Status of VIIRS On-orbit Calibration

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VIIRS Characterization Support Team (VCST), NASA GSFC

S-NPP/JPSS VIIRS SDR Team

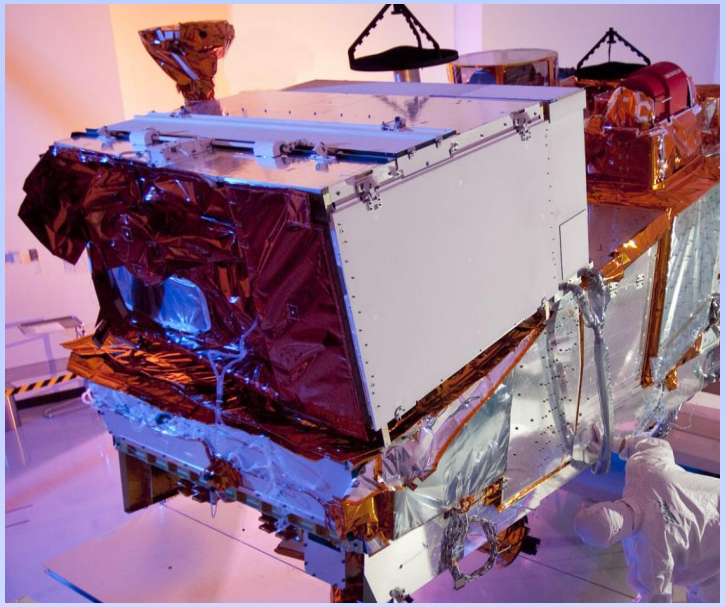
Outline

- Background
- On-orbit Calibration and Characterization
- Performance
- Status of VIIRS SDR and LUTs
- Summary

Background

Visible Infrared Imaging Radiometer Suite (VIIRS)

- **Key instrument on S-NPP and future JPSS satellites**
  - S-NPP launched on October 28, 2011
  - JPSS-1 launch in 2017
    - Sensor ambient phase 1&2 completed
    - Sensor TVAC testing in July, 2014
- **Strong MODIS heritage**
  - Spectral band selection
  - On-board calibrators
  - Operation and calibration
    - Strategies for planning/scheduling
    - Data analysis methodologies / tools



S-NPP VIIRS provides linkage btw EOS (MODIS) and future JPSS (VIIRS) and extends long-term data records for studies for the Earth's land, oceans, and atmosphere

VIIRS Spectral Bands

16 Moderate (radiometric) bands, 5 Imaging bands, 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

1 DNB

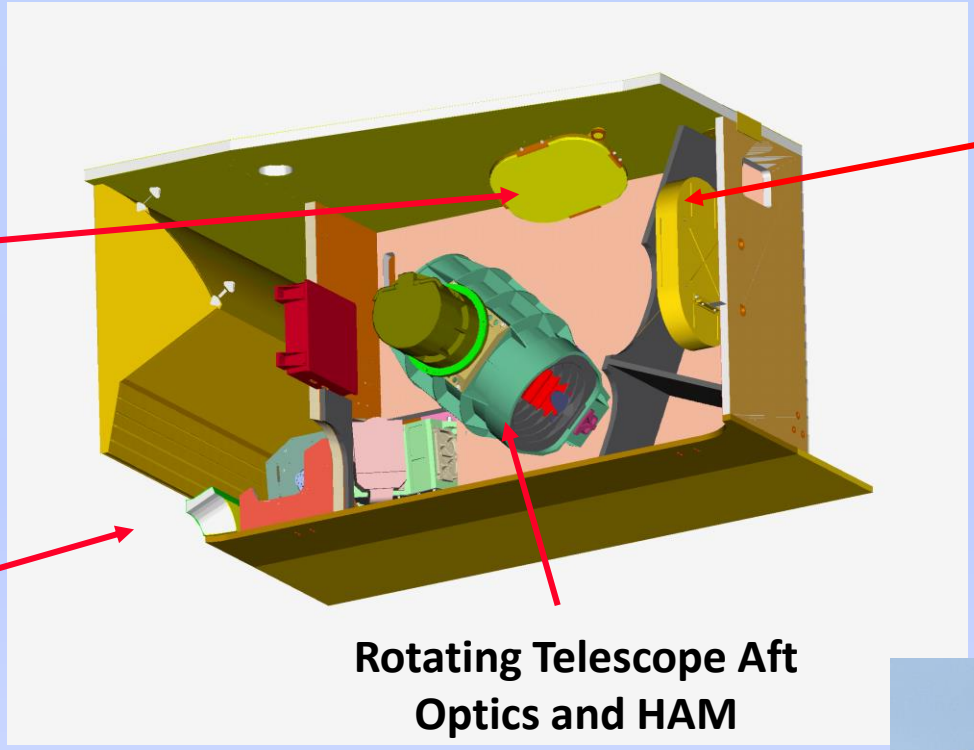
14 RSB
(0.4-2.3 μm)

Dual Gain Bands:
M1-M5, M7, M12

7 TEB
(3.7-12 μm)

VIIRS On-board Calibrators (MODIS Heritage)

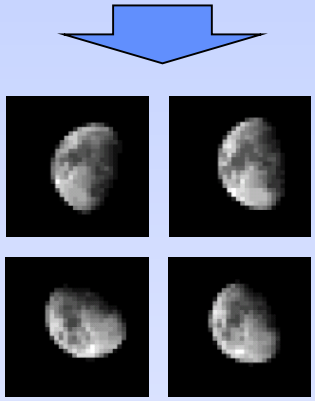
Solar Diffuser

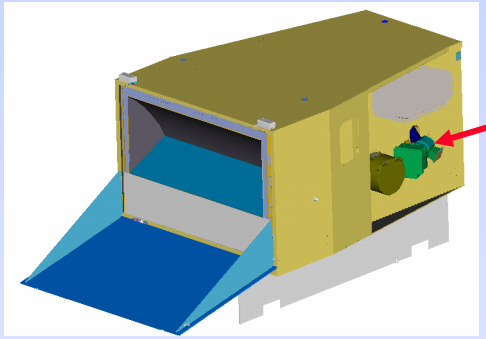


Rotating Telescope Aft Optics and HAM

Blackbody

Extended SV Port (Lunar Observations)





Solar Diffuser Stability Monitor

VIIRS On-orbit Calibration and Characterization

On-orbit Calibration Methodologies:

