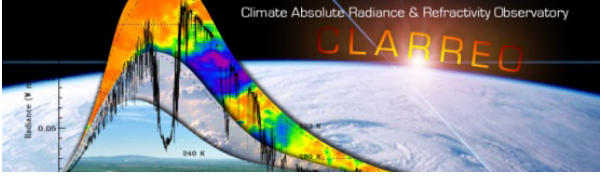

VIIRS Reflective Solar Calibration and Initial On-orbit Performance

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VIIRS Characterization Support Team (VCST)

CLARREO SDT Meeting, Laboratory for Atmospheric and Space Physics, Boulder, CO, Oct. 16-18, 2012

Outline

- Introduction
- On-orbit Operation and Calibration
- Preliminary Performance (reflective solar bands)
  - Results from on-board calibrators
  - Results from lunar observations (back-up slides)
  - Inter-comparisons with Aqua MODIS
- Future Effort
- Summary

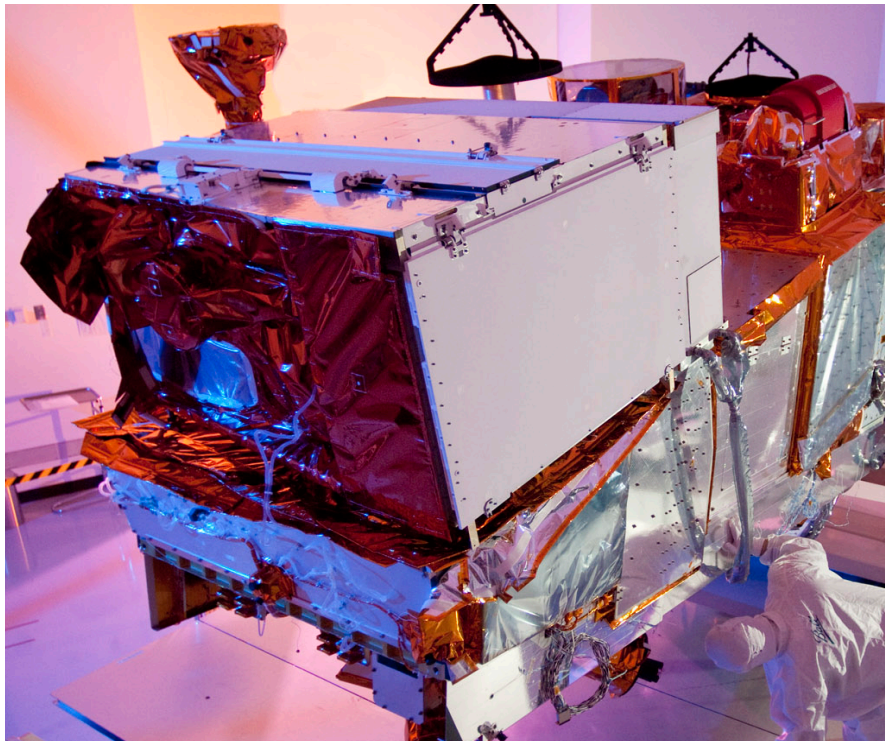
Introduction

- **SNPP and CLARREO Mission**
  - **SNPP was designed to bridge existing EOS and future JPSS missions**
    - Enables comprehensive earth observations
    - Extends heritage sensors' research and operational applications
    - VIIRS is a key instrument on SNPP – a MODIS follow-on instrument
  - **CLARREO is developed to address the need to observe climate change and to determine the accuracy of its projections**
    - Enables highly accurate and SI traceable decadal change observations
    - **Provides reference intercalibration of temporally and spatially coincident measurements from other on-orbit sensors**

Visible/Infrared Imager Radiometer Suite (VIIRS)

Description

- Purpose: Global observations of land, ocean, & atmosphere parameters at high temporal resolution (~ daily)
- Predecessor Instruments: AVHRR, OLS, SeaWiFS, MODIS
- Spectral range: 22 bands between 0.4 µm and 12.5 µm
- Spatial resolution: 375 and 750 m
- Swath Width: 3000 km



Key Features

- MODIS-like on-board calibrators
- 16 moderate (radiometric), 5 imaging, and 1 day/night bands
- Dual gains (7 bands)
- VIS/NIR, SMIR, and LWIR focal plane assemblies (FPA)
- Pixel aggregations and bowtie deletion

VIIRS and MODIS Spectral Bands

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

1 DNB

14 RSB
(0.4-2.3 μm)

Dual gains:
M1-M4, M6, M7
M12

7 TEB

On-orbit Operation and Calibration

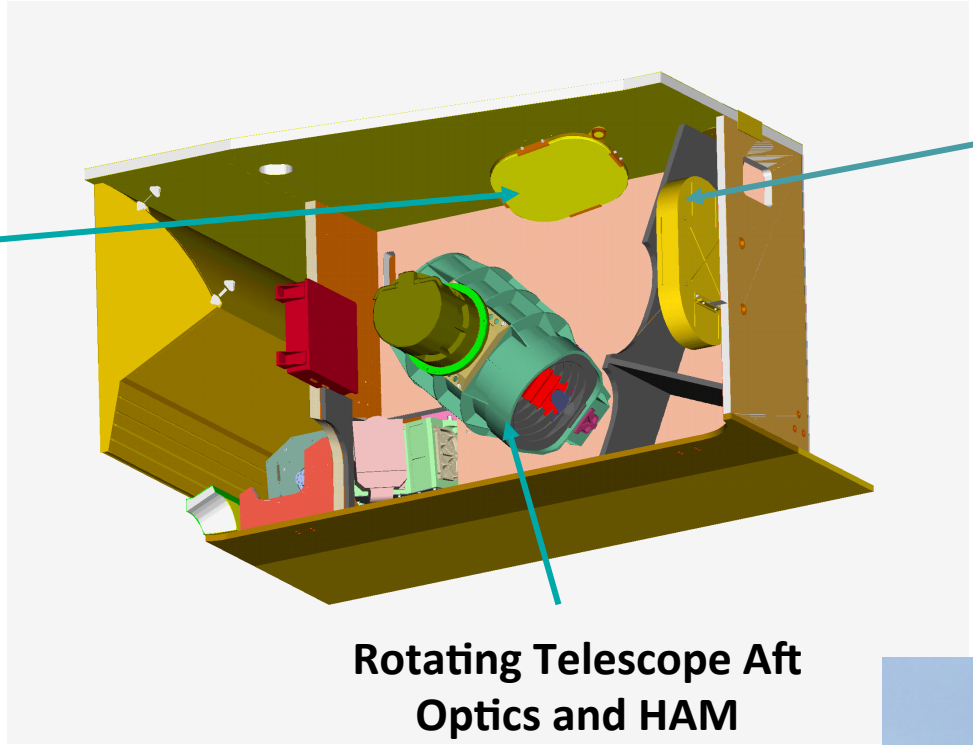
- **Key Events (operation/calibration activities)**
  - **Launch: 10/28/11**
  - **Instrument turn-on: 11/8/11**
  - **Nadir door open: 11/21/11 (first image from VIS/NIR)**
  - **RTA stow (4 times): 12/9/11 – 1/2/12**
  - **Cryo-cooler door open: 1/18/12 (observations from all bands)**

  - **Roll maneuvers: started from 1/4/12 (lunar observations for RSB)**
  - **Yaw maneuvers; 2/15/12 – 2/16/12 (SD/SDSM screen transmission)**
  - **Pitch maneuvers: 2/20/12 (TEB response versus scan angle)**

  - **BB warm-up/cool-down: started from 2/6/12 (TEB calibration)**
  - **Routine SD/SDSM calibration (RSB calibration)**

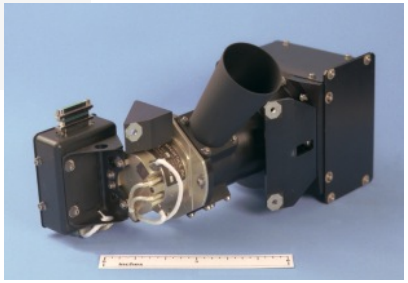
VIIRS On-board Calibrators

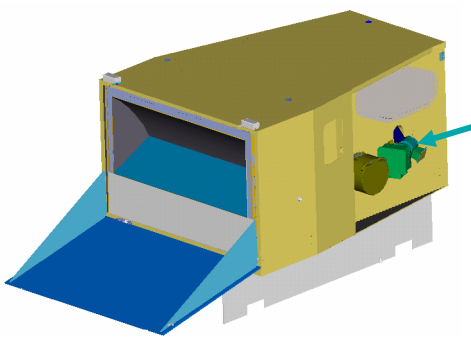
Solar Diffuser



Blackbody

Rotating Telescope Aft Optics and HAM





Solar Diffuser Stability Monitor

MODIS heritage OBC

Improved SD/SDSM system

Reflective Solar Bands Calibration Using SD and SDSM

Reflective Solar Bands Calibration – SD/SDSM

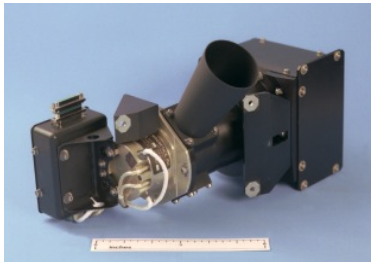
RSB Calibration F and H Factors

$$L_{EV} = F \cdot \left(c_0 + c_1 \cdot dn_{EV} + c_2 \cdot dn_{EV}^2\right)$$

$$L_{SD\_Meas} = F \cdot \left(c_0 + c_1 \cdot dn_{SD} + c_2 \cdot dn_{SD}^2\right)$$

