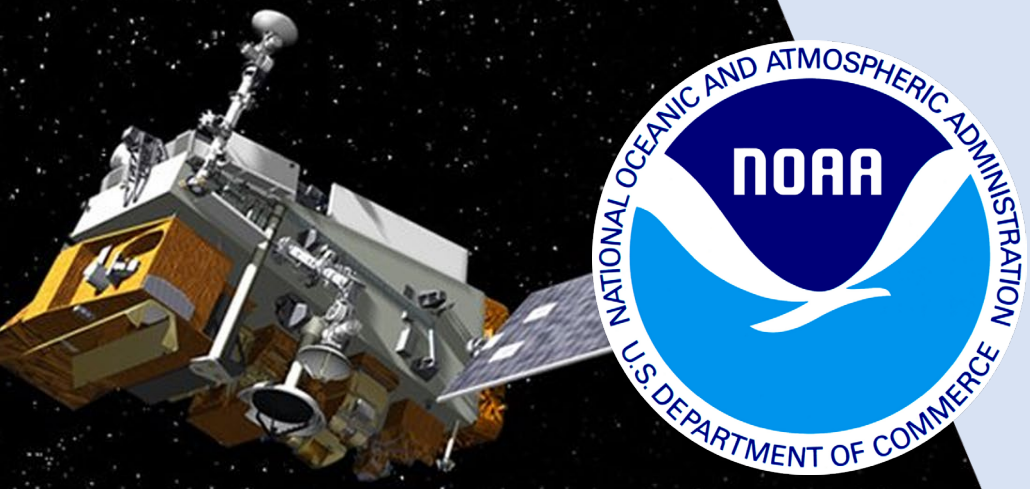

National Environmental Satellite, Data, and Information Service

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NOAA-21 VIIRS Thermal Emissive Band (TEB) On-Orbit Performance

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Acknowledgement: Dr. Changyong Cao (NOAA/STAR VIIRS Radiance team lead) and NOAA STAR VIIRS radiance team

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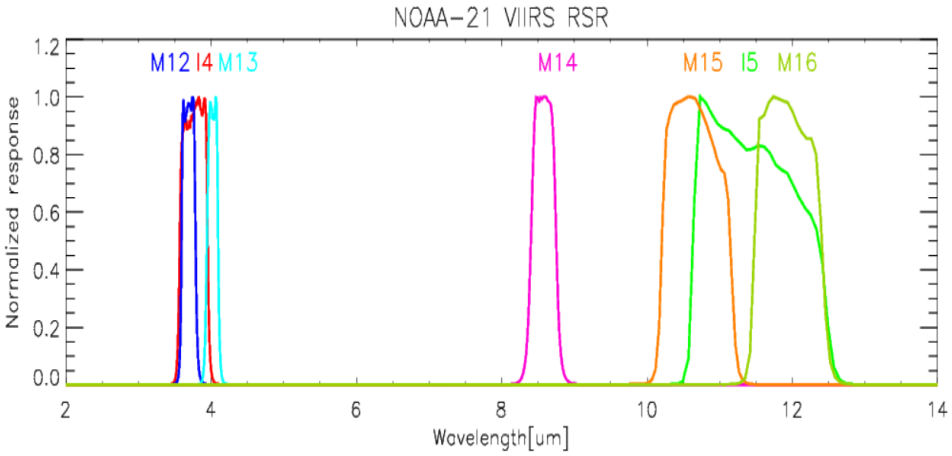
- NOAA-21 VIIRS blackbody and instrument temperature trending.
- NOAA-21 VIIRS TEB gains and degradations.
- NOAA-21 VIIRS TEB long-term calibration stability and biases, and on-orbit calibration improvements.
- Summary

Introduction

- The Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the NOAA-21 satellite was launched in Nov. 2022.
  - Following the successful operations of the VIIRS on the S-NPP/NOAA-20 satellites.

- There are 7 Thermal Emissive Bands (TEB) on VIIRS:
  - 3 MWIRs: I4 and M12-M13
  - 4 LWIRs: I5 and M14-M16
  - Calibrated scan-by-scan on-orbit, using Onboard Blackbody (OBCBB), space view, and prelaunch/on-orbit calibration parameters



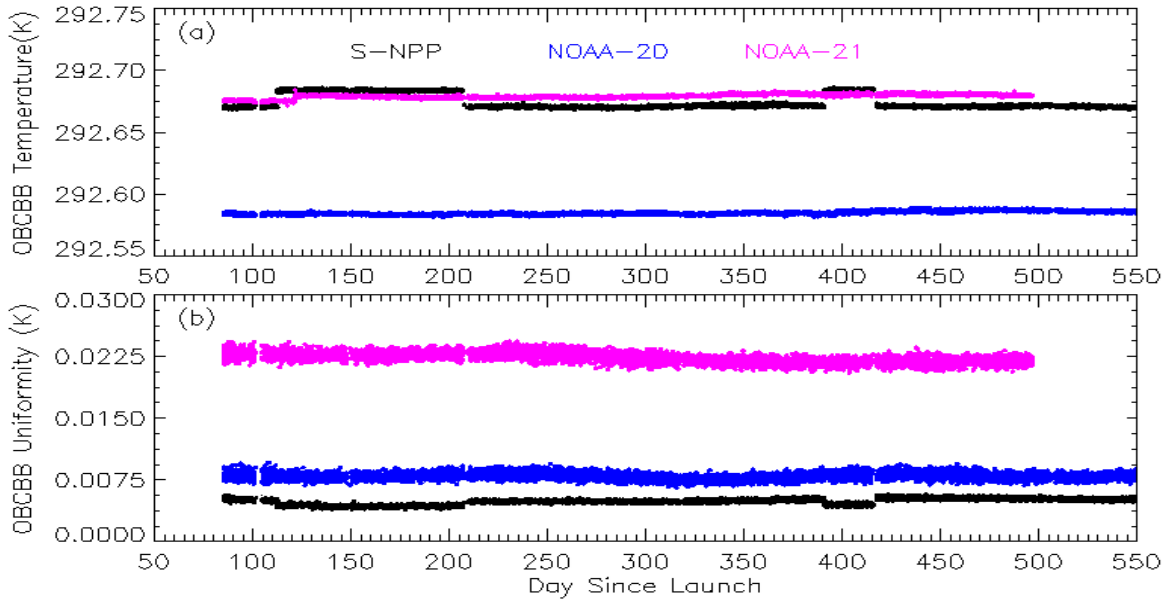
- Similar to NOAA-20 and S-NPP, NOAA-21 VIIRS TEB Sensor Data Records (SDR) are valuable for monitoring severe weather events and deriving a wide variety of Environmental Data Records (EDR).

