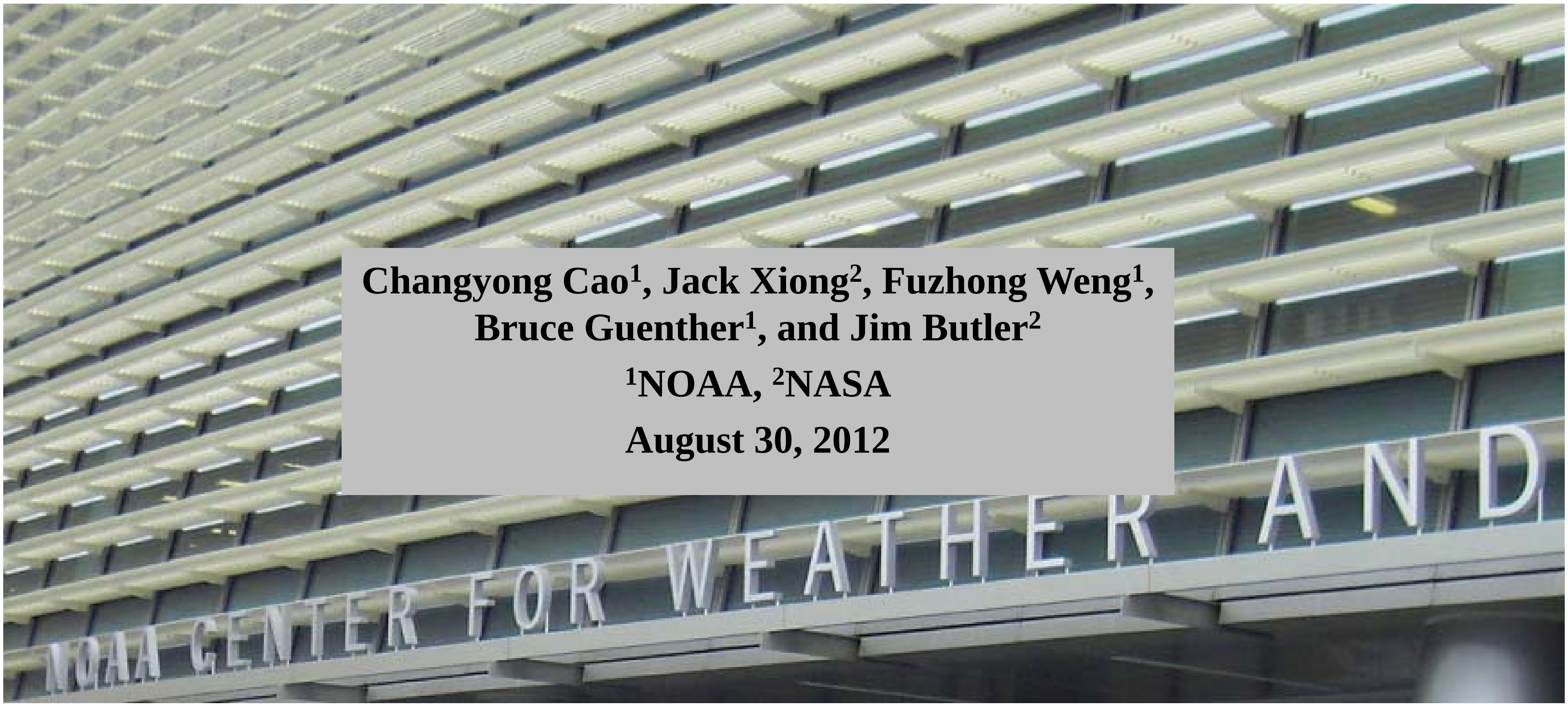
Suomi NPP VIIRS SDR postlaunch cal/val
- Overview of progress and challenges

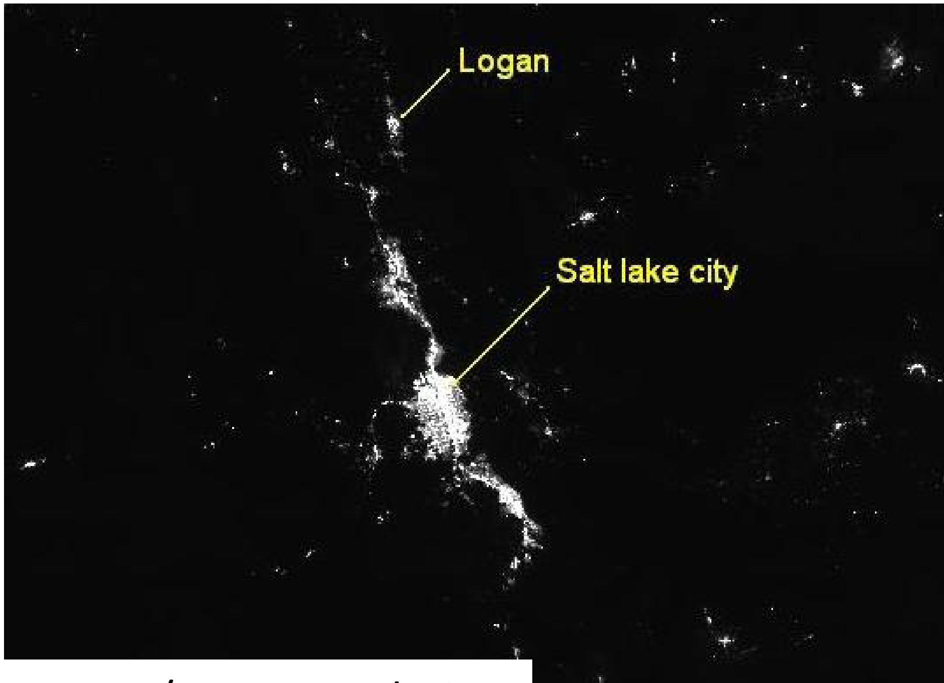


Changyong Cao[1], Jack Xiong[2], Fuzhong Weng[1], Bruce Guenther[1], and Jim Butler[2]