$$F = \frac{L_{SD\_Comp}}{L_{SD\_Meas}}$$

$$L_{SD\_Comp} \propto BRDF_{SD}(t) \cdot \tau_{SDS}$$



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

$$H_{SD}(t) = H(t) / H(t_0)$$

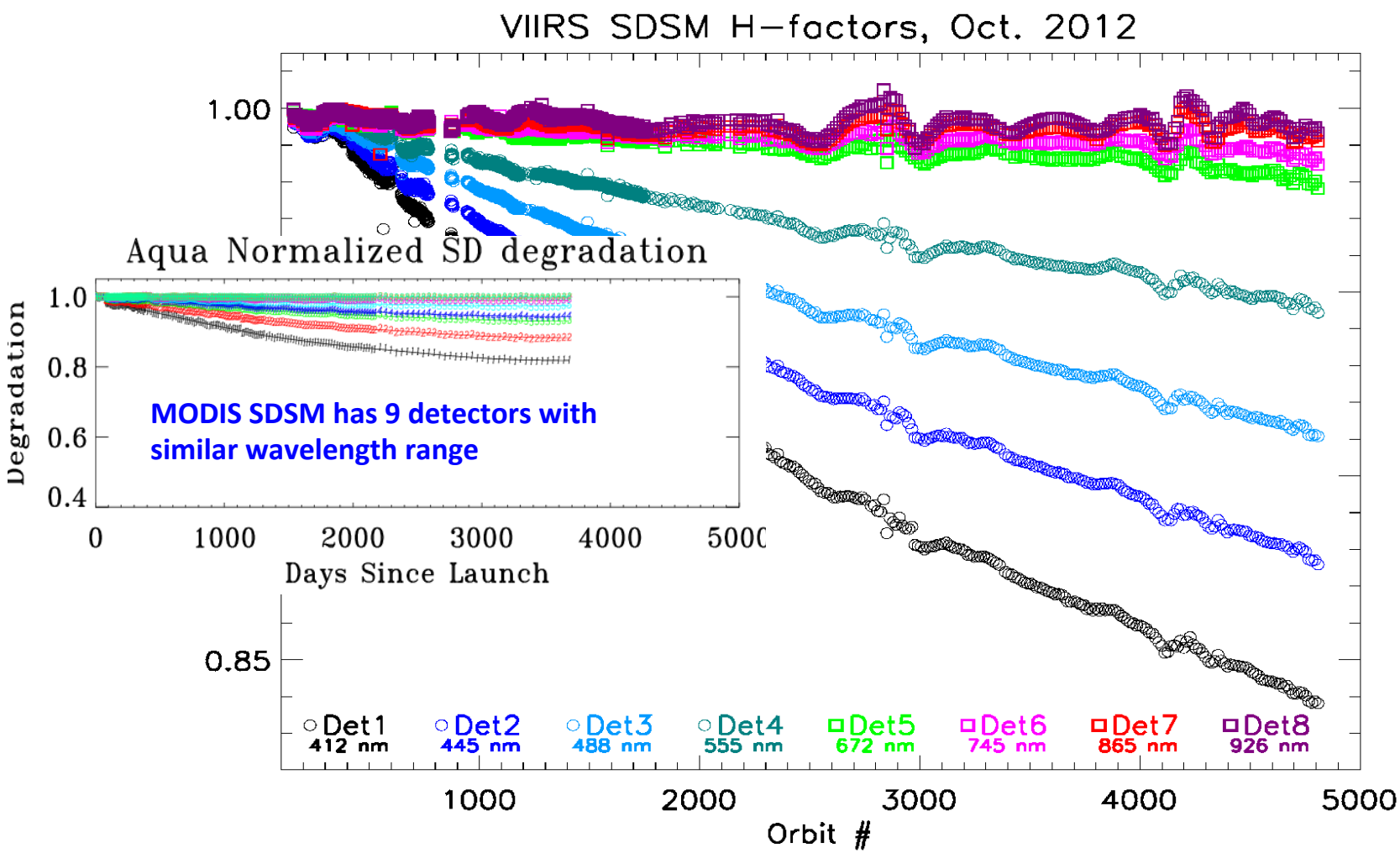
$$H(t) \propto \frac{dc_{SD} \cdot \tau_{SDSMS}}{dc_{SUN} \cdot \tau_{SDS}}$$

The dn and dc are VIIRS and SDSM detector "corrected" responses

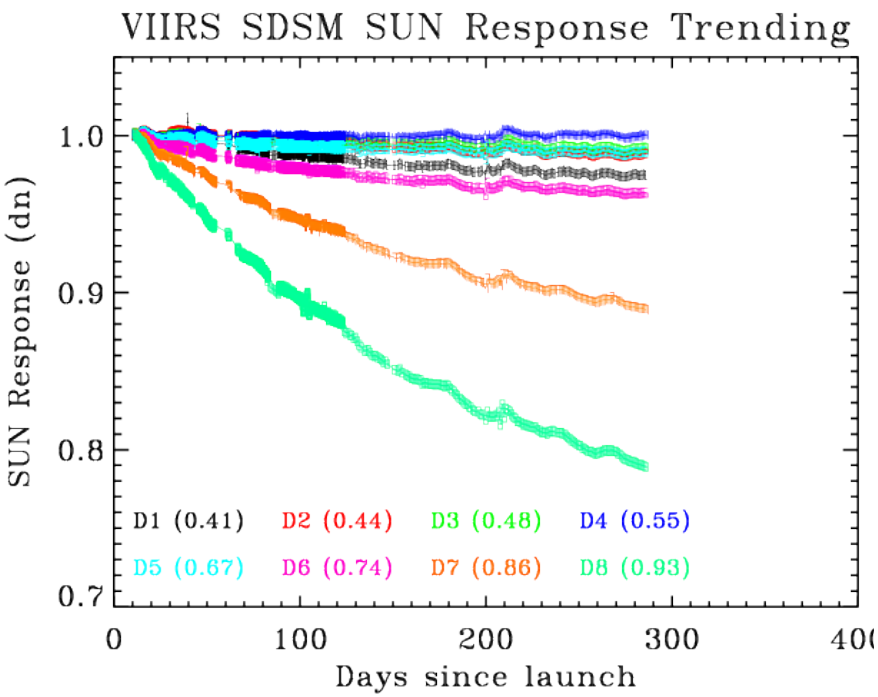
On-orbit Performance

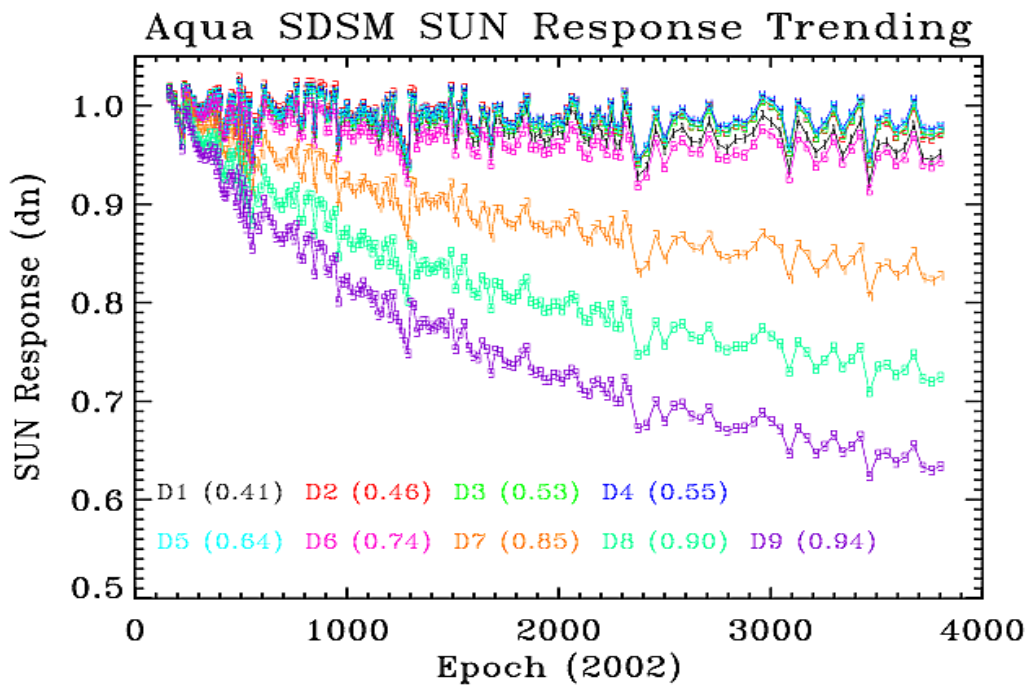
- **SD and SDSM Calibration**
  - **SD degradation (H-factor)**
  - **Detector response (F-factor)**
- **Yaw Maneuvers**
  - **Yaw: SD and SDSM screen transmission functions**
- **Lunar Calibration (backup slides)**
- **SNR Characterization**
- **Inter-comparison with Aqua MODIS**