- **Solar Calibration (RSB)**
  - Quadratic calibration algorithm
  - Linear calibration coefficients derived/updated from SD observations
  - SD degradation tracked by SDSM
- **Lunar Calibration (RSB)**
  - Regularly scheduled at the “same” phase angles
  - Observed through instrument SV port with a data sector rotation
  - Implemented via S/C roll maneuvers (some constraints)
  - Referenced to the ROLO model (USGS)
- **BB Calibration (TEB)**
  - Quadratic calibration algorithm
  - Linear calibration coefficients derived from BB observations

Calibration Activities

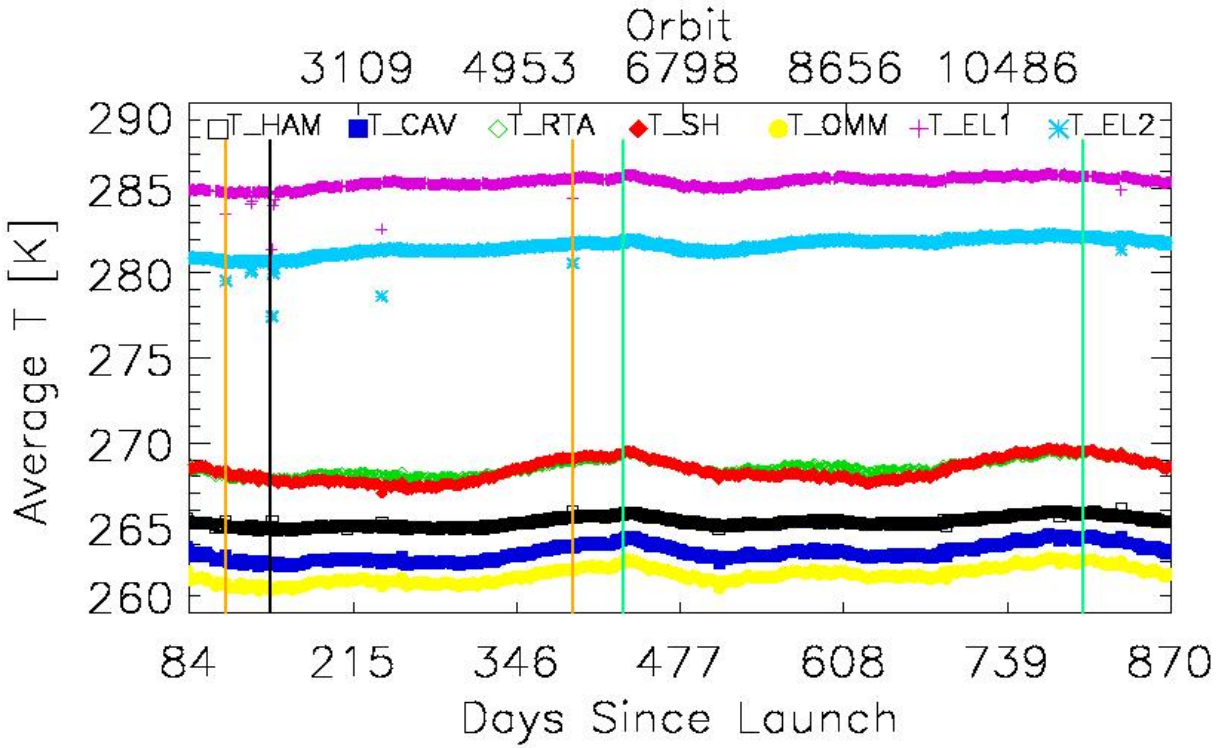
- **SD and SDSM**
  - SD calibration every orbit (no scheduling is needed)
  - SDSM currently scheduled for daily operation (**to be reduced to 3 SDSM operations each week**)
- **Lunar Calibration**
  - Regularly scheduled via S/C roll maneuvers (8-9 time / year)
- **BB Calibration**
  - Nominally controlled at 292 K (no scheduling is needed)
  - Periodic warm-up and cool-down (scheduled on a quarterly basis)
- **Calibration Maneuvers**
  - Pitch (during intensive CAL/VAL phase) – characterize TEB RVS
  - Yaw (during intensive CAL/VAL phase) – characterize SD and SDSM screen
  - Roll for lunar calibration

On-orbit Performance

- **Instrument and On-board Calibrators**
  - Key Telemetry (Instrument Temperatures)
  - SD Degradation
  - BB Stability
- **Changes in Spectral Band Response**
  - Reflective Solar Bands (RSB)
    - **Modulated RSR and impact**
  - Thermal Emissive Bands (TEB)
- **Detector SNR and NEdT**

Instrument Temperatures

Vertical lines: SC or sensor anomalies and resets



Telemetry:

Half Angle Mirror

Sensor Cavity

Rotating Telescope

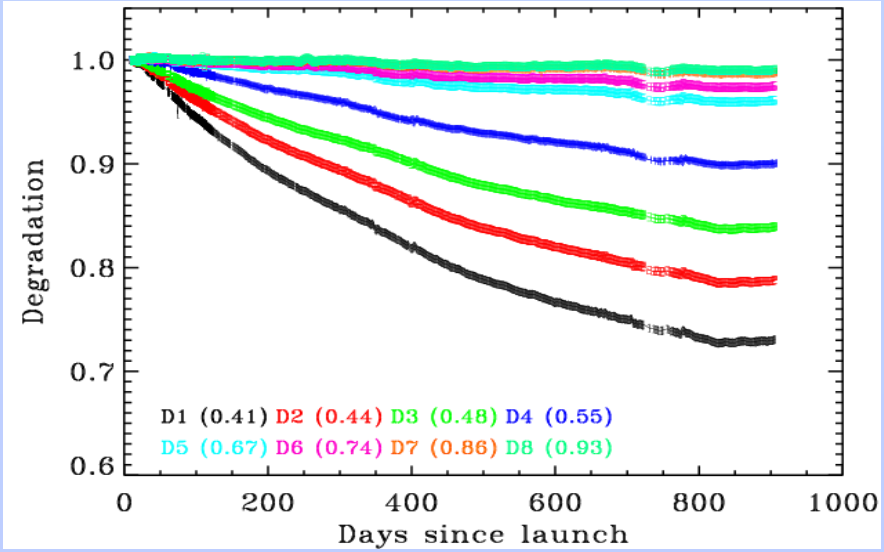
BB Shield

Opt. & Mech. Module

Electronics

Instrument temperatures have been very stable

SD Degradation

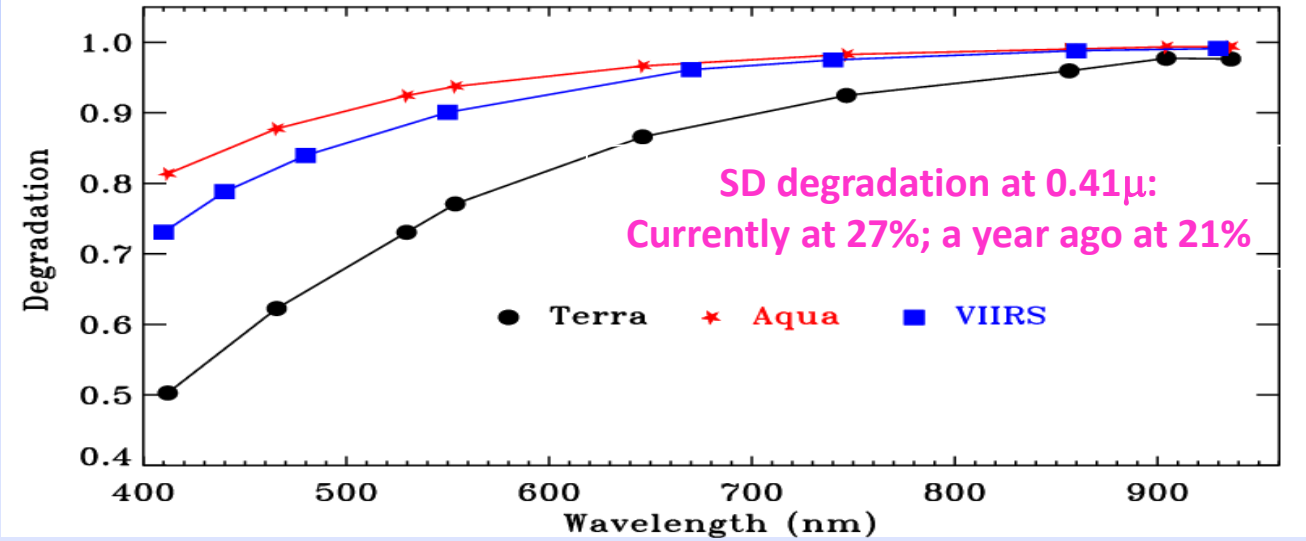


VIIRS SD Degradation

(As of April 2014)

