VIIRS TEB Calibration and Performance

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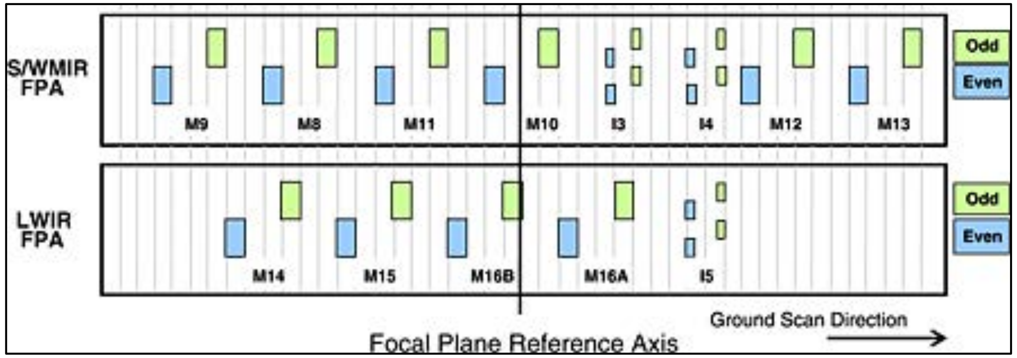
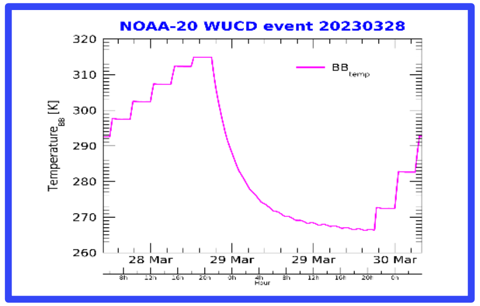
Overview

- TEBs are calibrated using on-board calibrator (OBC) black body (BB)
  - Calibration performed on a per-scan basis using the OBC-BB
  - Nominal temperature maintained at 292.5 K
- Warm-up and cooldown (WUCD) events are performed to fully characterize TEBs detector response and derive the offset and non-linear terms in the calibration algorithm
  - WUCD temperature range: ambient to 315 K
  - Stable trends observed in the derived offset and non-linear coefficients on-orbit
- Event frequency:
  - Launch → 06/2018 (quarterly) [SNPP-VIIRS]
  - 06/2018 → present (annually) [applies to each VIIRS]
  - Number of WUCD events to date: 32 (S-NPP) , 9 (N20), and 2 (N21)



TEB	375 m		750 m				
	I4	I5	M12	M13 (D.G.)	M14	M15	M16
λ [µm]	3.74	11.45	3.70	4.05	8.55	10.76	12.01



OBC-BB and an example of the WUCD cycle

TEB Calibration Methodology

VIIRS Earth view (EV) radiance is retrieved following the ATBD,

$$L_{EV}(B,\theta) = \frac{F(B)\sum_{i=0}^{2} c_i\,(B)dn^i(B) - \Delta L_{bg}(B,\theta)}{RVS(B,\theta)},$$

B: band θ : angle-of-incidence dn: detector response c_i: calibration coeffs derived from prelaunch characterization.

where the $\Delta L_{bg}(B,\theta)$ is the background difference between the EV and space view (SV) path:

$$\Delta L_{bg}(B,\theta) = \left(RVS(B,\theta) - RVS_{SV}(B)\right)\left[\frac{\left(1-\rho_{RTA}(B)\right)}{\rho_{RTA}(B)}L_{RTA} - \frac{1}{\rho_{RTA}(B)}L_{HAM}\right].$$

The F-factor is derived on a scan-by-scan basis and is band-, detector-, and HAM side-dependent:

$$F(B) = \frac{RVS_{BB}(B)L_{ap}(B) + \Delta L_{bg}(B,\theta_{BB})}{\sum_{i=0}^{2} c_i dn_{BB}^i}.$$

ρ: reflectance
L_{ap}: aperture radiance
RTA: rotating telescope assembly
HAM: half-angle mirror
RVS: response-versus-scan-angle

Same calibration approach used for three VIIRS instruments

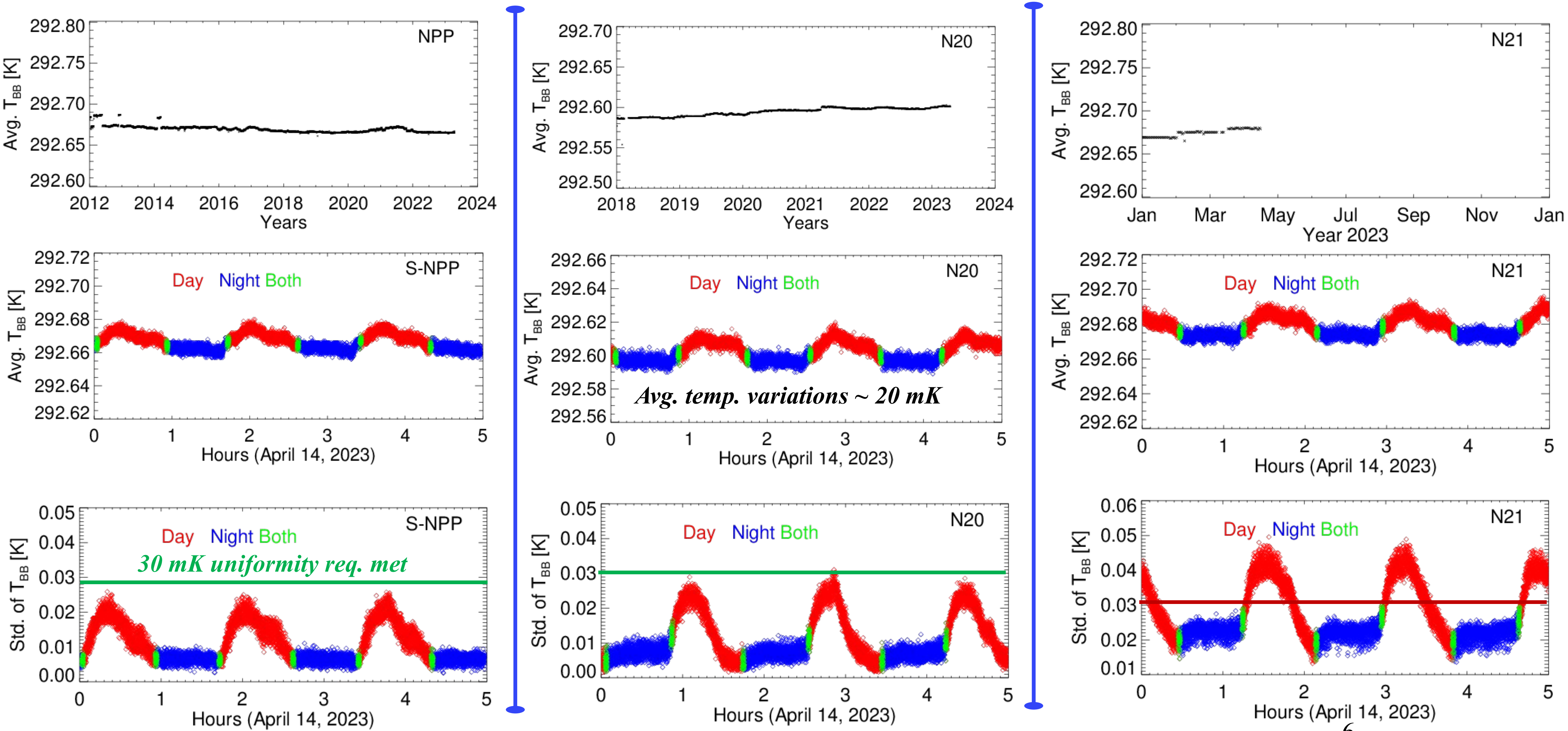
Key instrument events summary since last workshop (Feb, 2021)

