S-NPP/N20 VIIRS Thermal Emissive Bands On-Orbit Performance and Calibration

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MODIS/VIIRS Calibration Workshop
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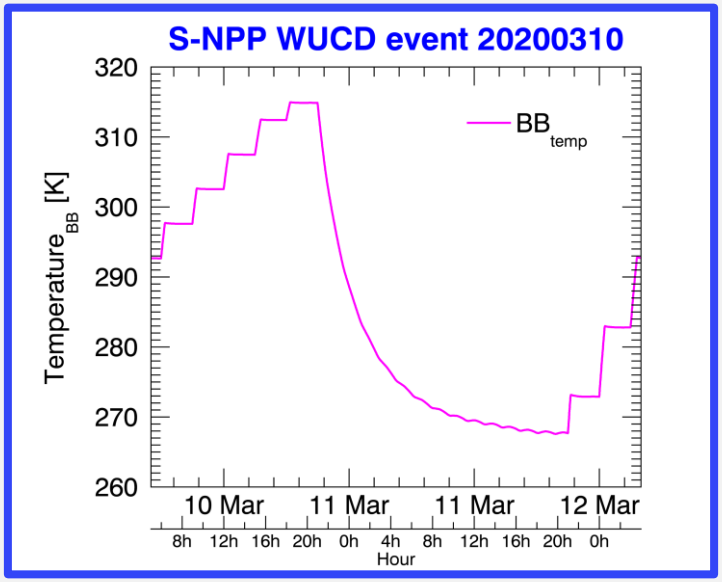
Outline

- **Instrument overview**
  - OBC black body
  - TEBs and their calibration algorithm
- **On-orbit performance**
  - BB short- and long-term stabilities
  - F-factor short- and long-term responses
  - Noise characterization (NEdT)
  - WUCD calibration coefficients trending
- **L1B Earth view trending (over ocean)**
- **L1B improvements**
- **Summary**

OBC black body

- TEBs are calibrated using on-board calibrator (OBC) black body (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
- Event frequency:
  - Launch → 06/2018 (quarterly)
  - 06/2018 → present (annually)
  - # of WUCD: **28** (S-NPP) and **6** (N20)

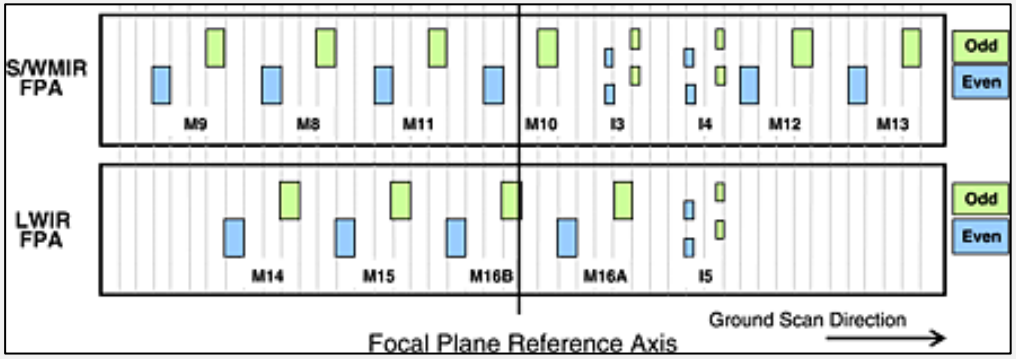


6 thermistors

Thermal Emissive Bands (TEBs)

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

- TEBs radiance source is BB reference
- BB has known emissivity and temperature
- Self-emission from inside the instrument must be subtracted
- Emissivities and temperatures from several instrument components are used
- Scaling factor (F-factor) is derived on a scan-by-scan basis



TEBs calibration algorithm

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.

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:

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

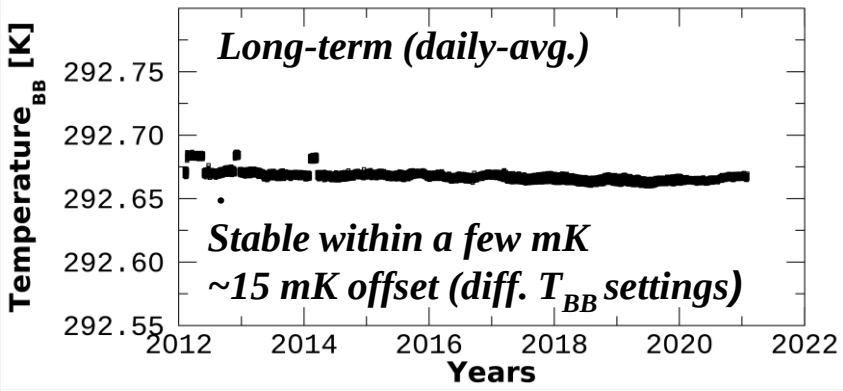
$$F(B) = \frac{RVS_{BB}(B)L_{ap}(B) + \Delta L_{bg}(B,\theta_{BB})}{\sum_{i=0}^{2} c_i dn_{BB}^i}.$$