NOAA-21 VIIRS TEB On-Orbit Events

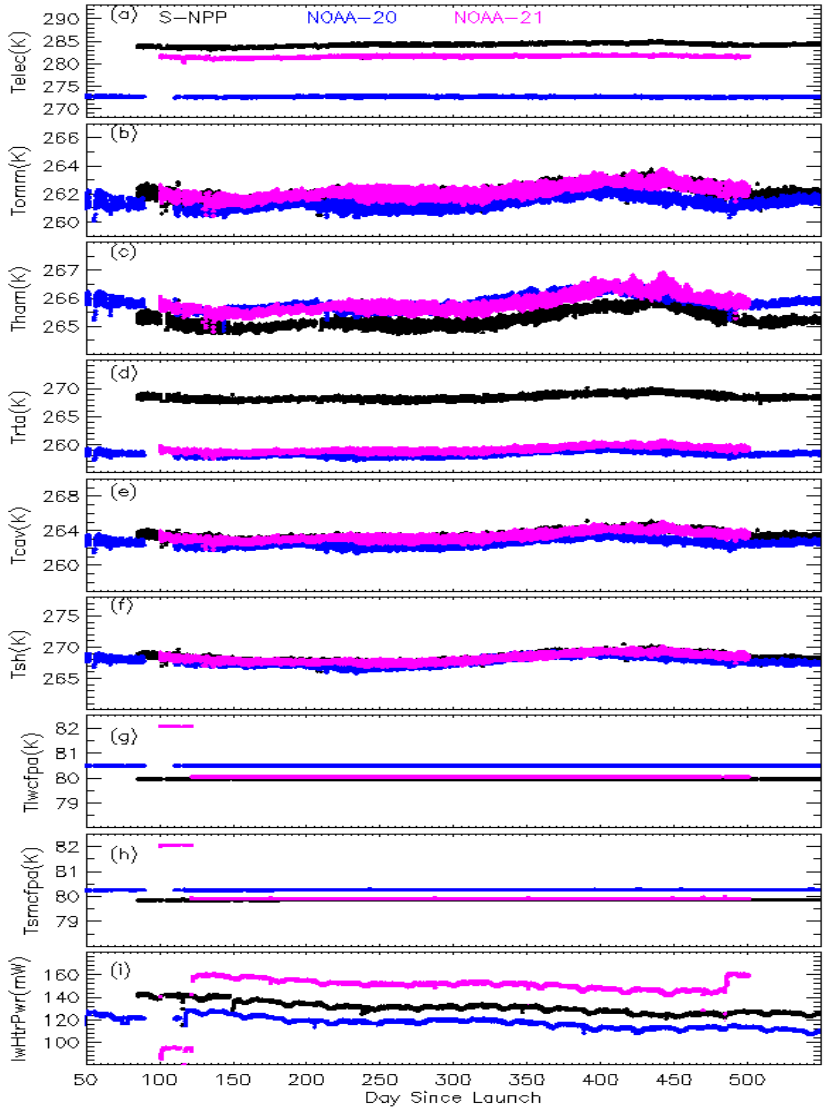
	Date	Event
1	Dec. 5, 2022	Nadir doors open
2	Feb. 8, 2023	Cryo-radiator door open
3	**Feb.10, 2023**	**CFPA temperatures reached 82 K**
4	Feb. 23, 2023	1st Mid-Mission Outgassing (MMOG-1)
5	**Mar. 3, 2023**	**CFPA temperatures 82 K → 80 K**
6	Mar. 10, 2023	Spacecraft Pitch Maneuver
7	Mar. 10-13, 2023	1st blackbody warm-up/cool-down (WUCD), 4-day
8	Mar. 16-18, 2023	2nd blackbody WUCD, 3-day
9	Mar. 23, 2023	Delta-C LUT for the 80 K CFPA temperatures implemented in the operations
10	Jun. 7, 2023	On-orbit pitch maneuver data derived LWIR responses versus scan angle (RVS) implemented.
11	Feb. 26, 2024	2nd mid-mission outgassing (MMOG-2)
12	Mar. 4, 2024	Operational WUCD bias correction implemented.
13	Mar. 5-7, 2024	3rd blackbody WUCD

Instrument Temperature Telemetry

- NOAA-21 VIIRS OBCBB temperature and uniformity has been stable since the beginning of the mission.
  - Less uniform than NOAA-20 and S-NPP, may > 40 mK during daytime.
- Other instrument temperatures are comparable with NOAA-20 and S-NPP.



Sweet-spot granules for solar calibration were used.

