

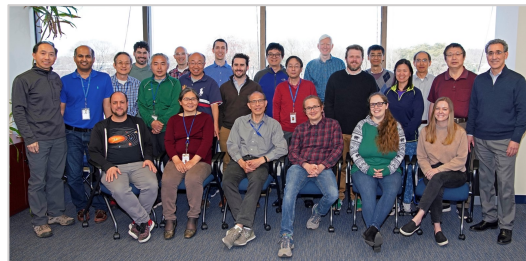
MODIS and VIIRS Calibration Update

Jack Xiong

Code 618.0, NASA Goddard Space Flight Center, Greenbelt, MD 20771

and

MODIS and VIIRS Characterization Support Team (MCST and VCST), NASA GSFC



Outline

- MODIS and VIIRS On-orbit Calibration
- Instrument Performance Update
- MODIS and VIIRS L1B Status
- Summary



1999 →



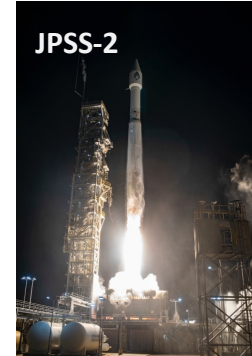
2002 →



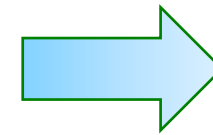
2011 →



2017 →



2022 →



JPSS-3/4 VIIRS
(2028/2032)

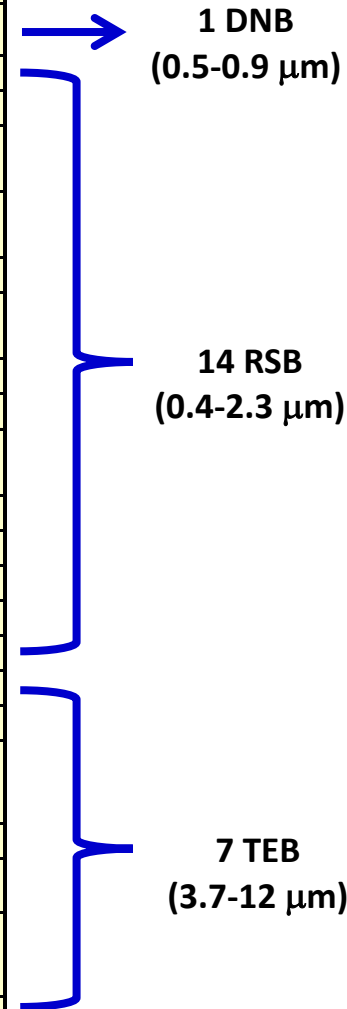
MODIS and VIIRS On-orbit Calibration

MODIS and VIIRS Spectral Bands

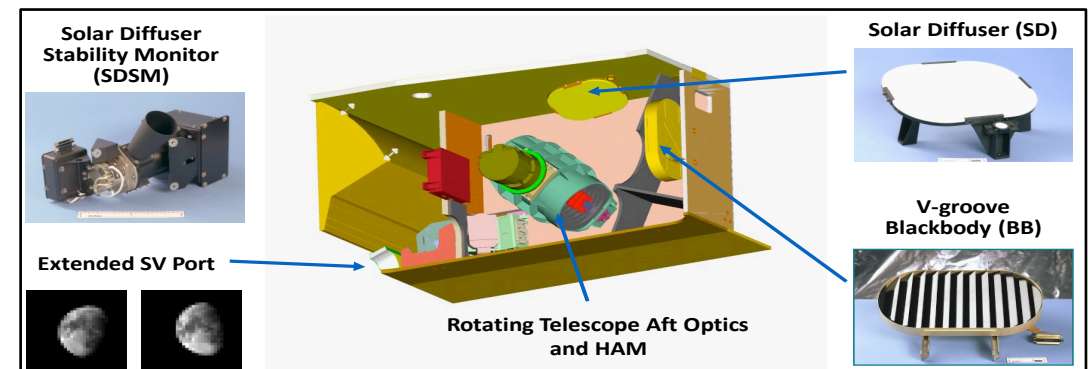
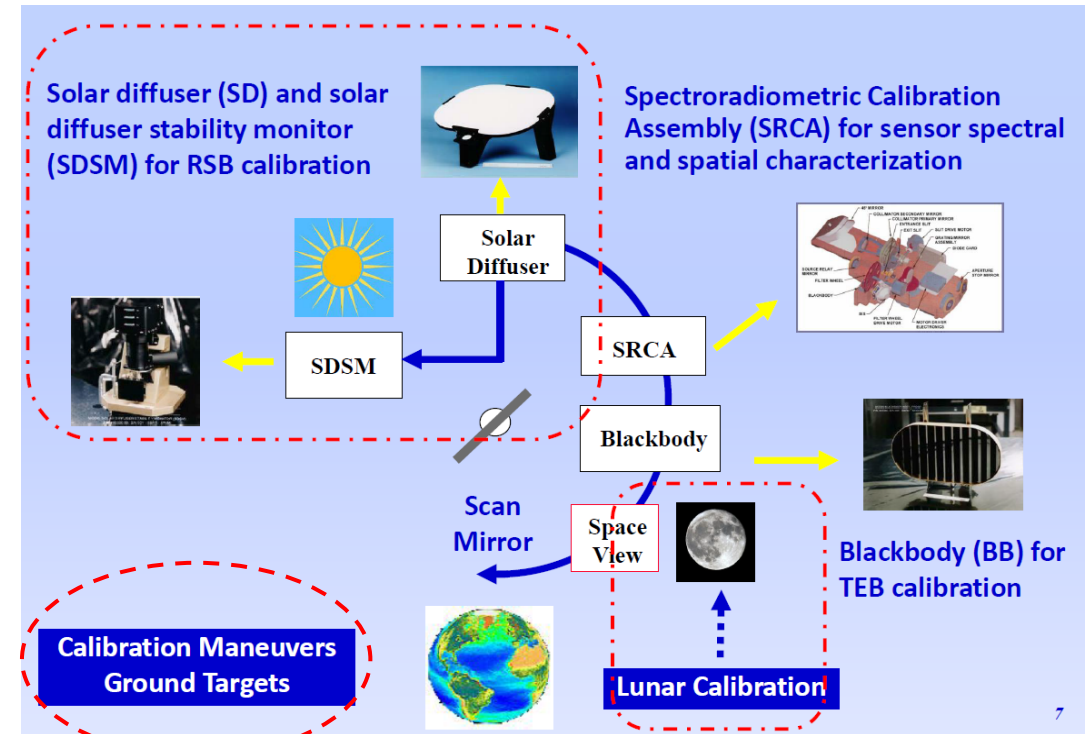
VIIRS Band	Spectral Range (um)	Nadir HSR (m)	MODIS Band(s)	Range	HSR
DNB	0.500 - 0.900				
M1	0.402 - 0.422	750	8	0.405 - 0.420	1000
M2	0.436 - 0.454	750	9	0.438 - 0.448	1000
M3	0.478 - 0.498	750	3 10	0.459 - 0.479 0.483 - 0.493	500 1000
M4	0.545 - 0.565	750	4 or 12	0.545 - 0.565 0.546 - 0.556	500 1000
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

Dual Gain: M1-M5, M7, M13

MODIS: Bands 33-36



Similar Calibration Methodologies



Instrument Performance Update: Terra MODIS

- **Instrument Operations and OBC Functions – Normal**

- Same configuration (A-side electronics with B-side formatter) since 2003
- CFPA at 83 K; BB at 290 K (285 K since 04/25/2020)