- S-NPP spacecraft and VIIRS safe mode on Aug 3, 2021 when the S/C tripped to Earth point (from mission point) after reenabling the star trackers during the star catalog V1.09 upload process.
  - Copied previous star catalog (v1.08) and recovered on Aug 4 (15:51z)
  - **Discontinuities can be seen in the F-factors (and noise) for all TEB. Magnitude of the discontinuities increases with wavelength. Maximum change in the gain of about 0.6% (LWIR)**
- SNPP SBC Lock up occurred on 6/28/2022 03:41z in the SAA region during orbit #55271. Recovered at 16:38:36z, to nominal state
  - **No impact on the TEB gains and noise performance**
- S-NPP spacecraft entered a non-nominal state at ~16:24:49 UTC on Jul 26, 2022, after which the spacecraft and all instruments were in a safe mode state. VIIRS recovered to operational mode at 15:50 UTC on August 10.
  - **LWIR bands I5, M14-M16 F-factors showed an increased by up to 0.7% after recovery and quickly settled in a few days; the MWIR have less changes. No major changes observed in the NEdT after the anomaly.**
- N20 VIIRS rotating telescope assembly (RTA) anomaly Feb 14, 2021 20:07 where the RTA did not recover after a sync error. Data outage for about 6 hours. **No TEB performance impacts**

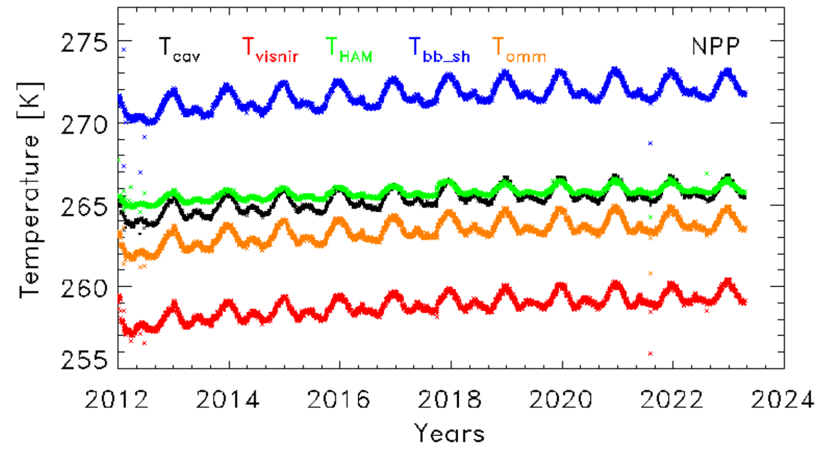
Key instrument events in N21 VIIRS

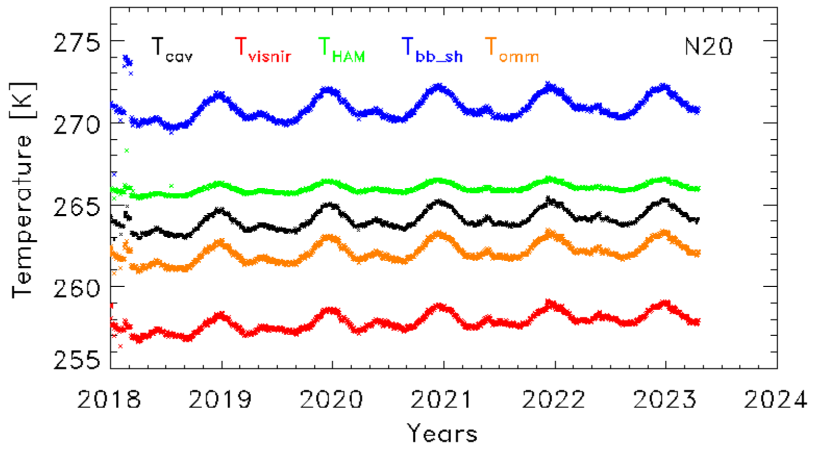
- VIIRS cryo radiator door (CRD) opening: 2/8/2023 ~15:50 UTC
- Starting 2/10/2023 ~14:00 UTC, CFPA temps kept dropping much more than expected and as a result at about 18:12 UTC, the SMIR CFPA heater was also turned on.
  - **Discontinuity in the F-factor trends across all bands as a result**
- LWIR gain degradation observed that prompted a mid-mission outgas (MMOG) was performed (Feb 23-26, 2023)
  - Similar activity also performed on N20 VIIRS
  - **LWIR gains have been restored to at-launch levels post the MMOG**
- Set CFPA 80K - Started cool down from 82K @19:33z on 3/3 and stabilized at 80K @20:29z.
  - **Operations continue to be performed using the LWIR heater only (nominal operational configuration)**
  - **Improved NEdT performance in the LWIR bands - expected changes in the LWIR gains after switch to 80K. All data reprocessed using VCST 82K and 80K LUTs.**
  - **No changes observed in the dynamic range (I4) after switch to 80K.**
- Pitch maneuver performed to validate the TEB RVS (March 10, 2023)
  - **Results show good agreement with prelaunch characterized TEB RVS**
- Post the WUCD, MWIR bands show a gain degradation of about 0.2%. Larger degradation observed in the SWIR bands (as shown earlier)