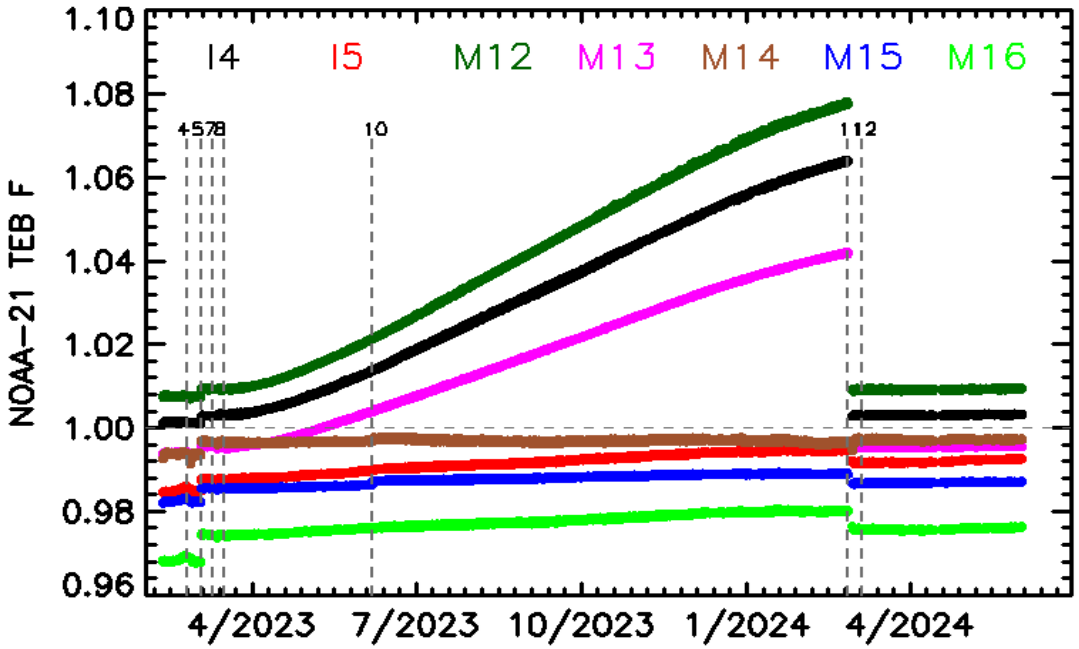


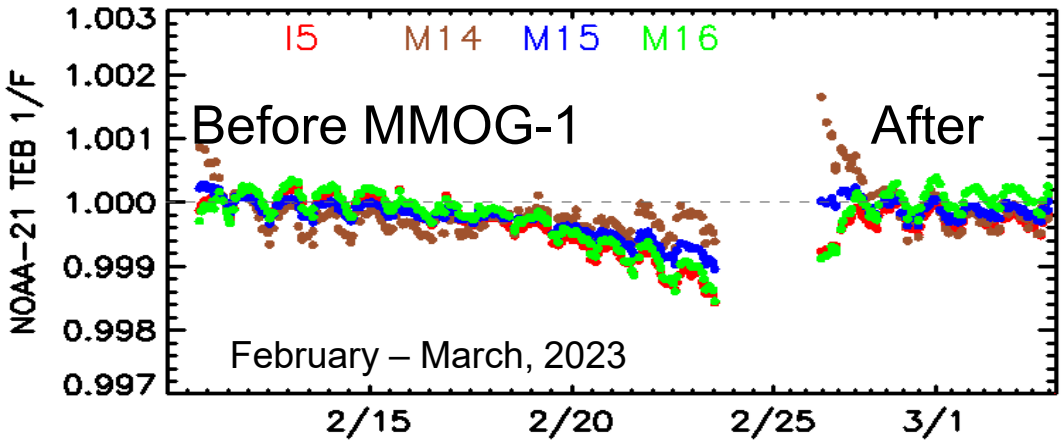
NOAA-21 TEB F-factors/Gains

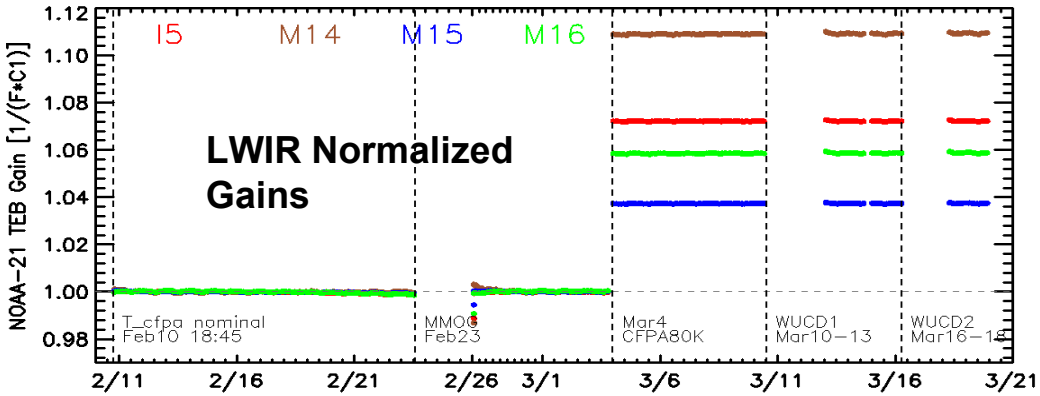
- Small LWIR degradations were observed early in the mission.

  MMOG-1 (Feb. 23, 2023) successfully removed potential ice contamination.

- CFPA temperatures was switched from 82 K to 80 K on March 3, 2023 to improve noise performance.
  - LWIR gains increases by 4-11%.