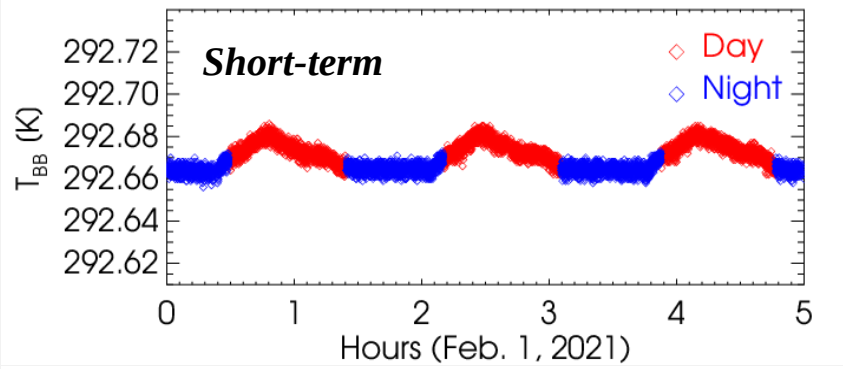
→ ***Estimated***

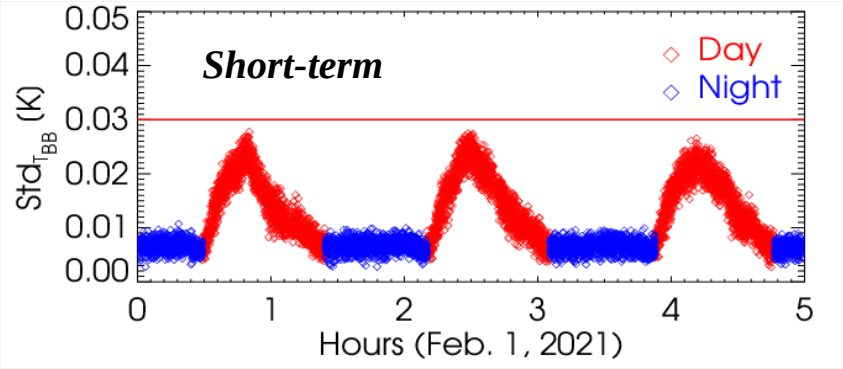
→ ***Retrieved***

BB performance

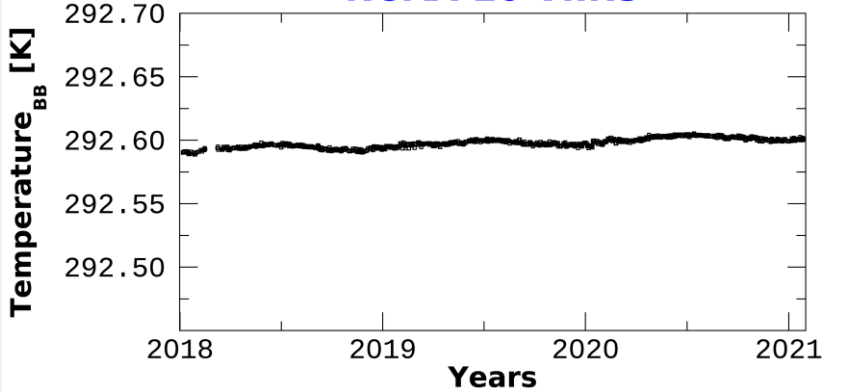
S-NPP VIIRS

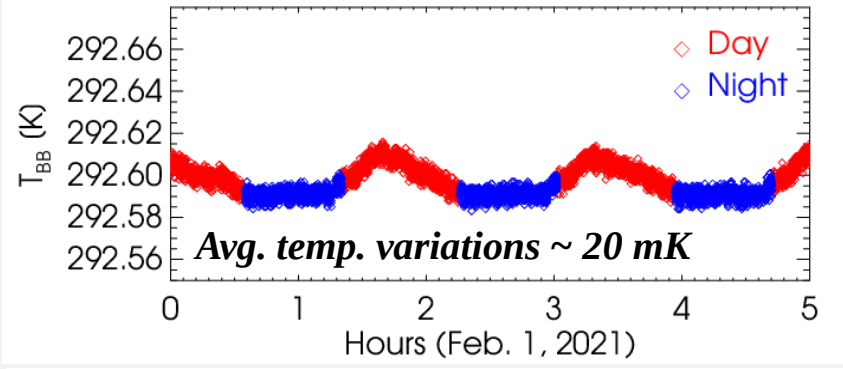


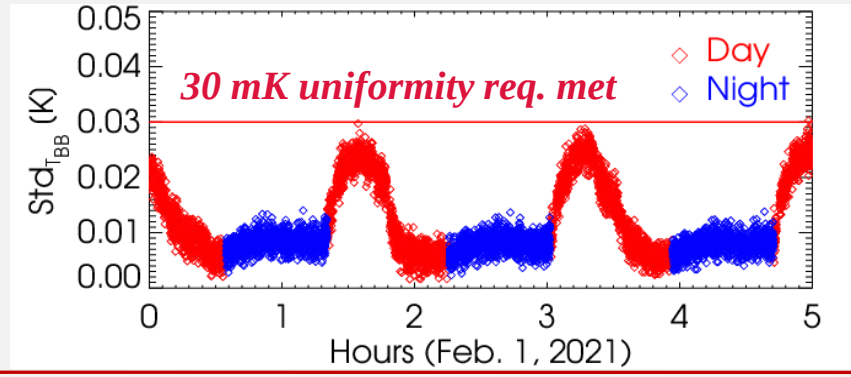




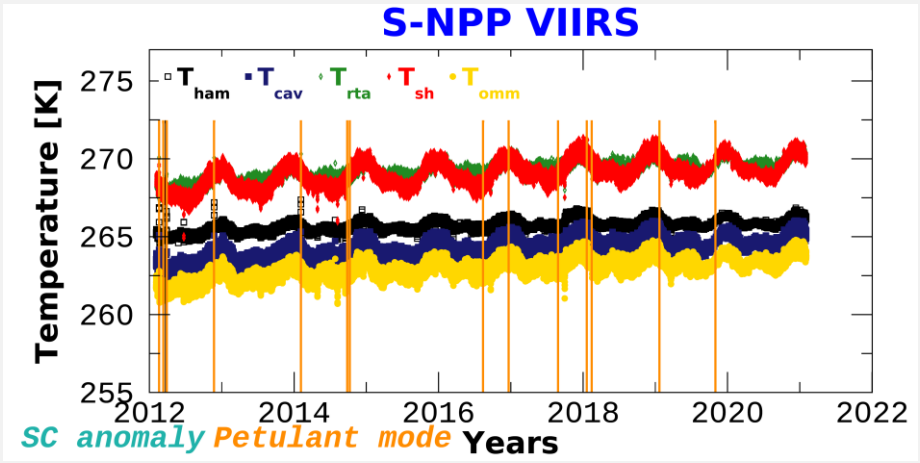
NOAA-20 VIIRS