- **Radiometric**

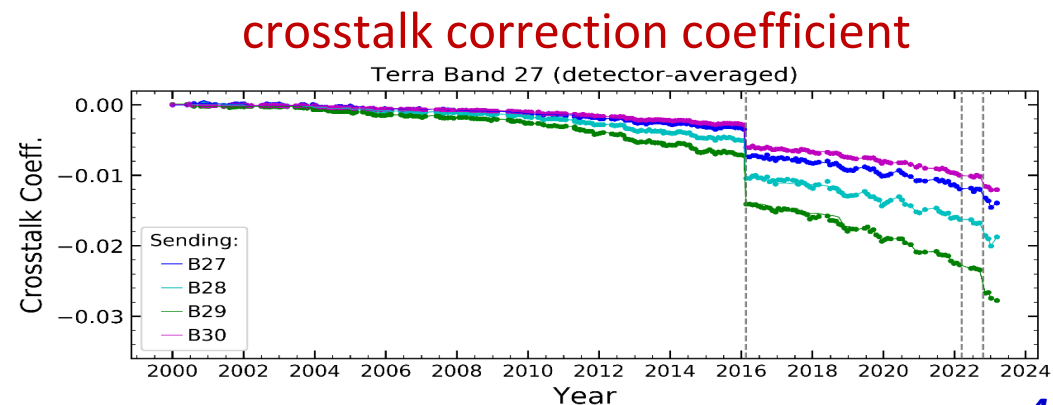
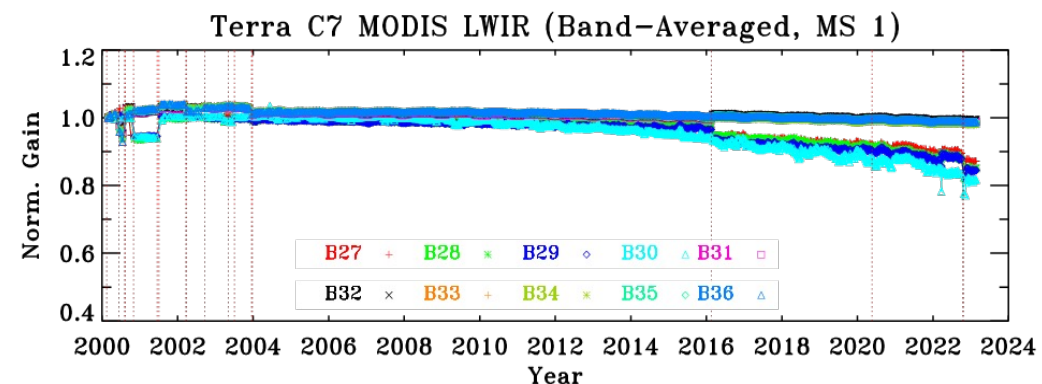
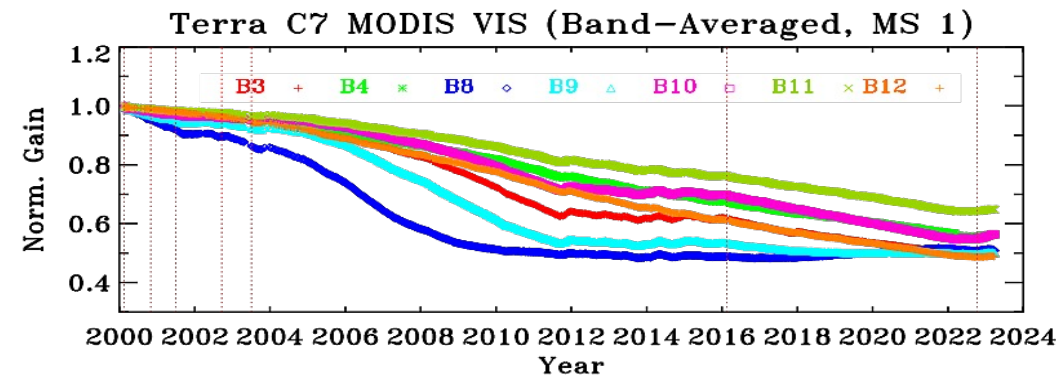
- Large changes in sensor response and RVS at short wavelengths (VIS/NIR bands)
- Changes in sensor performance parameters (e.g. TEB gains and crosstalk coefficients) due to sensor Safe Mode
- Large SD degradation at short wavelengths
- Terra LWIR PV crosstalk correction (implemented since C6.1) remains effective

- **Spatial and Spectral**

- Band-to-band registration (BBR): stable since launch
- Center wavelength and bandwidth: changes are within 0.5 nm and 1.0 nm, respectively, for most VIS/NIR bands

- **Geolocation**

- C6.1 RMSE Track: 43 m; Scan: 45 m, nadir equivalent



Instrument Performance Update: Aqua MODIS

- **Instrument Operations and OBC Functions – Normal**

- Same configuration (B-side electronics and formatter) since launch
- CFPA at 83 K; BB at 285 K

- **Radiometric**

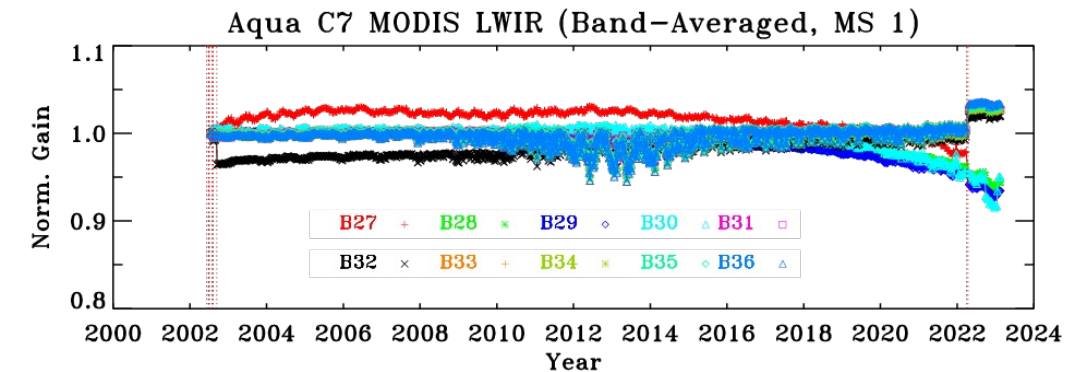
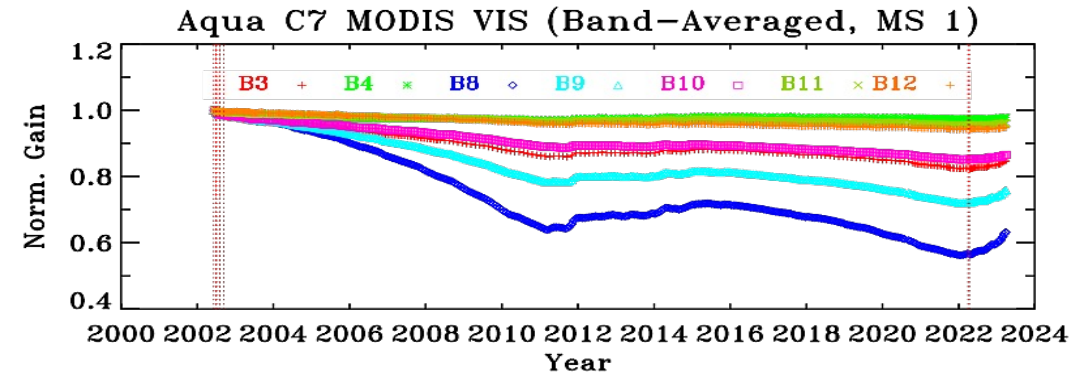
- Large changes in sensor response and RVS at short wavelengths (VIS/NIR bands)
- Changes in sensor performance parameters (e.g. TEB gains and crosstalk coefficients) due to sensor Safe Mode
- Large SD degradation at short wavelengths
- Aqua LWIR PV crosstalk correction in C7 (entire mission) and C6.1 (forward only) to address more recent increase of the crosstalk effects

- **Spatial and Spectral**

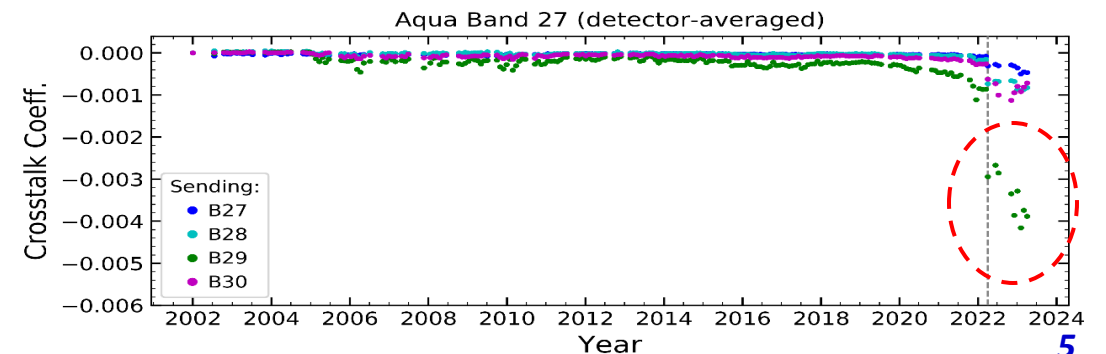
- Band-to-band registration (BBR): stable since launch
- Center wavelength and bandwidth: changes are within 0.5 nm and 1.0 nm, respectively, for most VIS/NIR bands