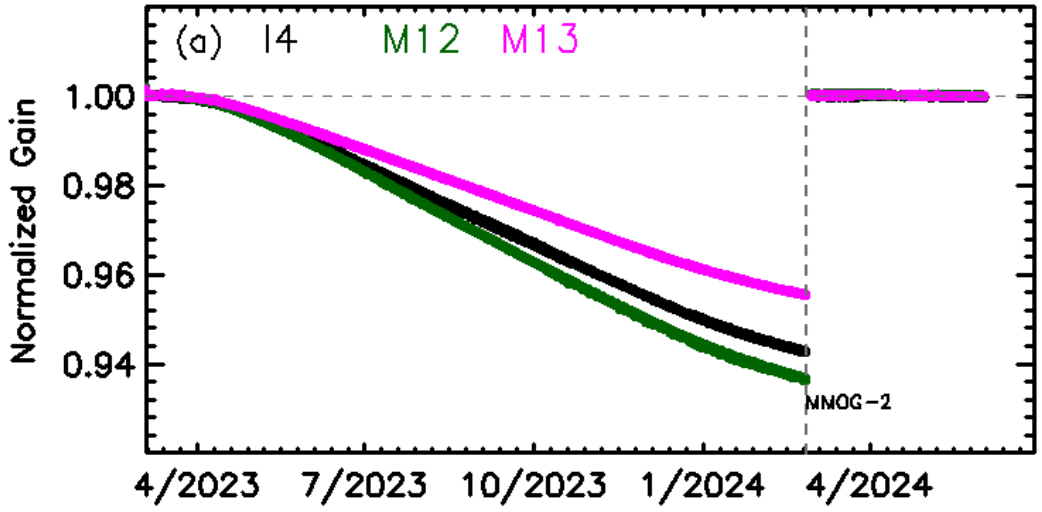


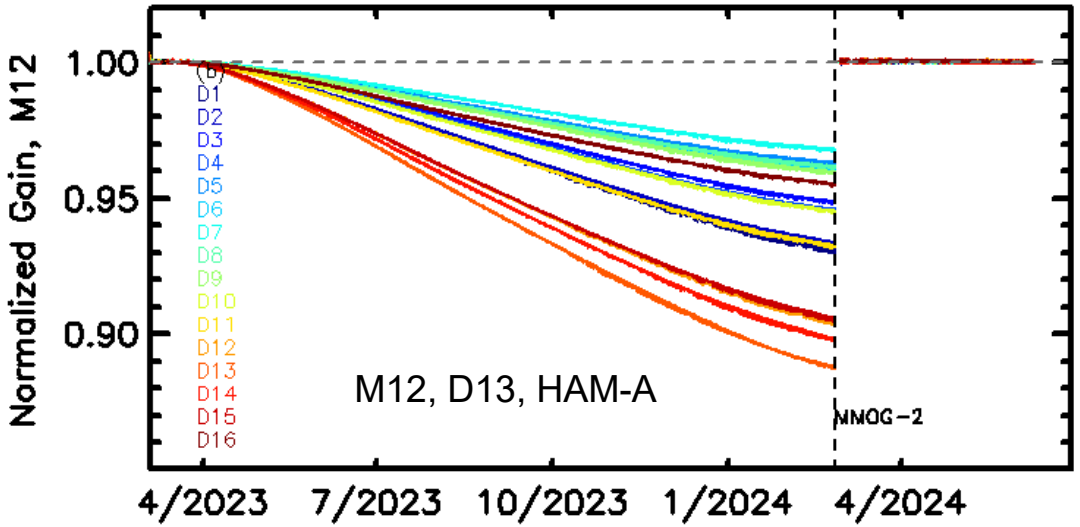




NOAA-21 TEB Gains

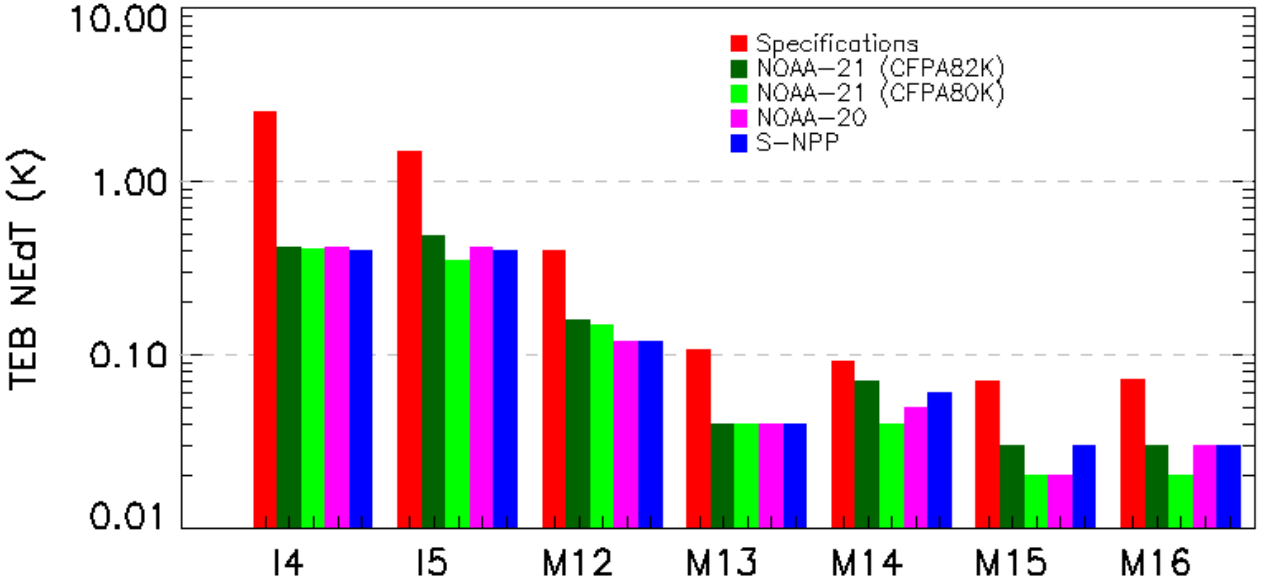
- MWIR gains degraded significantly from around mid-March, 2023 to Feb. 2024.
  - Band averaged degradations: 5.8% (I4), 6.4% (M12) and 4.4% (M13).
  - Detector dependent, up to ~12% for some I4/M12 detectors
  - Coincident with the even faster degradations observed in SWIR bands.
- The MMOG-2 was successfully performed on Feb. 26, 2024.
  - MWIR gains returned to the March 4, 2023 levels nearly perfectly, and have been stable to-date.
  - LWIR degradations were reversed ~50% or more compared to the March 4, 2023 levels and now appear similar to NOAA-20.