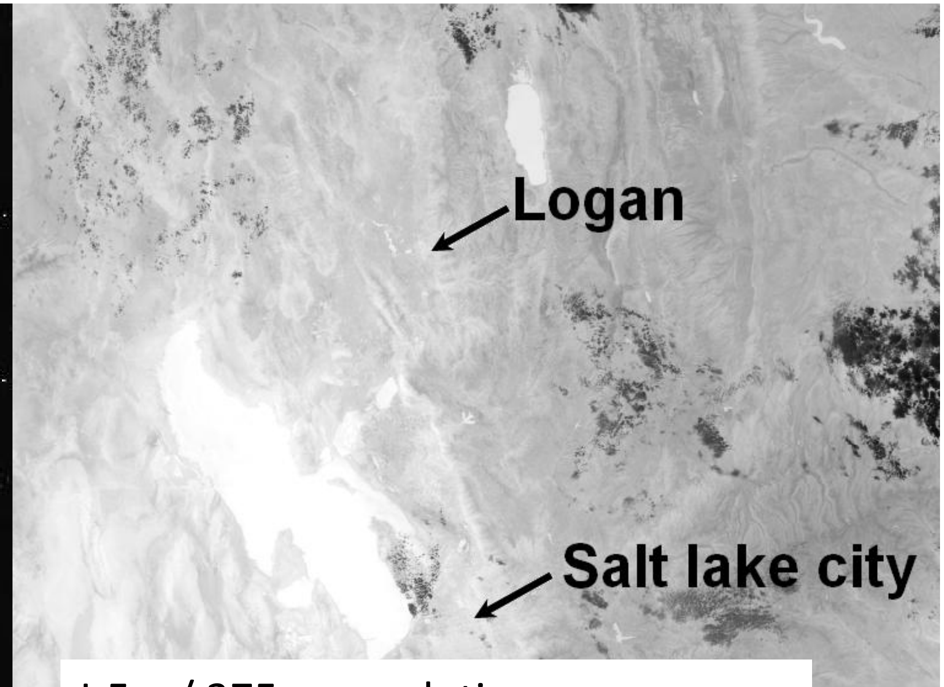
[1]NOAA, [2]NASA

August 30, 2012

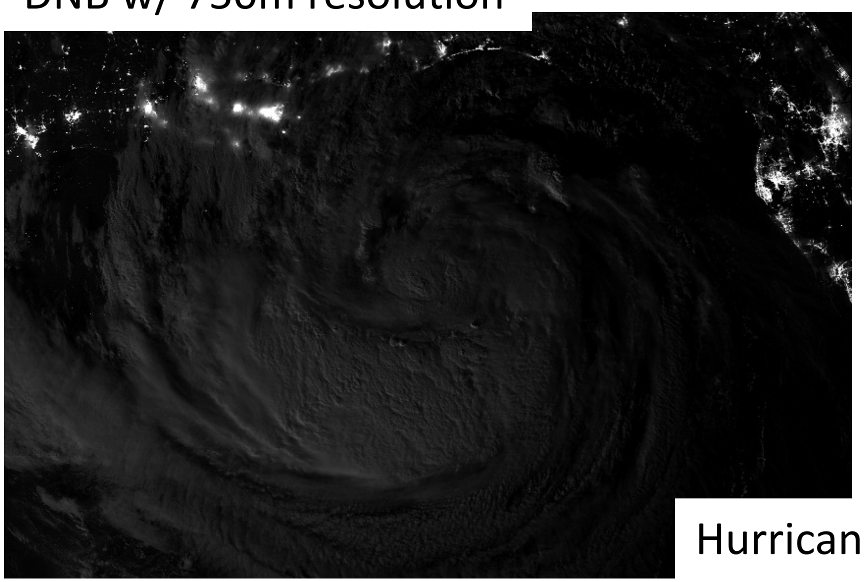
Sample VIIRS images from yesterday

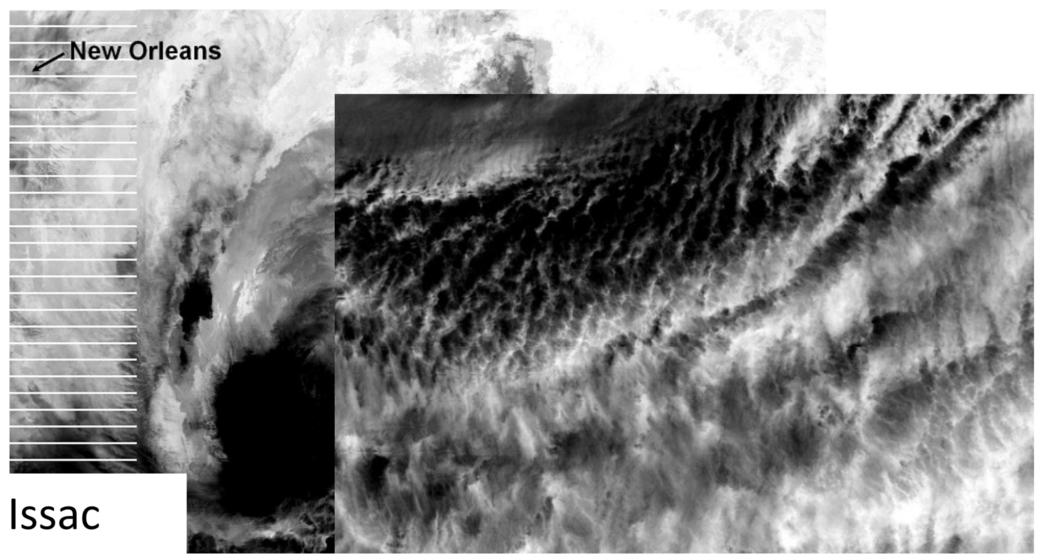


DNB w/ 750m resolution



I-5 w/ 375 m resolution





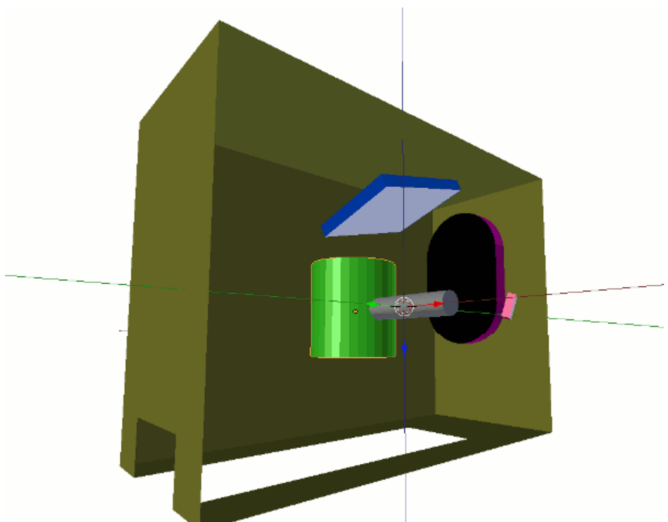
Hurricane Issac

The VIIRS SDR Team Members

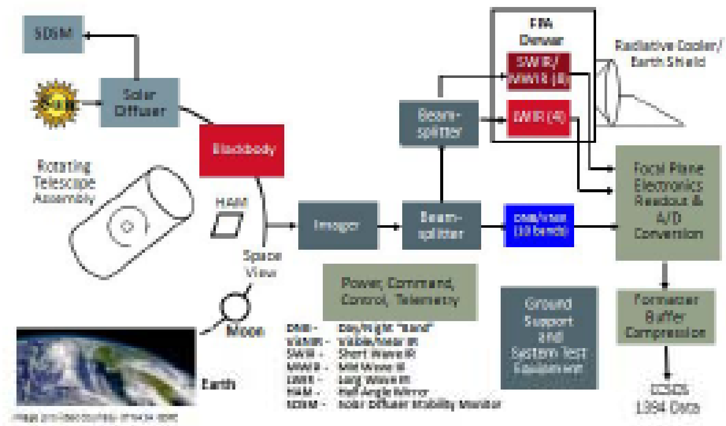
- NOAA/NESDIS/STAR
- The Aerospace Corp.
- NASA/VCST
- University of Wisconsin
- MIT Lincoln Laboratory
- Raytheon
- NGAS

•DPA/ADP
•NCEP Users
•NSOF
•EDR/SDR interaction

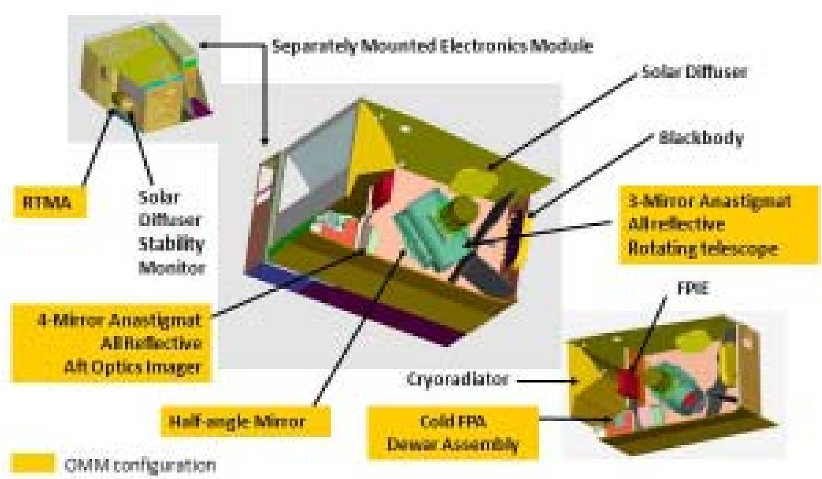
The VIIRS Instrument



Courtesy of D. Pogo



(a) Block Diagram

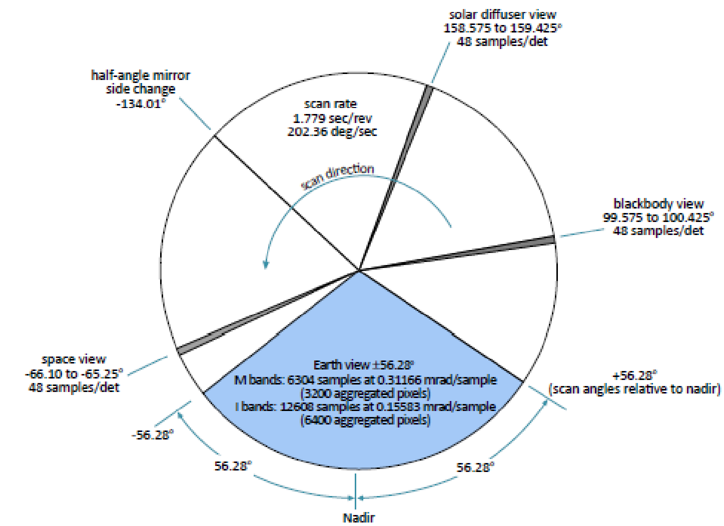


(b) Components

Source: VIIRS SDR User’s Guide https://cs.star.nesdis.noaa.gov/NCC/VIIRS

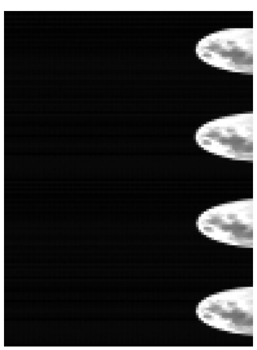
VIIRS Onboard Calibration Comparisons

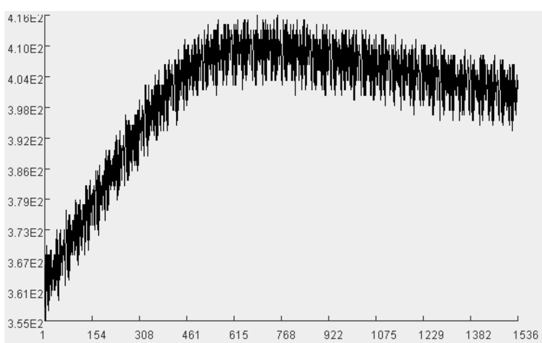
VIIRS	MODIS	AVHRR
Rotating telescope w/ half angle mirror	Paddle Mirror (large RVS effect)	45 deg mirror (image pixel rotation at high scan angles)
V-Grooved Blackbody	V-Grooved Blackbody	Honeycomb Blackbody
Space view	Space view	Space view
Solar diffuser + screen (VISNIR+DNB)	Solar diffuser +screen+door (VISNIR)	Vicarious (desert)
Solar diffuser stability monitor	Solar diffuser stability monitor	-
Lunar cal	Lunar cal	-
None	SRCA	None



