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

TEB group

VIIRS Characterization Support Team, NASA/GSFC

Acknowledgments: VIIRS SDR team and VCST members

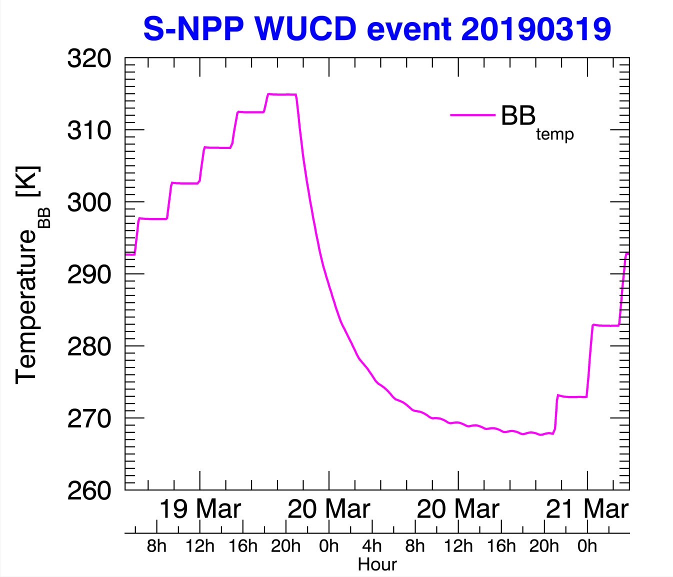
MODIS and VIIRS Science Team Meeting, College Park, MD
November 18th-22nd,2019

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
- **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: 27 (S-NPP) and 5 (N20)

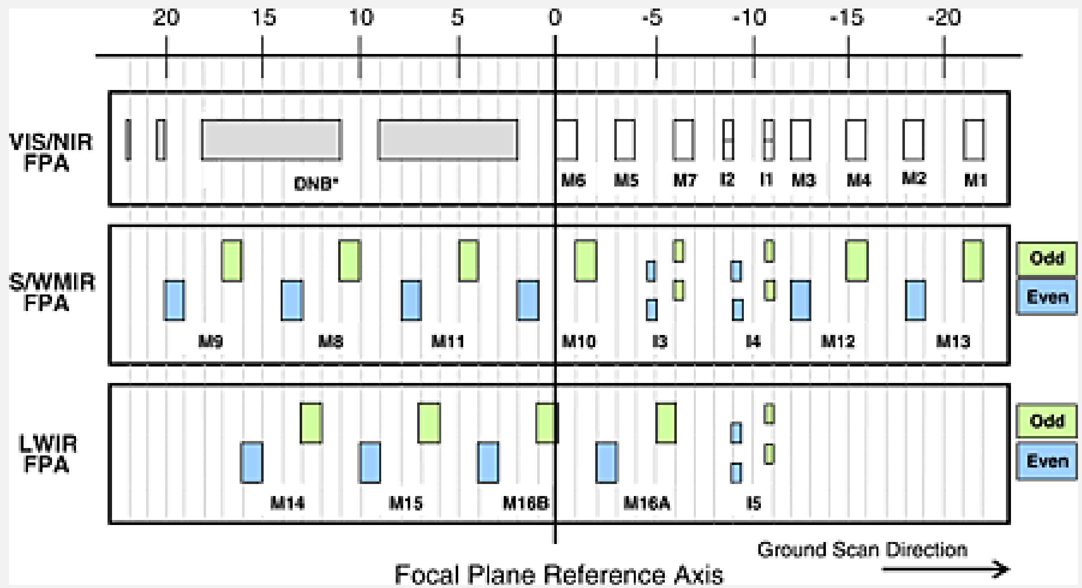


- 6 thermistors

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:

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

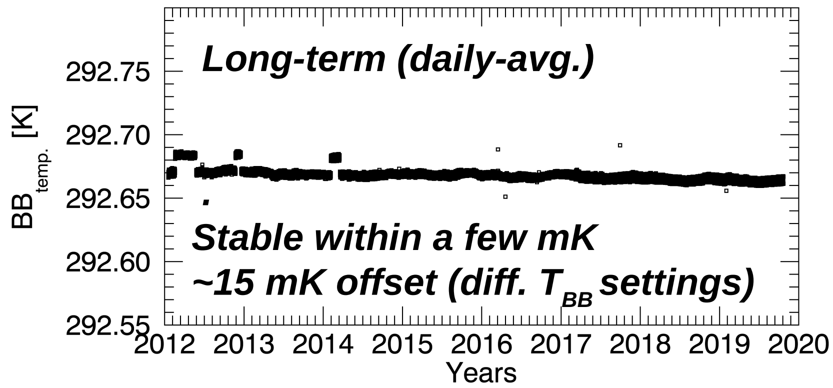
→ ***Estimated***

→ ***Retrieved***

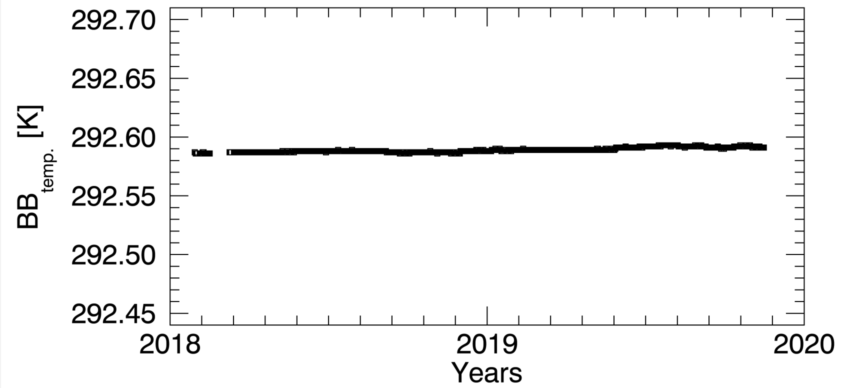
ρ: reflectance
L_{ap}: aperture radiance
RTA: rotating telescope assembly
HAM: half-angle mirror
RVS: response-versus-scan-angle