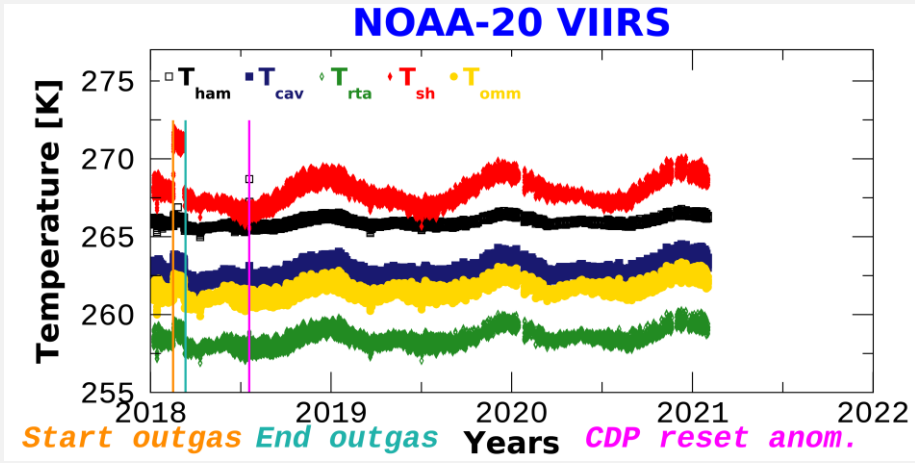


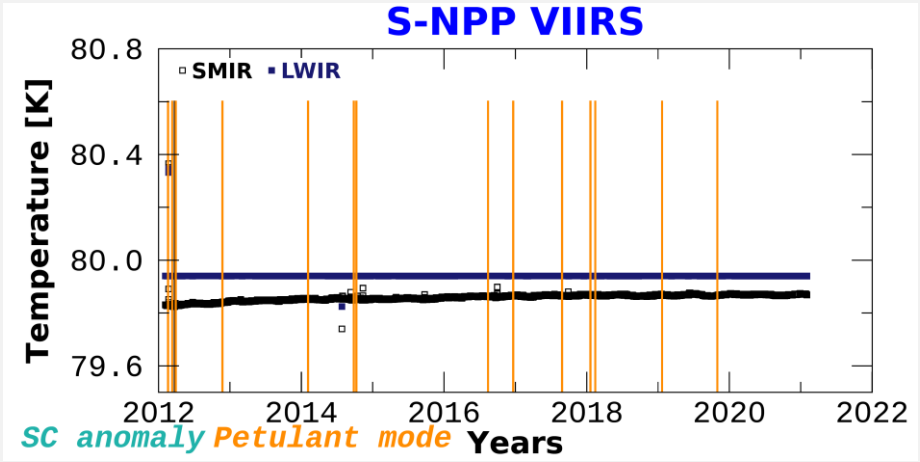


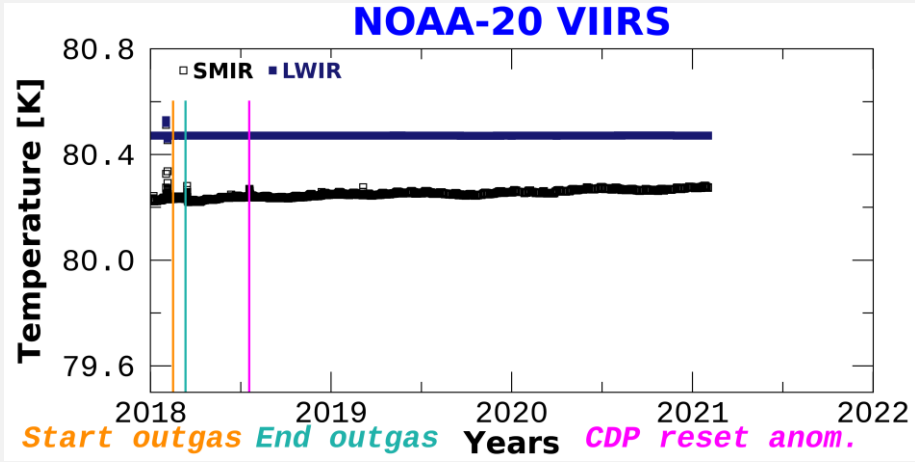


Telemetry temperatures





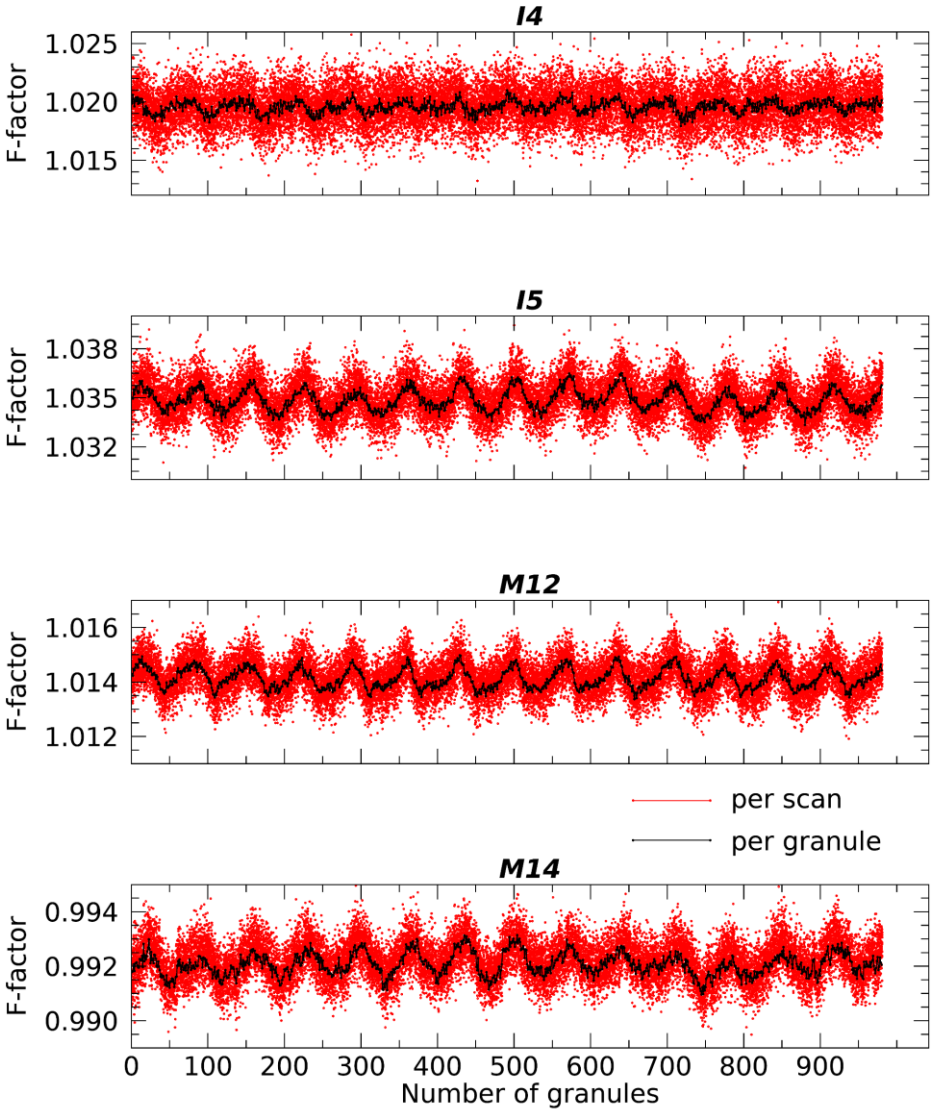




- Out-of-character features coincide with Earth passage through perihelion
- Small SMWIR focal plane temp. increasing trend that can be seen in MWIR TEBs (i.e. I4, M12, M13)