- **Geolocation**

- C6.1 RMSE Track: 46 m; Scan: 54 m, nadir equivalent

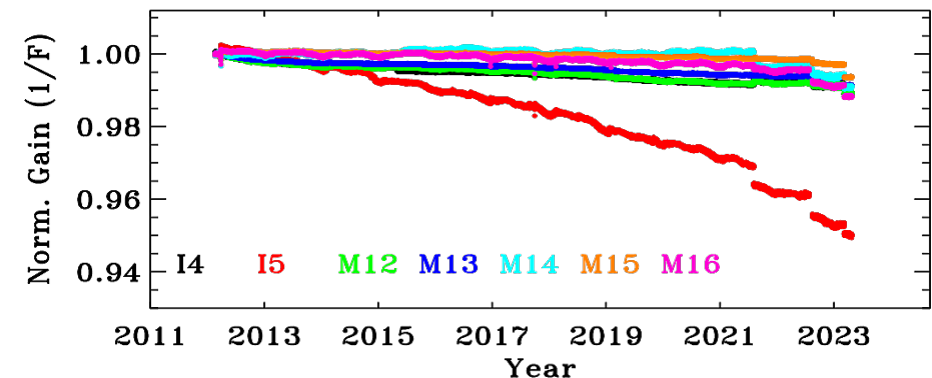
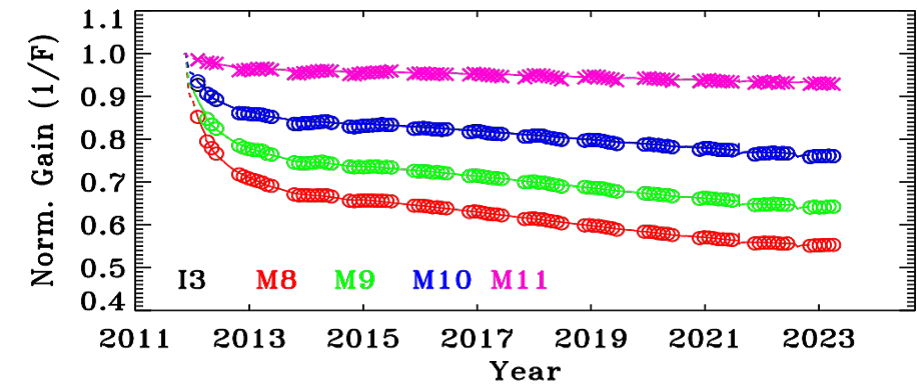
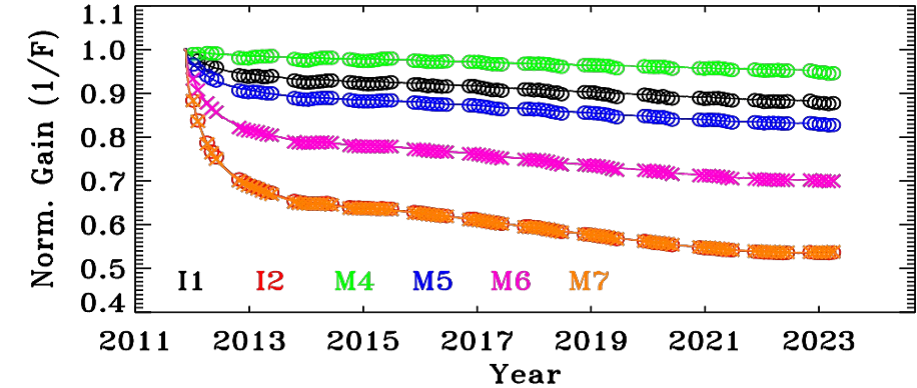


crosstalk correction coefficient



Instrument Performance Update: S-NPP VIIRS

- **Instrument Operations and OBC Functions – Normal**
 - Same configuration (B-side) since launch
 - CFPA at 80 K; BB at 292.5 K
- **Radiometric**
 - Large degradation in several NIR and SWIR bands, especially at mission beginning (a known issue due to RTA mirror coating contamination)
 - A gradual gain decrease for I5 (5% over 11 years)
 - Large SD degradation at short wavelengths
 - DNB stray light correction remains effective
- **Spatial and Spectral**
 - Band-to-band registration (BBR): stable since launch
 - Relative spectral response (RSR): on-orbit modulated RSR
- **Geolocation**
 - C2 RMSE Track: 59 m; Scan: 48 m



Instrument Performance Update: N-20 VIIRS

- **Instrument Operations and OBC Functions – Normal**

- Same configuration (A-side) since launch
- CFPA at 80 K; BB at 292.5 K

- **Radiometric**

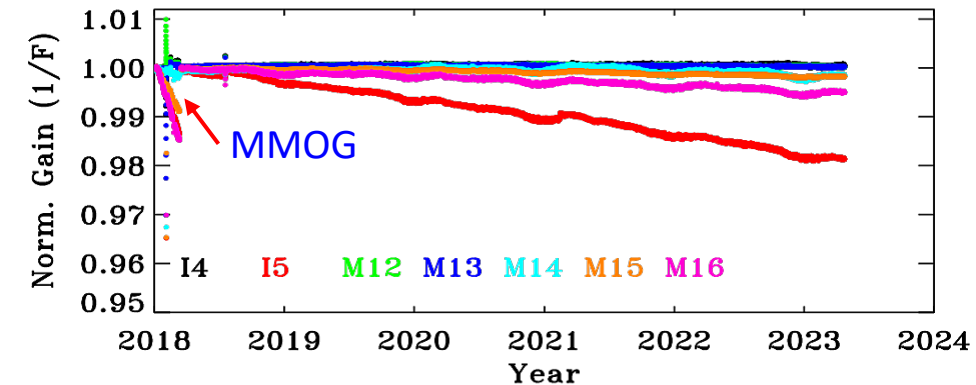
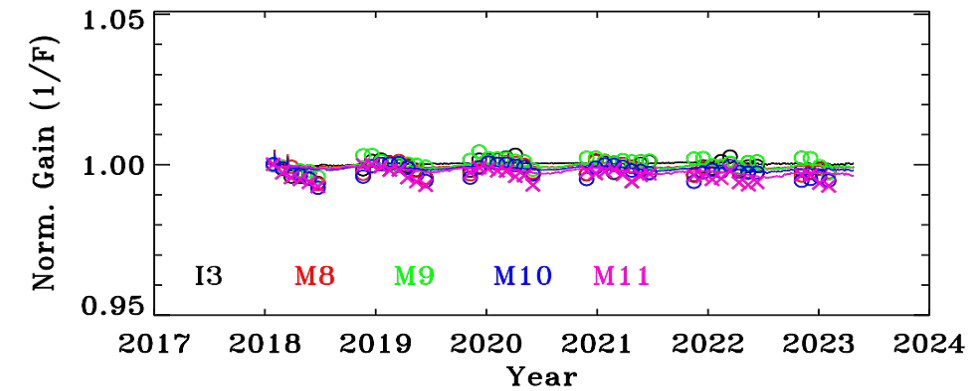
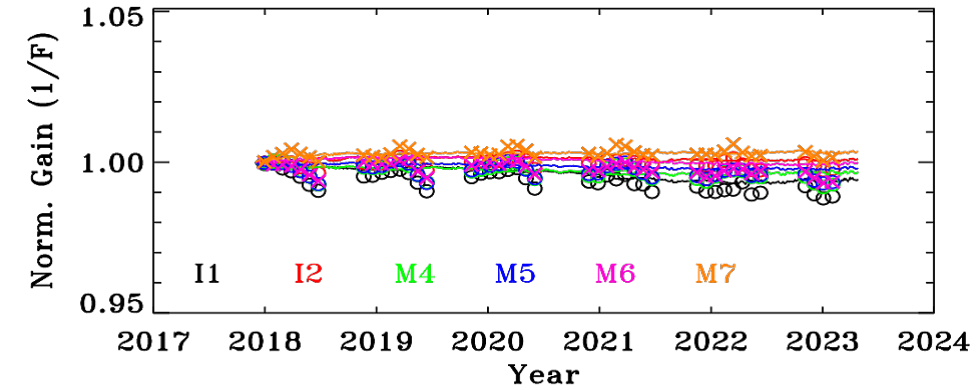
- RSB responses (detector gains) have been **extremely stable over the entire mission**
- TEB gains have remained stable since MMOG (mid-mission outgassing), a gain decrease for I5 (similar to SNPP; 1.8% over 5 years)
- Large SD degradation at short wavelengths
- DNB stray light correction remains effective