Source: VIIRS SDR User's Guide (v1.01)

https://cs.star.nesdis.noaa.gov/NCC/VIIRS





VIIRS Sensor Data Records (SDRs)

- SDRs = L1b = calibrated, geolocated radiance, reflectance and brightness temperature

- 22 types of SDRs
  - 16 moderate resolution (MOD),
    - 11 Reflective Solar Bands (RSB)
    - 5 Thermal Emissive Bands (TEB)
  - 5 imaging resolution (IMG),
    - 3 RSB; 2 TEB
  - 1 Day Night Band (DNB) imaging, broadband

- 6 non-gridded geolocation products
  - DNB, IMG, IMG terrain corrected, MOD, MOD terrain corrected, MOD unaggregated

- 2 gridded geolocation products
  - MOD, IMG

				Specification							Prelaunch	On Orbit	
		Band No.	Driving EDR(s)	Spectral Range (um)	Horiz Sample Interval (km) (track x Scan)		Band Gain	Ltyp or Ttyp (Spec)	Lmax or Tmax	Spec SNR or NEdT (K)	Measured SNR or NEdT (K) (2)	Measured SNR or NEdT (K) (1)	Measured SNR or NEdT (K) (2)
					Nadir	End of Scan							
Reflective Bands	VisNIR	M1	Ocean Color Aerosol	0.402 - 0.422	0.742 - 0.259	1.60 x 1.58	High	44.9	135	352	616.8	578	588.9
							Low	155	615	316	1092	974	1045.78
		M2	Ocean Color Aerosol	0.436 - 0.454	0.742 - 0.259	1.60 x 1.58	High	40	127	380	622.4	564	572.02
							Low	146	687	409	1118	975	1010.76
		M3	Ocean Color Aerosol	0.478 - 0.498	0.742 - 0.259	1.60 x 1.58	High	32	107	416	690	611	628.46
							Low	123	702	414	1111	1003	988.54
		M4	Ocean Color Aerosol	0.545 -0.565	0.742 - 0.259	1.60 x 1.58	High	21	78	362	581.1	522	534.96
							Low	90	667	315	963.2	846	856.51
		I1	Imagery EDR	0.600 - 0.680	0.371 - 0.387	0.80 x 0.789	Single	22	718	119	240.7	215	214.07
		M5	Ocean Color Aerosol	0.662 - 0.682	0.742 - 0.259	1.60 x 1.58	High	10	59	242	366.6	321	336.13
							Low	68	651	360	827.9	673	631.26
		M6	Atmosph. Correct.	0.739 - 0.754	0.742 - 0.776	1.60 x 1.58	Single	9.6	41	199	415.2	355	368.4
		I2	NDVI	0.846 - 0.885	0.371 - 0.387	0.80 x 0.789	Single	25	349	150	304.1	251	264.01
		M7	Ocean Color Aerosol	0.846 - 0.885	0.742 - 0.259	1.60 x 1.58	High	6.4	29	215	519.8	435	457.54
							Low	33.4	349	340	845.6	636	631.24
	S/WMIR	M8	Cloud Particle Size	1.230 - 1.250	0.742 x 0.776	1.60 x 1.58	Single	5.4	165	74	273	233	221
		M9	Cirrius/Cloud Cover	1.371 - 1.386	0.742 x 0.776	1.60 x 1.58	Single	6	77.1	83	253	231	227
		I3	Binary Snow Map	1.580 - 1.640	0.371 x 0.387	0.80 x 0.789	Single	7.3	72.5	6	172	149	149
		M10	Snow Fraction	1.580 - 1.640	0.742 x 0.776	1.60 x 1.58	Single	7.3	71.2	342	714	550	586
		M11	Clouds	2.225 - 2.275	0.742 x 0.776	1.60 x 1.58	Single	0.12	31.8	10	25	21.8	22
EmissiveBands		I4	Imagery Clouds	3.550 - 3.930	0.371 x 0.387	0.80 x 0.789	Single	270	353	2.5	0.4	0.4	0.4
		M12	SST	3.660 - 3.840	0.742 x 0.776	1.60 x 1.58	Single	270	353	0.396	0.13	0.13	0.13
		M13	SST Fires	3.973 - 4.128	0.742 x 0.259	1.60 x 1.58	High	300	343	0.107	0.04	0.042	0.04
							Low	380	634	0.423			
	LWIR	M14	Cloud Top Properties	8.400 - 8.700	0.742 x 0.776	1.60 x 1.58	Single	270	336	0.091	0.06	0.06	0.05
		M15	SST	10.263 - 11.263	0.742 x 0.776	1.60 x 1.58	Single	300	343	0.07	0.03	0.03	0.03
		I5	Cloud Imagery	10.500 - 12.400	0.371 x 0.387	0.80 x 0.789	Single	210	340	1.5	0.4	0.4	0.4
		M16	SST	11.538 - 12.488	0.742 x 0.776	1.60 x 1.58	Single	300	340	0.072	0.04	0.03	0.03

(1) The Aerospace Corporation (2) NASA NICSE

HSI uses 3 in-scan pixels aggregation at Nadir

Source: VIIRS user's guide. On orbit values (last two columns for March 8, 2012) are updated based on the Murphy table for RSB, provided by Aerospace; TEB values are provided by STAR and NASA.

Updated 05/01/2012

Environmental Data Products (EDRs) Derived from VIIRS SDRs

Land (10)	Active Fires (Application Related Product)
	Land Surface Albedo
	Land Surface Temperature
	Ice Surface Temperature
	Snow Ice Characterization
	Snow Cover/Depth
	Vegetation Index
	Surface Type
	Soil Moisture
	Net Heat Flux
Ocean (2)	**Sea Surface Temperature (KPP)**
	Ocean Color/Chlorophyll
Imagery (1) and Clouds (8)	**Imagery (KPP)**
	Cloud Mask (Intermediate Product)
	Cloud Optical Thickness
	Cloud Effective Particle Size
	Cloud Top Pressure
	Cloud Top Temperature
	Cloud Base Height
	Cloud Cover/Layers
	Precipitable Water
Aerosols (3)	Aerosol Optical Thickness
	Aerosol Particle Size
	Suspended Matter
Low Light Imaging (1)	Near Constant Contrast (NCC) Imagery

Cal/Val to Ensure Product Maturity

- Beta (L+150)
  - Early release product, initial calibration applied, minimally validated and may still contain significant errors
  - Available to allow users to gain familiarity with data formats and parameters
  - Product is not appropriate as the basis for quantitative scientific publications studies and applications
- Provisional (Beta+2mo)
  - Product quality may not be optimal
  - Incremental product improvements are still occurring as calibration parameters are adjusted with sensor on-orbit characterization
  - General research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing
  - Users are urged to contact NPP Cal/Val Team representatives prior to use of the data in publications
- Validated/Calibrated (L+20mo)
  - On-orbit sensor performance characterized and calibration parameters adjusted accordingly
  - Ready for use by the Centrals, and in scientific publications
  - There may be later improved versions

VIIRS 58 Cal/Val tasks

- Functional Performance & Format Evaluation (7)
- Calibration System Evaluation (7)
- Image Quality Evaluation (4)
- Radiometric Evaluation (24)
- Geometric Evaluation (9)
- Performance and Telemetry Trending (7)

VIIRS SDR team Weekly telecons, reports, technical tagup, SDR/EDR interactions, blogs, and wiki.