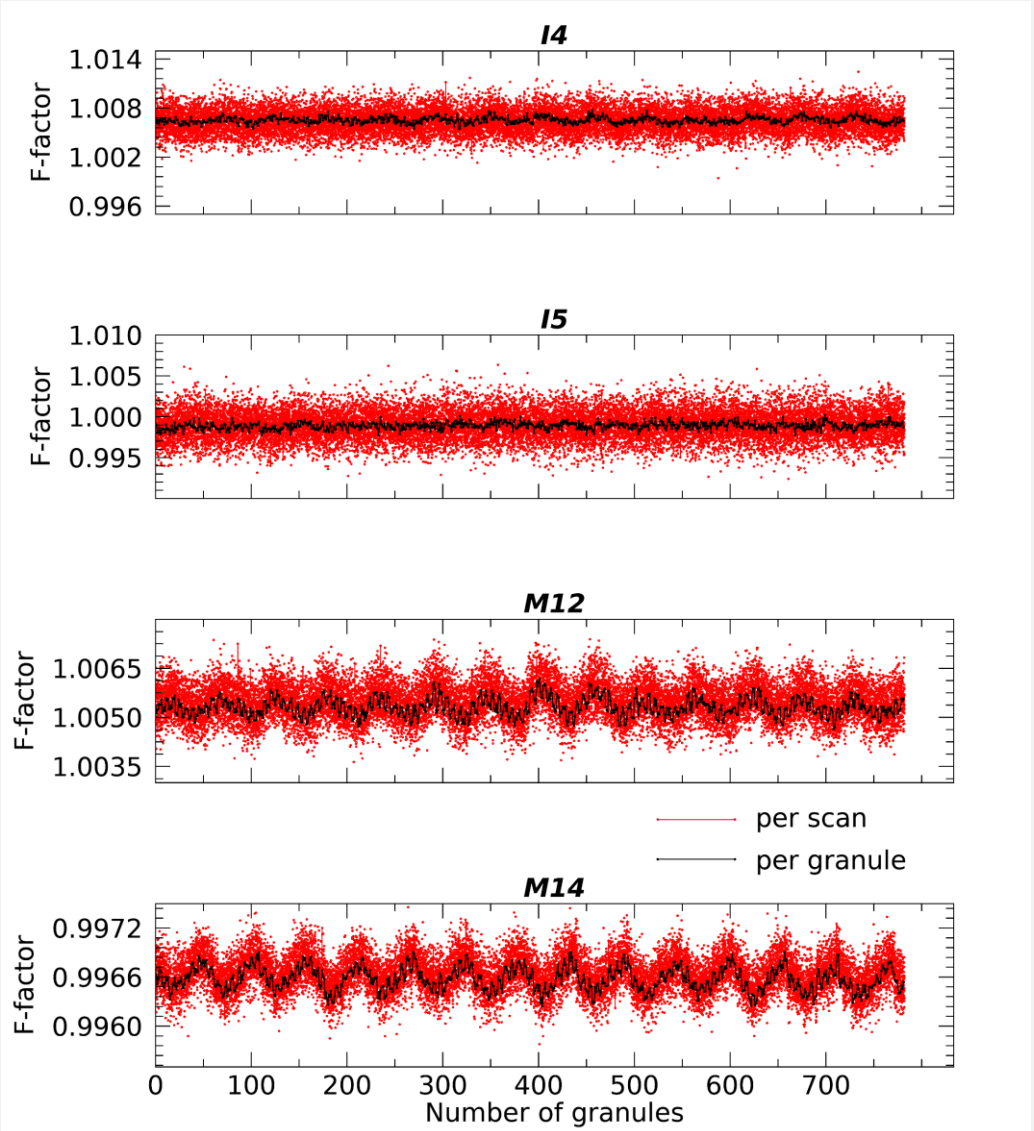
Short-term detector response (S-NPP)

- 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
- Data from Feb. 1st, 2021