On-orbit Changes in SD BRF (H-factor)



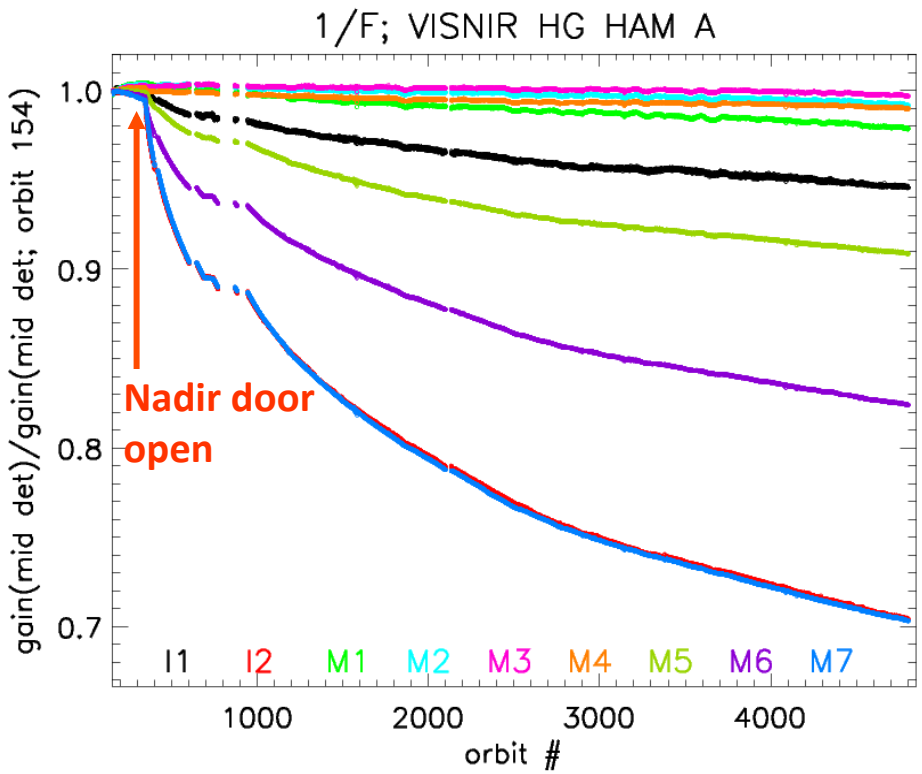
On-orbit Changes in SDSM Response

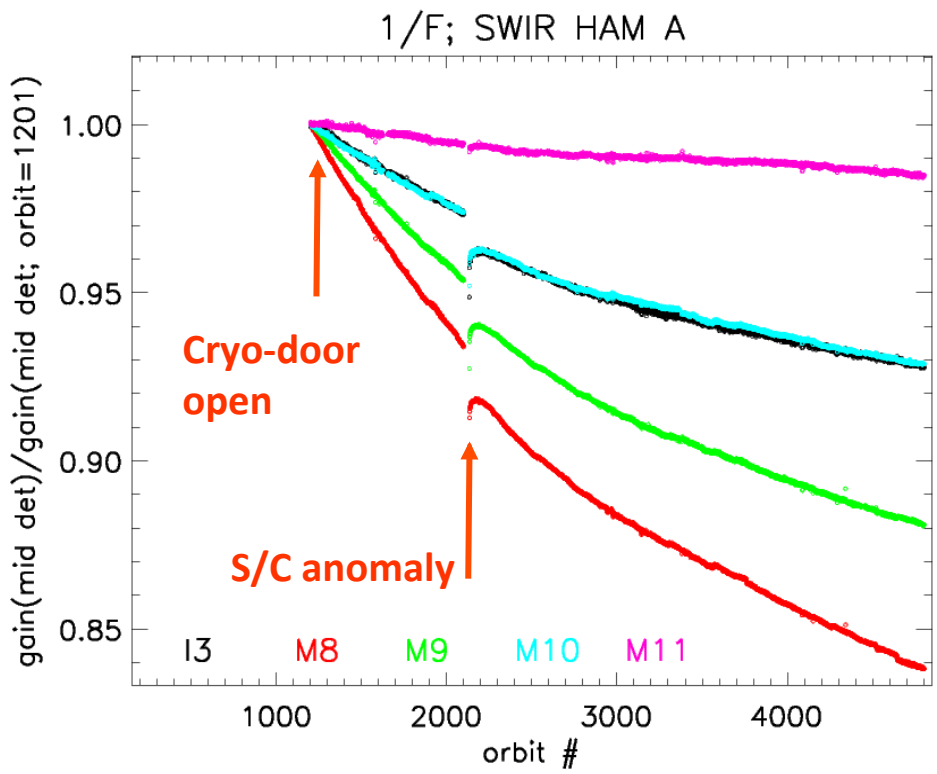




Similar trends like MODIS with faster degradation rate

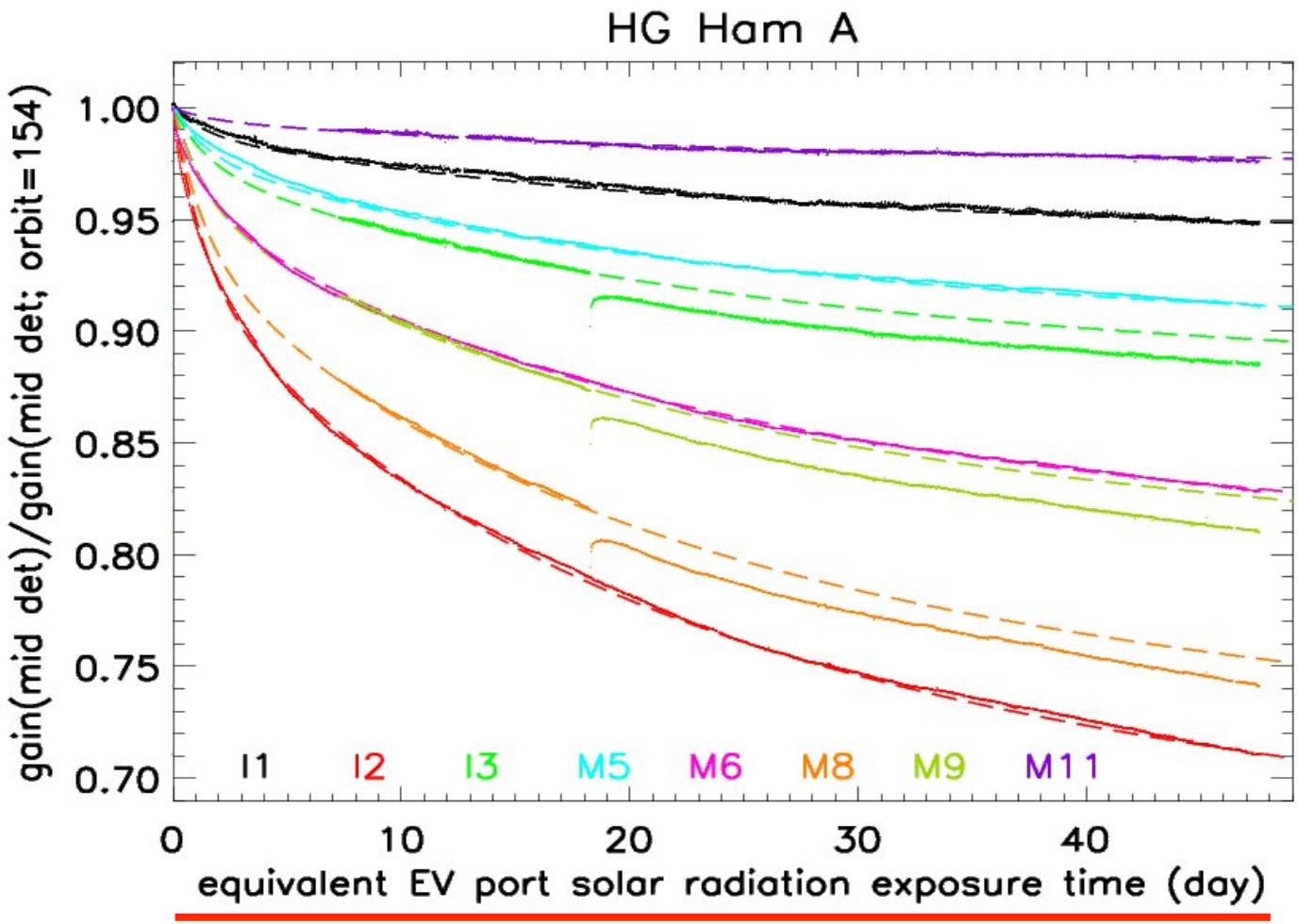
On-orbit Changes in Detector Response (F-factor)





M7/I2 (0.85μm), M6 (0.75μm), M5 (0.67μm), I1 (0.64μm)
M8 (1.24μm), M9 (1.38μm), M10/I3 (1.61μm), M11 (2.24μm)