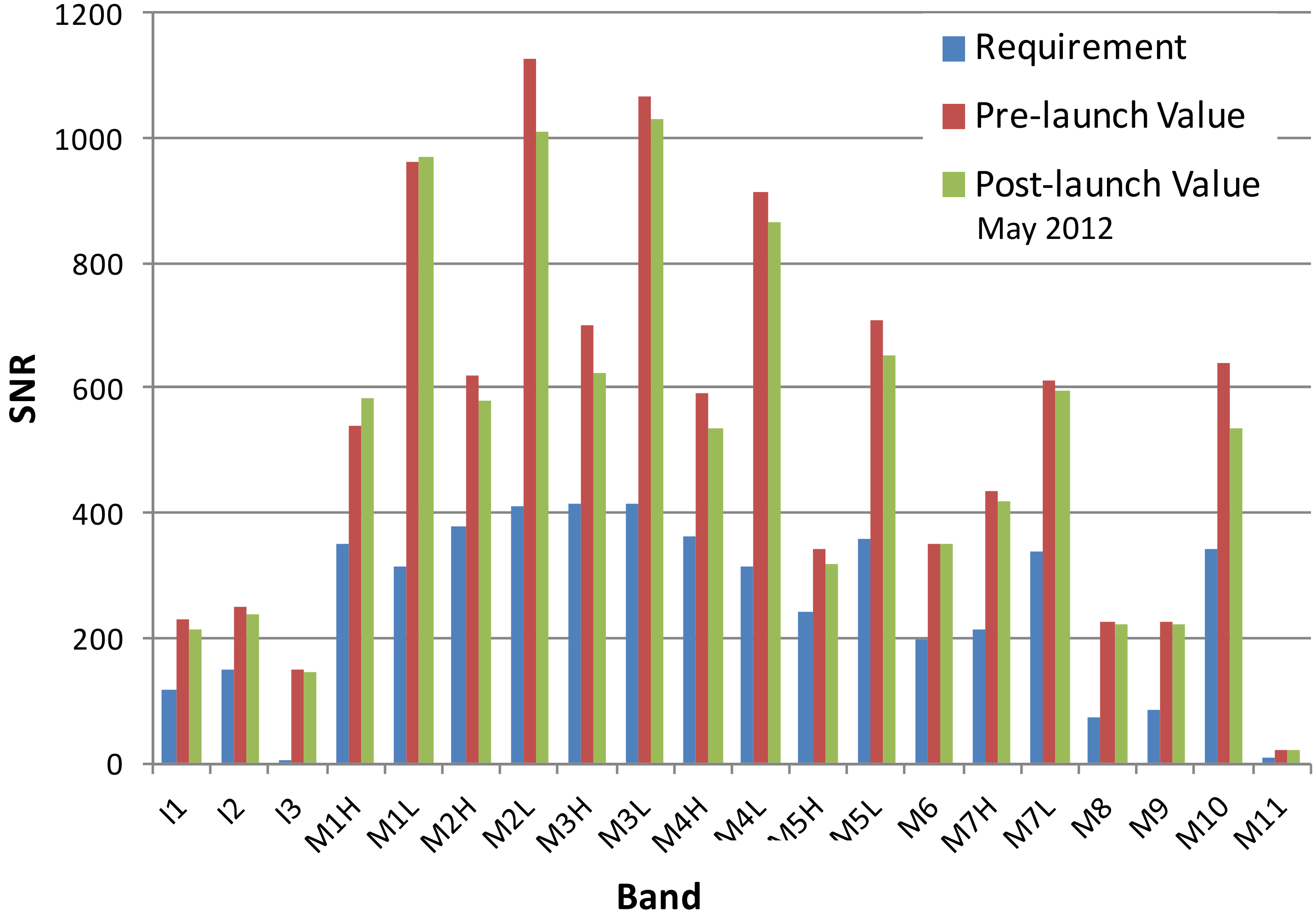
VIIRS SDR Data Access and Calibration Knowledge Base

- The VIIRS SDR team developed the Calibration Knowledge base and made available on the website at https://cs.star.nesdis.noaa.gov/NCC/VIIRS with a wealth of information including user's guide, relative spectral response, SNO predictions, image gallery, standardized parameters, conference presentations, etc.

- The VIIRS SDR User's Guide is being actively maintained and updated.

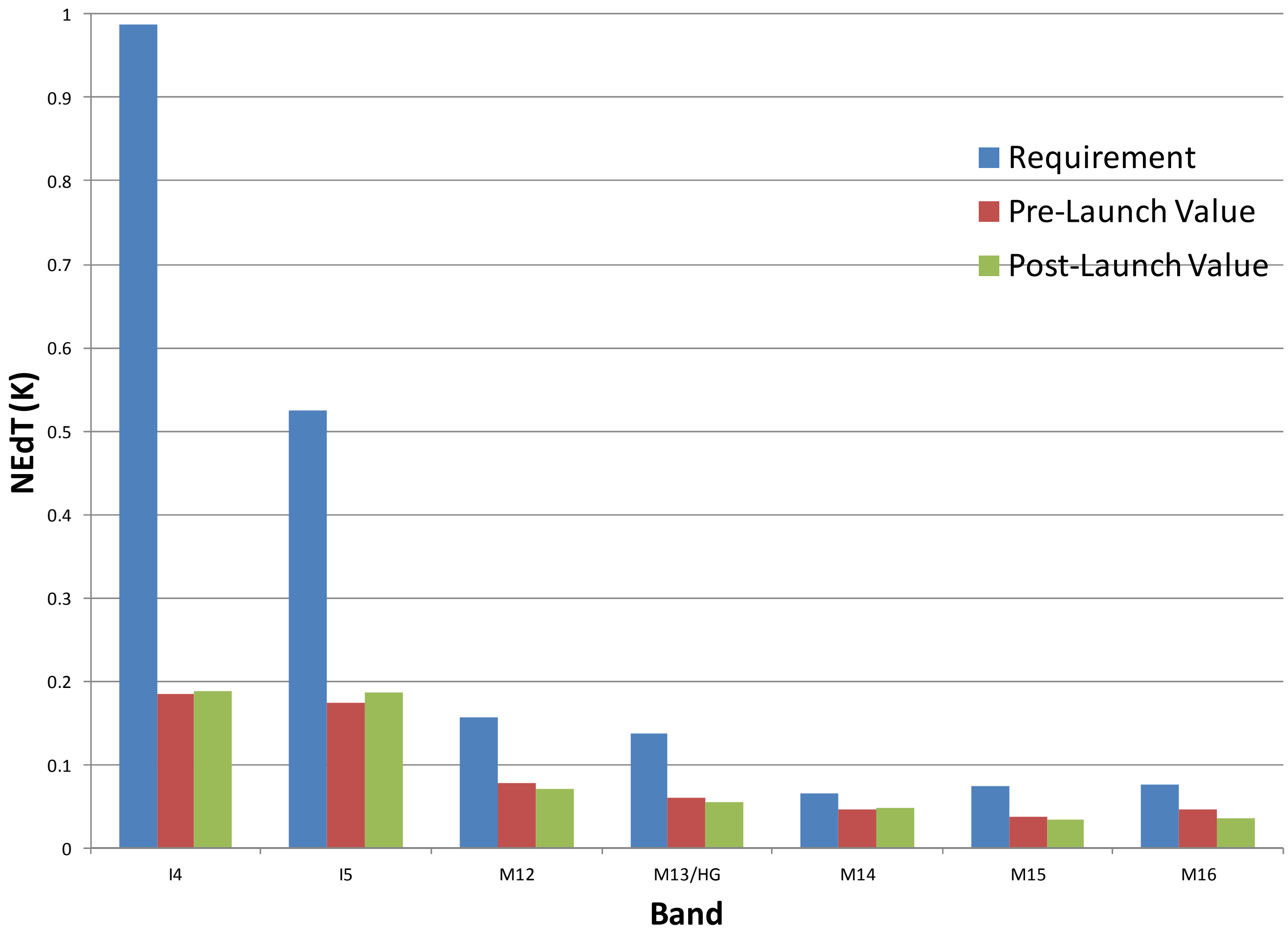
- VIIRS SDR data is now open to the public on the NOAA CLASS archive at http://www.class.noaa.gov

RSB Radiometric Performance



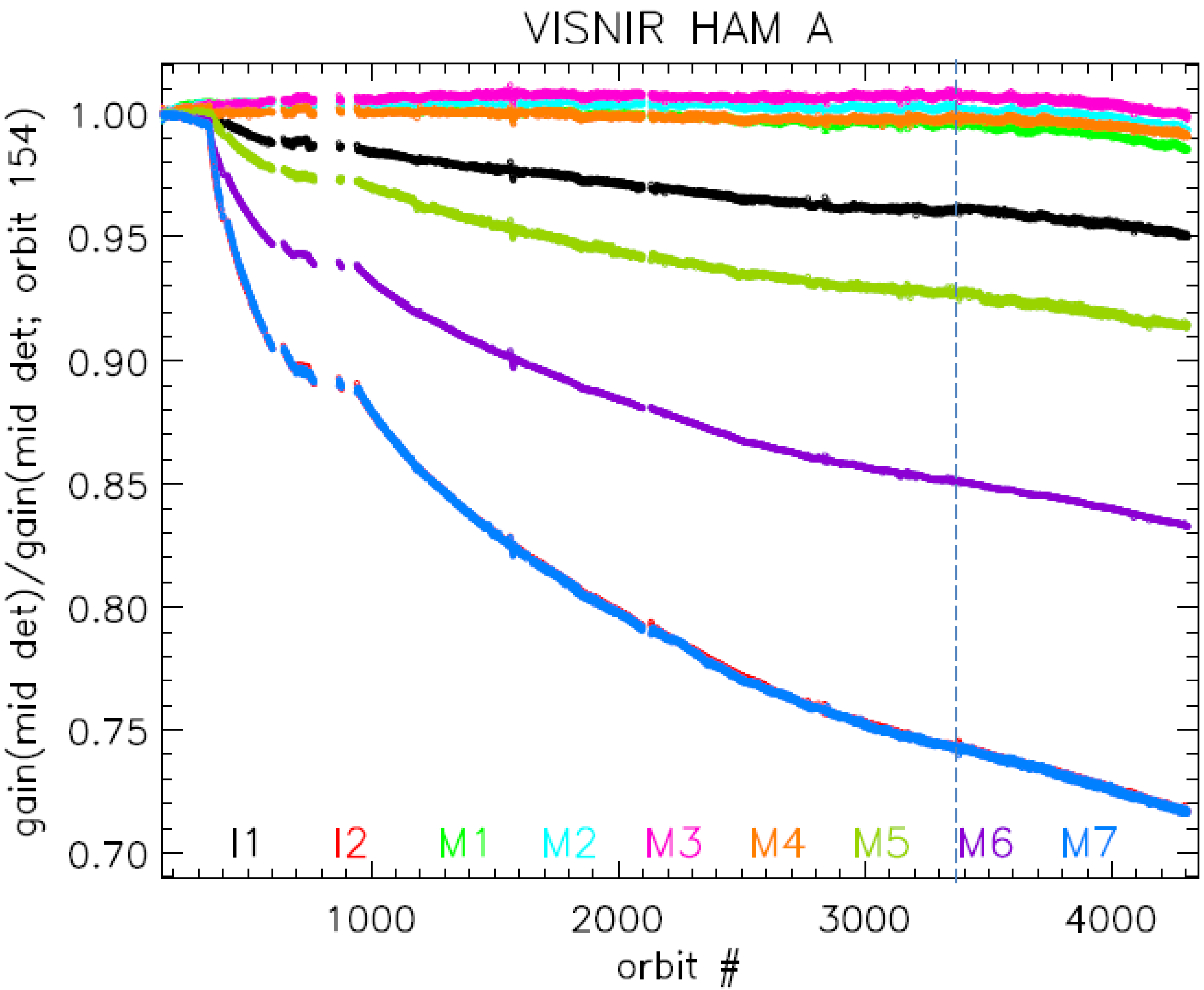
SNR performance is exceeding requirements for all bands