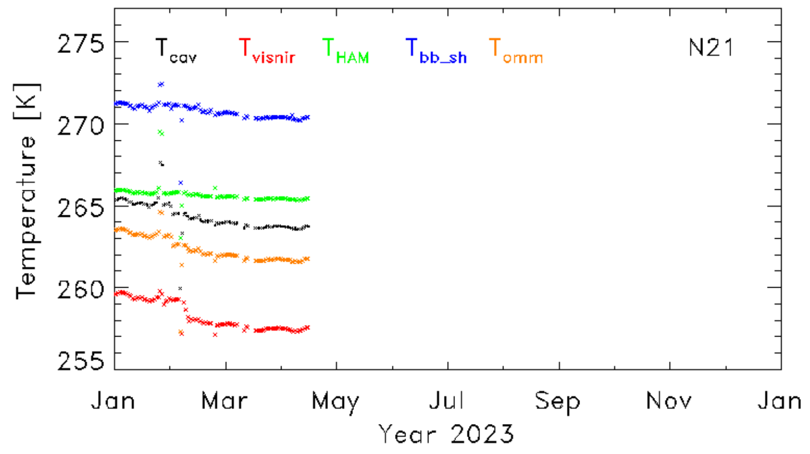
OBC-BB Performance

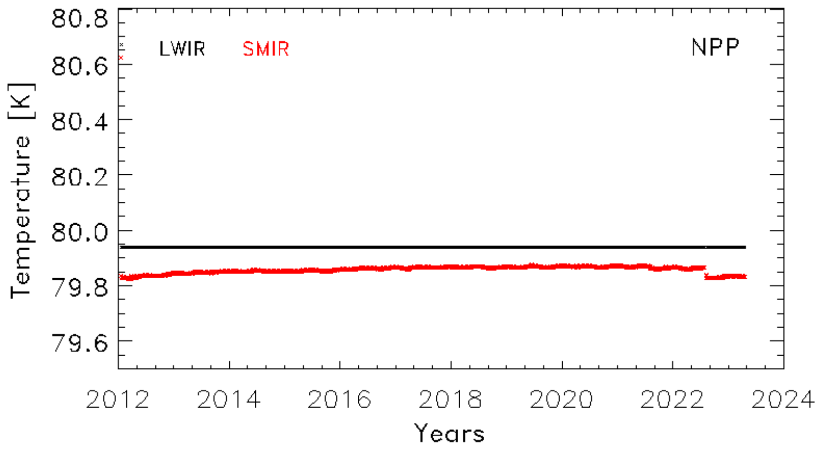


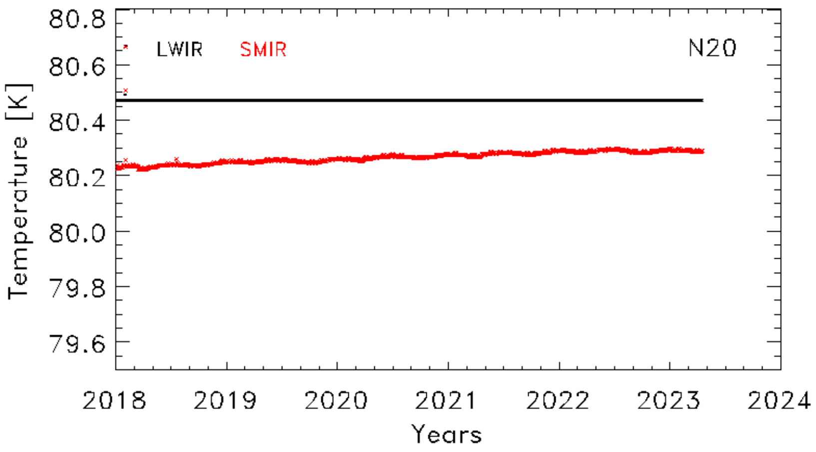
Telemetry Performance

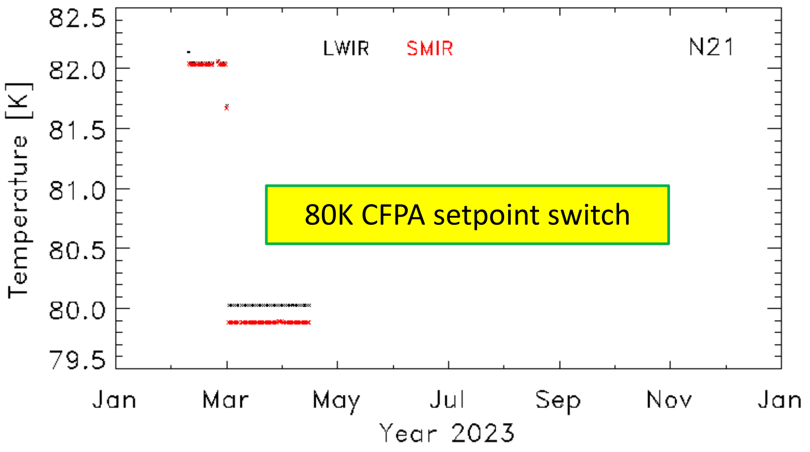








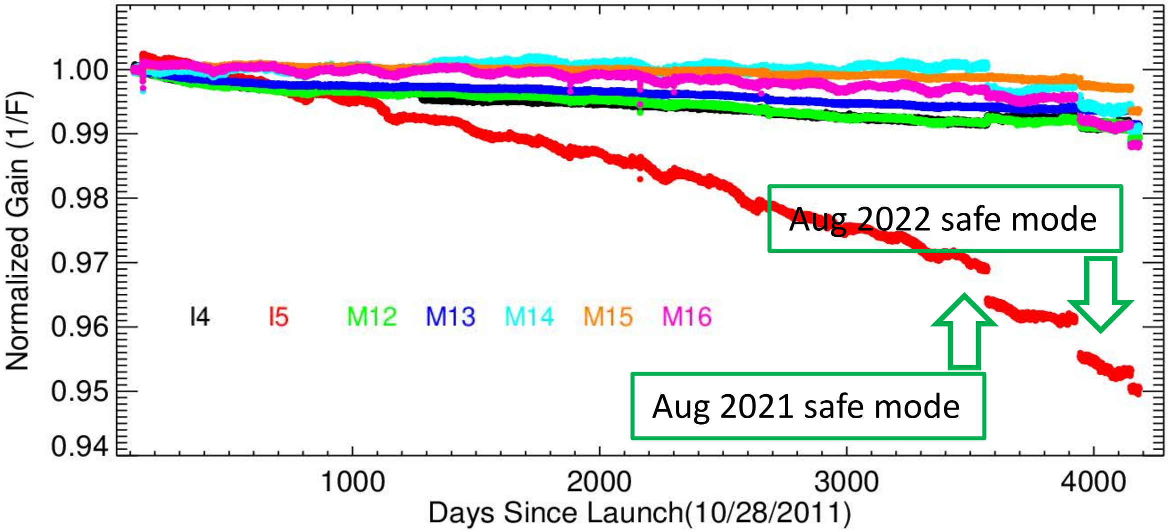


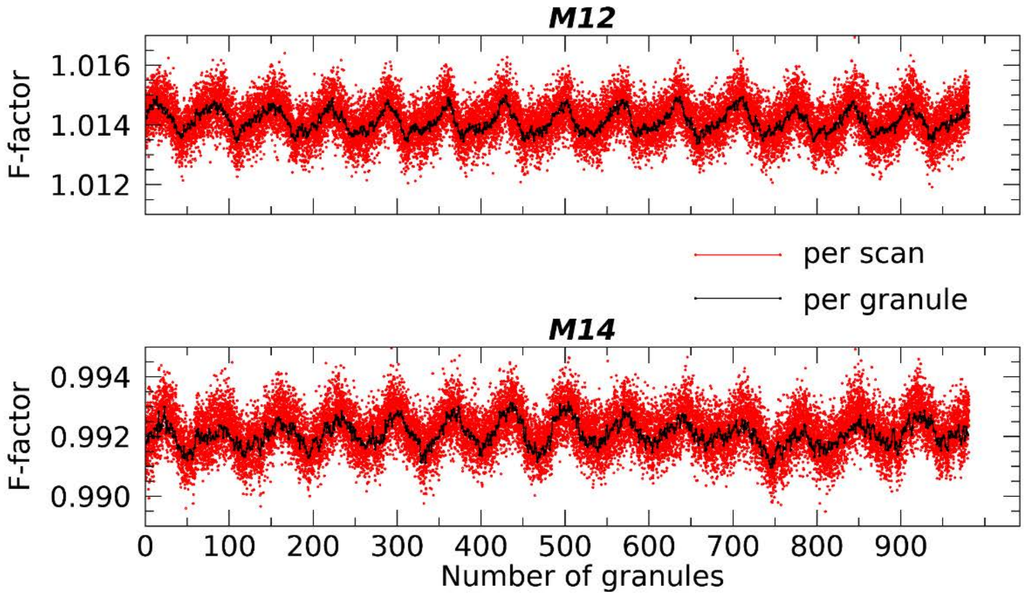


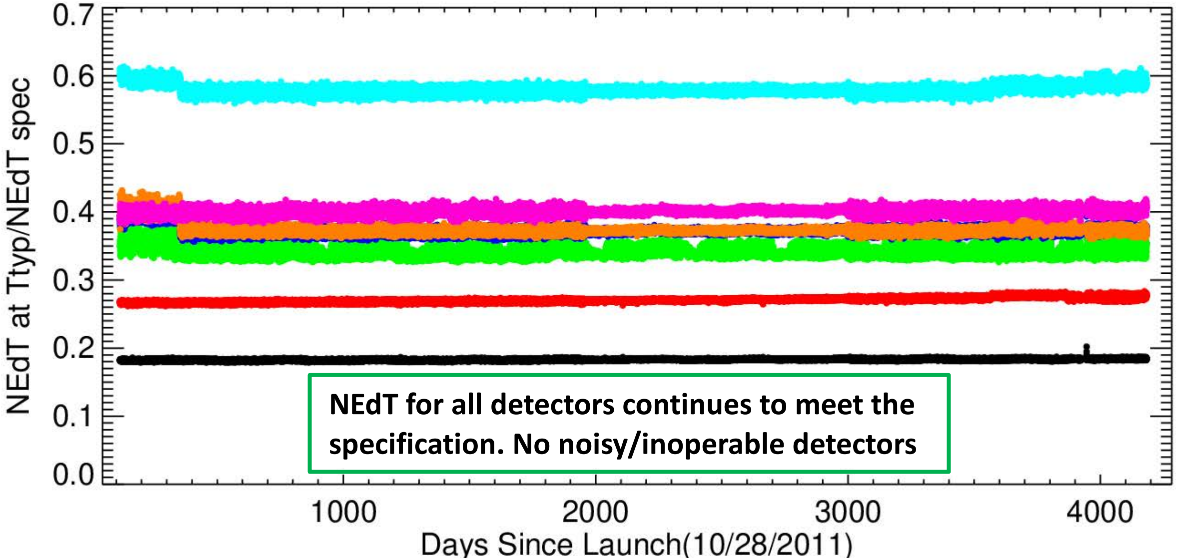
Small change in the SMIR FPA temperature after the Aug 2022 safe mode

Starting 2/10/2023 ~14:00 UTC, CFPA temps kept dropping much more than expected and as a result at about 18:12 UTC, the SMIR CFPA heater was also turned on.