On-orbit Changes in Detector Response (F-factor)



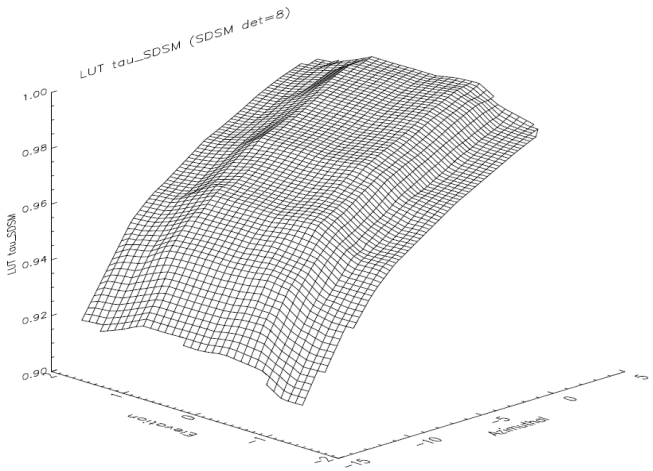
Wavelength dependent degradation – consistent with Tungsten absorption profile (under UV exposure), confirmed with witness sample measurements

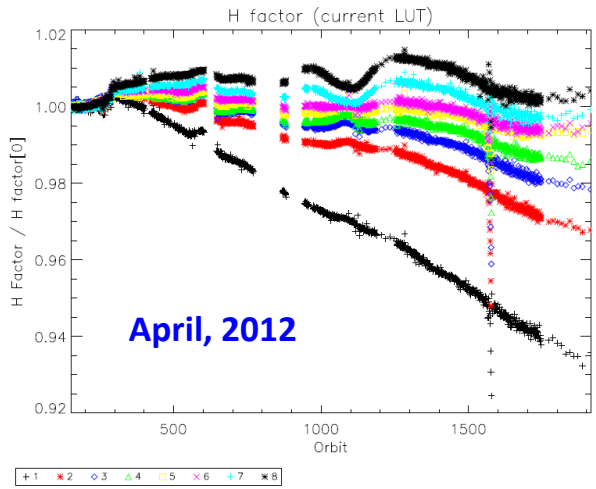
Yaw Maneuvers – SD and SDSM Screen Transmission Characterization

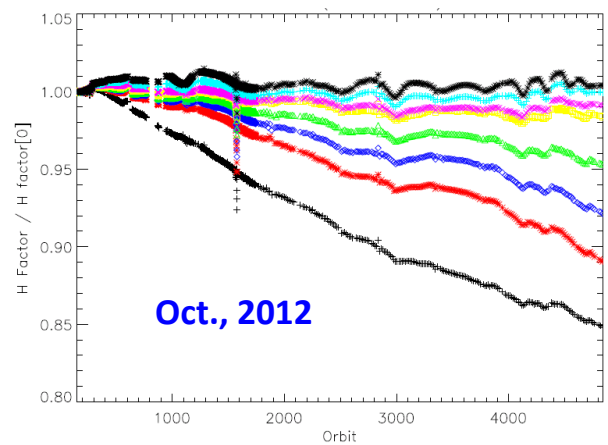
Date	Orbit	Yaw #	Center Time	Latitude	Solar AZ	Solar DEC	Solar Beta	Yaw	Solar AZ with Yaw	Solar AZ implemented
2/15/2012	1563	1	13:46:44	-61.36	19.68	16.75	18.9	-5.98	13.7	13.59
	1564	2	15:28:14	-61.38	19.67	16.75	18.9	-4.67	15	14.88
	1565	3	17:09:45	-61.41	19.67	16.75	18.9	-3.37	16.3	16.17
	1566	4	18:51:15	-61.43	19.67	16.75	18.9	-2.07	17.6	17.46
	1567	5	20:32:45	-61.46	19.67	16.75	18.9	-0.77	18.9	18.75
	1568	6	22:14:16	-61.48	19.67	16.75	18.9	0.53	20.2	20.04
	1569	7	23:55:46	-61.5	19.67	16.75	18.89	1.83	21.5	21.32
2/16/2012	1570	8	1:37:16	-61.53	19.67	16.75	18.89	0	19.67	19.51
	1571	9	3:18:47	-61.55	19.66	16.75	18.89	3.14	22.8	22.61
	1572	10	5:00:17	-61.58	19.66	16.75	18.89	4.44	24.1	23.9
	1753	11	6:41:47	-61.6	19.66	16.75	18.89	5.74	25.4	25.18
	1574	12	8:23:18	-61.63	19.66	16.75	18.89	7.04	26.7	26.47
	1575	13	10:04:48	-61.65	19.66	16.75	18.88	8.34	28	27.75
	1576	14	11:46:18	-61.68	19.66	16.75	18.88	9.64	29.3	29.03
	1577	15	13:27:49	-61.7	19.66	16.75	18.88	10.94	30.6	30.31

- **Maneuvers were performed approximately 4 minutes before the center time and returned to yaw angle = 0 approximately 3 minutes after the center time**
- **Maneuvers covered solar azimuth angles ranging from 13.7 to 30.6 degrees**

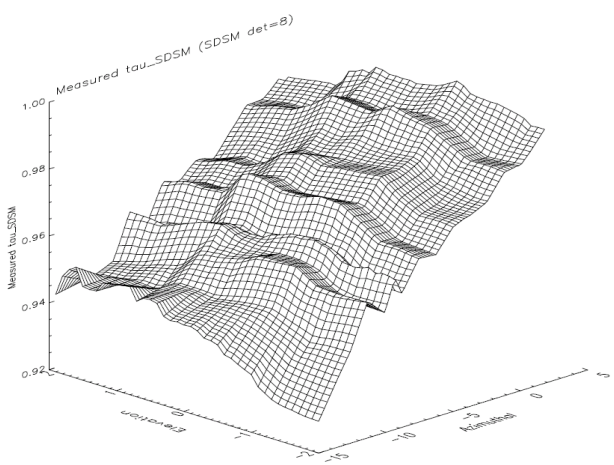
H-factors from Pre-launch SDSM Screen Transmission (LUT)

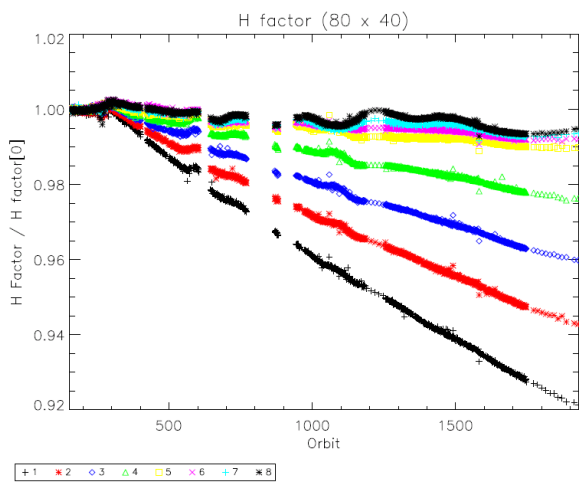


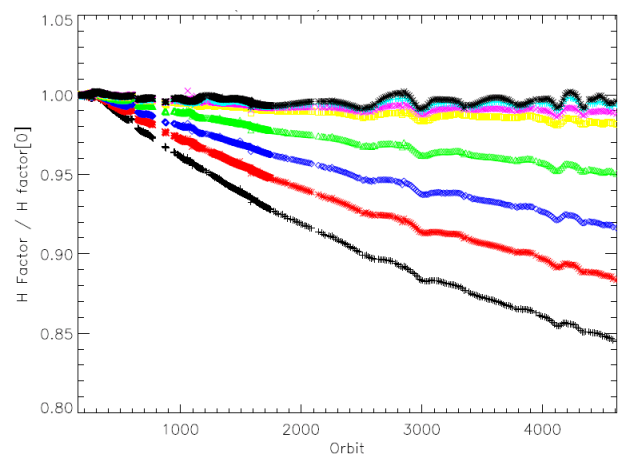




H-factors from On-orbit SDSM Screen Transmission (LUT) – In Op



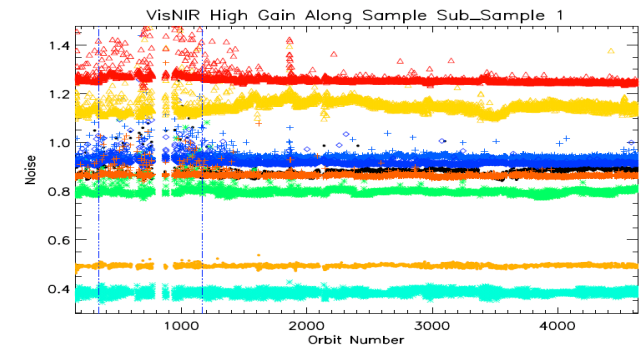


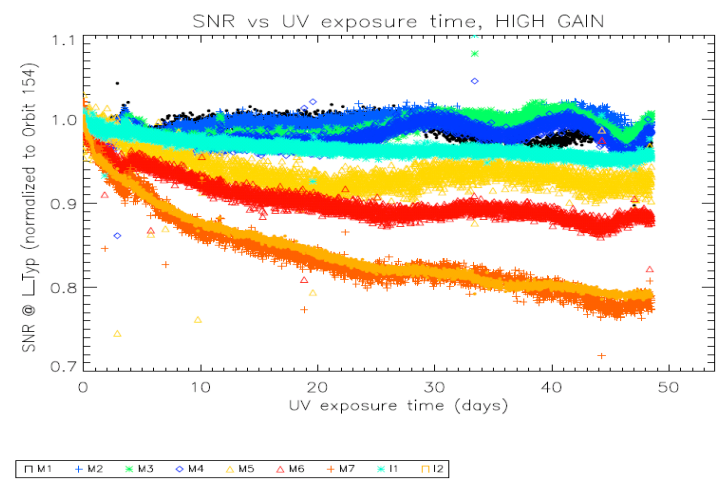


On-orbit SNR Characterization (VIS/NIR/SWIR)