- **Spatial and Spectral**

- Band-to-band registration (BBR): stable since launch
- Relative spectral response (RSR): pre-launch characterization

- **Geolocation**

- C2.1 RMSE Track: 57 m; Scan: 47 m



Instrument Performance Update: N-21 VIIRS

- **Instrument Operations and OBC Functions – Normal**

- Same configuration (A-side) since launch
- CFPA at 80 K (82 K prior to 03/03/2023); BB at 292.5 K

- **Radiometric**

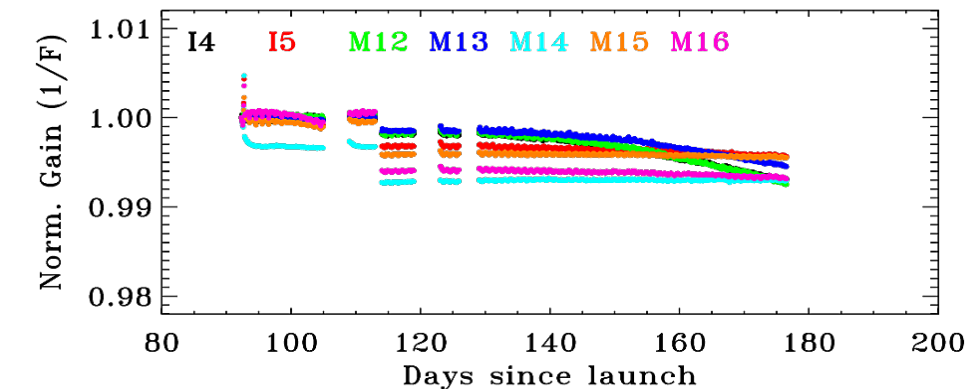
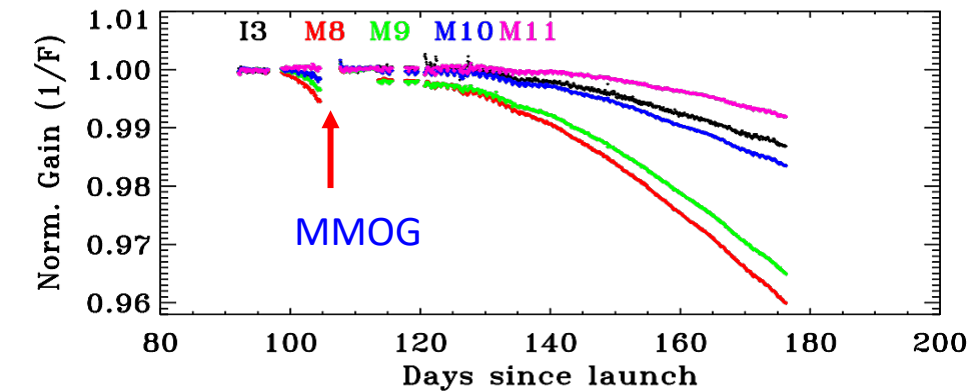
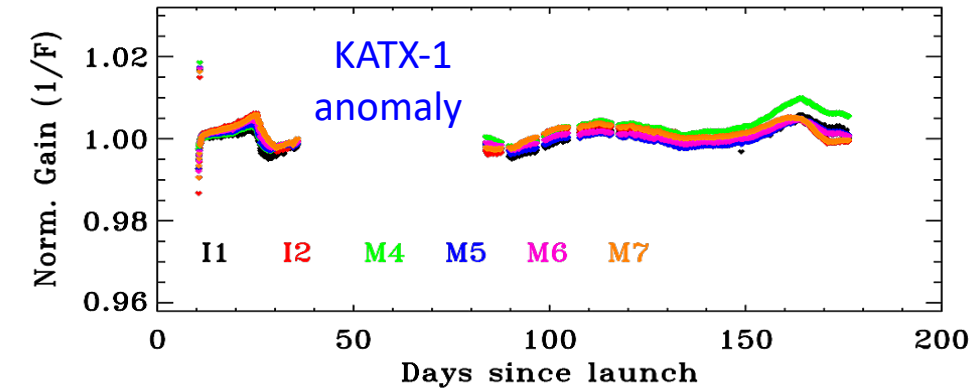
- Stable responses (detector gains) for most spectral bands (VIS/NIR/LWIR) under the same operating condition
- Relatively large decrease in SWIR (M8, M9) responses
- Small decrease in MWIR (I4, M12, M13) responses
- Large SD degradation at short wavelengths
- DNB stray light: smaller than S-NPP and N-20

- **Spatial and Spectral**

- Band-to-band registration (BBR): stable since launch (preliminary with limited measurements)
- Relative spectral response (RSR): pre-launch characterization

- **Geolocation**

- “C2” RMSE Track: 61 m; Scan: 48 m (likely to improve as more data become available)



MODIS L1B Status

- Versions in operation
 - Collection 6.1: Terra V6.2.2; Aqua V6.2.3
- Aqua C6.1 update to V6.2.3 in forward processing to address the increase of PV LWIR crosstalk effect after the safe-mode event in March 2022
 - The forward processing started on 7/27/2022
 - The reprocessing between the safe mode and 7/27/2022 was completed in Nov. 2022
- Terra MODIS C6.1 partial reprocess after recovery from anomaly
 - CP/FP Reset – March 2022 (2022075 onwards)
 - CEMs – Oct 2022 (2022296.2200 onwards)
- C7 L1B code/LUT are undergoing science testing
 - 1st set of code/LUT delivered in March 2021 with subsequent improvements.
 - C7 L1B reprocess is expected in Spring of 2024
- Started merging C7 RSB calibration algorithm to C6.1 forward production (03/2023)
 - Phase-in period: Aqua – 3 months; Terra – 10+ months

MODIS C7 Reprocessing Plan (Tentative)

- C7 MODIS L1B (Jan 2024 – June 2024)
 - MODIS L1B algorithm changes and LUT delivered by MCST
 - Integration of C7 L1 PGEs and downstream select set of C61 L2 atmosphere and land PGEs completed
 - Science test in progress for atmosphere, expected to complete in May 2023.
 - Science test for land expected to start in May 2023
 - Geolocation change delivery in June 2023
- C7 Atmosphere reprocessing (early 2024 – fall 2024)
 - Algorithm change delivery and integration in progress
- C7 Land reprocessing (late 2024 – early 2026)
 - Currently in planning

Details from MODIS and VIIRS Science Team Meeting (May 1-4, 2023) Presentations at:

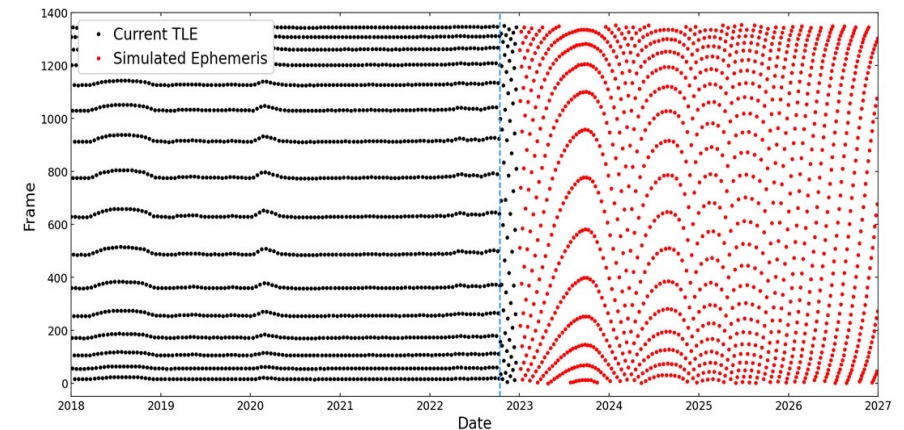
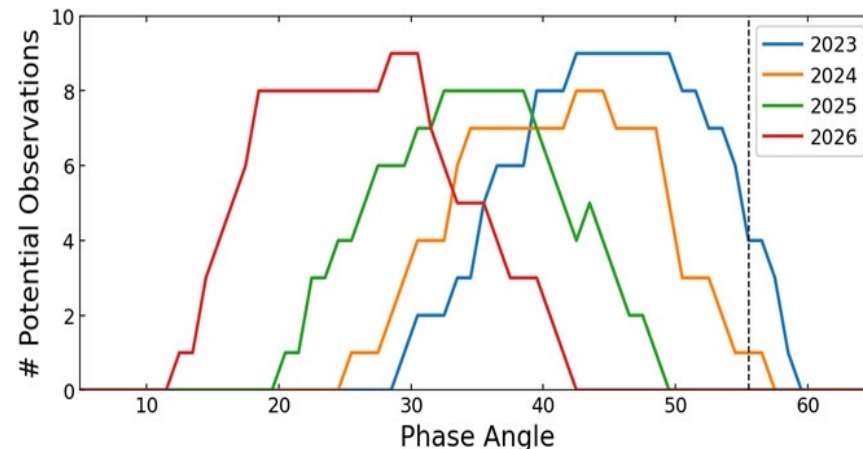
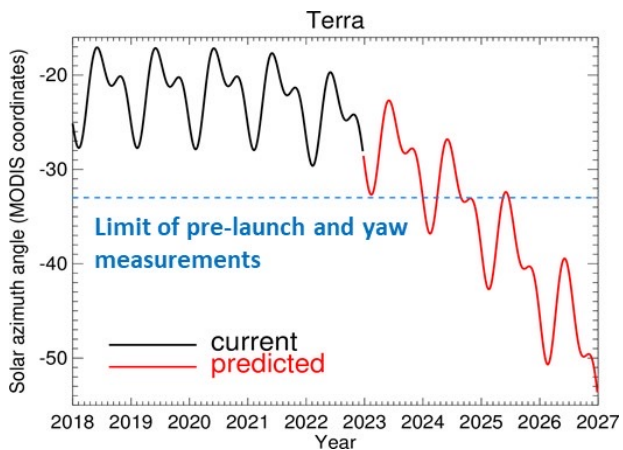
https://modis.gsfc.nasa.gov/sci_team/meetings/

