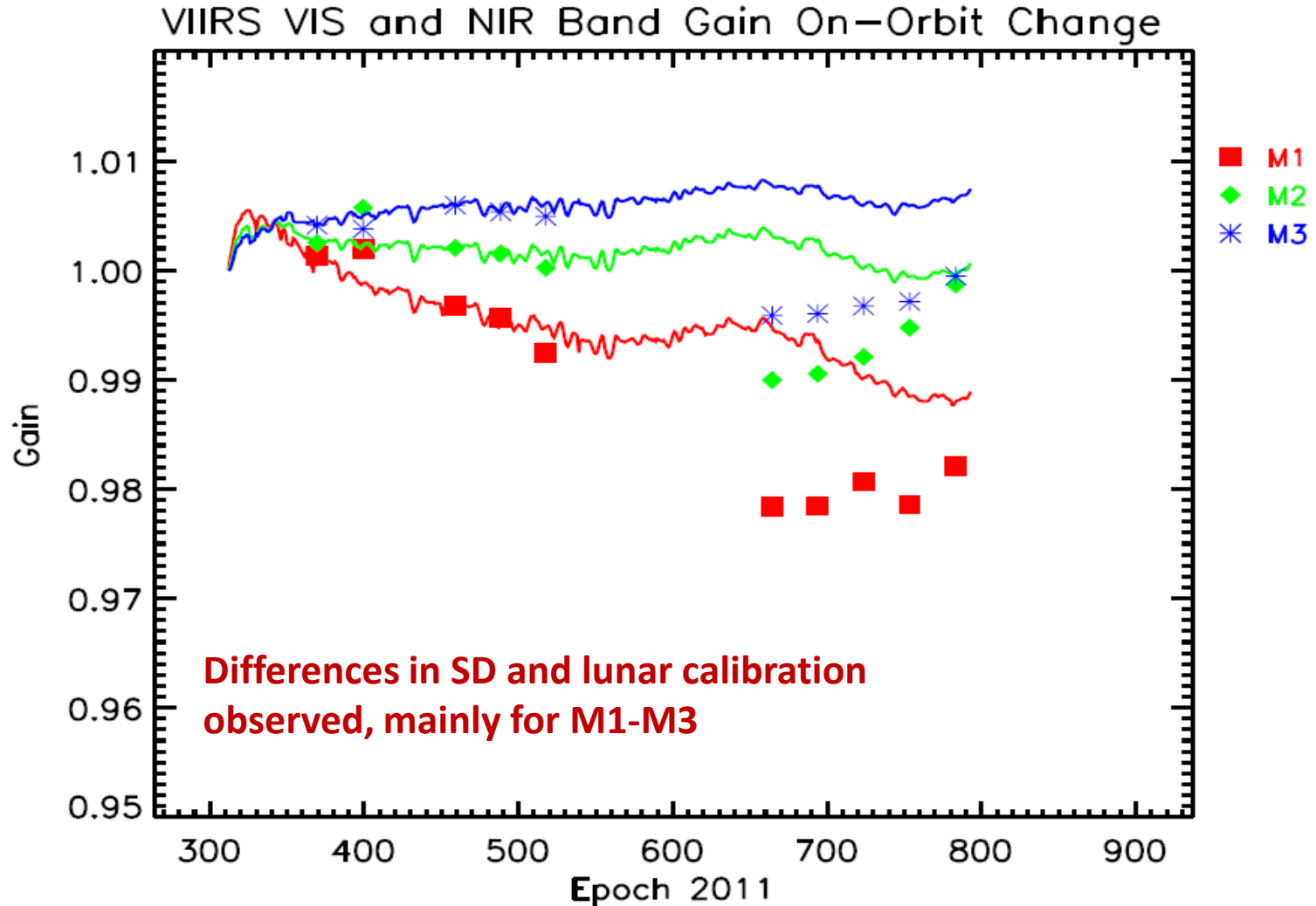
Changes in Spectral Band Response



Changes in Spectral Band Response

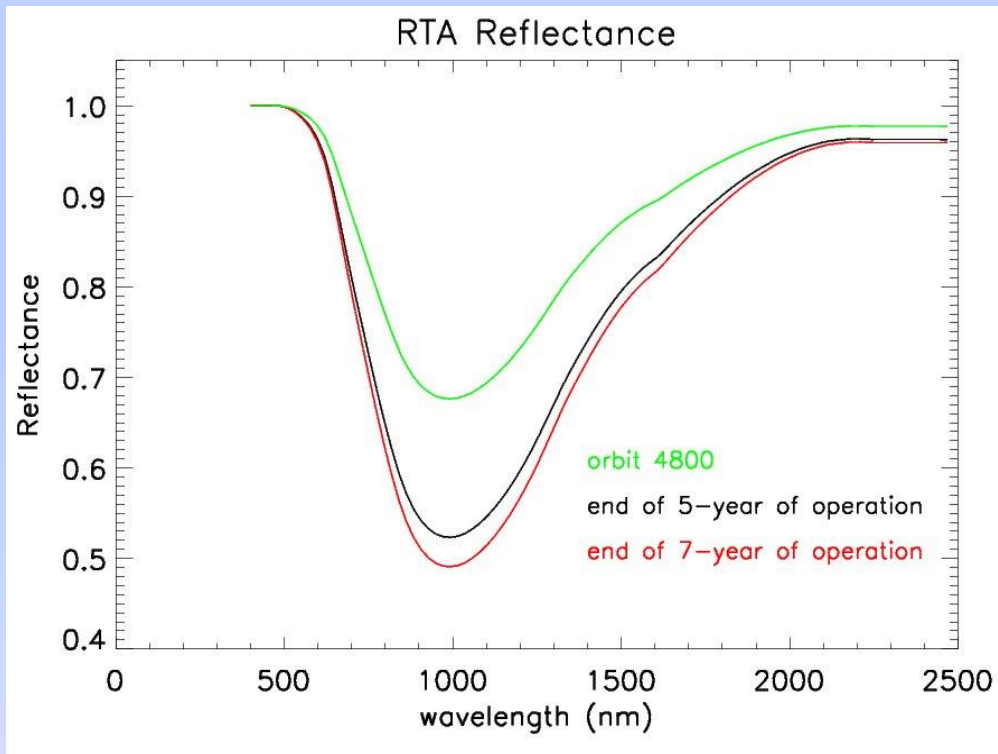