			Pre-Launch (TV)	Post-Launch (SD)	Pre-Launch (TV)	Post-Launch (SD)
Band	Gain	SNR Spec	SNR @ L_typ	SNR @ L_Typ	Margin to Spec	Margin to Spec
M1	Low	316	1092	1012.64	246%	220%
M1	High	352	616.8	582.07	75%	65%
M2	Low	380	1118	1060.91	194%	179%
M2	High	409	622.4	588.37	52%	44%
M3	Low	416	1111	1046.40	167%	152%
M3	High	414	690	655.48	67%	58%
M4	Low	315	963.2	877.97	206%	179%
M4	High	362	581.1	552.24	61%	53%
M5	Low	360	827.9	613.91	130%	71%
M5	High	242	366.6	323.90	51%	34%
M6	High	199	415.2	344.93	109%	73%
M7	Low	340	845.6	551.13	149%	62%
M7	High	215	519.8	403.21	142%	88%
I1	Single	119	240.7	209.80	102%	76%
I2	Single	150	304.1	233.36	103%	56%
M8	Single	74	240.7	201.29	225%	172%
M9	Single	83	304.1	210.91	266%	154%
M10	Single	342	240.7	574.88	-30%	68%
M11	Single	10	304.1	21.51	2941%	115%
I3	Single	6	240.7	144.42	3912%	2307%

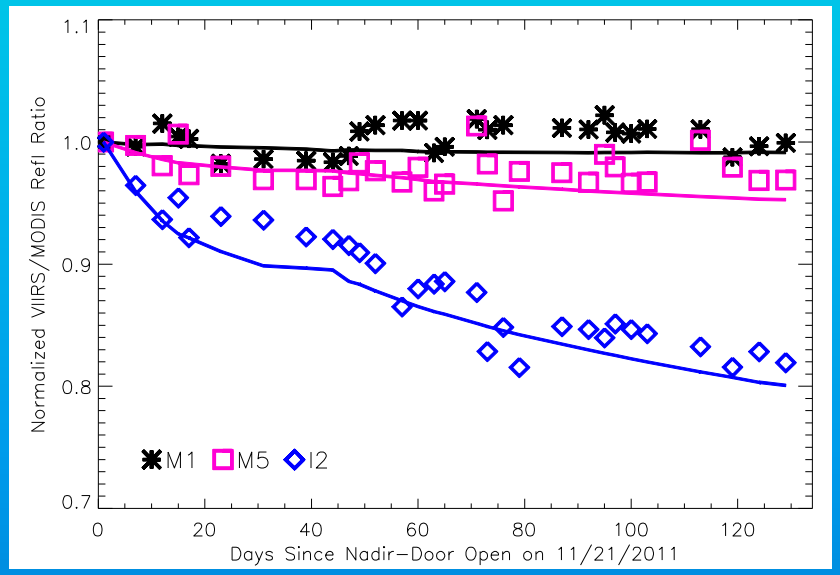
- **SNR post-launch (as of 09/19/2012)**
- **Current SNR values still meet design specification with margin.**





Inter-Calibration with MODIS (Aqua)

- Ratios of VIIRS and MODIS (SNO) reflectance track VIIRS on-orbit change (relative to MODIS)
  - VIIRS reflectance determined from fixed F factor (pre-launch)
  - MODIS reflectance determined from current L1B data product
- VIS/NIR degradation derived from inter-comparison is consistent with that from SD/SDSM calibration

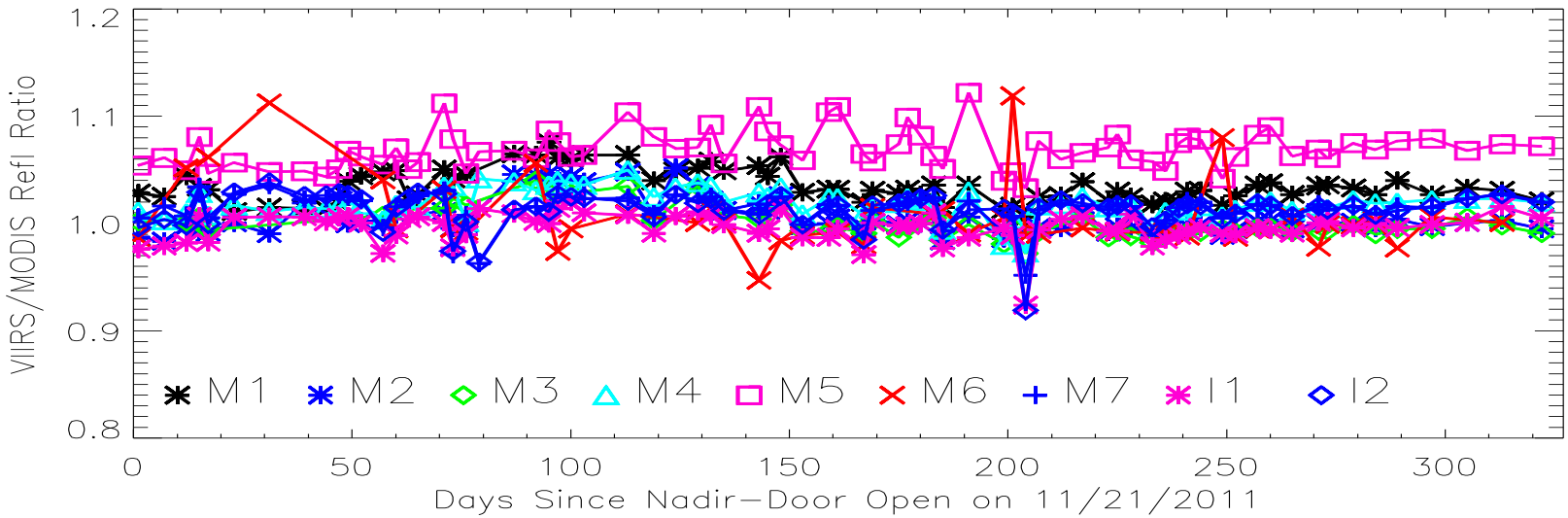


Symbols: trending relative to MODIS; Lines: trending from SD/SDSM calibration

Results played important role in support of VIIRS degradation anomaly investigation

Early effort to track/verify on-orbit changes in NIR response

Inter-Calibration with MODIS (Aqua)



Band	M1	M2	M3	M4	M5	M6	M7	I1	I2
C5	3.5	0.6	0.1	1.9	6.9	0.7	1.4	-0.4	1.3
C6	-1.4	-1.0	0.2	1.8	6.9	1.2	1.3	-0.4	1.3
Mod	-0.4	0.6	-0.6	0.0	4.6	-0.9	0.6	0.9	-1.3
Diff	**1.0**	**1.6**	**0.8**	**1.8**	**2.3**	**2.1**	**0.7**	**1.3**	**2.6**