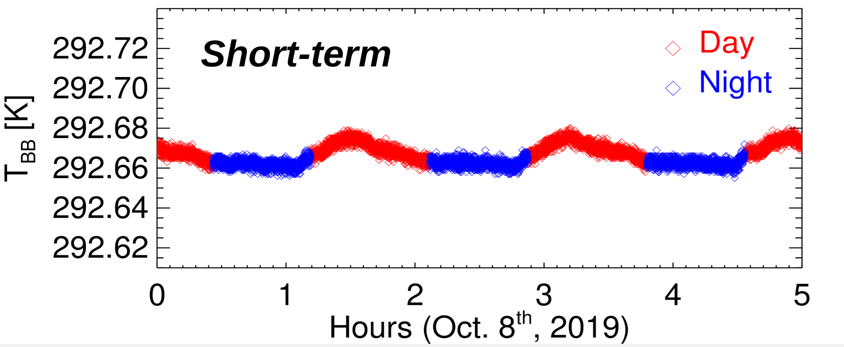
BB performance

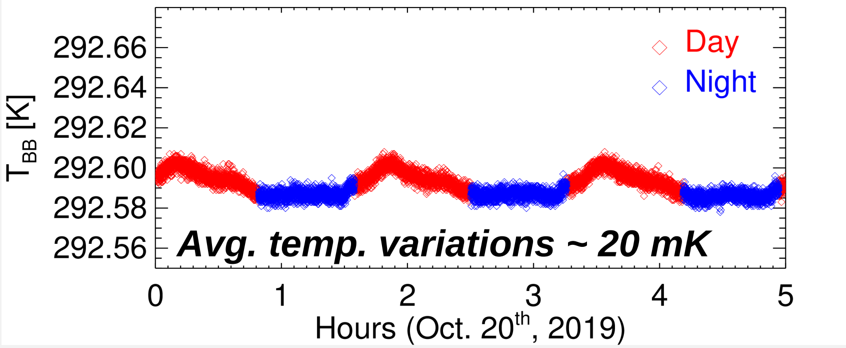
S-NPP

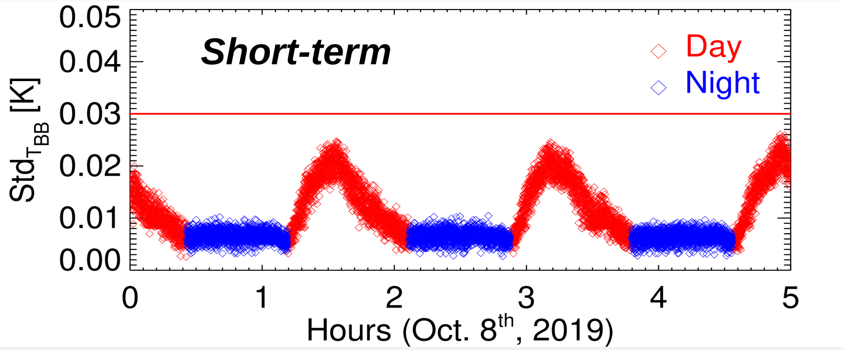


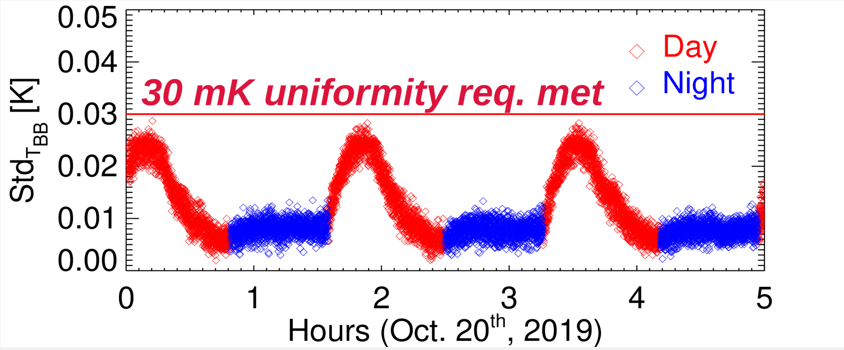
NOAA-20