SNPP VIIRS TEB performance

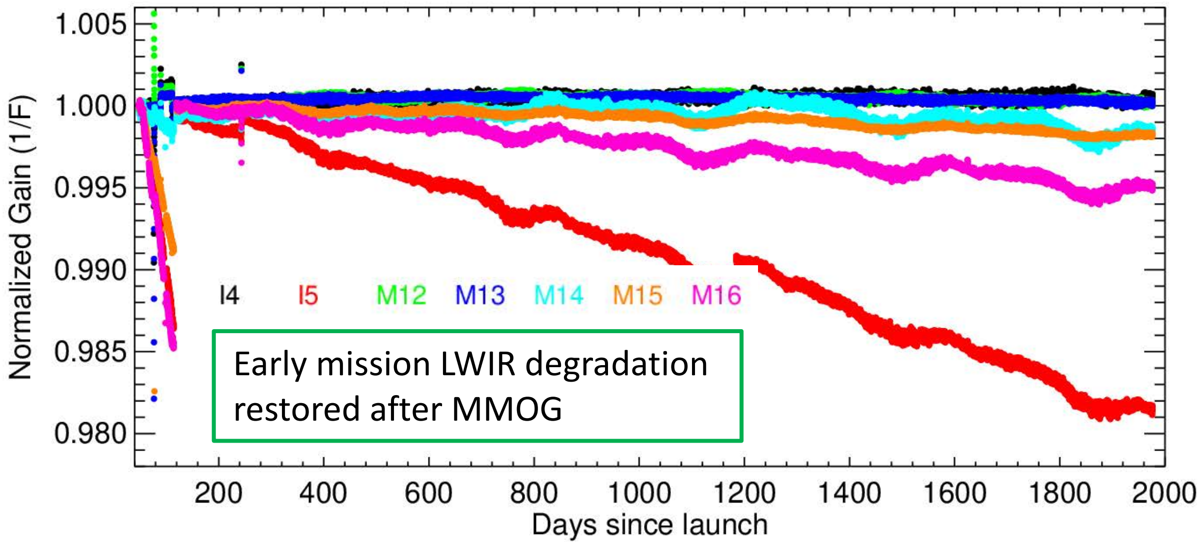


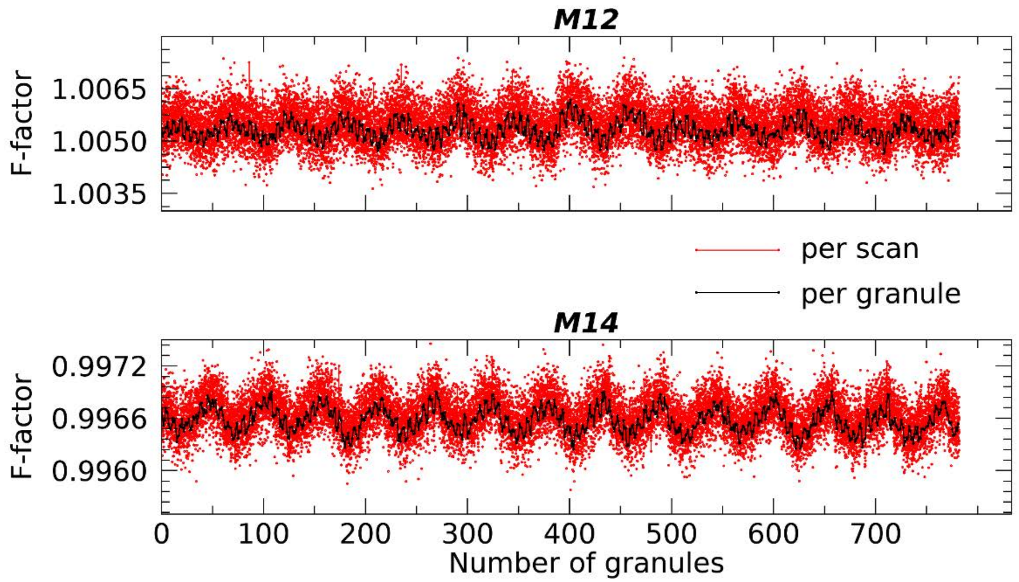


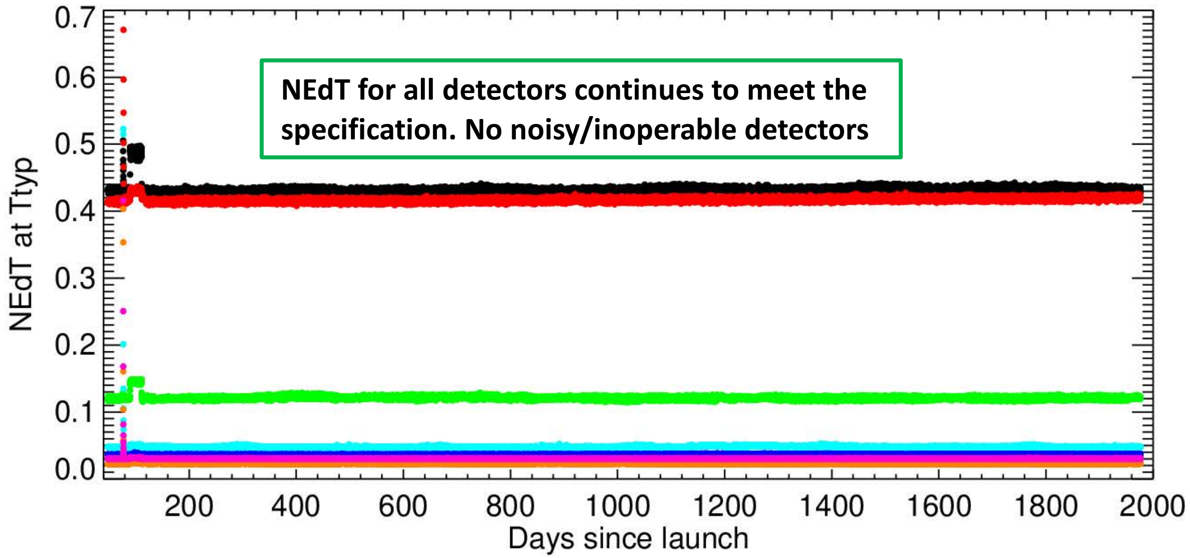


- Detector responses show small orbital variations.
  - ± 0.2 % or less on a scan-by-scan basis
  - ± 0.1 % or less on a per granule basis
- F-factor fluctuations can be correlated to T_{BB} and instrument temperature variations