Changes in Spectral Band Response



Changes in Relative Spectral Response

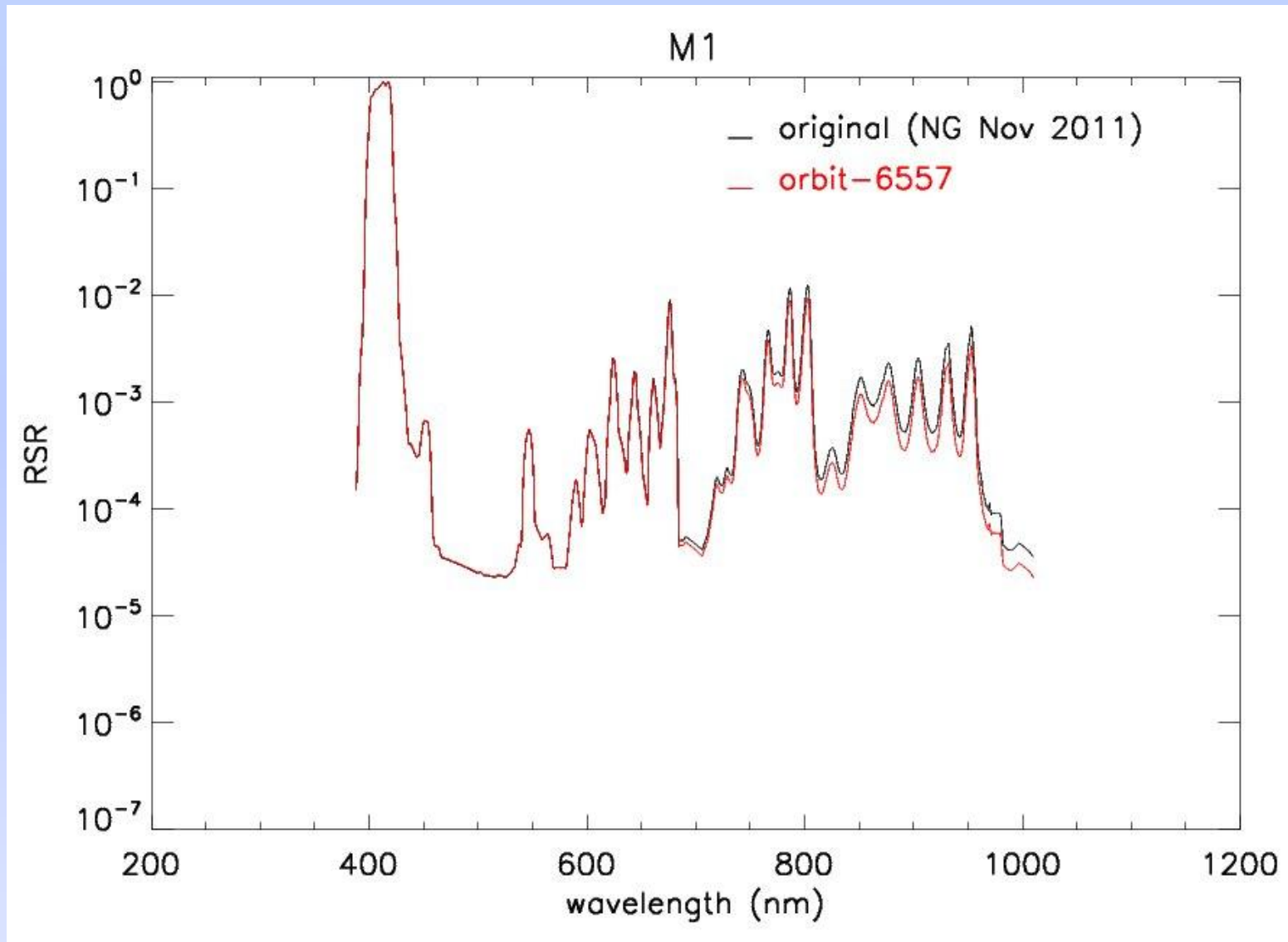
Mirror Degradation Impact On Calibration