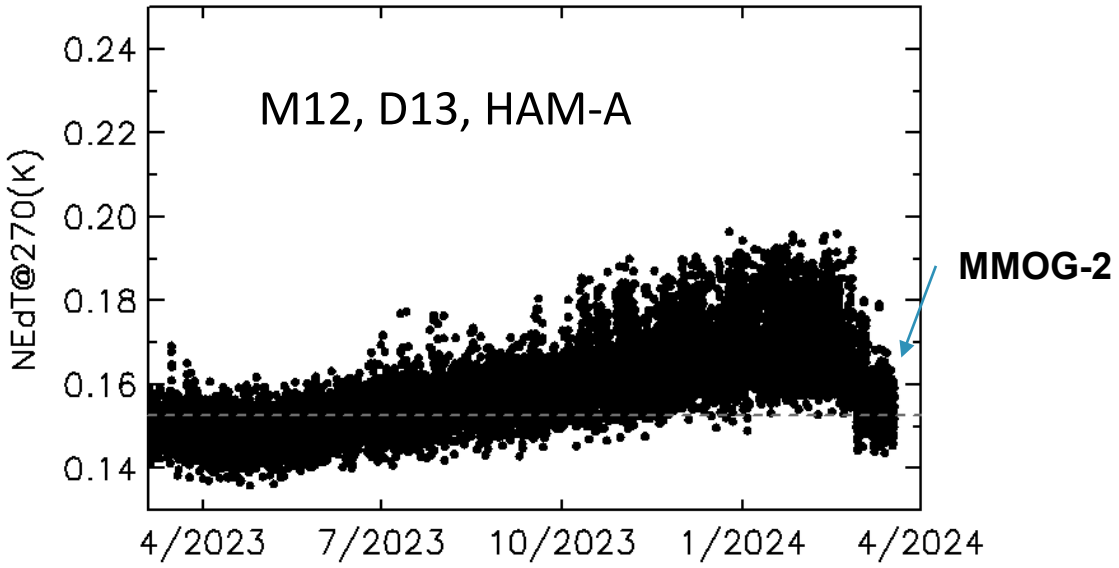




TEB Noise/NEdTs

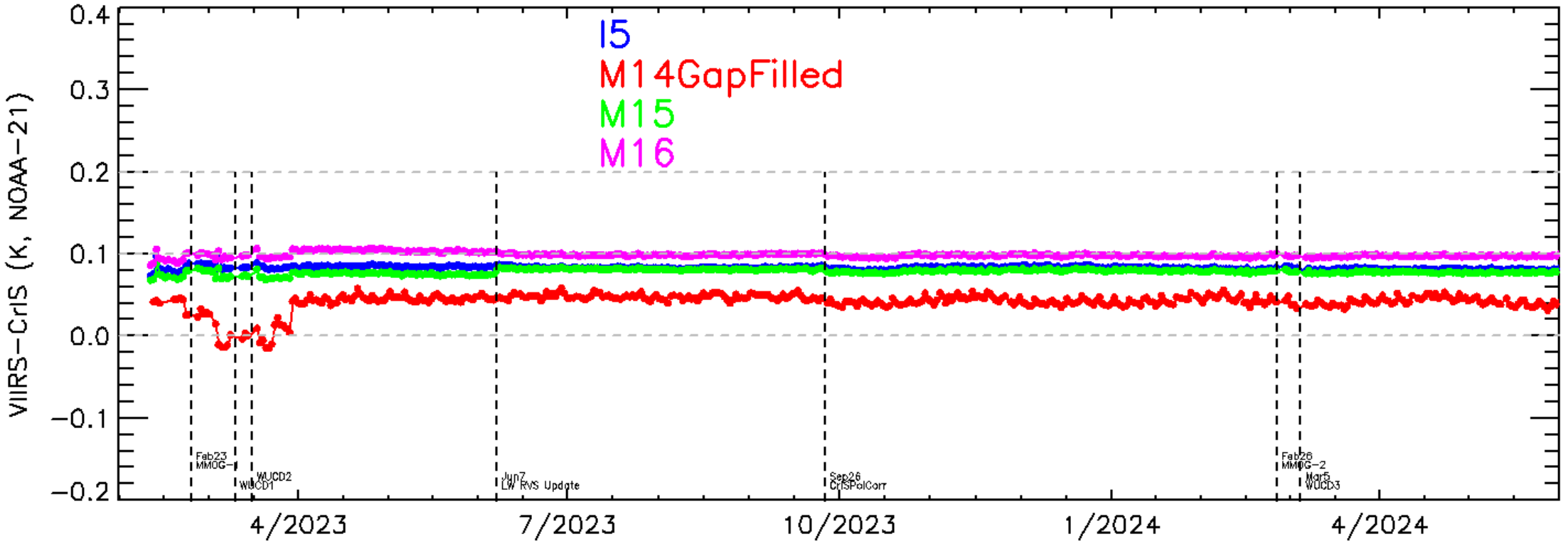
- NOAA-21 VIIRS TEB NEdTs have been comparable to NOAA-20/S-NPP.
  - All well within specifications.
  - LWIR NEdTs were further improved after the CFPA temperatures switched to 80K
  - The impacts of the post-MMOG-1 degradations on NEdT became obvious on MWIR detectors with large degradations, but were successfully reversed by the MMOG-2.