Shorter wavelength: larger degradation

Comparison of MODIS & VIIRS SD Degradation

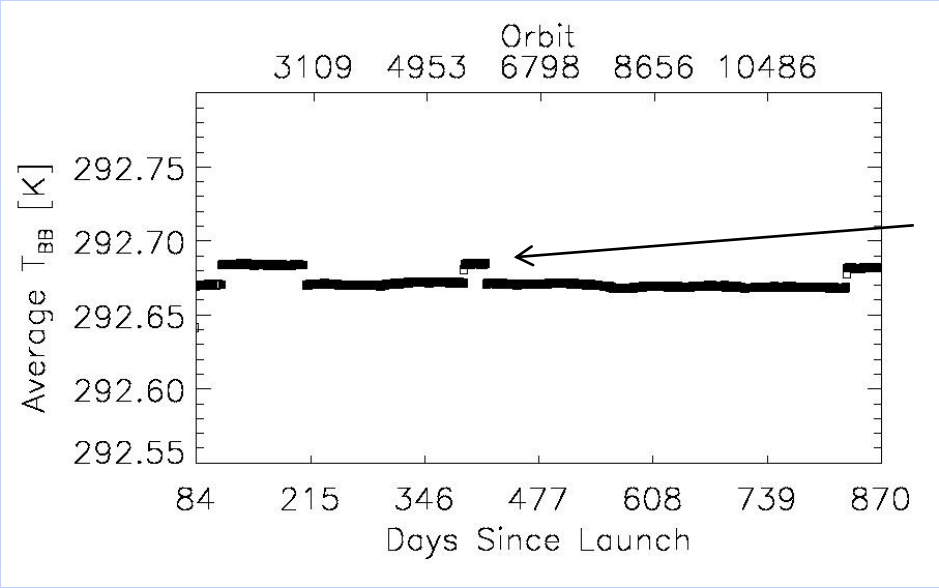


VIIRS has no SD door

A-MODIS SD door is closed when no calibration is scheduled

T-MODIS SD door fixed at open since July 2003

BB Stability

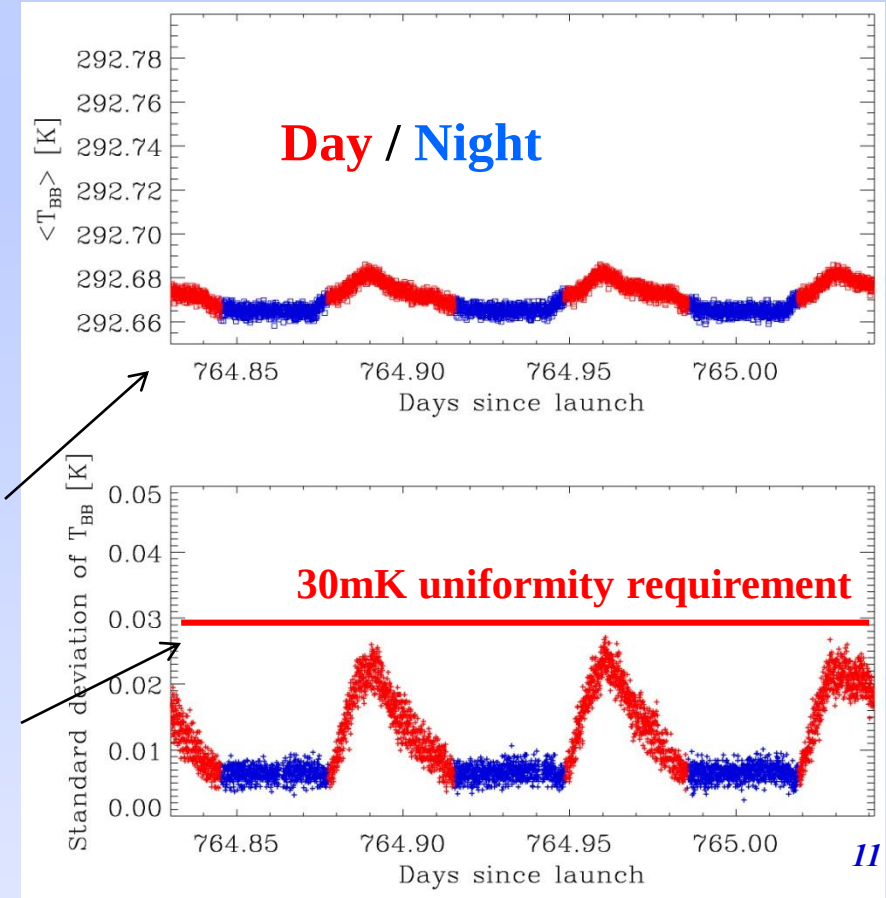


Long-term trend of daily-averaged T_{BB}

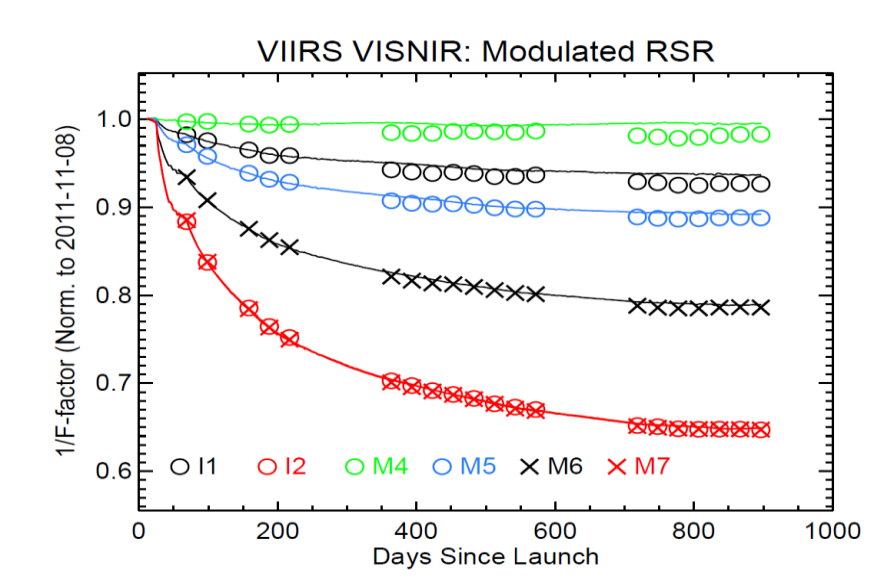
- Stable to within a few mK.
- ~15mK offsets were due to the use of different T_{BB} settings.

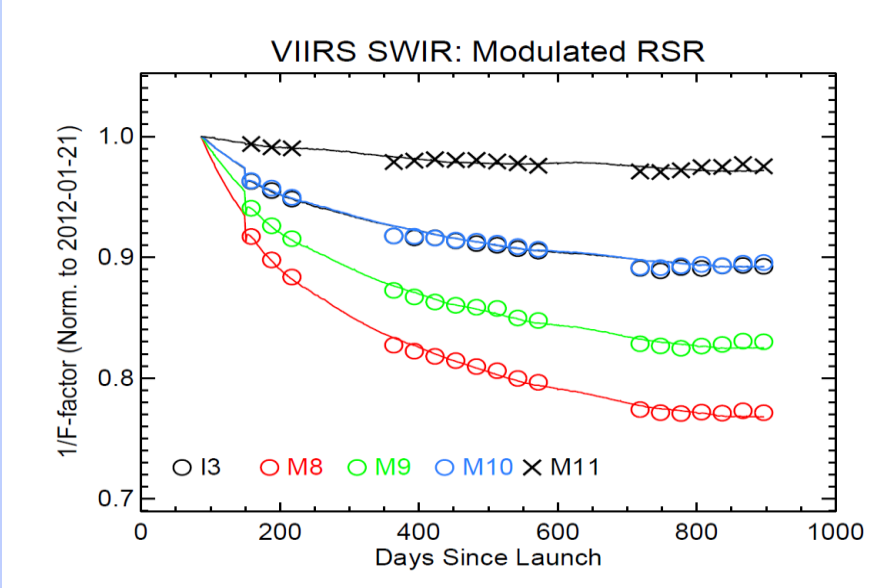
Short-term stability (scan-by-scan T_{BB})

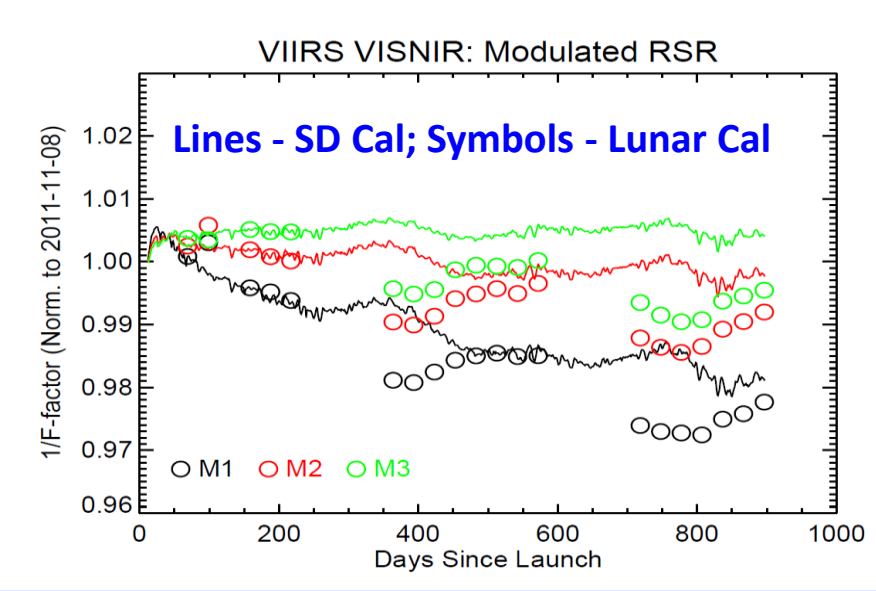
- Orbital variations of individual thermistors up to 40mK
- Variations in average temperature ~ 20mK
- Temperature difference between individual thermistors up to 60mK
- BB uniformity meets the requirement with standard deviation less than 30mK



Changes in Spectral Band Response (RSB)







SD and lunar calibration made at the same angle of incidence (AOI)