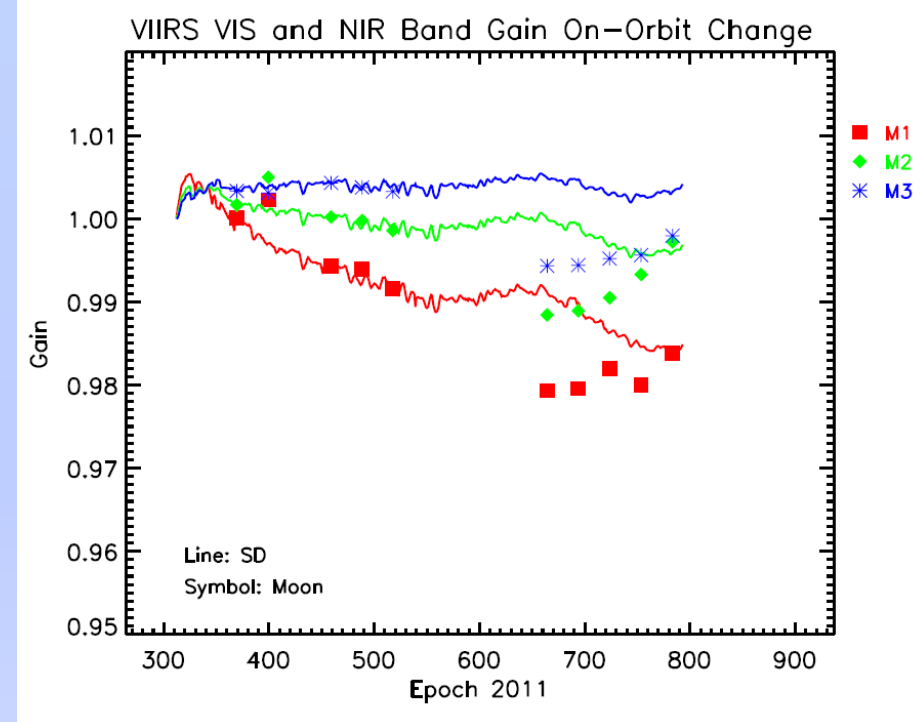
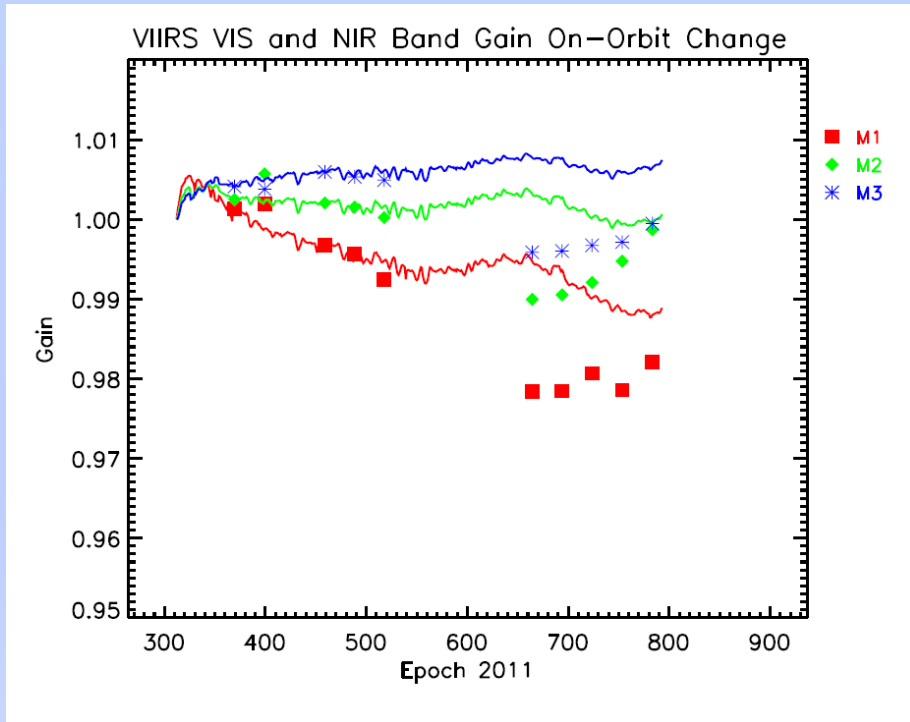
Modulated Sensor RSR

Ongoing Effort for Future Improvement: Modulate RSR in SDR Calibration

Changes in Relative Spectral Response