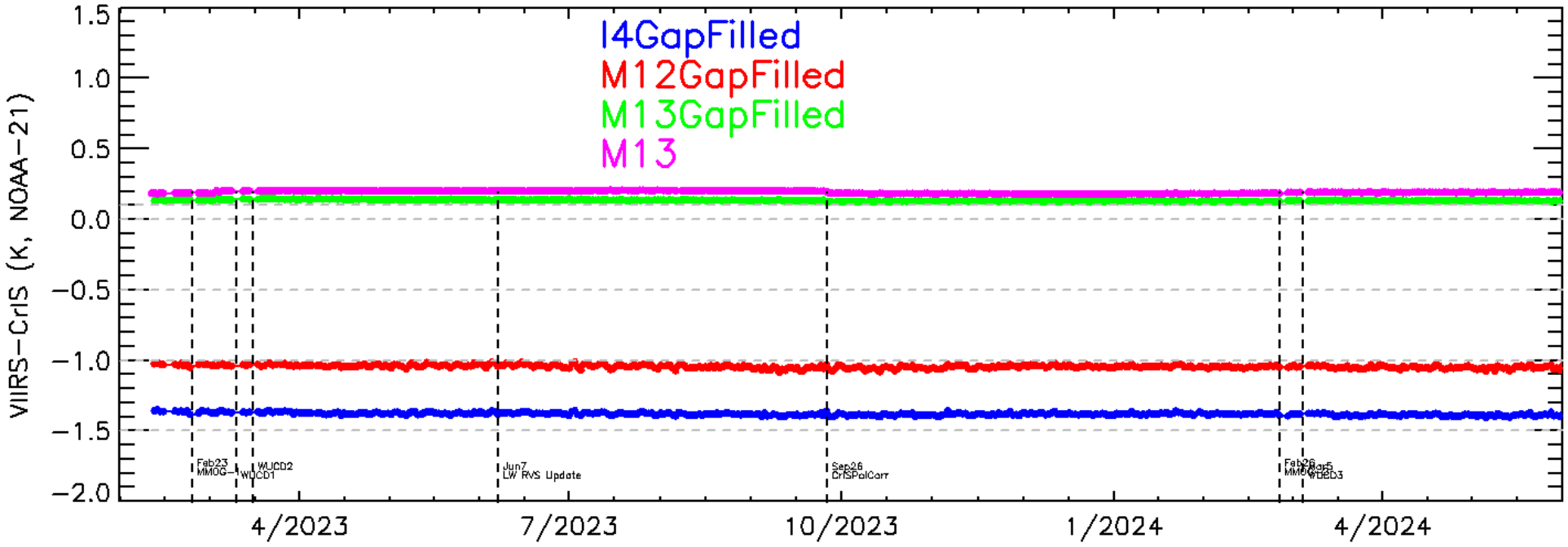
NOAA-21 VIIRS-CrIS Daily Averaged BT Biases (LWIR)

- I5 and M14-M16 agree well with co-located CrIS data during nominal operations.
  - Biases are within ~0.1 K, comparable to NOAA-20 and S-NPP.
  - M14 was evaluated using CrIS gap-filled spectra (Xu et al. 2019).



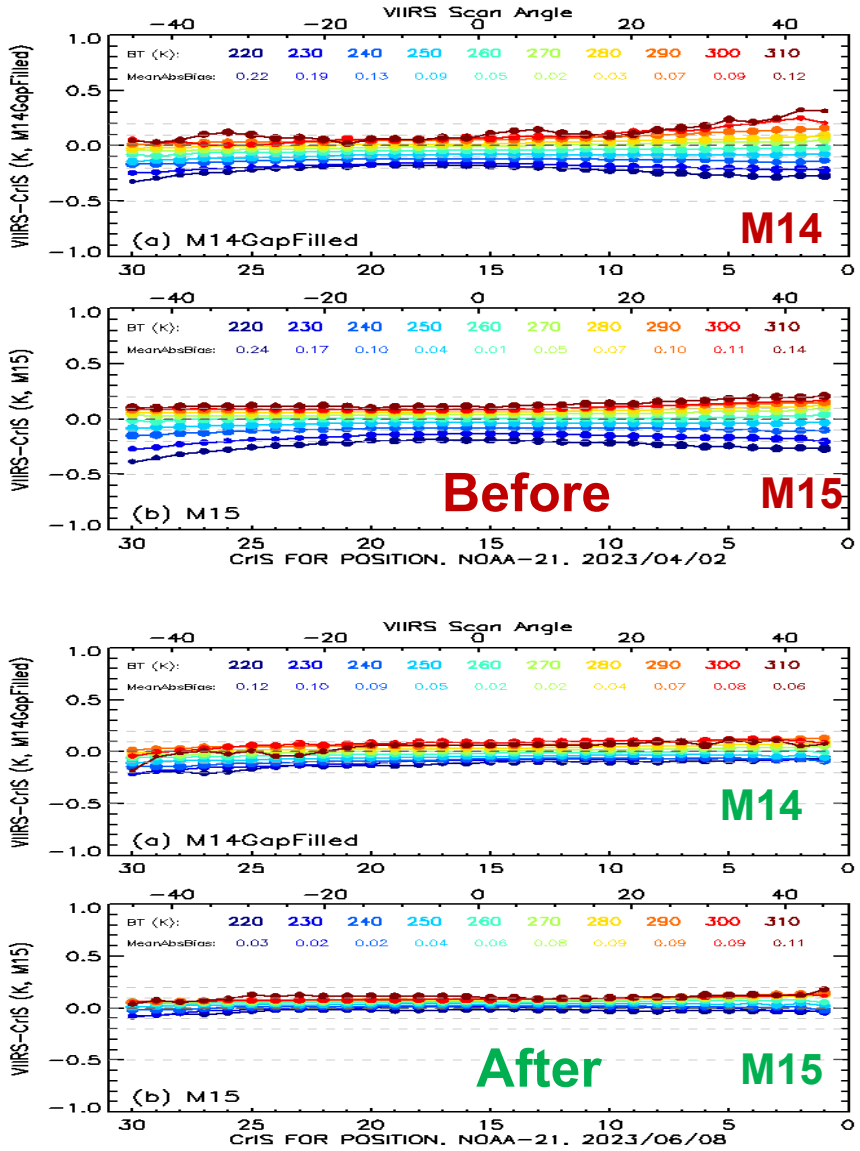
NOAA-21 VIIRS-CrIS Daily Averaged BT Biases (MWIR)

- M13 on-orbit calibration is also stable, relative to co-located CrIS data.
  - Bias: ~0.13 K (based on VIIRS - CrIS gap-filled spectra, nighttime)
  - CrIS gap-filled spectra improve RSR coverage: 96.7% (observed) → 99.8%
- The calibration of I4 and M12 are also stable.
  - The constant biases are mainly due to the spectral mismatch (only ~80% covered by the CrIS gap-filled spectra).