VIIRS L1B Status

- S-NPP L1B C2 is ongoing at Land SIPS – LSIPS Archive Set 5200 using L1B software V3.1.
- S-NPP L1B C1 is ongoing at Land SIPS for Level-2 downstream process – LSIPS Archive Set 5000 (using SDR Mx software and LUT) and 5110 (using L1B software V2.0).
- NOAA-20 (JPSS-1) C2.1 is ongoing – LSIPS Archive SET 5201 using L1B software V3.1.
- NOAA-21 (JPSS-2) L1B is ongoing – LSIPS Archive SET 4014 using L1B software V3.2 (released in Nov 2022) and VCST LUT.
 - On-orbit L1B LUTs have been delivered to SIPS for ongoing Cal/Val, including [the first mission consistent LUTs](#) derived using parameters from on-orbit yaw maneuvers
 - Not publicly available yet

Current and Future Activities: Terra and Aqua MODIS

- Continue to monitor sensor performance and to derive and update calibration LUTs in support of C6.1 data production and C7 on a regular basis when forward production begins.
- Continue to monitor and address [crosstalk impact on Terra and Aqua PV LWIR bands 27-30](#). Further adjustments may be needed to address changes due to recent and future safe mode events.
- [Enhance and expand post-CEM calibration strategies](#) in support of extended Terra and Aqua MODIS missions (use of OBC, lunar observations, vicarious calibration targets, and alternative approaches) – to address impact due to drifting orbits
- Support Terra and Aqua FOT for planning and preparation of [special end-of-mission maneuvers and decommissioning activities](#)



Current and Future Activities: S-NPP, N-20, and N-21 VIIRS

- Continue to monitor sensor performance and to derive and update calibration LUTs in support of SIPS for VIIRS data production (S-NPP, N-20, and N-21) **with special effort on relatively large changes in N-21 SWIR response**
- Continue to monitor detector-to-detector calibration differences and implement corrections as necessary (already applied in S-NPP C2 for a few VIS bands; **likely to extend to N-20 SWIR bands**)
- Continue to track VIIRS calibration stability, including potential changes in the RVS, using different EV targets and DCC
- Complete and implement the saturation rollover pixel flagging and uncertainty index for all three instruments, including L1B code changes.
- **Further improve N-21 VIIRS RSB calibration** (SDSM Sun view screen transmittance, use of both SD and lunar measurements for LUT updates, ...)
- Further improve DNB calibration accuracy and stray light characterization and correction
- Develop strategies to assess and address **S-NPP, N-20, and N-21 RSB calibration differences** (a major challenge for producing consistent long-term data records)

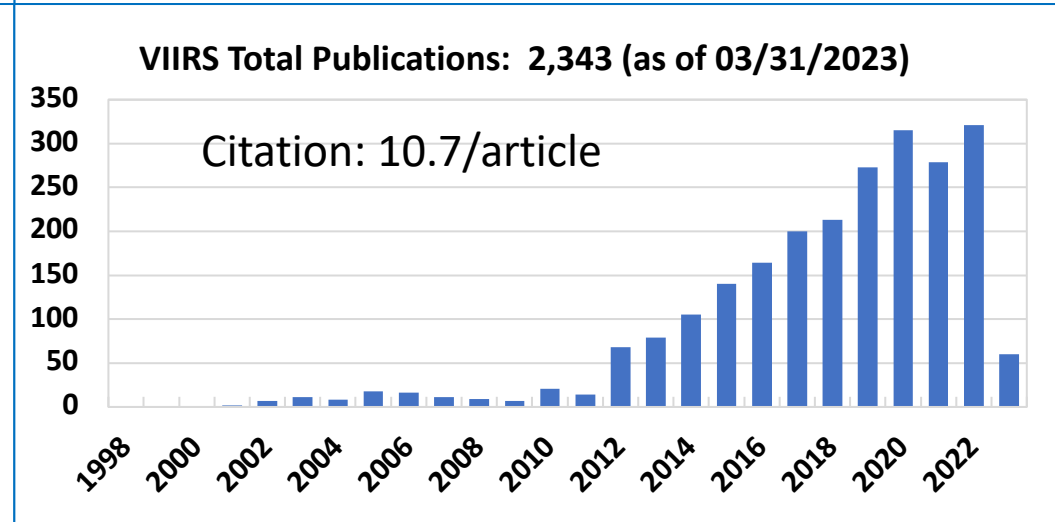
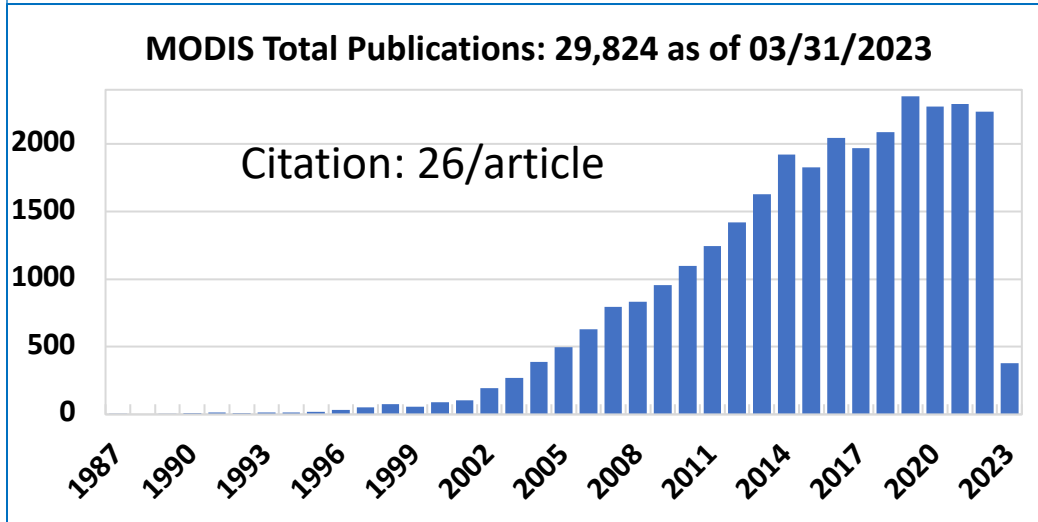
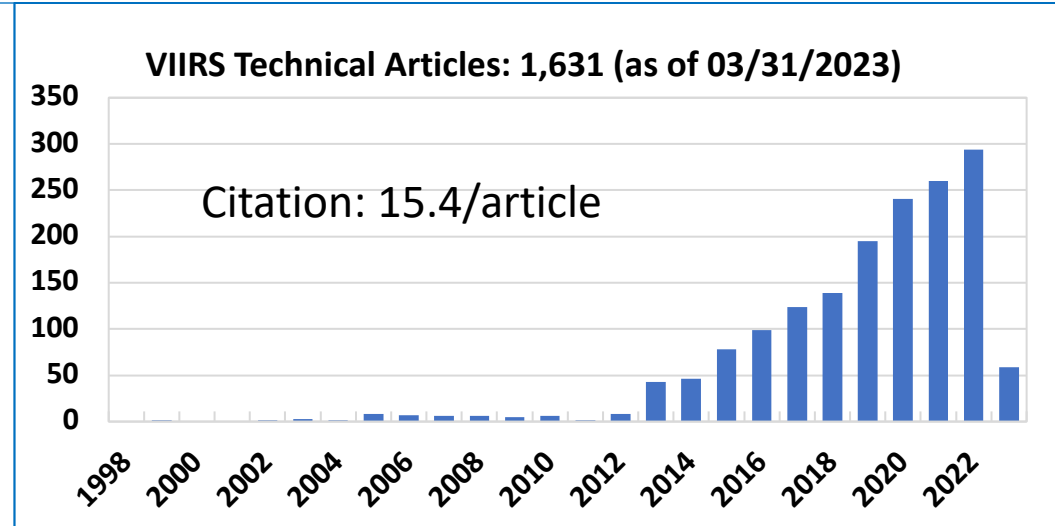
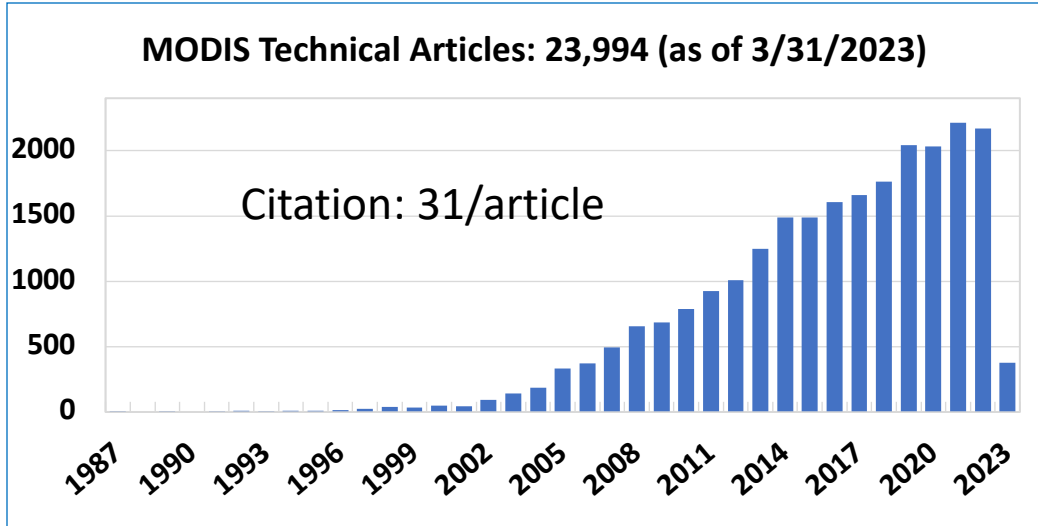
Summary