Impact due to Modulated RSR - Preliminary

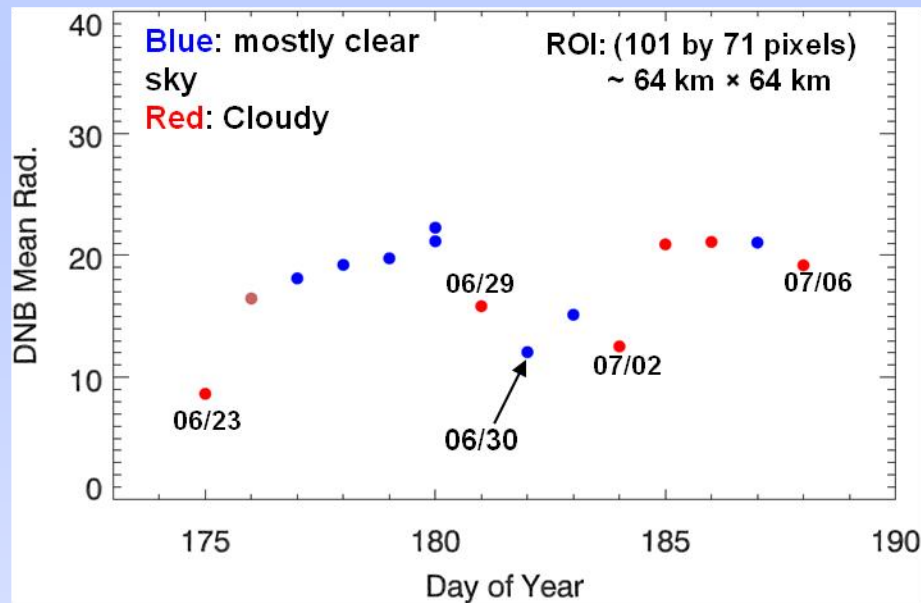


Normalized SD calibration gains (1/F-factors) – **current operational version**
Normalized lunar calibration gains (normalized to 4/2/2012 lunar observation)