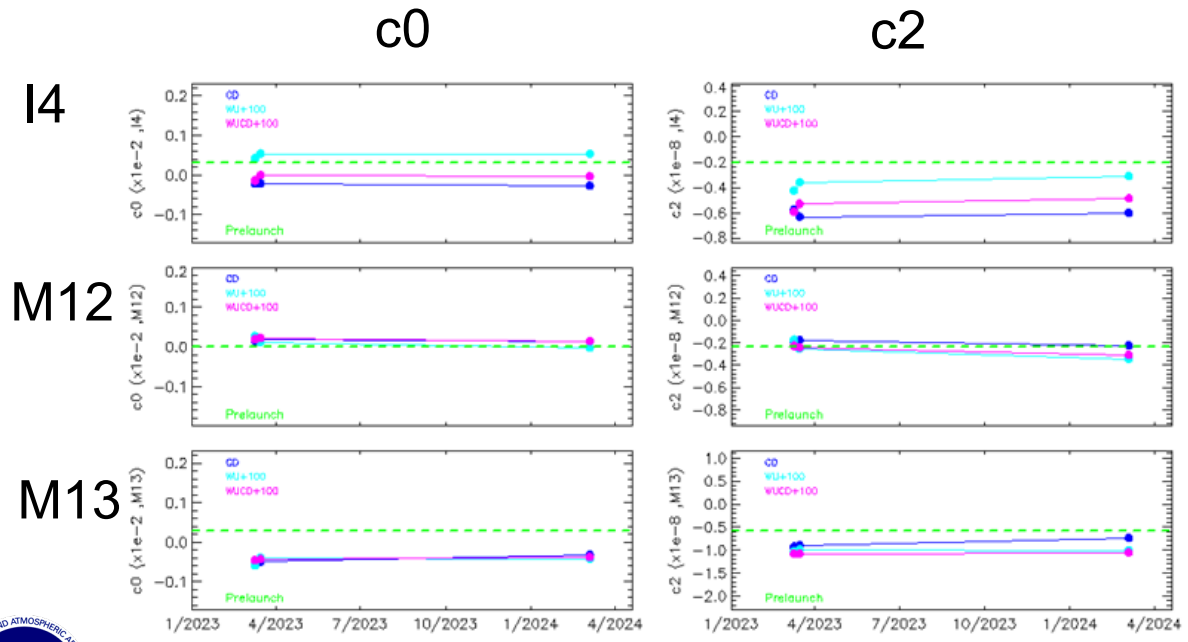
Correction of LWIR Scan Angle/Scene Temperature Dependent Biases

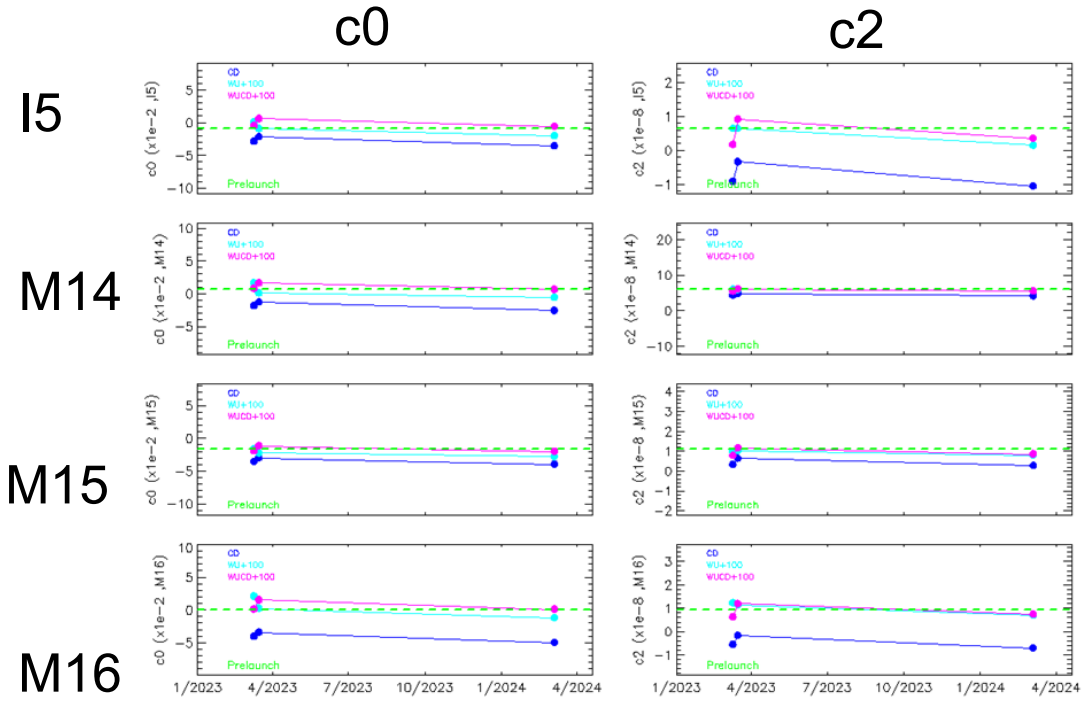
- During nominal operations, persistent scan angle/scene temperature dependent biases were observed when pre-launch calibration LUTs were used.
  - M15: up to ~0.5 K @ 220 K near the beginning of scans.
  - Confirmed by the CrIS team and VIIRS pitch maneuver data analyses.
- On-orbit pitch maneuver data derived LWIR calibration coefficients have been implemented operationally since June 7, 2023.
  - The biases were reduced at all scan angles and scene temperatures (within ±0.15 K).
  - Further reduced after the CrIS polarization correction.