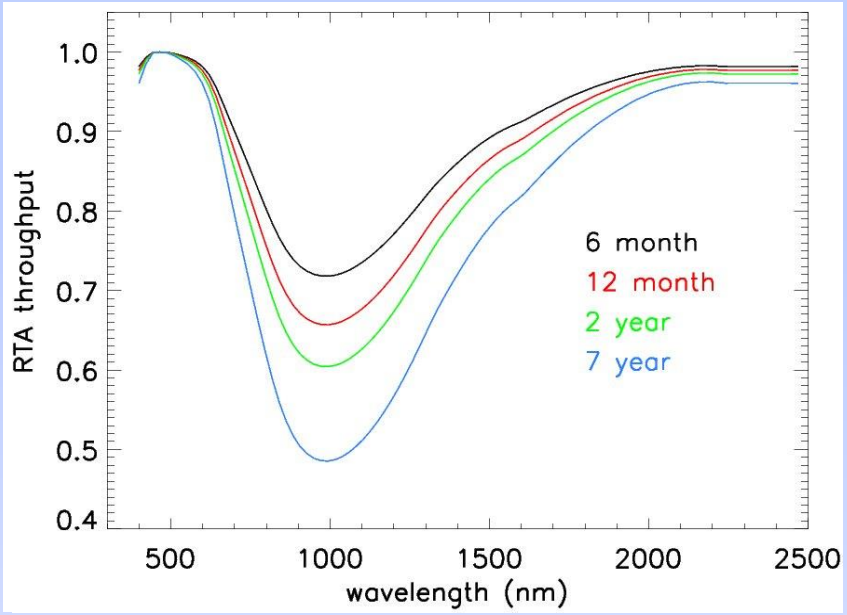
Large changes in NIR/SWIR response

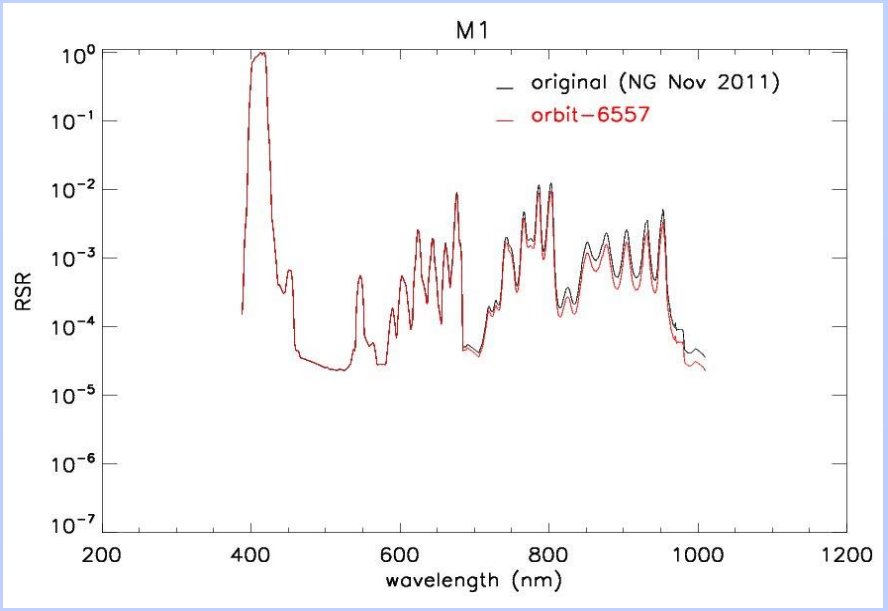
Noticeable SD and Lunar calibration seasonal difference in VIS (M1-M3)

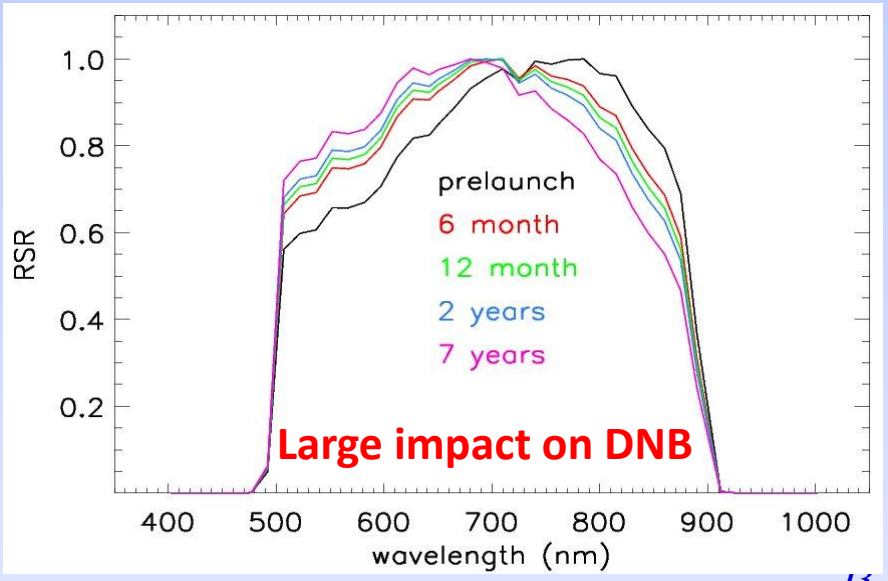
Impact of λ-dependent Changes in Detector Response