- Both Terra and Aqua MODIS and their OBC continue to operate and function normally
- S-NPP, N-20, and N-21 VIIRS and their OBC continue to operate and function normally
- On-orbit changes in sensor responses and key performance parameters are well characterized using OBC measurements, lunar observations, and select earth view targets (e.g. PICS and DCC); further improvements for N-21 is expected as more calibration data sets become available
- Overall performance of VIIRS is more stable than MODIS
- Strategies have been developed and implemented to address calibration challenges due to recent drifting orbits (Terra and Aqua)
- Continuing efforts by the MCST and VCST to
 - Address issues (to be) identified, including changes of sensor characteristics resulting from spacecraft and instrument anomalies (e.g. crosstalk effects) and calibration differences among sensors (VIIRS-VIIRS, MODIS-VIIRS)
 - Derive and deliver calibration parameters in support of sensor L1B and science data processing and reprocessing (Terra/Aqua MODIS C6.1/C7, S-NPP/N-20 VIIRS C2.0/C2.1, N-21 VIIRS “C2”)

More Details in Presentations at MODIS and VIIRS Calibration Workshop (May 1, 2023)

Backup Slides

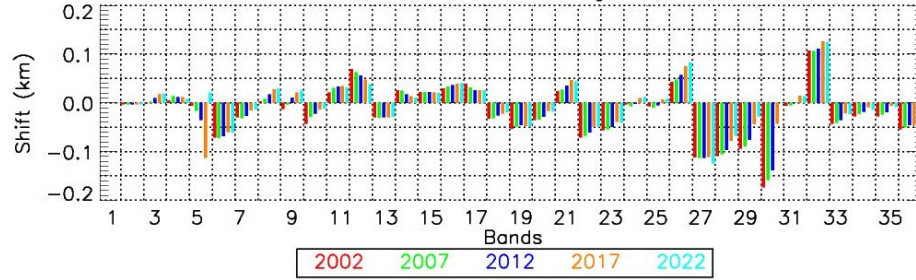
MODIS and VIIRS Publications



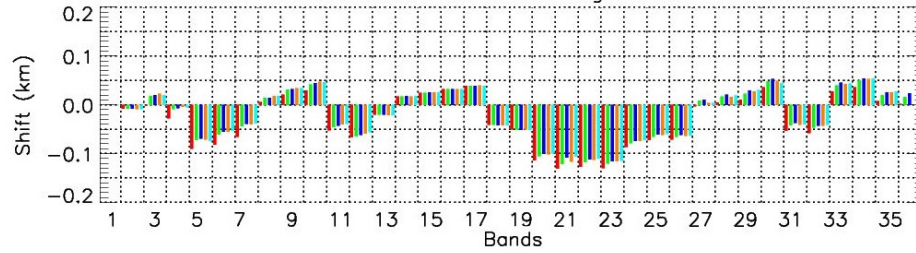
MODIS Spatial and Spectral Characterization