N20 VIIRS TEB performance

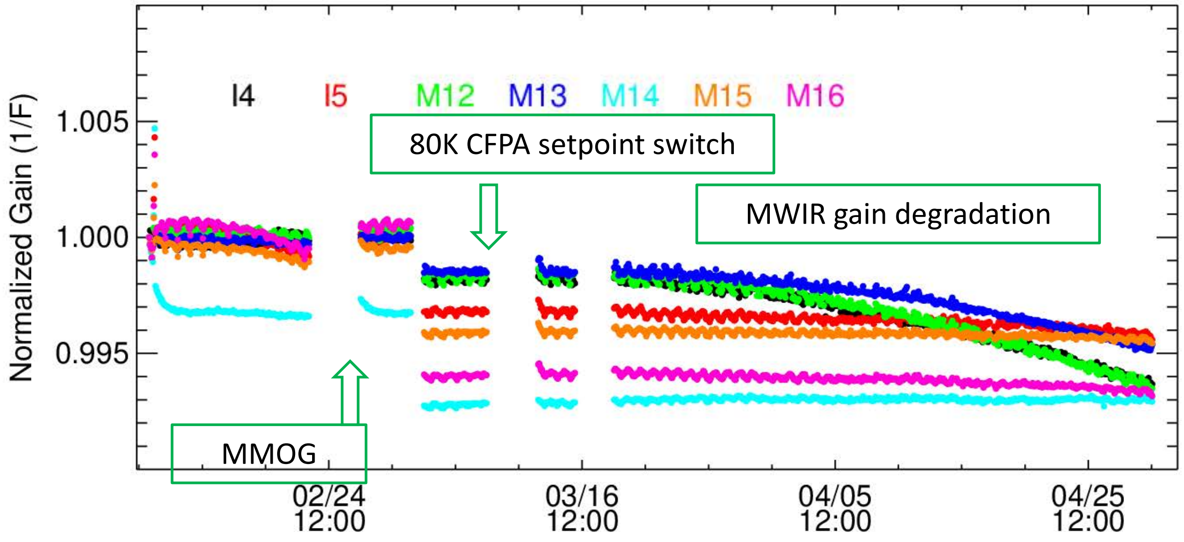


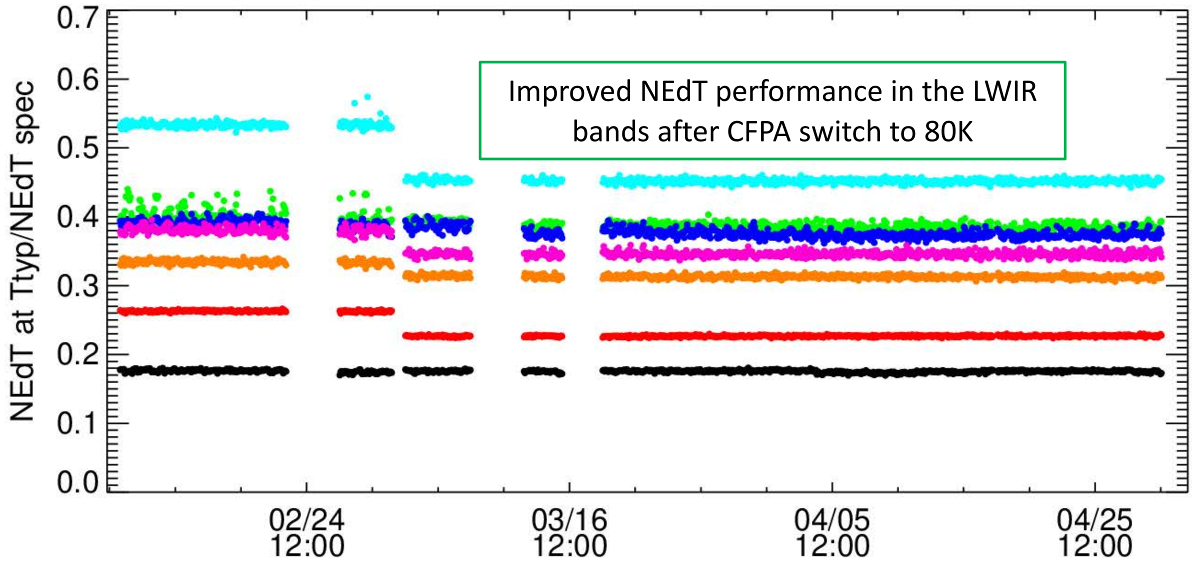


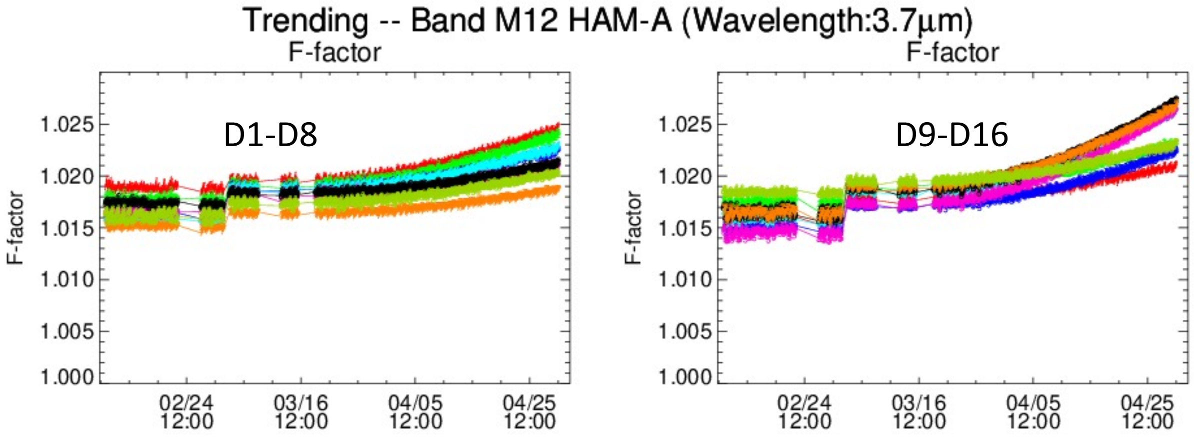


- Detector responses show small orbital variations.
  - ± 0.2 % or less on a scan-by-scan basis
  - ± 0.1 % or less on a per granule basis
- Performance similar to SNPP VIIRS TEB. Largest gain degradation observed in I5 (~0.4%/year)

N21 VIIRS TEB performance







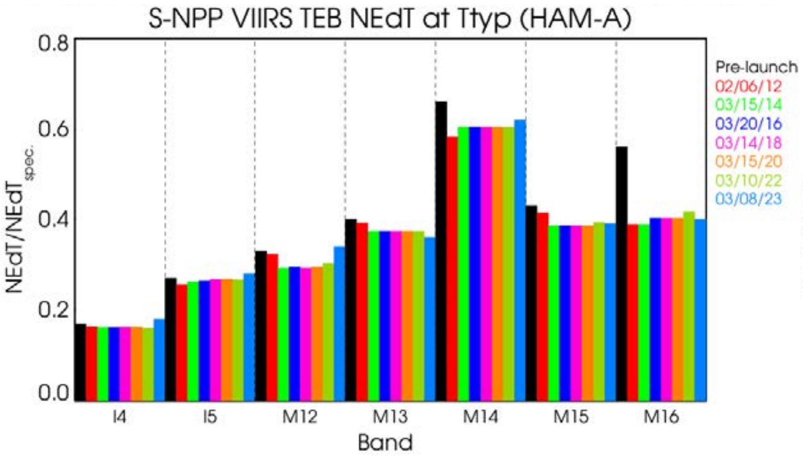
Larger degradation in the higher number of detectors. Similar trend, attributed to possible icing, in the early days of J1 VIIRS. Per-scan calibration of the TEB mitigates the impacts due to this degradation

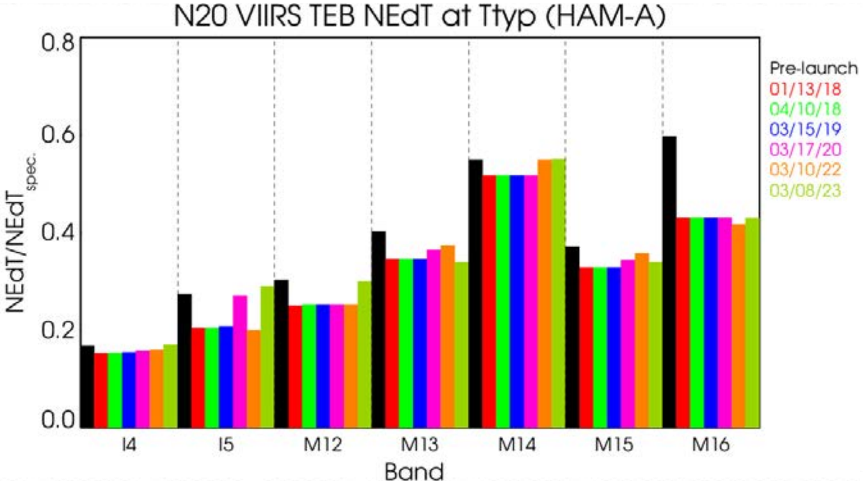
- Short-term stability comparable with SNPP and J1 VIIRS
- Continued monitoring of the MWIR gain degradation is required, currently impacting bands I4, M12, M13. Minimal impact on the L1B product as per-scan calibration is used