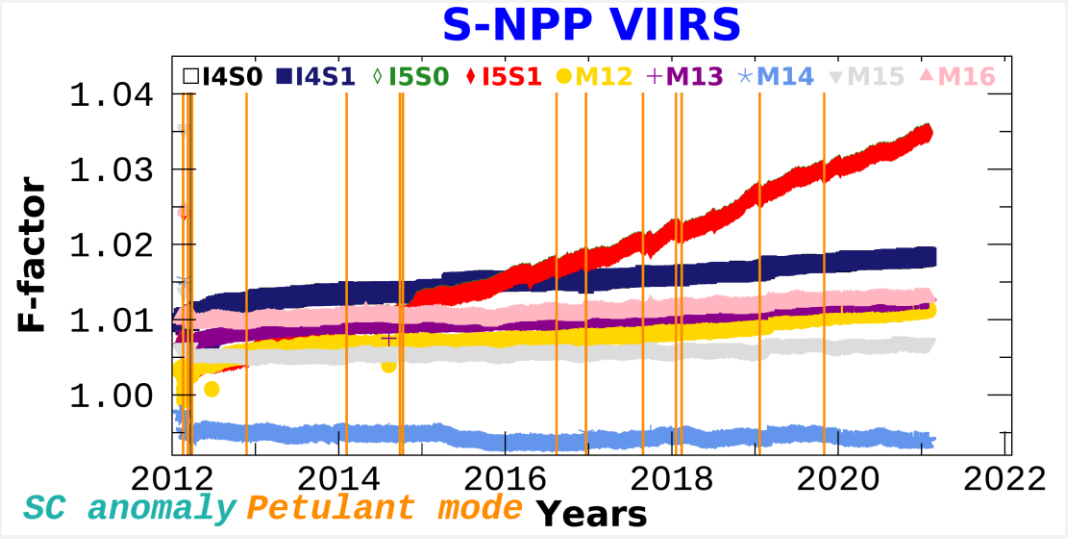


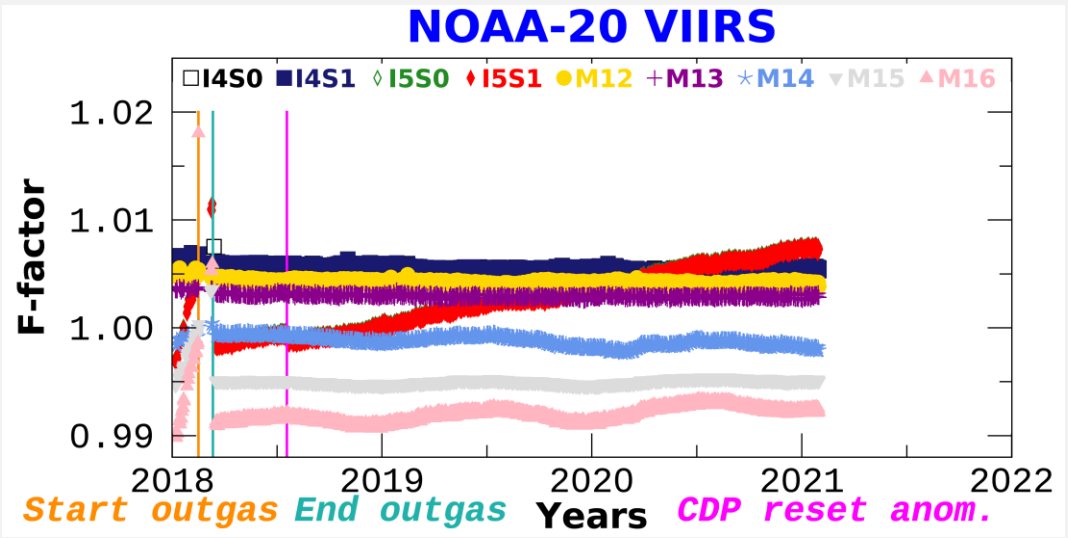
Short-term detector response (N20)

- 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
- Data from Feb. 1st, 2021



Long-term detector response



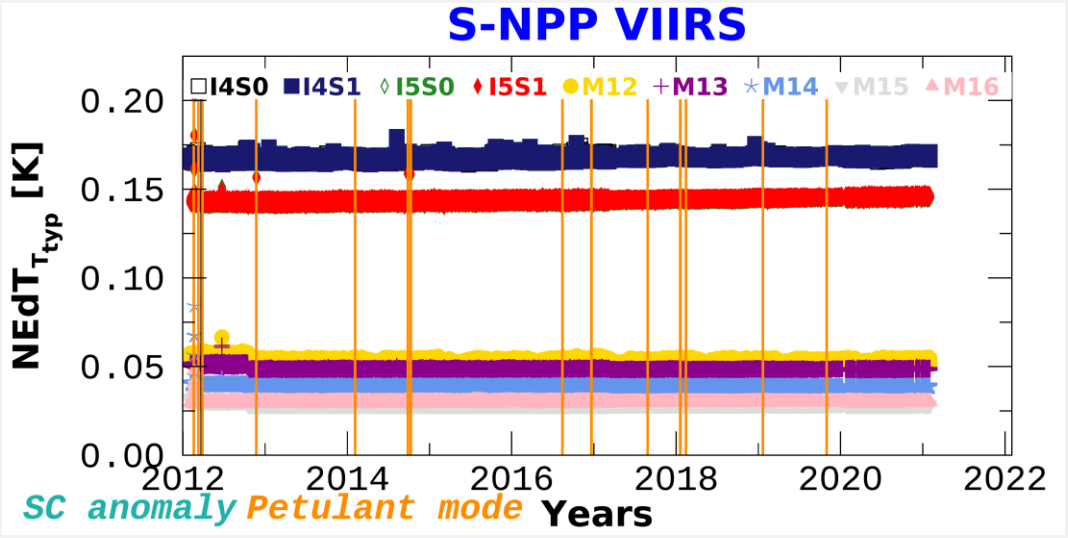


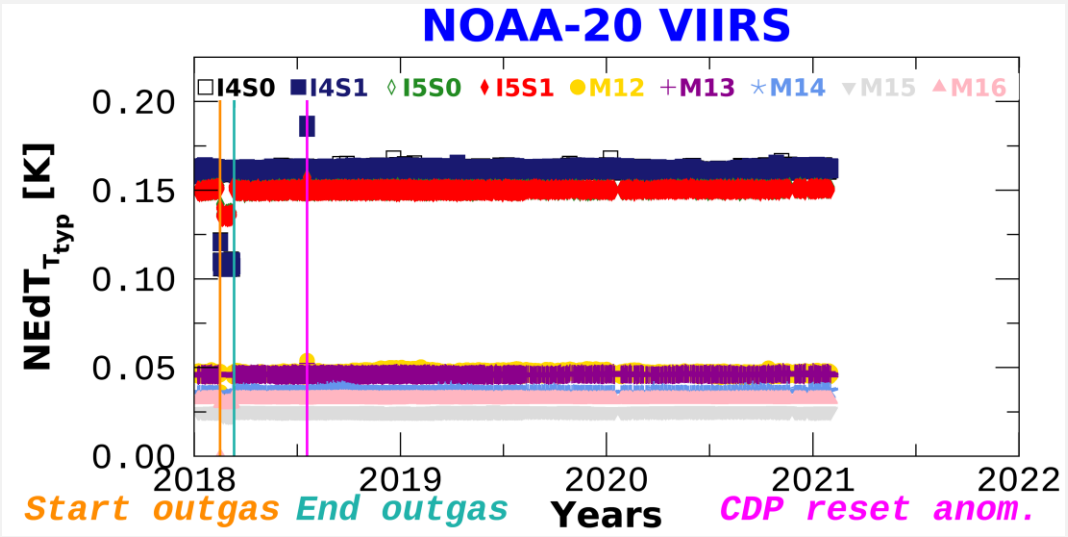
TEB	S-NPP Trend (%)	N20 Trend (%)
I4	0.81	-0.05
I5	3.08	0.91
M12	0.77	-0.07
M13	0.57	-0.03
M14	-0.08	-0.10
M15	0.11	0.02
M16	0.28	0.15

All TEBs exhibit relatively stable trends. I5 displays largest trend (~0.31 % / yr) for both instruments.

★ Band- and daily-averaged. S-NPP trend: 03/2012 to 02/2021. N20 trend: 04/2018 to 02/2021.