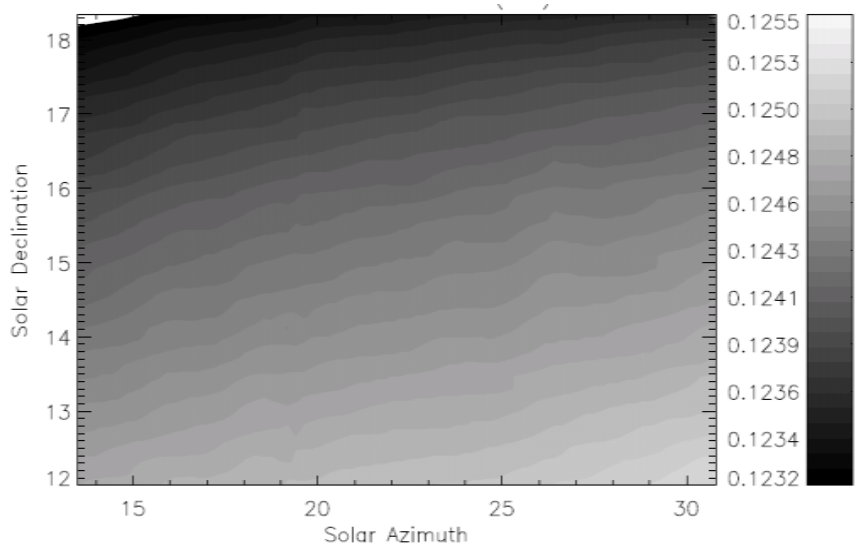
Importance for CLARREO-like Mission

Future Work

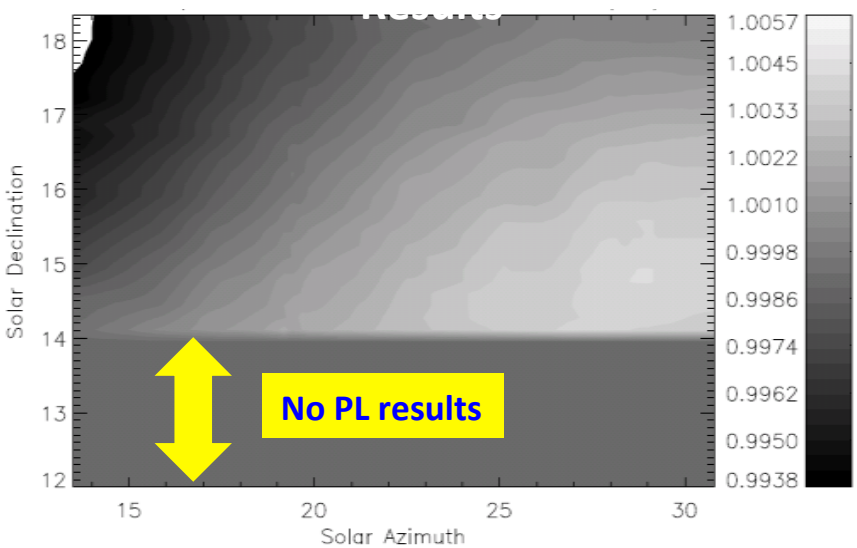
- **Use of SD BRF*tau derived from yaw maneuvers**
  - **Testing underway for operational applications**
- **NIR degradation monitoring**
  - **Continuous monitoring and modeling effort**
  - **Study of impact on relative spectral response (RSR)**
- **SDSM detector OOB leak**
  - **Identified post-launch**
  - **Impact on SD degradation and RSB calibration**
- **Response versus scan angle (RVS) characterization**
- **Traceable uncertainty analysis**
- **Inter-comparison with Aqua MODIS**
  - **Improvements**

SD BRF and SD Screen Transmission

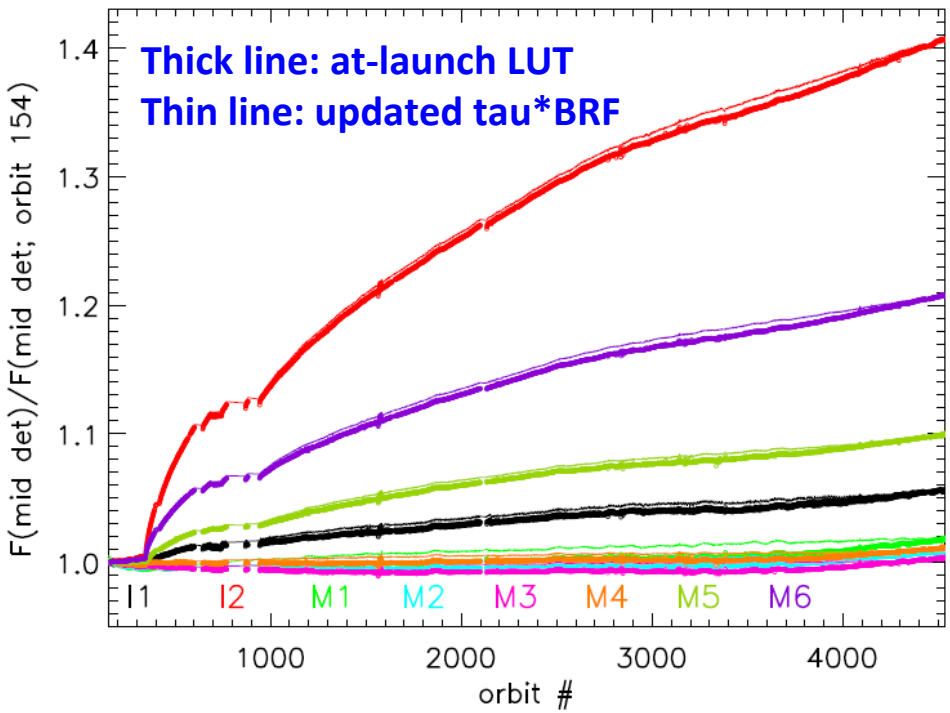
From Yaws



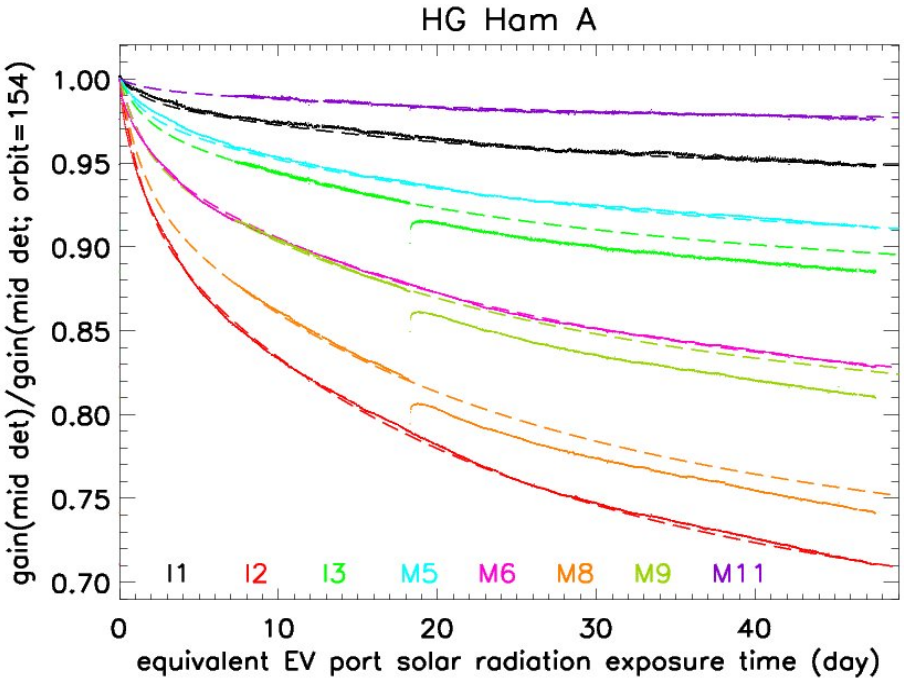
Ratio of Pre-launch LUT to Yaw

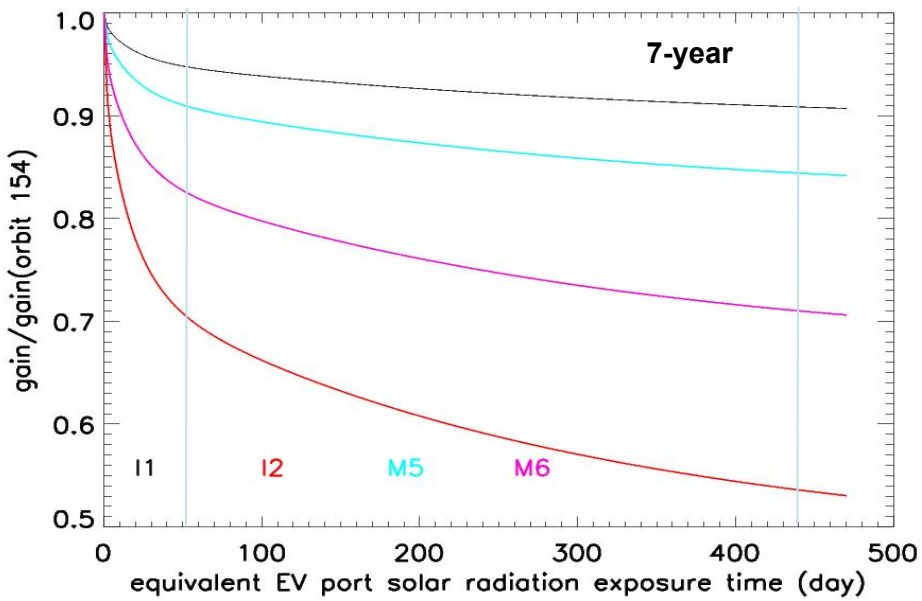


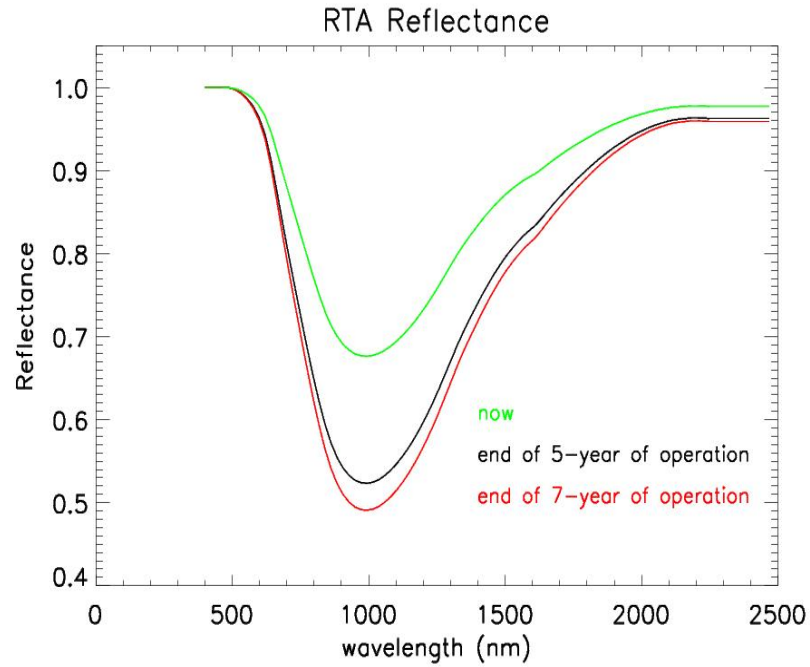
- Tau_{SAS}*SD BRF derived from VIIRS detectors (e.g. M1, detector 9, HG, HAM A)
- Wider angle range used in yaw measurements
- Differences with LUT less than ~0.7 %
- Effect on F factors up to ~0.3 %
- Updated transmission factors delivered on 9/13/2012