NOAA-21 VIIRS TEB WUCD Data Analysis

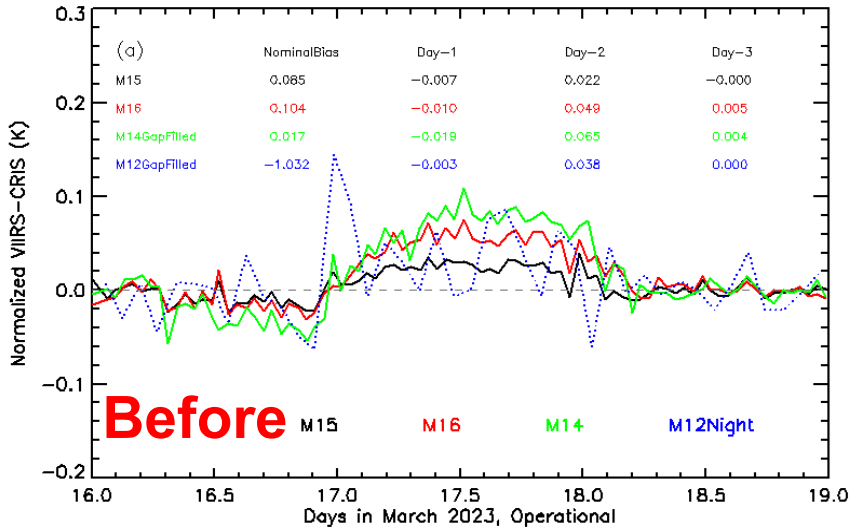
- Three WUCDs tests have been performed to characterize NOAA-21 VIIRS TEB on-orbit calibration offset (c0) and nonlinearity (c2) changes over time.
  - MWIRs: agree well with prelaunch values.
  - LWIRs: larger differences exist, but similar to NOAA-20.

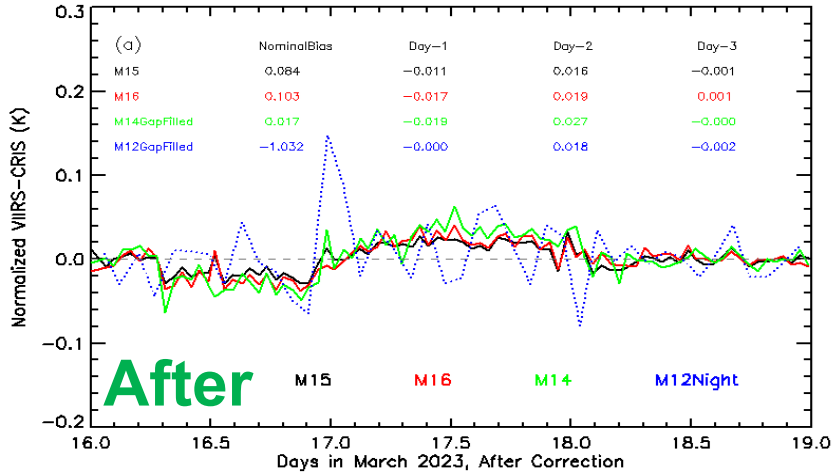




Correction of NOAA-21 TEB Calibration Biases during WUCD

- TEB calibration anomalies during WUCD were observed, similar to NOAA-20 and S-NPP.
  - M15-M16: daily averaged biases ~ 0.05 K during the cool-down phase.
  - Introducing spurious spikes in the daytime daily SST – *in situ* time series.
- WUCD bias correction coefficients were developed and implemented on March 4, 2024, to support SST retrieval.
  - Evaluated using reprocessed SDRs and the reprocessed daily SST – *in situ* time series.
  - Further verified using the 3rd WUCD data (March 5-7, 2024).
  - Residual M15-M16 biases are ~0.01 K, similar to NOAA-20 and S-NPP.





Summary

- **NOAA-21 VIIRS TEBs have been performing generally well after launch.**
  - OBCBB and instrument temperatures are stable during nominal operations.
  - NEDTs are well within specifications; LWIR NEdTs further reduced after the CFPA temperature was switched to 80 K.
  - TEB on-orbit degradations have been successfully mitigated by the two MMOG events.
    - MMOG-1 (Feb. 2023) successfully reversed the small LWIR degradation in the early mission.
    - MMOG-2 (Feb. 2024) successfully reversed the post-MMOG-1 MWIR and LWIR degradations.
- **NOAA-21 VIIRS TEB SDRs are stable and agree well with co-located CrIS data.**
  - I5 and M14-M16 BT biases within 0.1 K; M13: ~0.13 K.
  - Pitch maneuver data derived calibration coefficients have been performing well, and LWIR scan angle/scene temperature dependent biases are within ± 0.15 K relative to CrIS.
  - Operational WUCD bias correction was implemented on March 4, 2024, to support SST retrieval.

Acknowledgements, Funding, Disclaimer

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- **Disclaimer:** The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author(s) and do not necessarily reflect those of NOAA or the Department of Commerce.

Backups

Impacts of MMOG-2 on NOAA-21 RSBs

- NOAA-21 VIIRS SWIRs (M8-M11, and I3) had experienced significant post-MMOG-1 degradations.
  - More rapid than MWIRs.
  - Band averaged: up to 25% for M8 (up to 60% at detector level).
- The MMOG-2 was very successful:
  - SWIR bands F-factors went back to initial levels near perfectly.
  - SWIR gains have been stable after the MMOG-2.
- No significant degradations were observed NOAA-21 VISNIR bands (M1-M7, I1 and I2).