Noise characterization (NEdT)





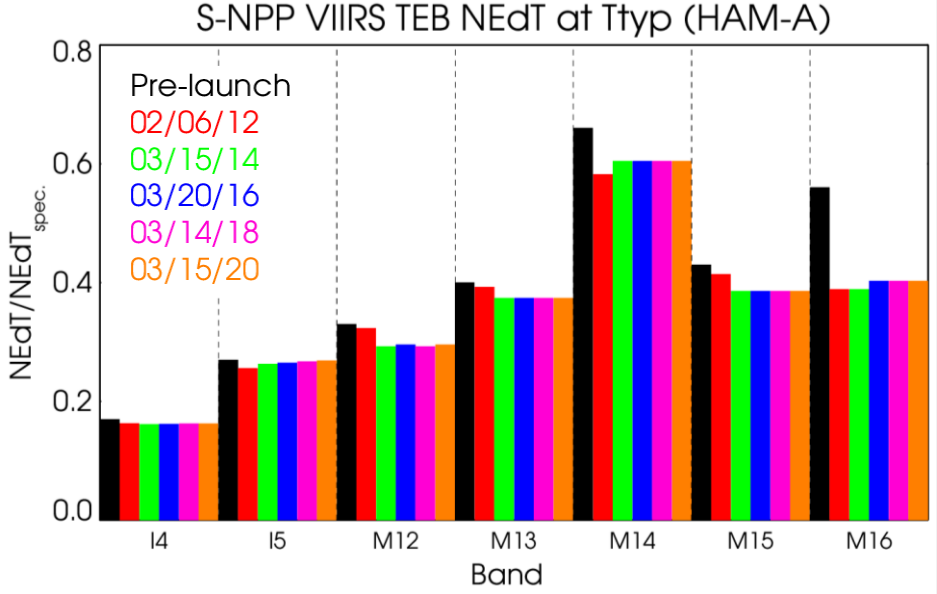
- All TEBs meet specification
- NEdT trended at 292.5 K

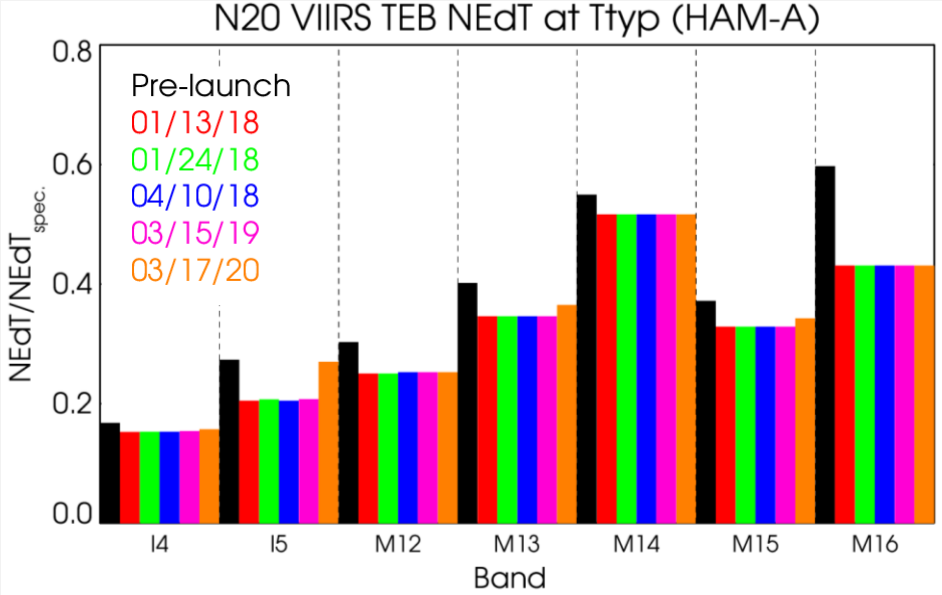
$$NEdT = \frac{NEdL}{\partial L / \partial T}$$

TEB	T_{typ} (K)	NEdT Spec. (K)
I4	270	2.5
I5	210	1.5
M12	270	0.396
M13	300	0.107
M14	270	0.091
M15	300	0.070
M16	300	0.072

★ Band- and daily-averaged

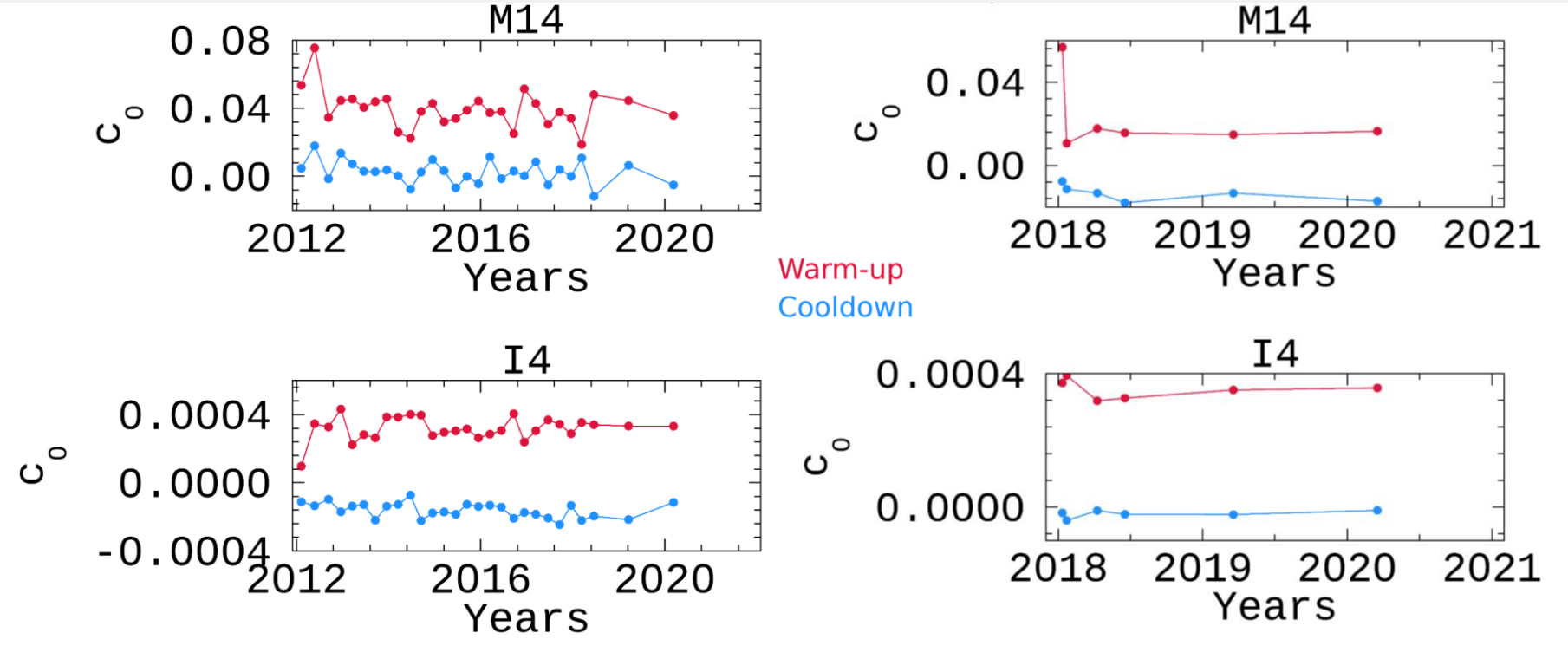
Noise characterization (NEdT)