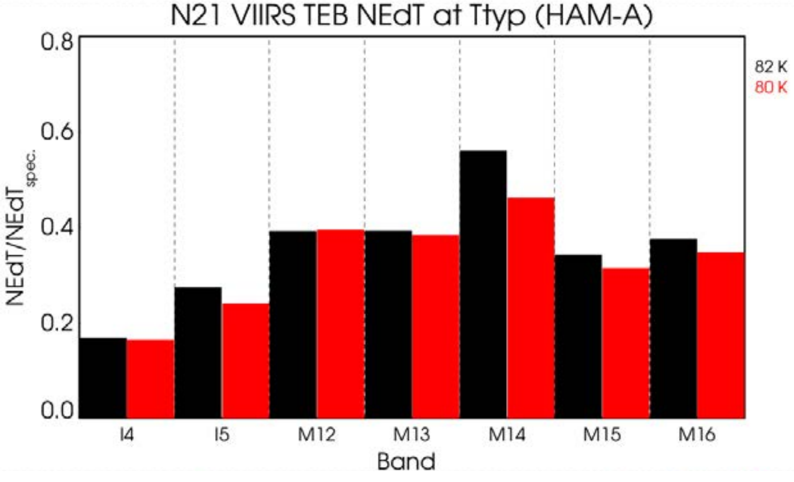
Summary

- On-orbit BB short- and long-term performances for S-NPP (~12 years) and NOAA-20 (~5 years) VIIRS are quite stable. Recently launched NOAA-21 VIIRS also showing stable performance with the exception of some MWIR bands
- Detector response (F-factor) trending is stable for both S-NPP and NOAA-20 VIIRS. S-NPP VIIRS TEB I5 shows the maximum band-averaged trend of 3.1 %, followed by M12 and I4. NOAA-20 VIIRS TEB I5 displays a maximum trend of 0.9 %.
    - Early mission LWIR degradation corrected after MMOG. Signs of gain degradation evident in the MWIR bands
- The TEBs detector noise characteristics are stable for all instruments. The NEdT at T_{TYP} is compliant with the requirements.
    - Improved NEdT performance for N21 VIIRS TEB after the CFPA switch to 80K
- L1B Earth view trending over ground targets for S-NPP and N20 VIIRS demonstrates all TEBs are well-calibrated. N21 VIIRS TEBs will be monitored in the future using same methodology.
- Recent calibration improvements include the development of a TEB uncertainty algorithm that can provide per-pixel uncertainty and improved flagging for the rollover pixels in the L1B products (to be included in a future reprocess)

Backup


S-NPP VIIRS TEB NEdT at Ttyp (HAM-A)
0.8
0.6
0.4
0.2
0.0
NEdT/NEdT spec.
Pre-launch
02/06/12
03/15/14
03/20/16
03/14/18
03/15/20
03/10/22
03/08/23
I4
I5
M12
M13
M14
M15
M16
Band


N20 VIIRS TEB NEdT at Ttyp (HAM-A)
0.8
0.6
0.4
0.2
0.0
NEdT/NEdT spec.
Pre-launch
01/13/18
04/10/18
03/15/19
03/17/20
03/10/22
03/08/23
I4
I5
M12
M13
M14
M15
M16
Band

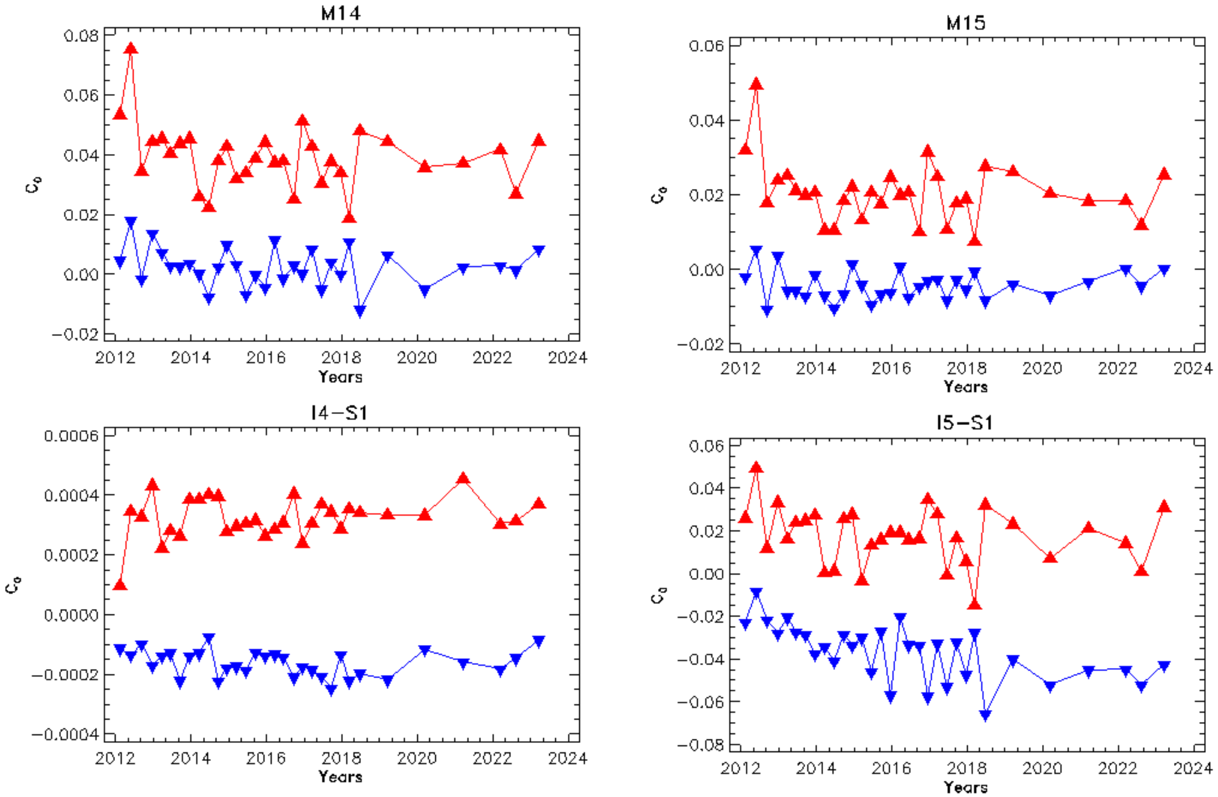

N21 VIIRS TEB NEdT at Ttyp (HAM-A)
0.8
0.6
0.4
0.2
0.0
NEdT/NEdT spec.
82 K
80 K
I4
I5
M12
M13
M14
M15
M16
Band