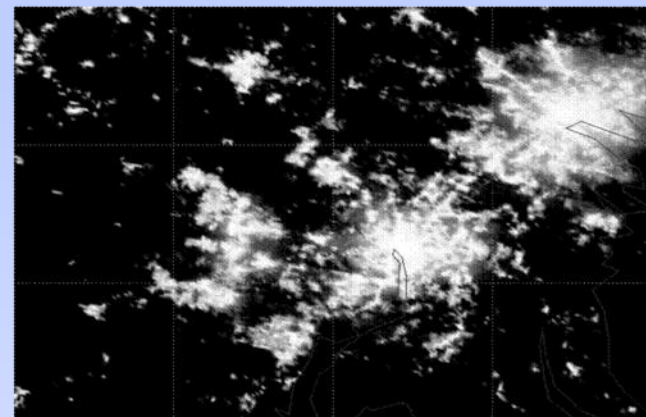
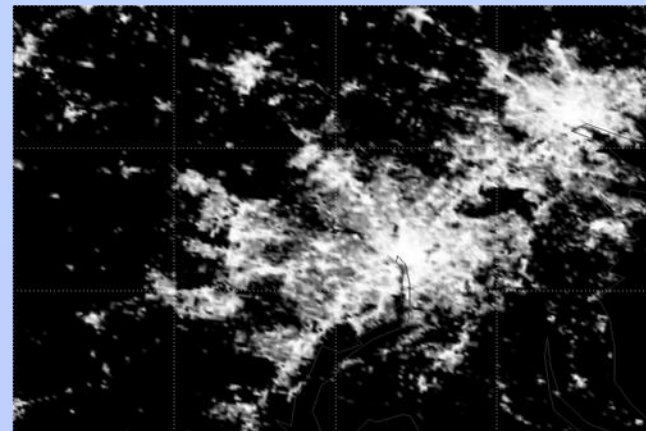
Normalized SD calibration gains (1/F-factors) – **modulated RSR correction**
Normalized lunar calibration gains (normalized to 4/2/2012 lunar observation) – **modulated RSR correction**

DNB: Power Outage Monitoring

- The Day/Night Band has been used to detect a major power outage in the Washington, DC on the night of the Direcho storm on June 29, 2012.
- An analysis of the data after the storm showed that most areas had power restored within 3 days.



VIIRS DNB radiance time series before and after the power outage (6/29) shows that most of the power was restored in three days.



VIIRS DNB of the Washington/Baltimore area on June 26th (top) and June 30th. The suburbs west of DC and Baltimore, in particular show dark areas.

From GSICS presentation (Can and Xiong)

Way Forward

Overall Performance Meets Sensor Design Requirements

- **Comparison of SDR operational F-factors with VCST F-factors (no corrections)**
 - Nearly completed (current agreement to within 0.5%)
- **Comparison of SDR new operational F-factors with VCST F-factors (both applied with modulated RSR and H-factors)**
 - Modulated solar spectra (due to SD spectrally dependent degradation) coupled with detector OOB responses
- **Characterization of all identified factors that could contribute to the current SD and lunar cal difference**
 - Use of modulated RSR in ROLO model (a series modulated RSR corresponding to the time of lunar observations sent to USGS)
 - Effect due to SD attenuation screen transmission and BRF (uncertainties)
- **Calibration inter-comparison of S-NPP VIIRS and Aqua MODIS**
 - Preliminary progress made
 - Improvements needed with re-processed VIIRS SDR and use of Aqua MODIS C6 L1B

Acknowledgements

- **VIIRS Characterization Support Team (VCST)**
- **MODIS Characterization Support Team (MCST)**
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