TEB Radiometric Performance

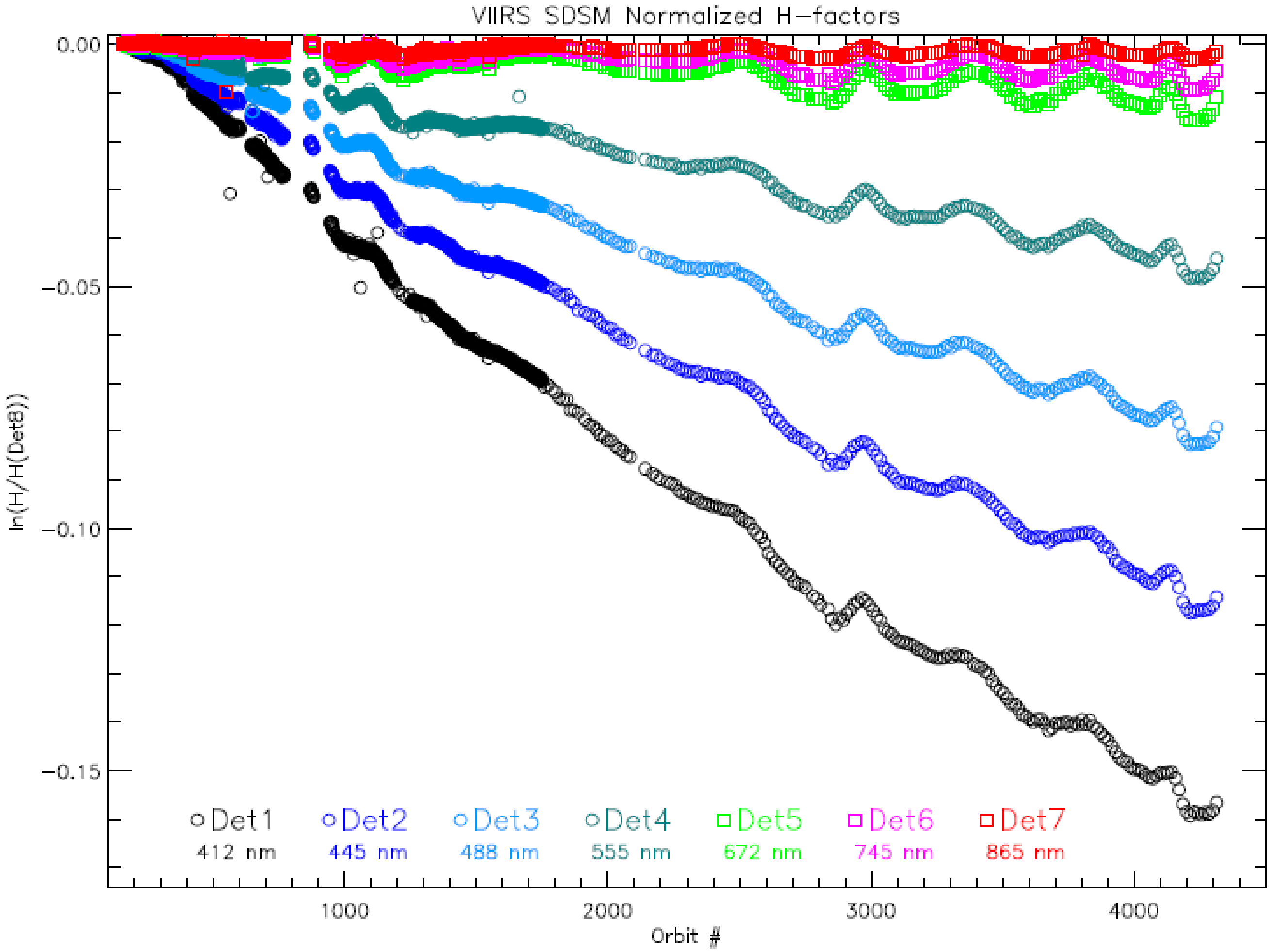


NEdT performance is exceeding requirements for all bands

VIIRS Mirror Degradation - Recent Trend

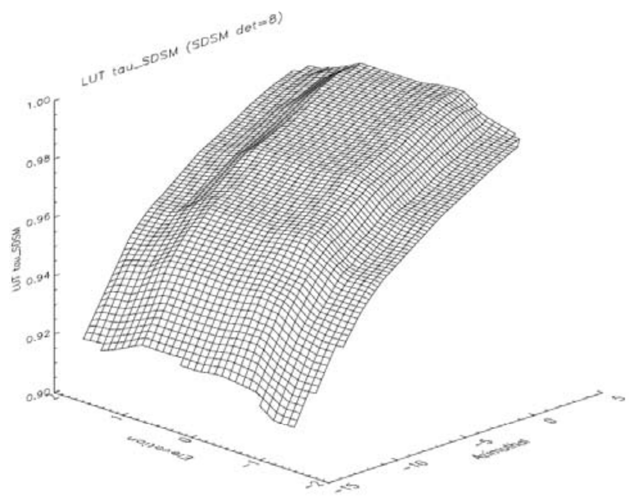


Solar Diffuser Degradation

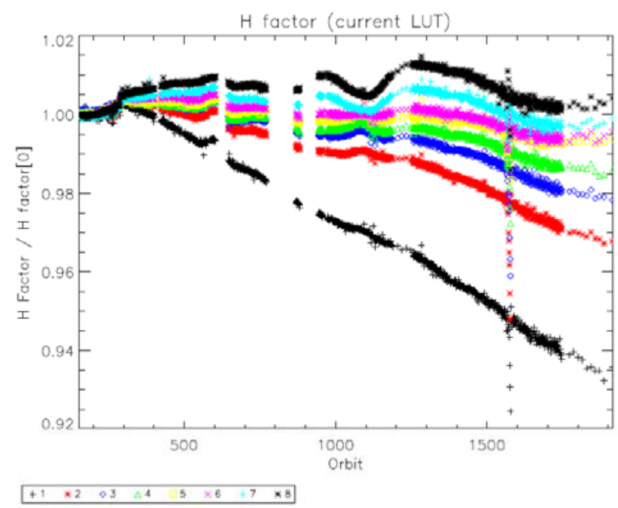


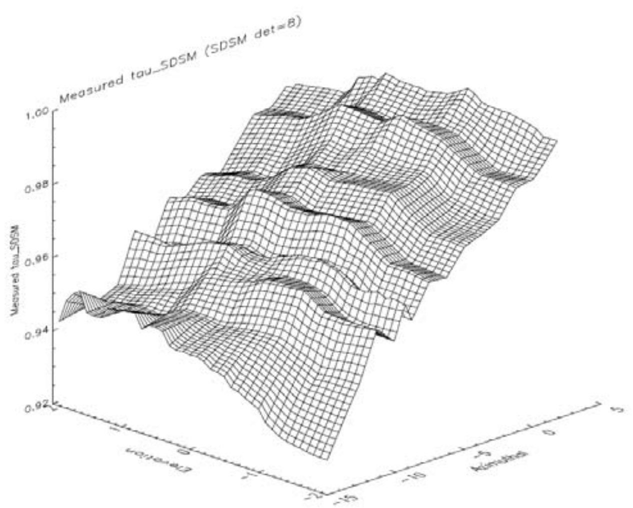
Yaw Maneuvers - SD and SDSM Screen

A series of (15) yaws performed (February 15 and 16, 2012), covering solar azimuthal angles from 13.7 to 30.6 degrees.
Verified SD BRF and screen transmission; improved SDSM screen transmission