Terra MODIS

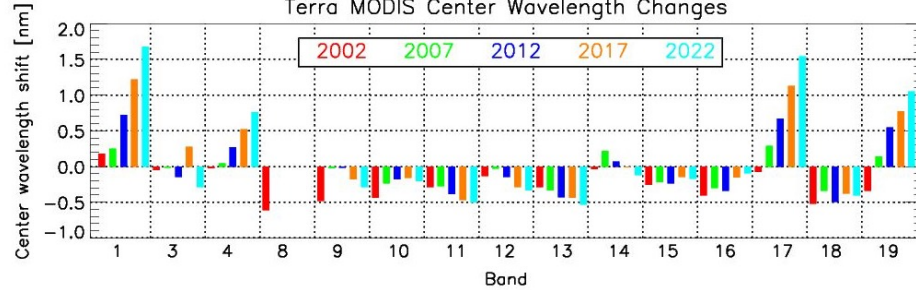
Terra BBR Shift Along-scan



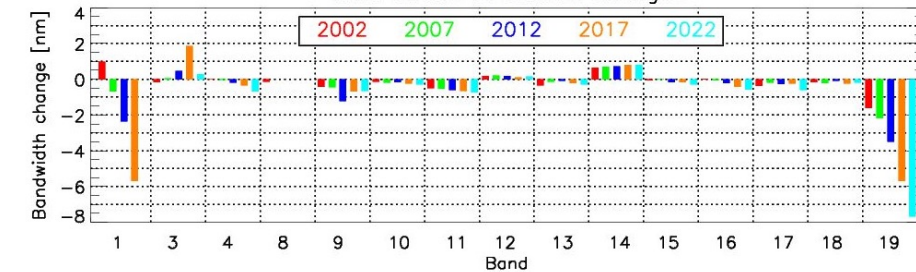
Terra BBR Shift Along-track



Terra MODIS Center Wavelength Changes

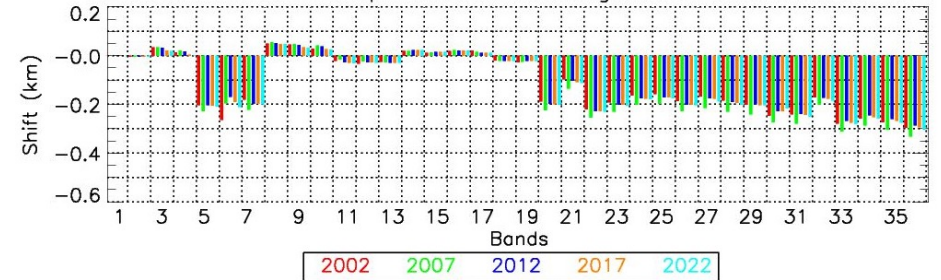


Terra MODIS Bandwidth Changes

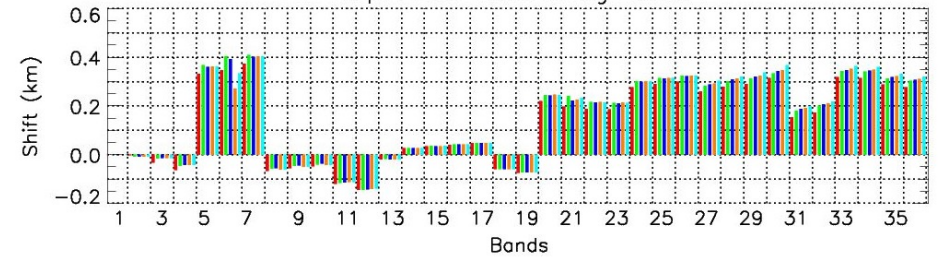


Aqua MODIS

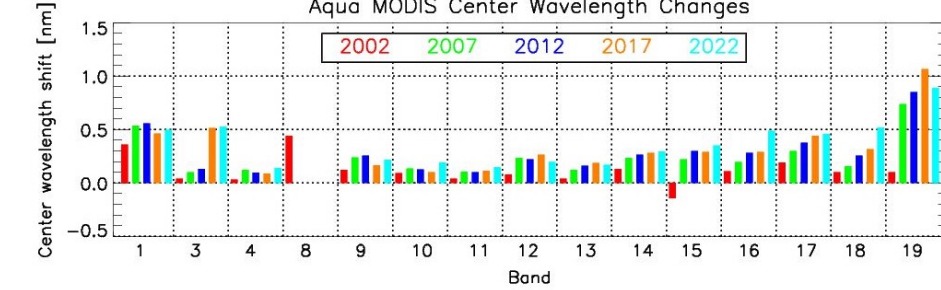
Aqua BBR Shift Along-scan



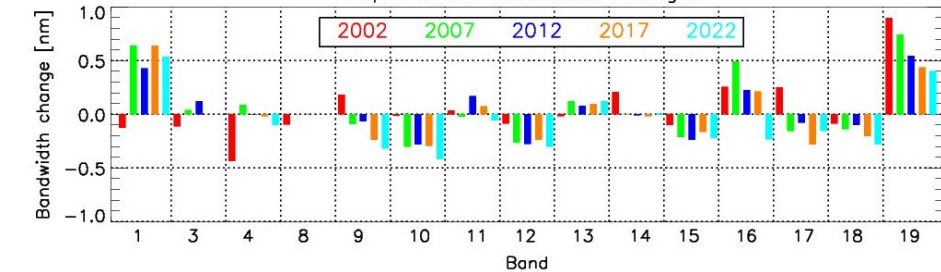
Aqua BBR Shift Along-track



Aqua MODIS Center Wavelength Changes



Aqua MODIS Bandwidth Changes



Along-scan BBR

Along-track BBR

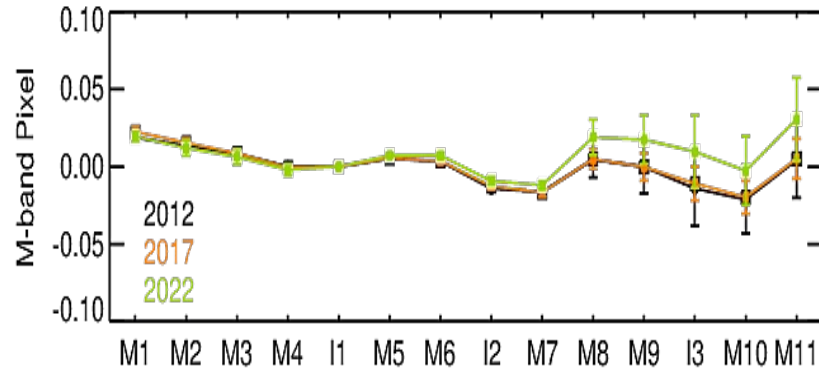
Changes in CW

Changes in BW

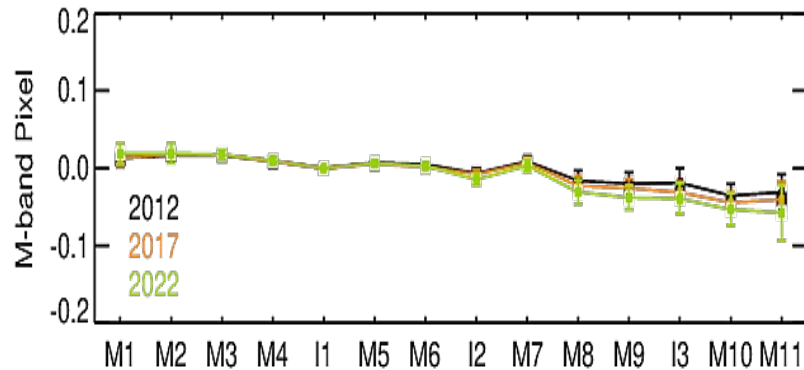
VIIRS Spatial Characterization

S-NPP VIIRS