NIR degradation model/prediction



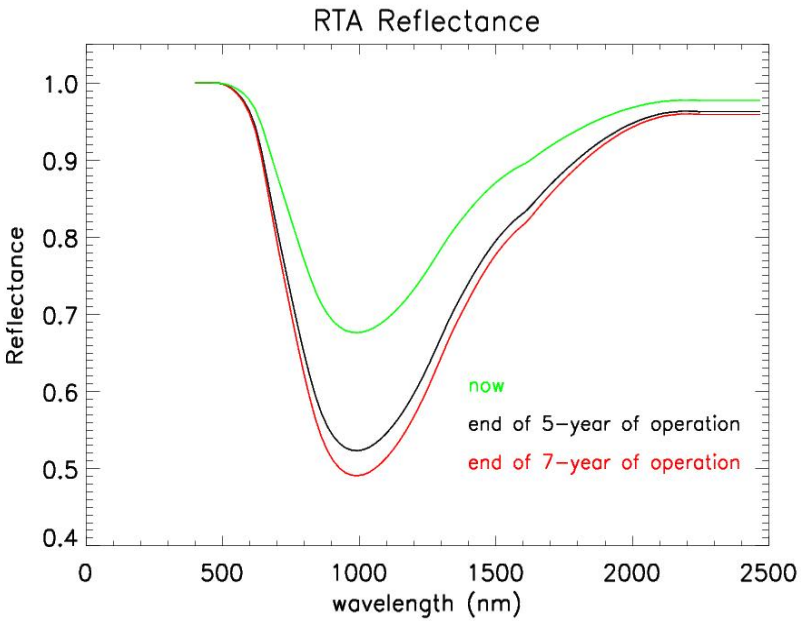


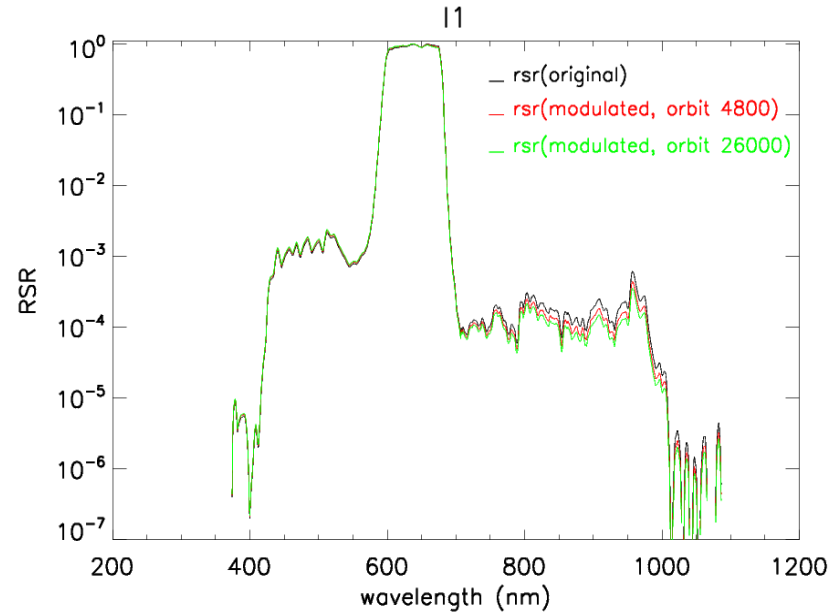


NIR degradation impact on RSR

RSR used in the *F* computation:

$$RSR(\lambda, t) = \frac{RSR_{original}(\lambda) \times G(\lambda, t)}{\max\left[RSR_{original}(\lambda) \times G(\lambda, t)\right]}$$





$$\left[\text{reflectance(new RSR)} - \text{reflectance(old RSR)}\right] / \text{reflectance(old RSR)} \times 100$$

band	I1	I2	I3	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
1 year	-0.02	-0.00	0.00	-0.07	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00
5 year	-0.10	-0.03	0.00	-0.80	-0.07	-0.06	-0.04	-0.05	-0.04	-0.04	0.00	0.00	0.00	0.00

Summary

- **VIIRS has been operated and calibrated as planned**
  - Exceptions: reduced SDSM calibration and BB WUCD frequency; sector rotation applied for lunar observations
- **Early sensor on-orbit performance has been satisfactory**
  - A few code bugs identified/fixed and revised/improved algorithms implemented
  - Frequent LUT updates applied to capture degradation of sensor (NIR) response
  - SNPP SDR data quality review (next week): from beta to provisional
- **Importance of CLARREO**
  - Inter-comparisons and consistent (and traceable) long-term data records

VIRIS Lunar Calibration

Jan 4, 2012 Lunar Cal

M/ D/ Y	H: M: S	Rol_ang	SMnVr	SEaVr	Lat
1/4/2012	8:48:53	-9.49	55.41	35.9	-49.63

Feb 3, 2012 Lunar Cal

Two orbits with roll angle fine tuning

M/ D/ Y	H: M: S	Rol_ang	SMnVr	SEaVr	Lat
2/3/2012	4:21:32	-5.4452	56.19	41.3	-51.17
2/3/2012	6:03:34	-5.2794	55.38	39.6	-49.31

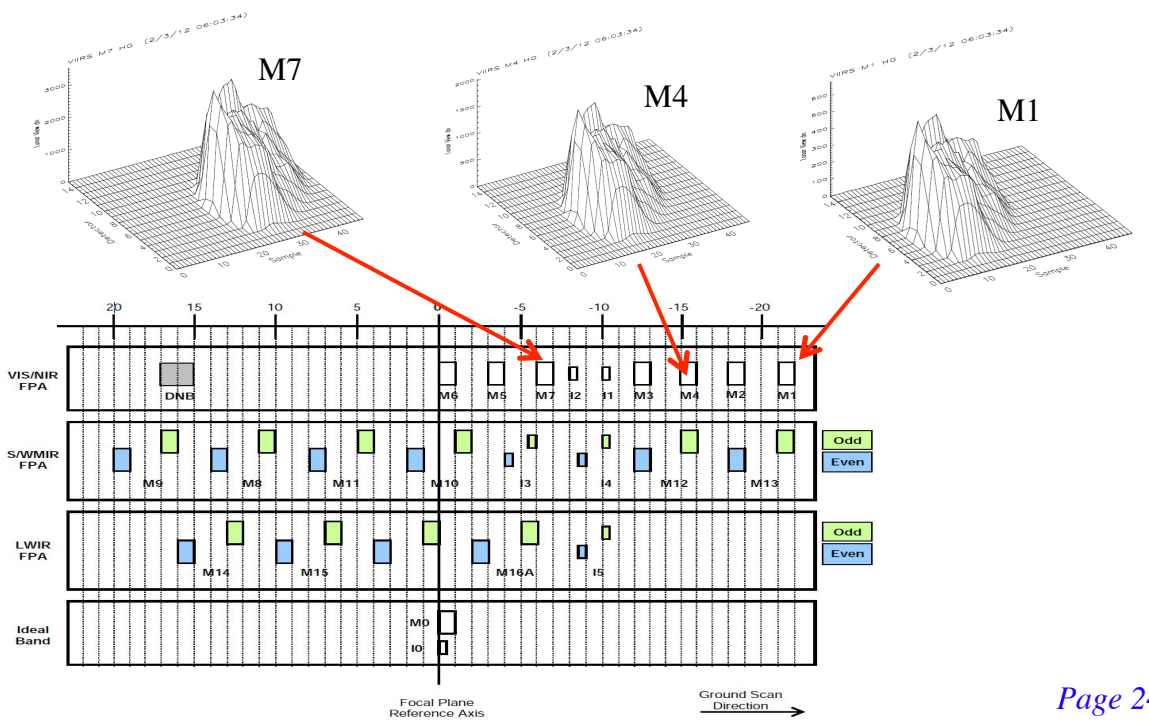
Green: Covers bands M1-M5, M7 and I1-I2; Shift 11 samples toward M1 side