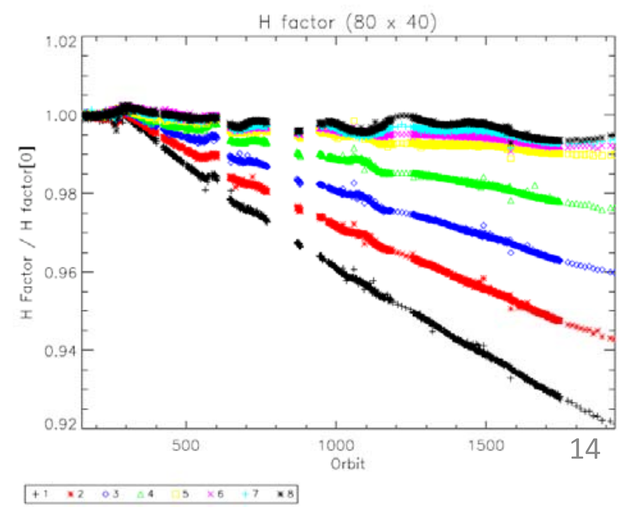


Prelaunch LUT





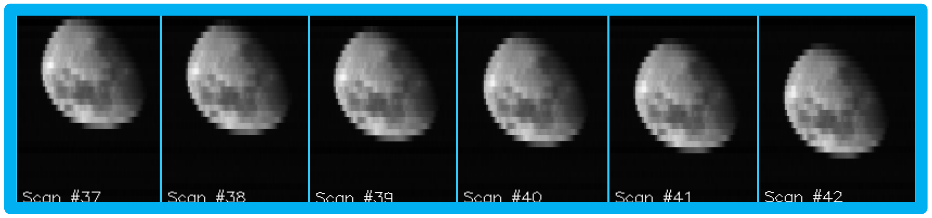
Yaw-derived LUT



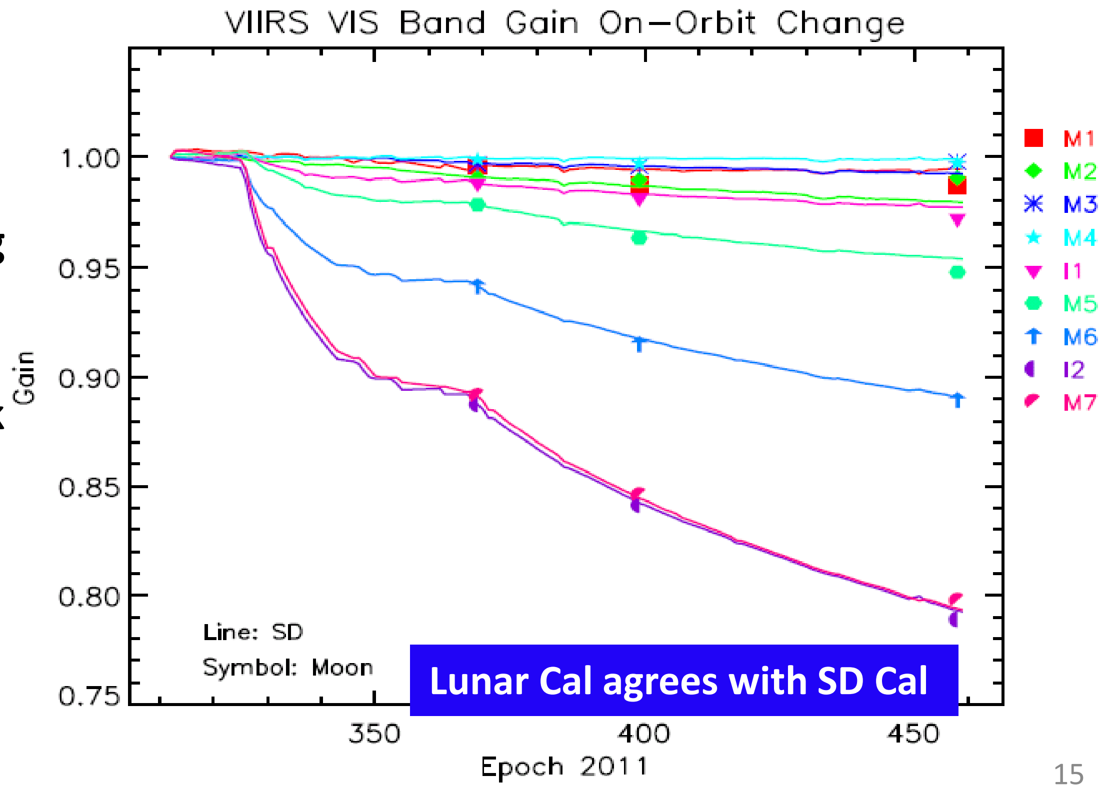
Roll Maneuvers - Lunar Calibration

VIIRS lunar observations have been made via SC roll maneuvers; different roll angles used to keep lunar phase angles to within a small range

Examples of band I1 lunar images from 6 consecutive scans (Jan 4, 2012)



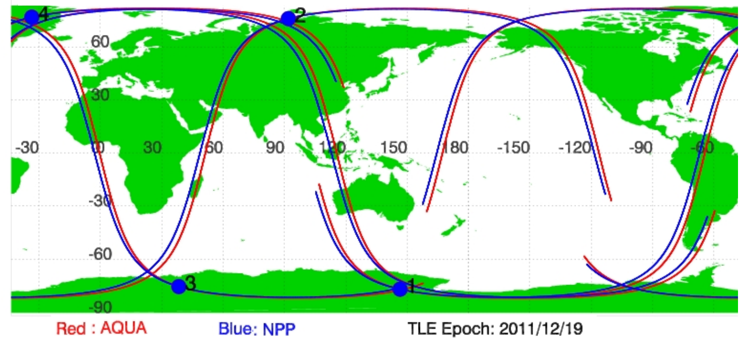
- Corrections for lunar view geometry differences applied using the ROLO model (USGS)
- Lunar observations are used track VIS/NIR calibration stability



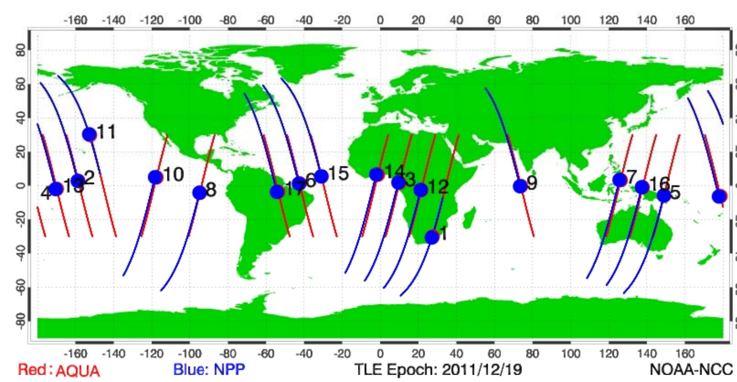
SNO and SNO extension to the Low Latitudes (SNOx) - Aqua/MODIS vs. SNPP/VIIRS

	SNO	SNOx
Time diff	30 sec	~10 mins
Nadir distance	< 10 km	~100 km
Location	Polar regions	Low latitudes
Surface	Snow/ice/ tundra	Ocean, desert, forest, etc.
Uncertainty factors	High solar zenith angle (sza), ozone, ground truth	Sun glint, clouds, atmosphere, sza diff
Use for inter-comparisons	Radiometric, Spectral	Radiometric, Geospatial, RVS, spectral

SNO (Simultaneous Nadir Overpass)