Mirror Degradation Impact on Sensor Relative Spectral Response

λ dependent optics degradation



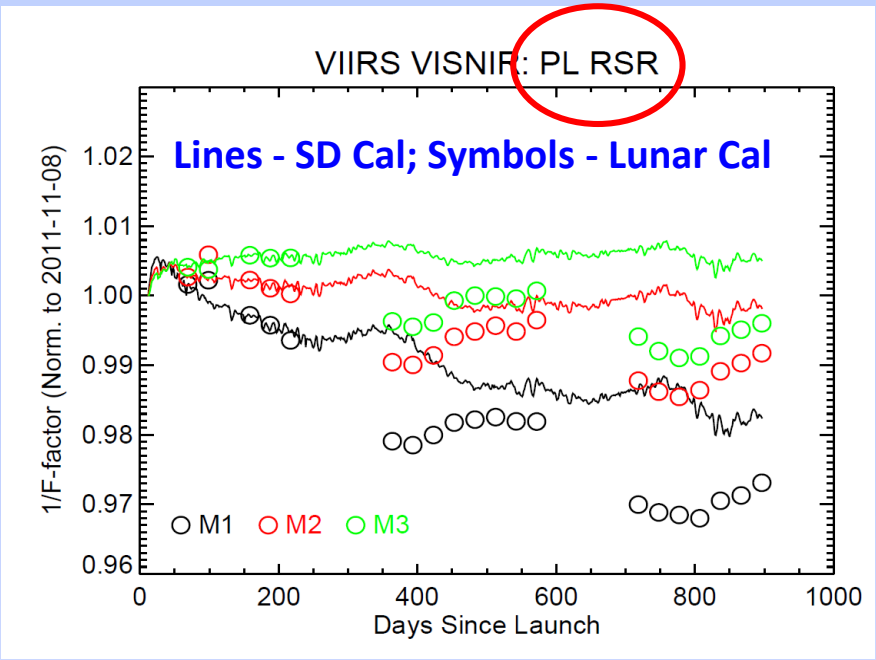


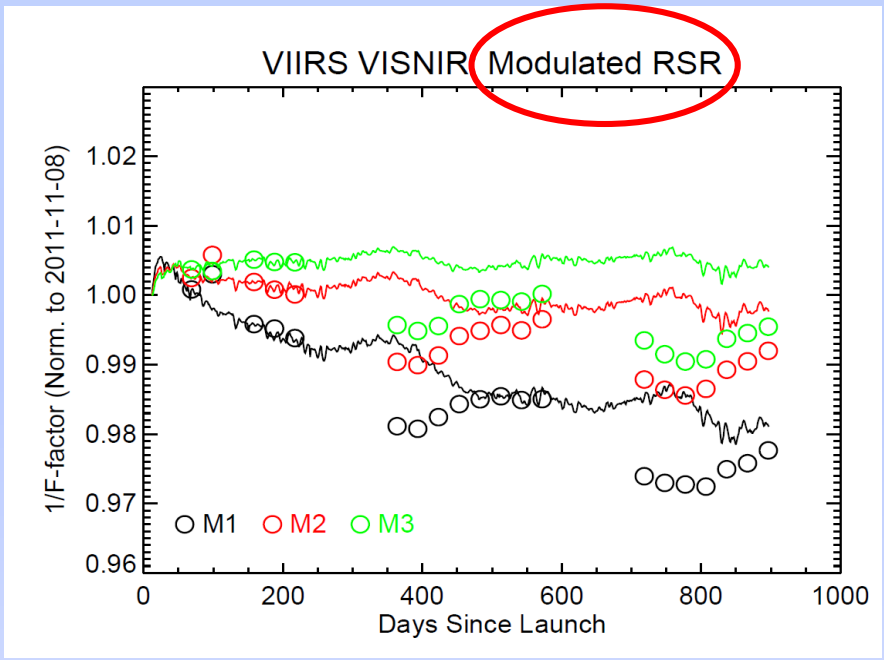


Modulate RSR has been applied to VIIRS calibration and data production

Impact of λ-dependent Changes in Detector Response

Modulated RSR should be applied to both solar and lunar calibration





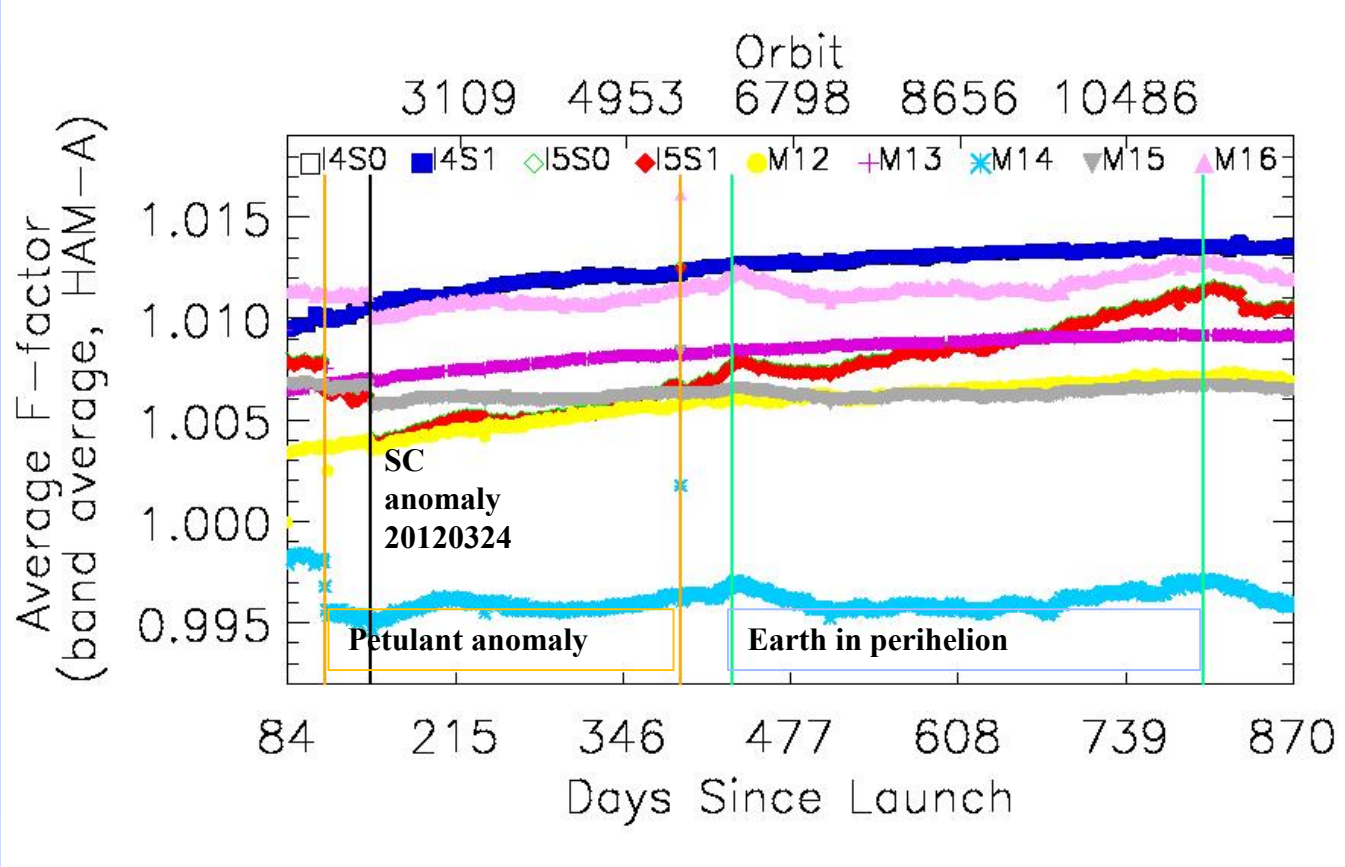
Remaining issues:

(1) lunar model uncertainty (to be investigated)

(2) solar vector calculation error (in IDPS common geolocation library)

Changes in Spectral Band Response (TEB)

The discontinuities in the F-factor are coincident with SC maneuvers and anomalies during which the cold FPA temperatures changed



Band	I4	I5	M12	M13	M14	M15	M16
Average F-factor: 03 26 2012	1.0105	1.0040	1.0035	1.0070	0.9946	1.0056	1.0102
Average F-factor: 03 16 2014	1.0135	1.0106	1.0068	1.0092	0.9960	1.0065	1.0119
Trend [%]	0.30	0.65	0.33	0.21	0.14	0.09	0.18

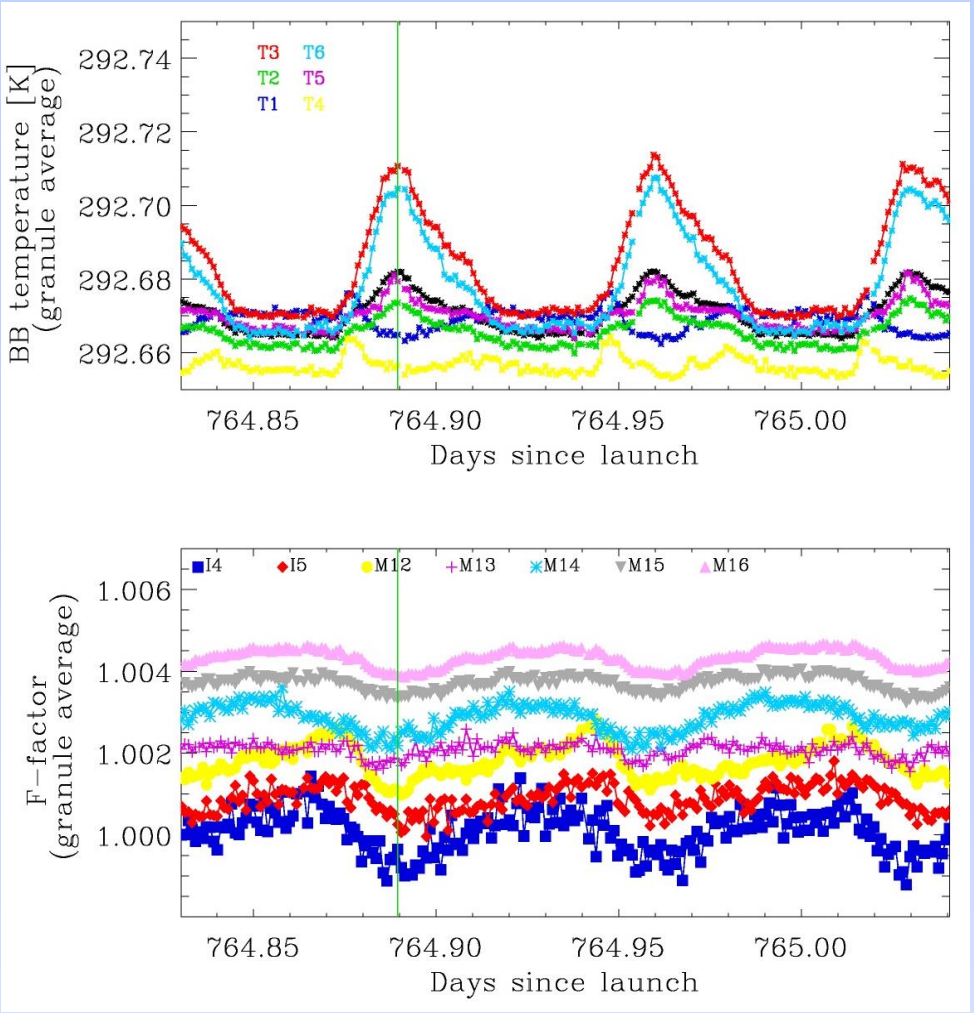
TEB Detector Short-term Stability

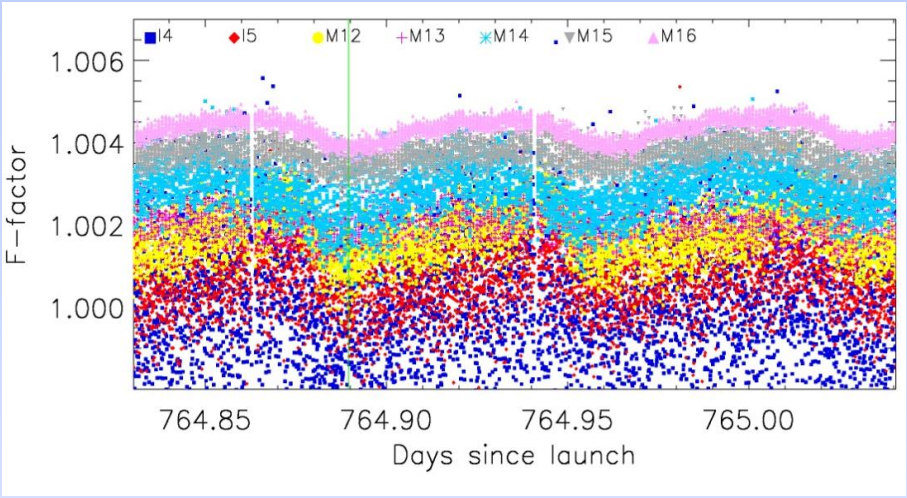
Detector responses (F-factors) show small orbital variations:

- **±0.2% or less for scan-by-scan**
- **±0.1% or less for granule average**

F-factor orbital variations correlate with T_{BB} variations

Orbits: 10853, 10854,





Scan-by-scan (HAM-A)