Blue: Covers M6, M8, M10, M11; Shift 10 samples toward DNB side

Mar 3, 2012 Lunar Cal (missed)

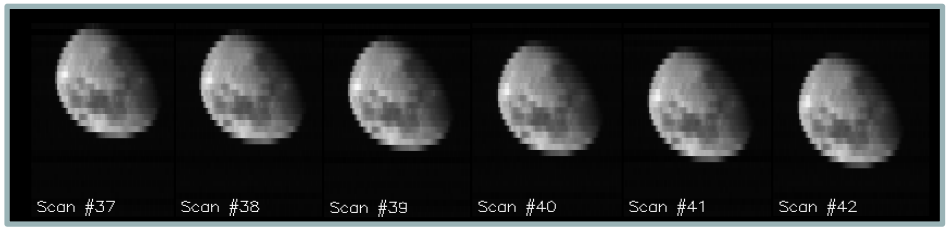
Apr 2, 2012 Lunar Cal (sector rotation, HG)

Lunar Images from 2/3/2012 lunar calibration



Sector rotation is applied so that all bands can record the lunar images in each lunar calibration event

Reflective Solar Bands Calibration – Moon



Multiple scans of I1 lunar images (Jan 4, 2012)

- Compute sensor integrated lunar irradiance (or radiance)

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

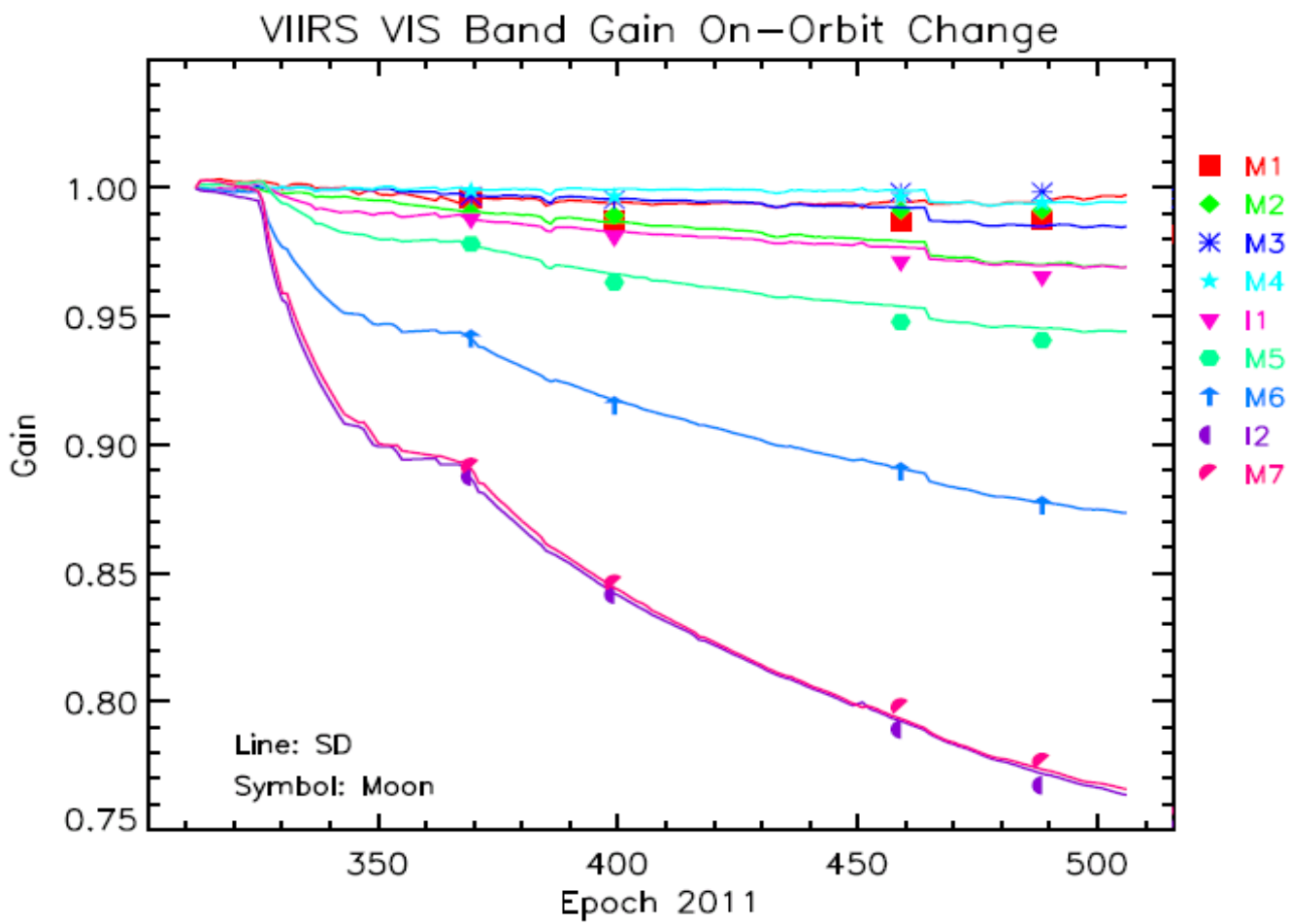
  - *B*: Band; *M*: HAM side; *G*: Gain stage; *d*: Detector; *s*: Sub-frame
  - dn: Background subtracted response
  - c_0, c_1, and c_2: calibration coefficients

- Normalize to lunar model predication (derive relative *F*)

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

  - Lunar model (ROLO) predication provided by Tom Stone (USGS)

Changes in Detector Response from Lunar Observations



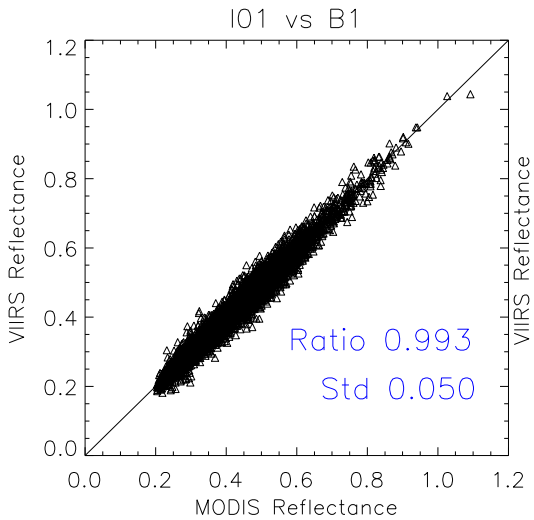
- **Corrections are made for lunar view geometry differences (ROLO model)**
- **VIS/NIR degradation based on lunar calibration is consistent with that from SD/ SDSM calibration**

Definitions of Data Product Maturity Levels (SNPP)

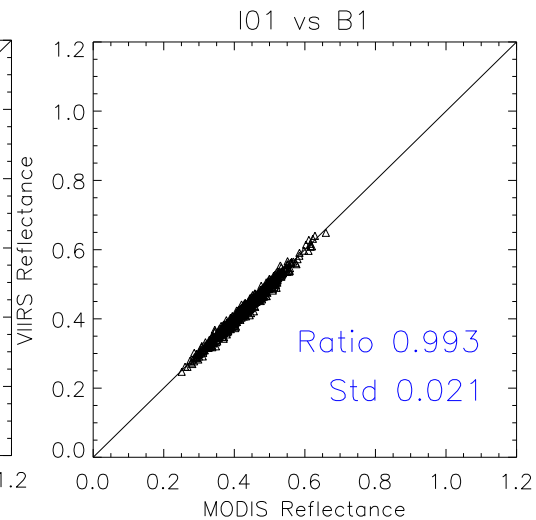
- **Beta**
  - early release product, initial calibration applied, minimally validated and may still contain significant errors
  - available to allow users to gain familiarity with data formats and parameters
  - product is not appropriate as the basis for quantitative scientific publications studies and applications
- **Provisional**
  - 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 NPOESS NPP Cal/Val Team representatives prior to use of the data in publications
- **Validated/Calibrated**
  - 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

SNO Data Sampling

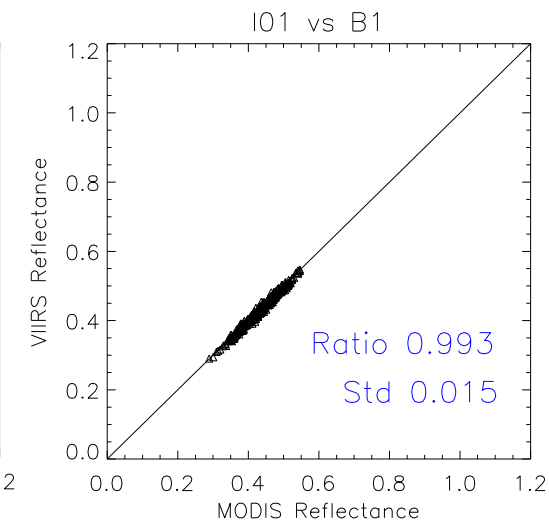
Pixel by pixel match



1 by 1



10 by 10



20 by 20

Grid by grid match

1 degree by 1 degree (latitude and longitude)