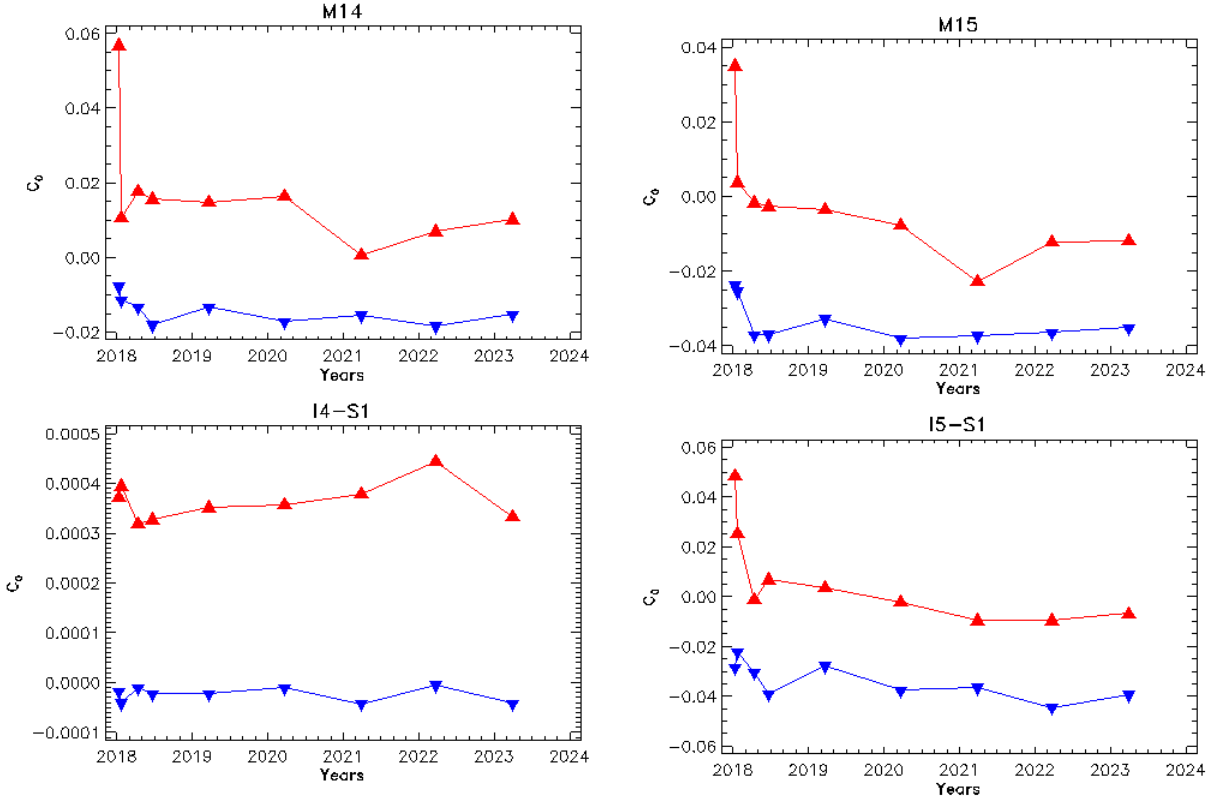
Calibration coefficients (c_0)

S-NPP

Warm-up
Cooldown

N20



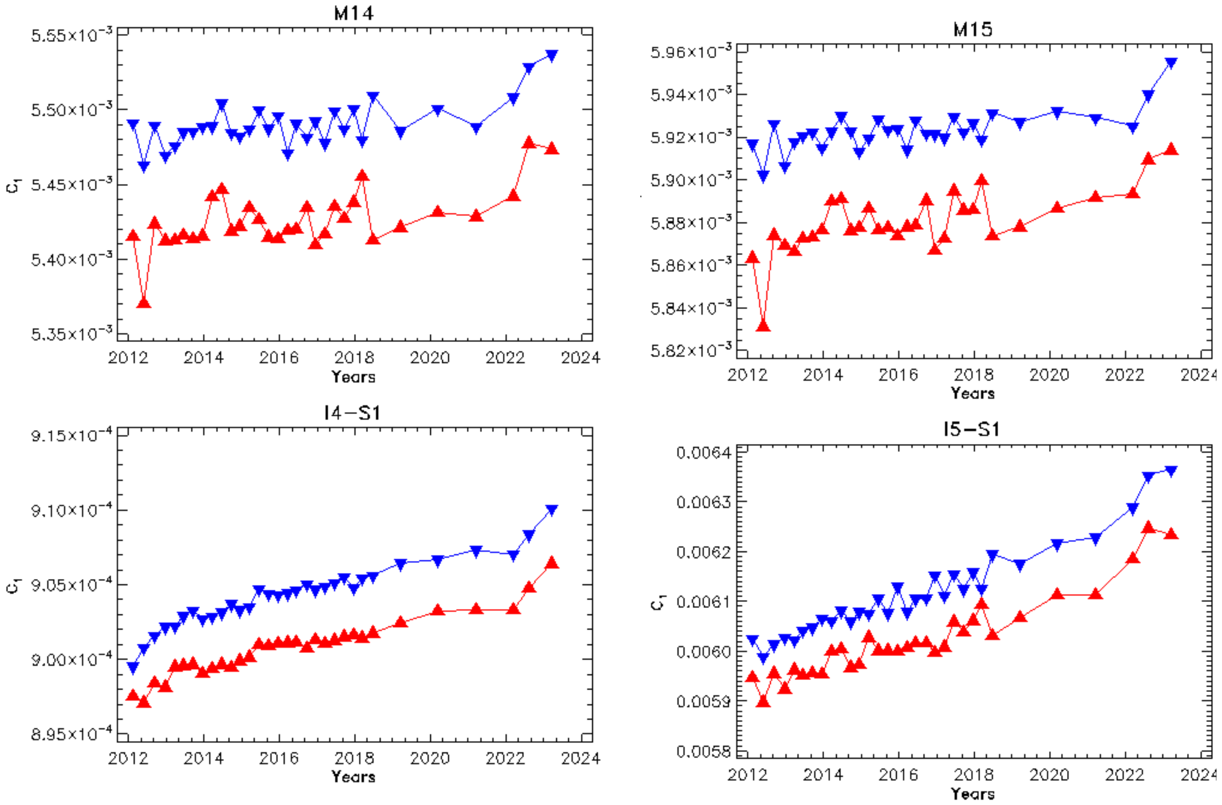


Band-avg. c_0 calibration coeffs.
Derived from 32 (S-NPP) and 9 (N20) WUCD operations through March 2023.
All other bands display similar trends.
S-NPP and N20 VIIRS TEBs exhibit similar trends for offset coefficients.

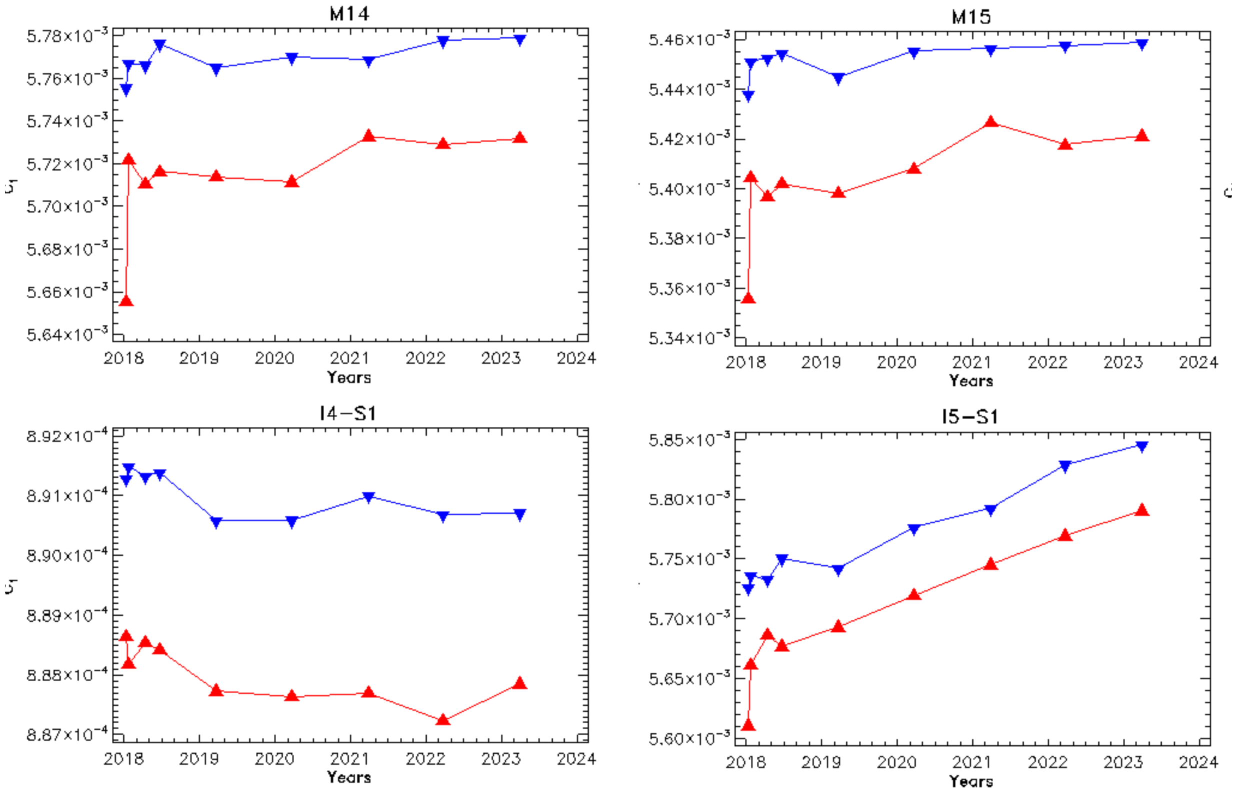
Calibration coefficients (c_1)