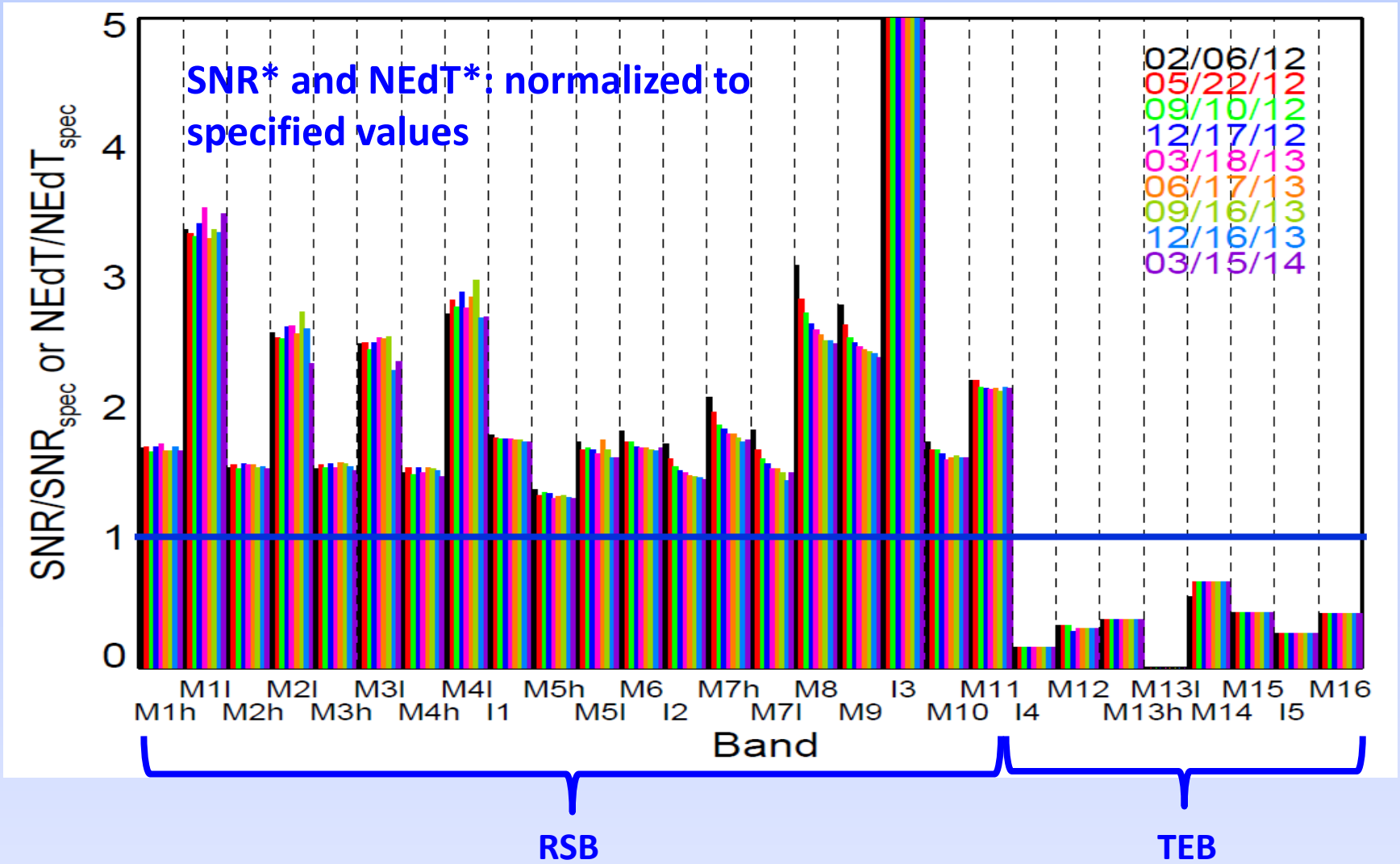
Granule average (HAM-A)

*** For clarity the F-factors are shifted.**

Detector SNR (RSB) and NEdT (TEB)

RSB SNR* > 1: performance better than specified requirements

TEB NEdT* < 1: performance better than specified requirements



Status of VIIRS SDR and LUTs

- **IDPS VIIRS SDR Code/LUTs (radiometric)**
  - 18 code versions post launch; numerous LUT updates.
  - Improved LUT update strategy (on demand -> weekly -> automated).
- **VIIRS SDR Cal/Val Maturity**
  - Beta review: April 5, 2012
  - Provisional review: October 24, 2012
  - Validated review: December 19, 2013

Improved SD BRF and screen transmission and SDSM screen transmission LUT

Moon in space view algorithm (RSB)

Modulate relative spectral response (RSR)

RSB auto-calibration in SDR

Solar vector error correction to be implemented

Status of VIIRS SDR Code/LUTs

- **NASA Land PEATE SDR Code/LUTs and Data Reprocess (C1.0 and C1.1)**
  - Enabling independent data quality assessment and validation, and improvements
  - 13 sets of LUTs for VISNIR/SWIR and DNB delivered to Land PEATE for SDR/EDR assessment and data reprocess.
    - Jan 31, 2013: LUTs from Jan 2012 to Jan 2013 generated using IDPS algorithm Mx6.3 but *with smoothed functions to remove outliers*.
    - Nov 13, 2013: LUTs from Jan 2012 to Oct 2013 generated with calibration improvements based on Mx6.4, including *SD/SDSM screen transmission, SD BRDF, RTA mirrors degradation model, modulated RSRs, and smoothed fitting functions*.
    - Mar 12, 2014: LUTs from Jan 2012 to Nov 2013 generated with "best" sensor characterization improvements based on Mx7.2 algorithm for Land PEATE reprocess Collection 1.1, including *DNB Stray Light Correction algorithm and smoothed fitting functions*.
    - Apr 1, 2014: Latest LUTs update for Dec 2013, and Jan/Feb 2014.

Summary

- **VIIRS has continued its nominal operation and calibration**
  - No changes are made in sensor operation configurations
  - SD/SDSM, BB WUCD, and lunar calibration activities are regularly performed
  - Changes in sensor response are accurately tracked by the OBC
  - Calibration LUTs are frequently updated
- **Sensor overall performance meets its design requirements**
  - VIIRS SDR maturity has reached the “Validated” status
- **Dedicated calibration effort remains critically important to assure SDR quality**
  - The modulated RSRs, as a result of mirror degradation, have been developed and applied to sensor SDR calibration and data production
  - SDR impact due to newly identified solar vector error has be assessed and will be addressed in the future updates
  - Small solar and lunar calibration differences to be investigated

Operation and 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 calibration)
- Yaw maneuvers; 2/15/12 – 2/16/12 (SD/SDSM screen transmission)
- Pitch maneuvers: 2/20/12 (TEB response versus scan angle)
- OBC calibration activities: SD, SDSM, and BB

Product Maturity Definition

- **Beta (L+150) – April 05, 2012**
  - 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) – October 24, 2012**
  - 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+1 yr) – December 19, 2013**
  - 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
  - There will be strong versioning with documentation

Major IDPS SDR Code/LUTs Update Timeline (Radiometric)