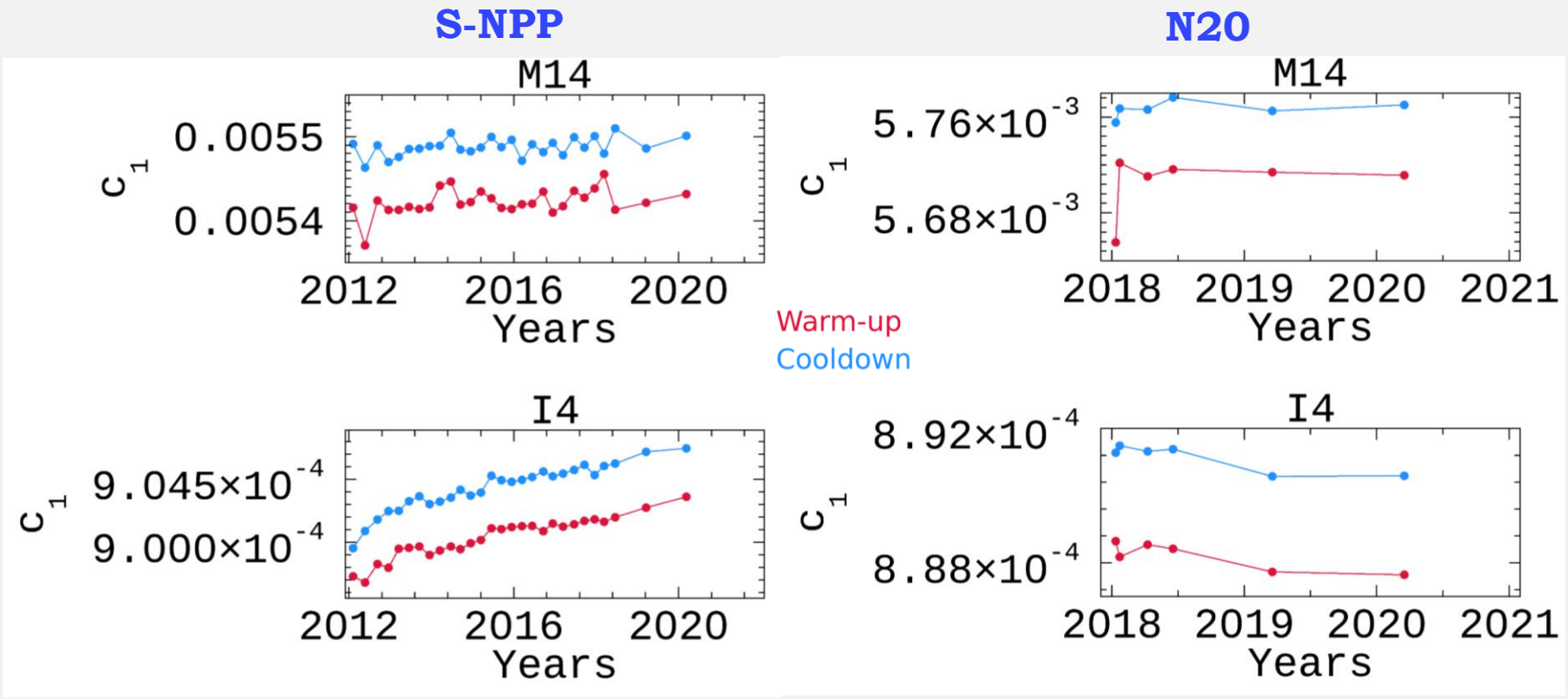
- $NEdT_{Ttyp}$ derived from BB CD data – TEBs meet sensor design req.

Calibration coefficients (c_0)



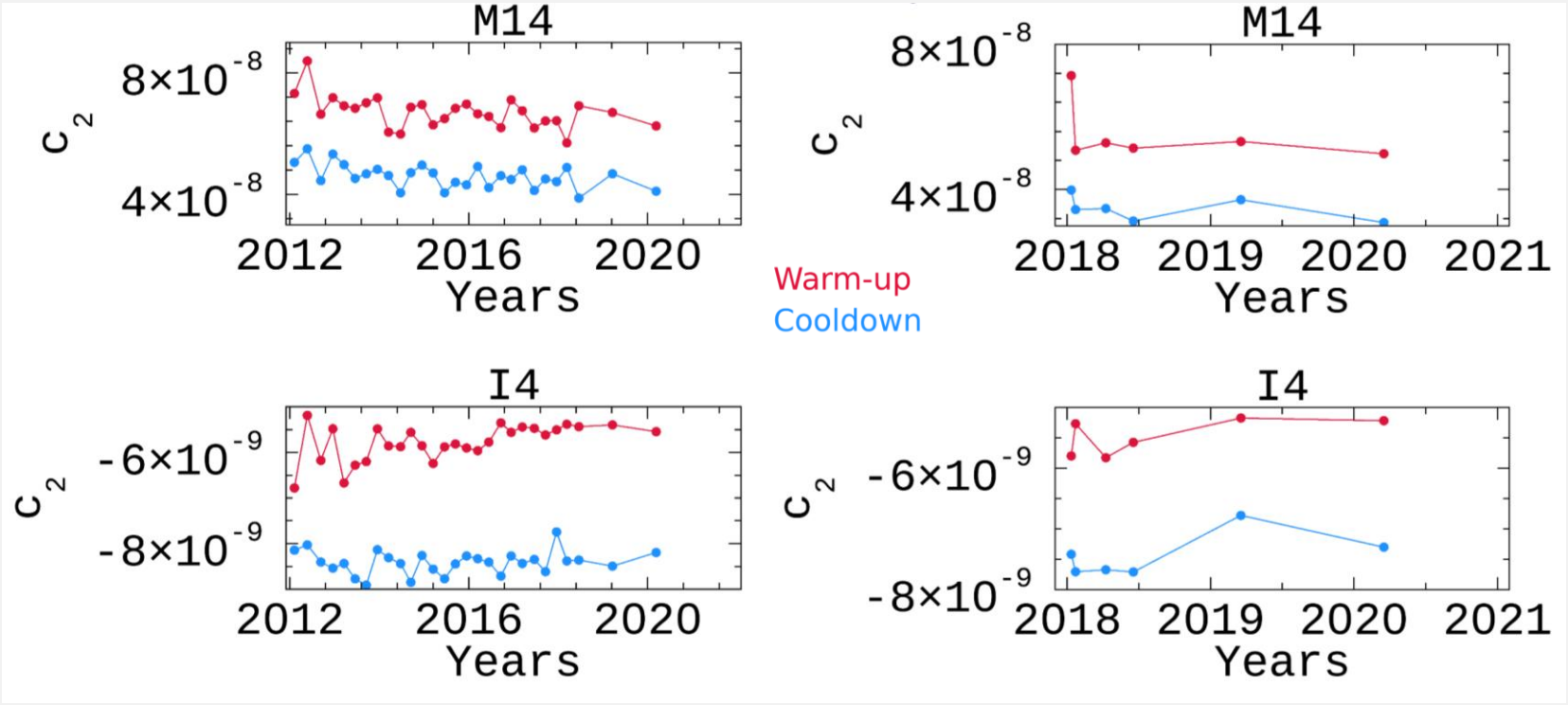
Band-avg. c_0 calibration coeffs.
Derived from 28 (S-NPP) and 6 (N20) WUCD operations through February 2021.
All other bands display similar trends.
S-NPP and N20 VIIRS TEBs exhibit similar trends for offset coefficients.