Warm-up
Cooldown

S-NPP



N20

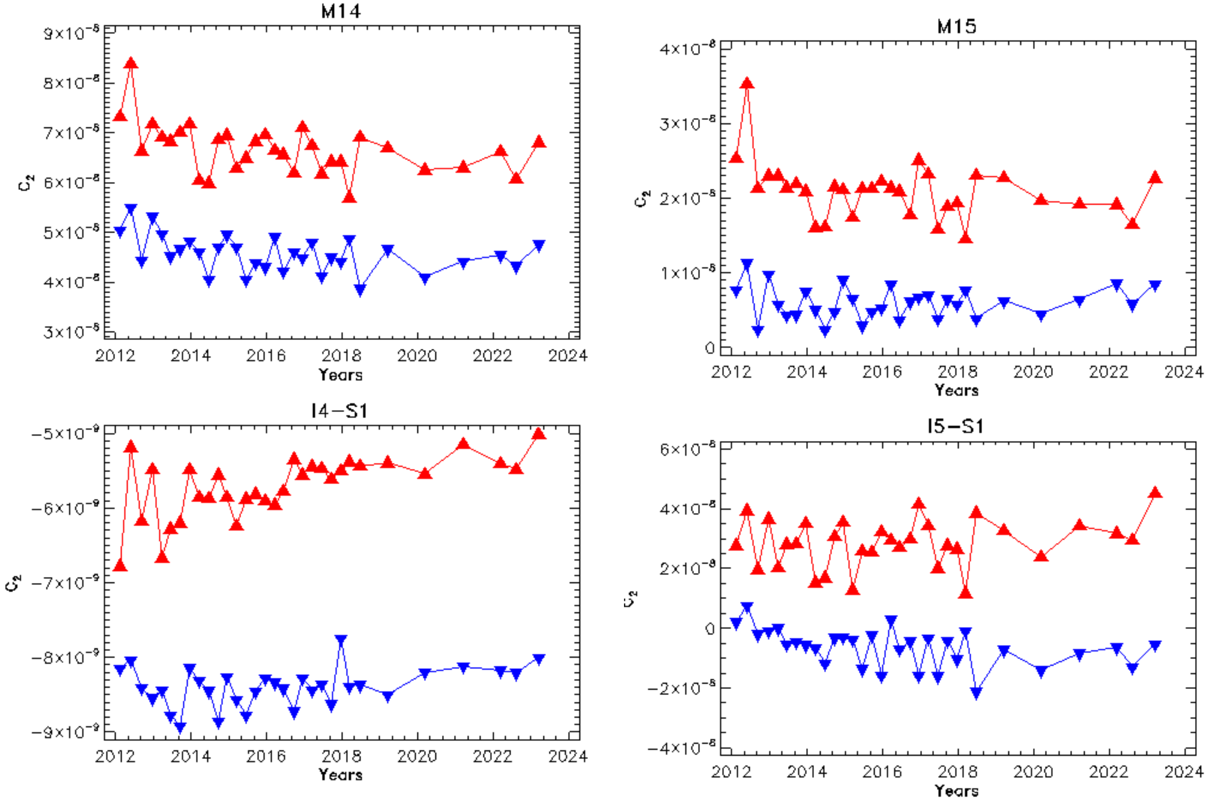


S-NPP and N20 VIIRS TEBs display similar trends for linear calibration coefficients.
All other bands exhibit similar trends.

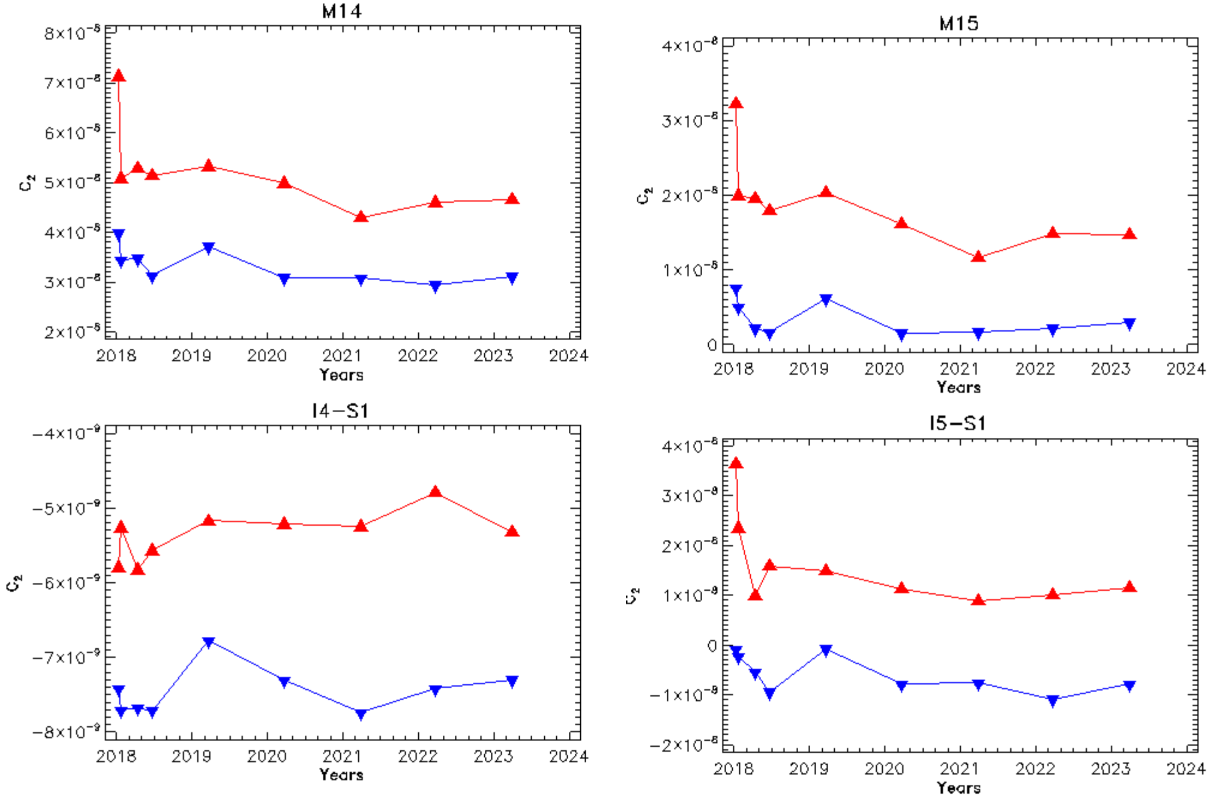
Calibration coefficients (c_2)

Warm-up
Cooldown

S-NPP



N20



S-NPP and N20 VIIRS TEBs exhibit similar trends for non-linear coefficients.
All other bands display similar trends.