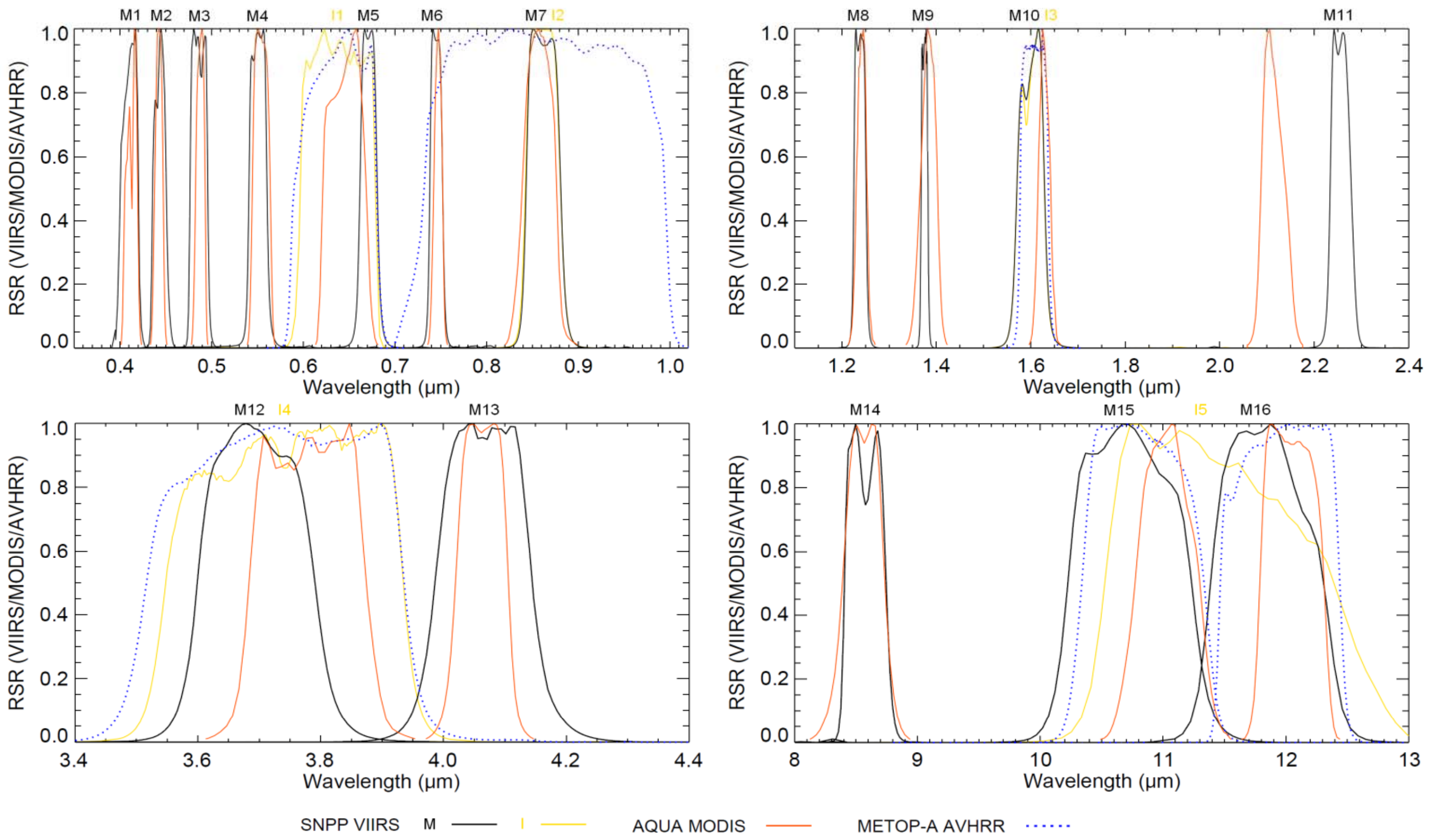


SNOx = SNO extension to low latitudes



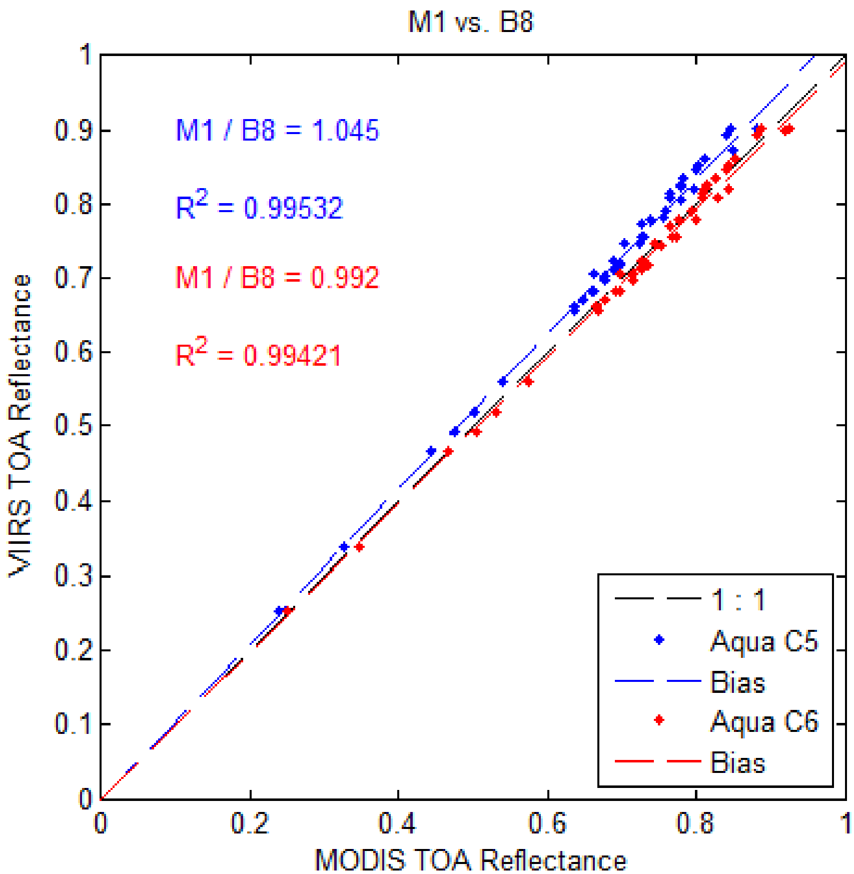
The SNO/SNOx as well as daily SNPP orbital predictions are available at: https://cs.star.nesdis.noaa.gov/NCC/SNOPredictions

VIIRS, AVHRR, and MODIS Spectral Response Comparisons



NOAA/STAR and NASA/VCST work together to assess radiometric biases between VIIRS and MODIS

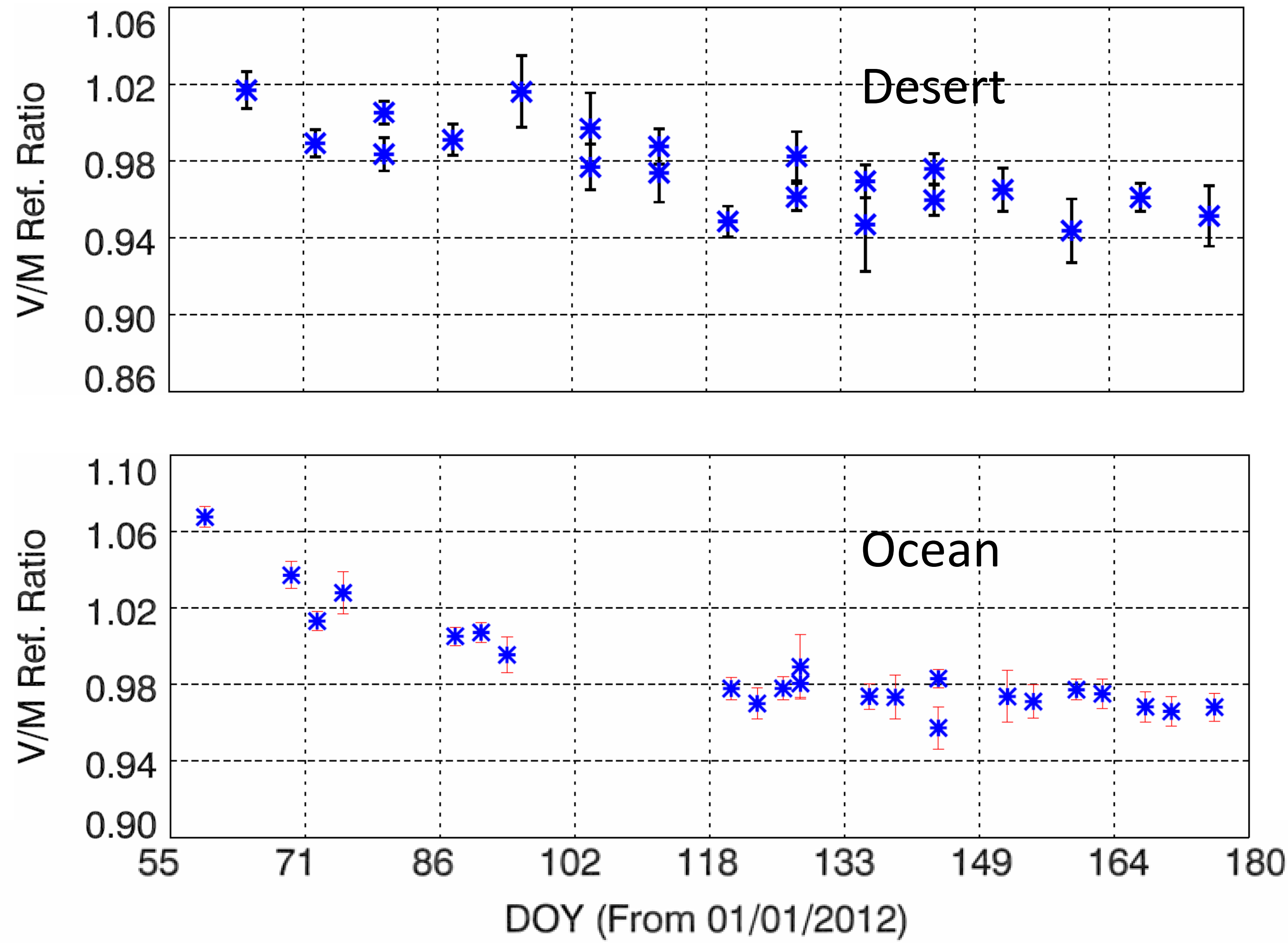
- A radiometric bias on the order of 5% between VIIRS M1 vs. MODIS B8 was found since February 2012.
- After a thorough investigation by the VIIRS SDR team, the bias was found to be due to MODIS calibration drift in the Collection 5 (C5) data set
- The bias disappears when compared with MODIS Collection 6 (C6) data, which will be released publicly soon.
- It is expected that VIIRS M1 and MODIS B8 will match well once their C6 data are released.