Calibration coefficients (c_1)



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

Calibration coefficients (c_2)

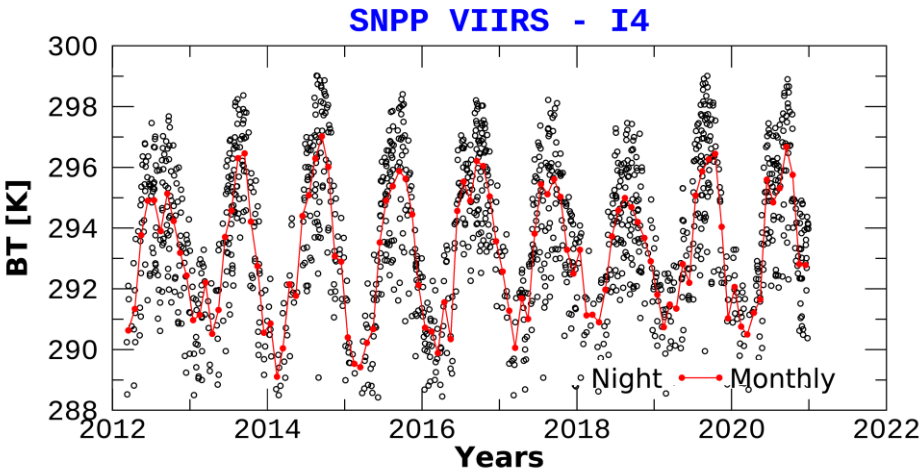


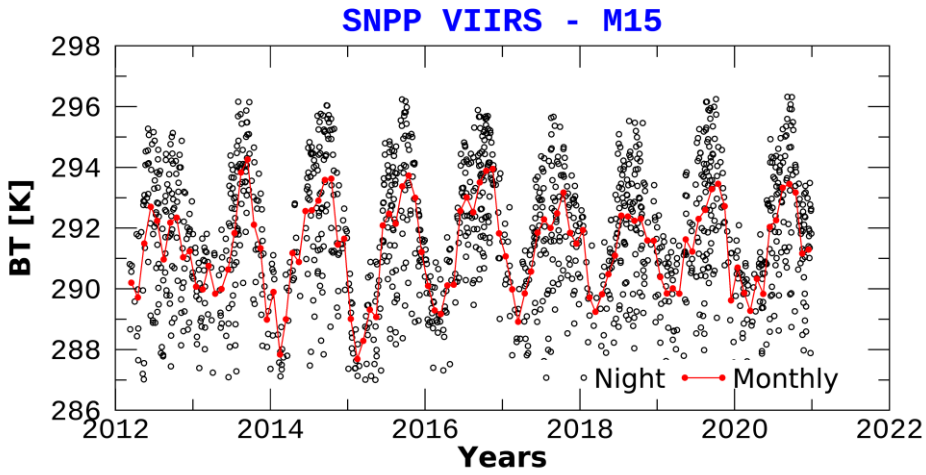
S-NPP and N20 VIIRS TEBs exhibit similar trends for non-linear coefficients.
All other bands display similar trends.

L1B Earth view trending (over ocean)

- **NASA L1B data over ocean site in the Pacific Ocean near Hawaii**
  - **Nighttime observations only**
  - **Average brightness temperature value is calculated over a 20 km x 20 km region-of-interest**
  - **For S-NPP VIIRS:**
    - **Collection 1**
    - **Cloud-covered pixels are excluded using Level 2 cloud mask.**
  - **For NOAA-20 VIIRS (in progress):**
    - **Collection 2**
    - **Cloud-covered pixels are excluded using I5 or M15.**

L1B Earth view trending (over ocean)





Temperature change rate [K/yr]						
I4	I5	M12	M13	M14	M15	M16
0.004	0.004	-0.016	0.022	0.001	0.003	0.004

S-NPP VIIRS M13 exhibits the largest temperature drift
(~ 0.19 K since launch; when compared to M15) amongst all TEB.
All TEB display reasonably stable trends.

NASA L1B TEBs improvements

- **TEB improvements in V3.1:**
  - **Increase of M13 brightness temperature (BT) resolution was done in V3.0. An error in M13 BT conversion table and metadata has been fixed in V3.1.**
  - **Scan and pixel Quality Flags during lunar calibration have been corrected, corresponding to sector rotation and missing EV data, respectively.**
  - **NOAA-20 pre-launch RVS (reflectance vs. scan angle) table for all bands has been redacted in V3.1.0.1 LUT.**
- **TEB improvements in progress:**
  - **Uncertainty analysis and Uncertainty Index (UI) implementation in L1B.**
  - **Earth view trending over typical temperature scenes.**

Summary

- **On-orbit BB short- and long-term performances for S-NPP (~10 years) and NOAA-20 (~3 years) VIIRS are quite stable.**
- **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 %.**
- **The TEBs detector noise characteristics are stable for both instruments. The NEdT at T_{TYP} is compliant with the requirements.**
- **L1B Earth view trending over ocean site (T_{TYP}) for S-NPP VIIRS demonstrates all TEBs are well-calibrated. N20 VIIRS TEBs will be monitored in the future using same methodology.**
- **Following N20 VIIRS anomaly (abnormal HAM/RTA syncing that resulted in data loss for over 6 hours), no significant change in the on-orbit performance of the instrument's TEBs.**