BBR Scan

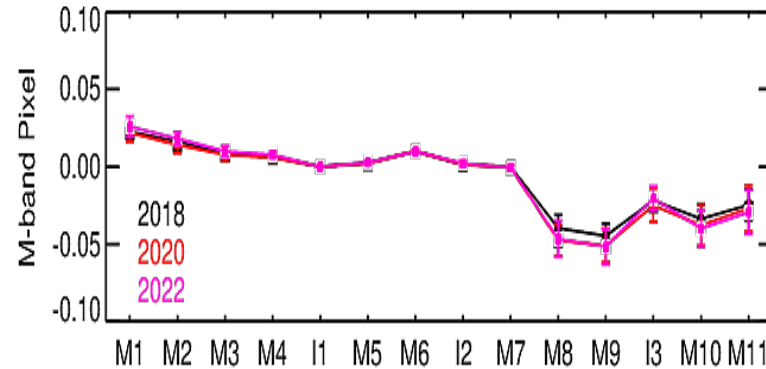


BBR Track

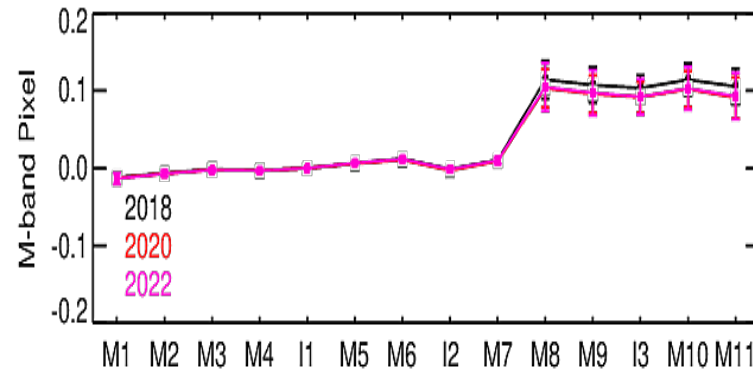


N-20 VIIRS

BBR Scan

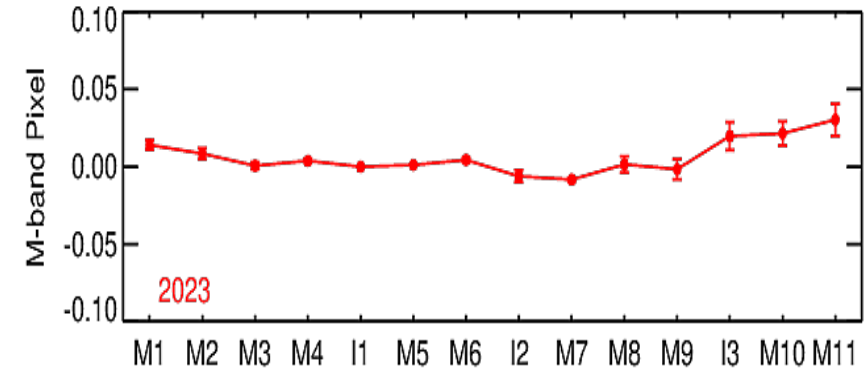


BBR Track

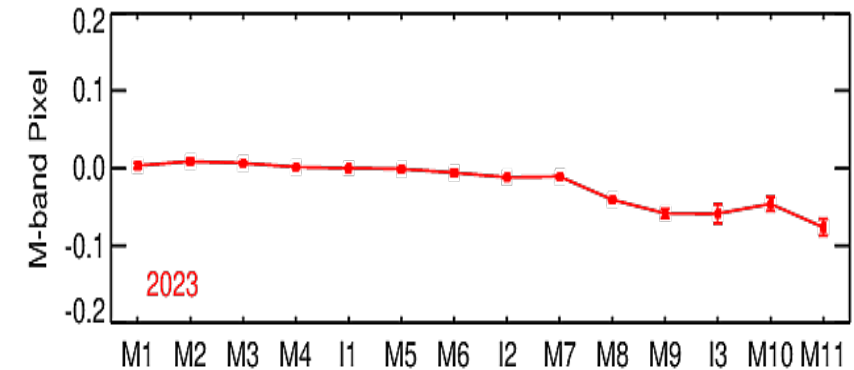


N-21 VIIRS

BBR Scan



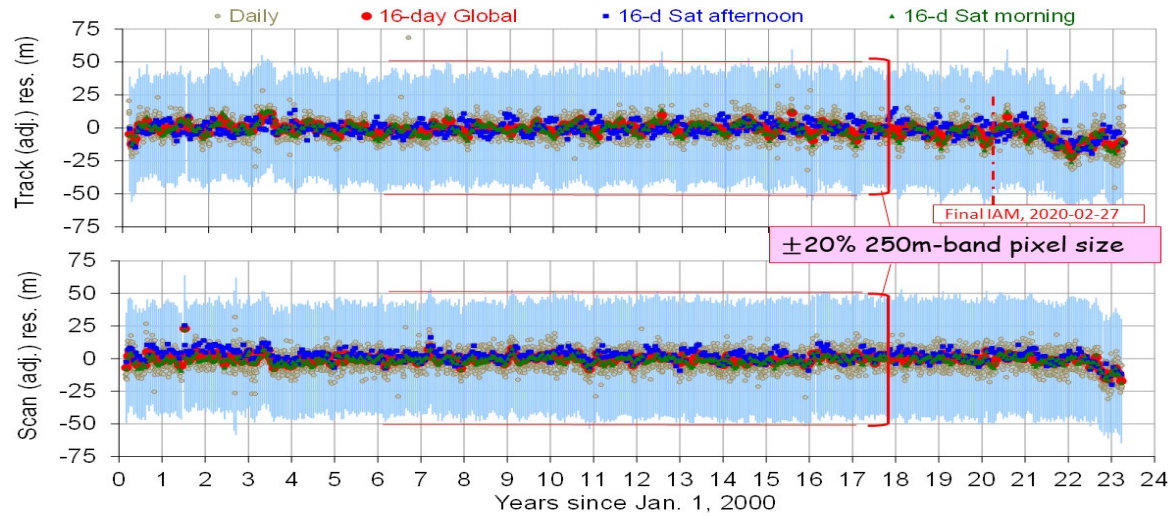
BBR Track



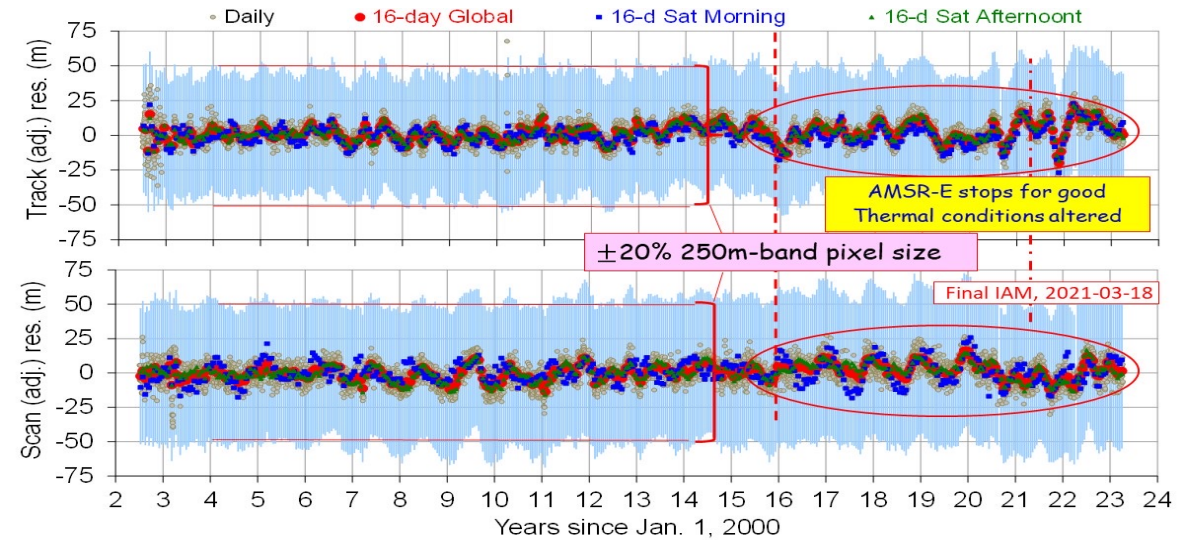
N-21 results are based on the average from the first two lunar observations

MODIS and VIIRS Geolocation

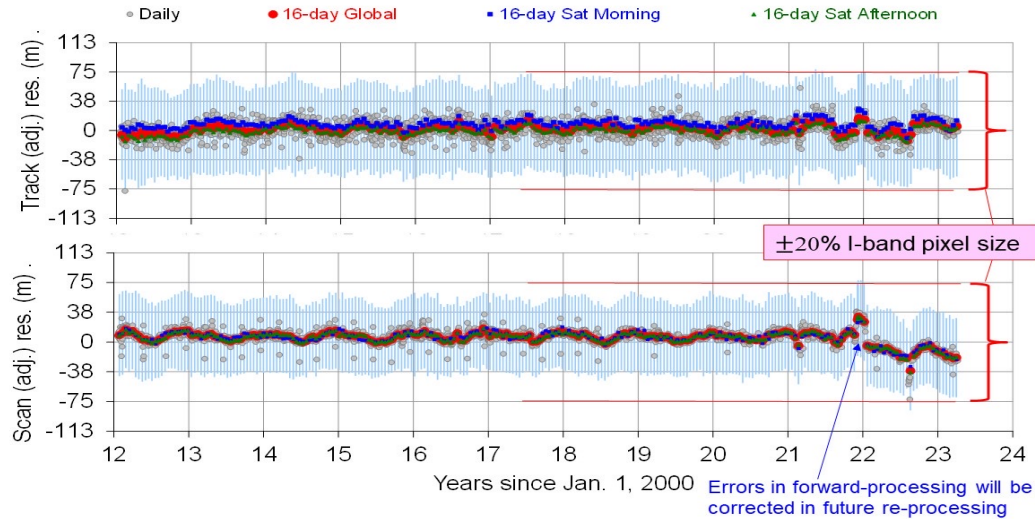
Track: 43 m; Scan: 45 m (Terra C6.1)



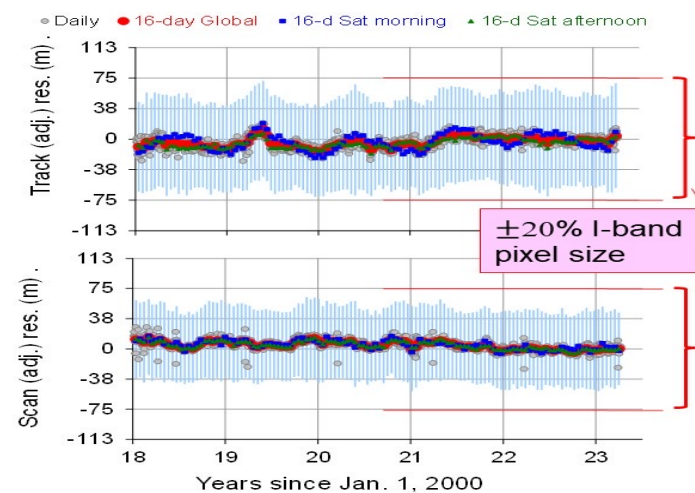
Track: 46 m; Scan: 54 m (Aqua C6.1)



Track: 59 m; Scan: 48 m (S-NPP C2)



Track: 57 m; Scan: 47 m (N-20 C2.1)



Track: 61 m; Scan: 48 m (N-21 C2)