VIIRS M1 vs. MODIS B8 (C5&C6) band radiometric comparisons

VIIRS vs. Aqua/MODIS at SNOx

VIIRS M1 and MODIS B8 (Collection 6)



See Calcon poster by Uprety et al for more details

Radiometric Biases between VIIRS and MODIS bands

Comparisons between VIIRS and MODIS matching bands at the SNO/SNOx show that radiometrically:

-Bands match relatively well such as M3, M4, M7

-TEB bands performing well in general (M13-M16) but there are issues, such as temperature dependent bias for M15 (per CrIS Team)

-Blue bands M1-M2 (for ocean color) show biases up to 5% with MODIS C5, while bias much reduced with MODIS C6

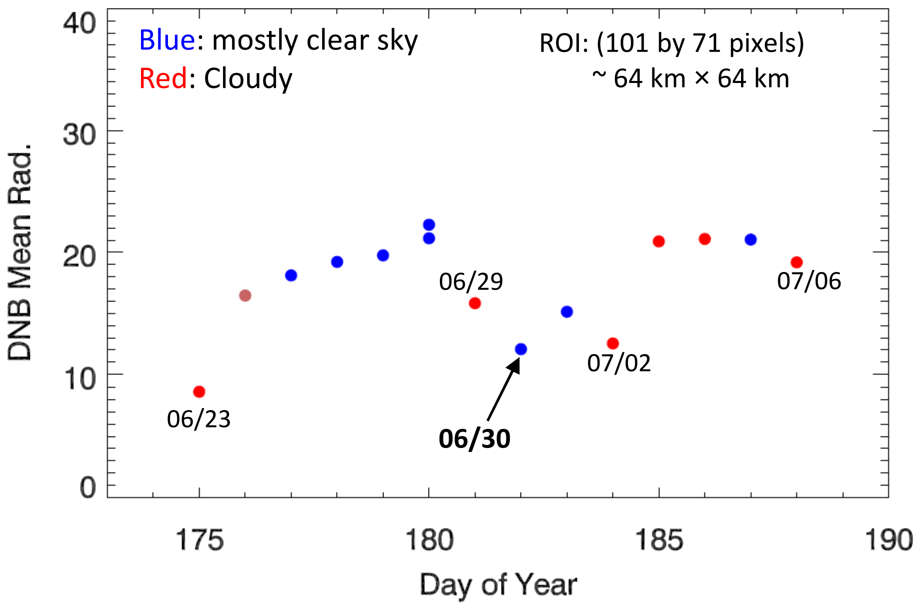
-Bands have large biases due to relative spectral response differences (RSR) such as M5, and M12 (day time reflected solar)

-Bands require further investigation: M4, M6, M8, M9, M10

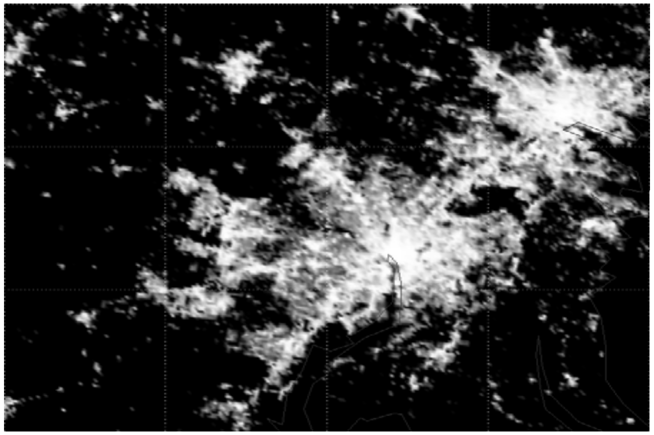
-Bands do not have matching spectral response: M11

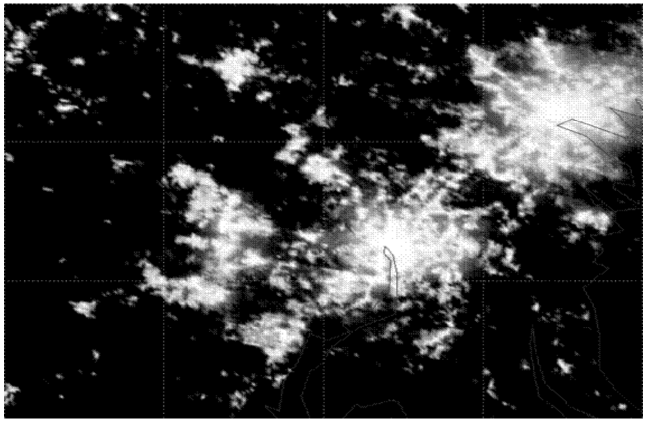
Suomi NPP VIIRS DNB band

- Despite the straylight effect, the Day/Night Band has been used to detect a major power outages in the Washington, DC on the night of 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.

Challenges and Way Forward

- The dynamics of instrument degradations (mirror responsivity, solar diffuser, and SDSM detectors) and mitigation
- A-side vs. B-side
- M6 band rollover when saturated
- Early VIIRS SDR data and reprocessing
- DNB straylight mitigation
- Further investigation on striping
- Instrument and spacecraft maneuver
- Other issues

- Transition to operations
- J1, J2 and beyond
- Continue relying on the VIIRS SDR team for the heavy lifting

Summary

- VIIRS radiometric performance is very good
  - Extensive pre-launch test program provided highly accurate calibration onorbit
  - SNR performance is consistent with pre-launch measurements and complies with requirements
  - Data quality appears to be comparable to that of MODIS (if not better)
  - RSB throughput degradation is being mitigated
  - DNB images are excellent except in regions affected by stray light
  - Additional tuning of SDR LUTs expected to improve radiometric quality

- VIIRS geometric performance is excellent (~80m or ~1/4 pixel)

- The VIIRS SDR team provided mission critical support, and will continue to work together to address challenges going forward, and transition to operations

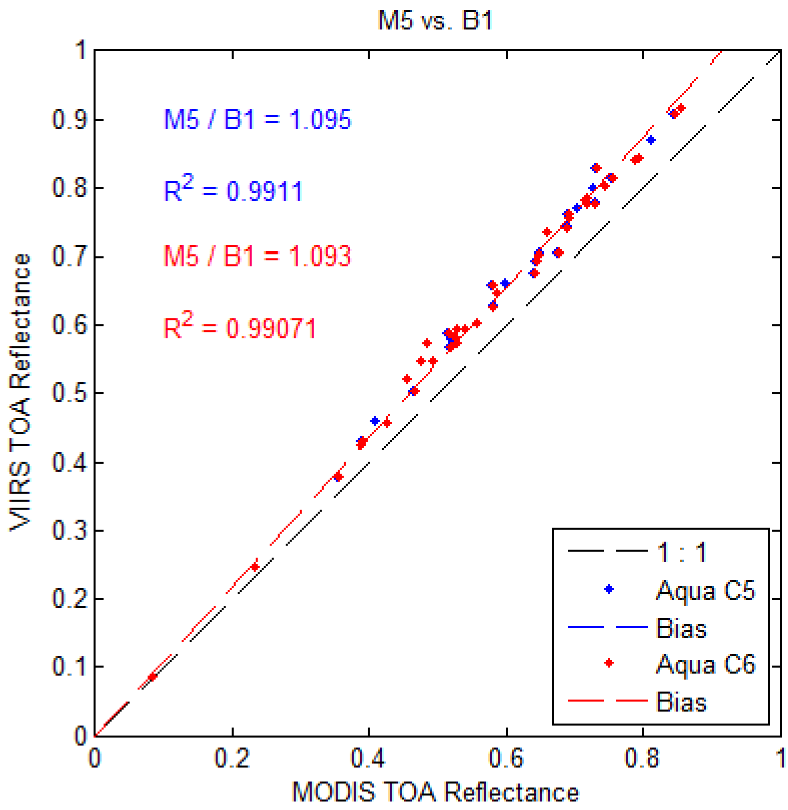
Backup

Bias due to Spectral Response Differences

The bias in M5 vs. MODIS B1 (on the order of 9%) is primarily due to spectral response differences, according to radiative transfer calculations

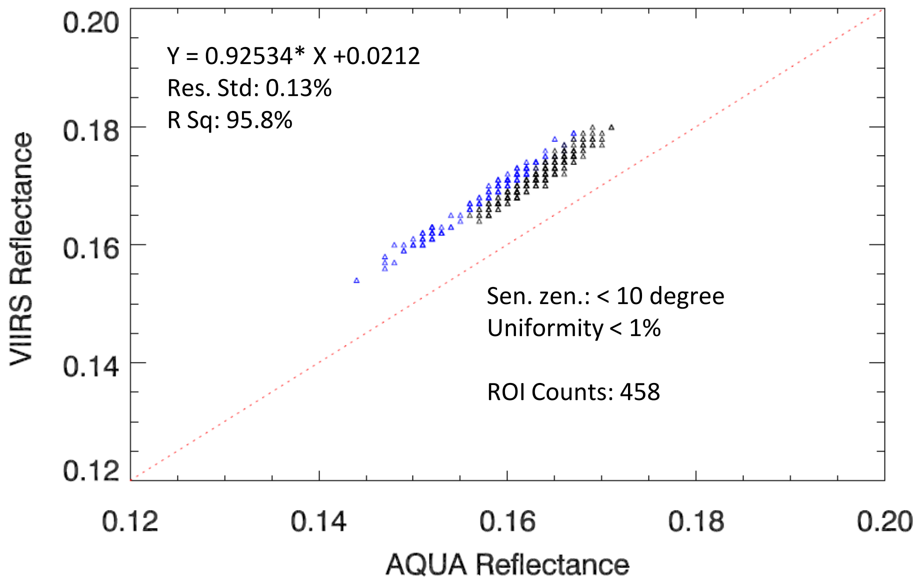
This bias amount remains the same between MODIS C5 and C6, as expected

EDR users should keep in mind of this issue in product comparisons



VIIRS M1 vs. MODIS B8 (collection 5)

–Ocean Example (at SNOx)



- Suggests small changes. Need longer SNO time series to validate.
- Variability in the bias scatter plot increases with longer time period.