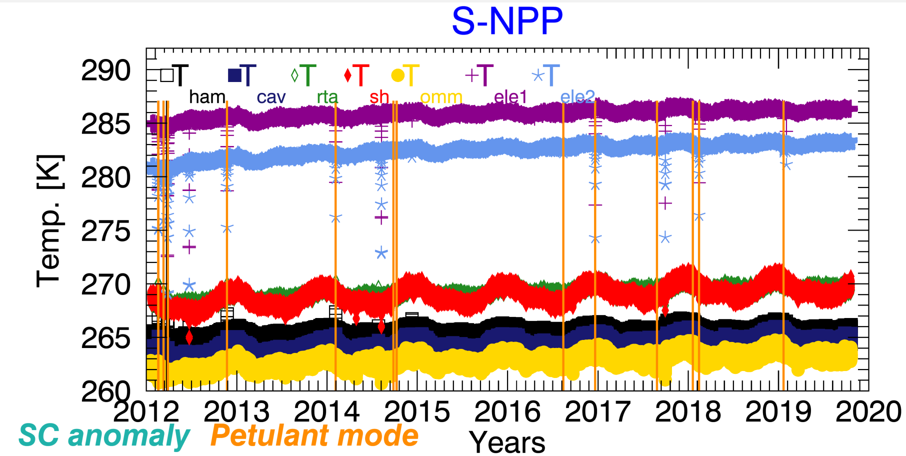


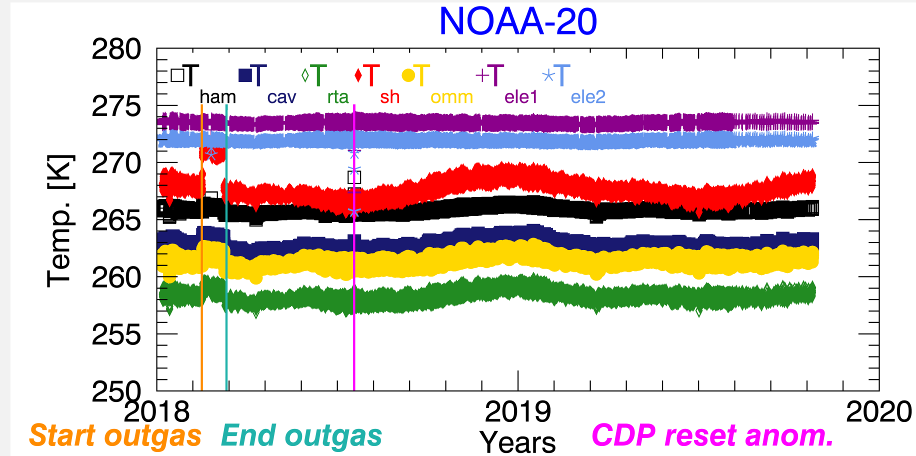


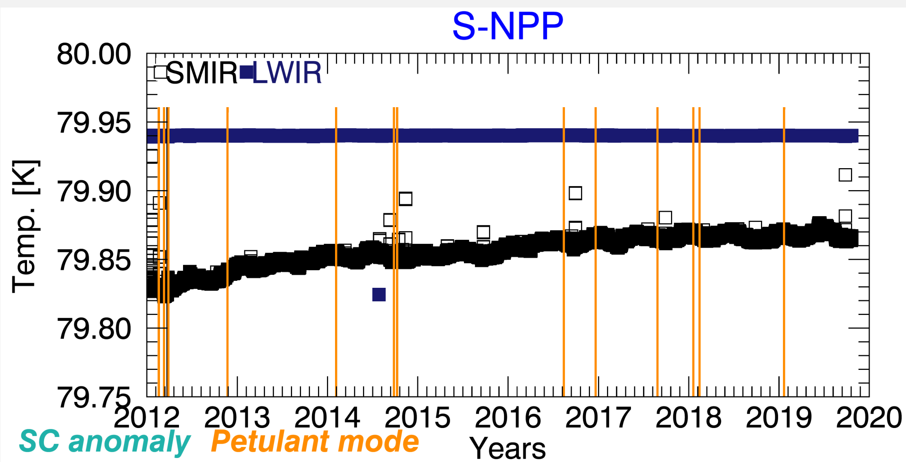


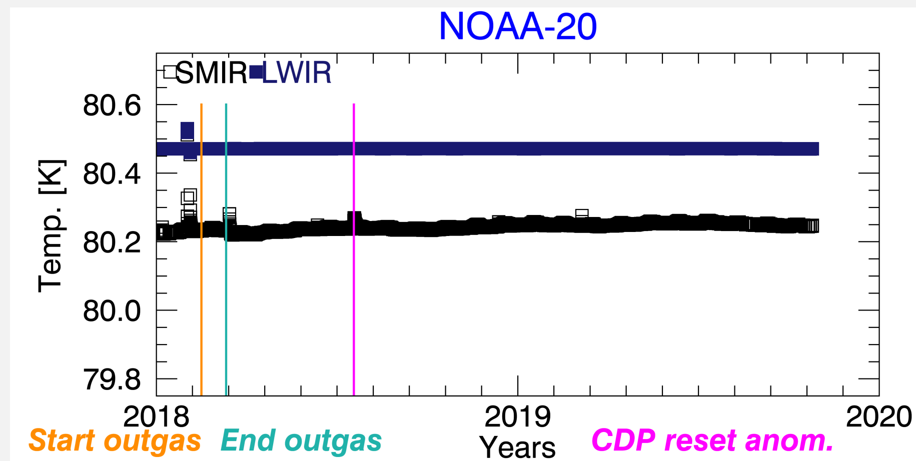


Telemetry temperatures (Daily-avg.)





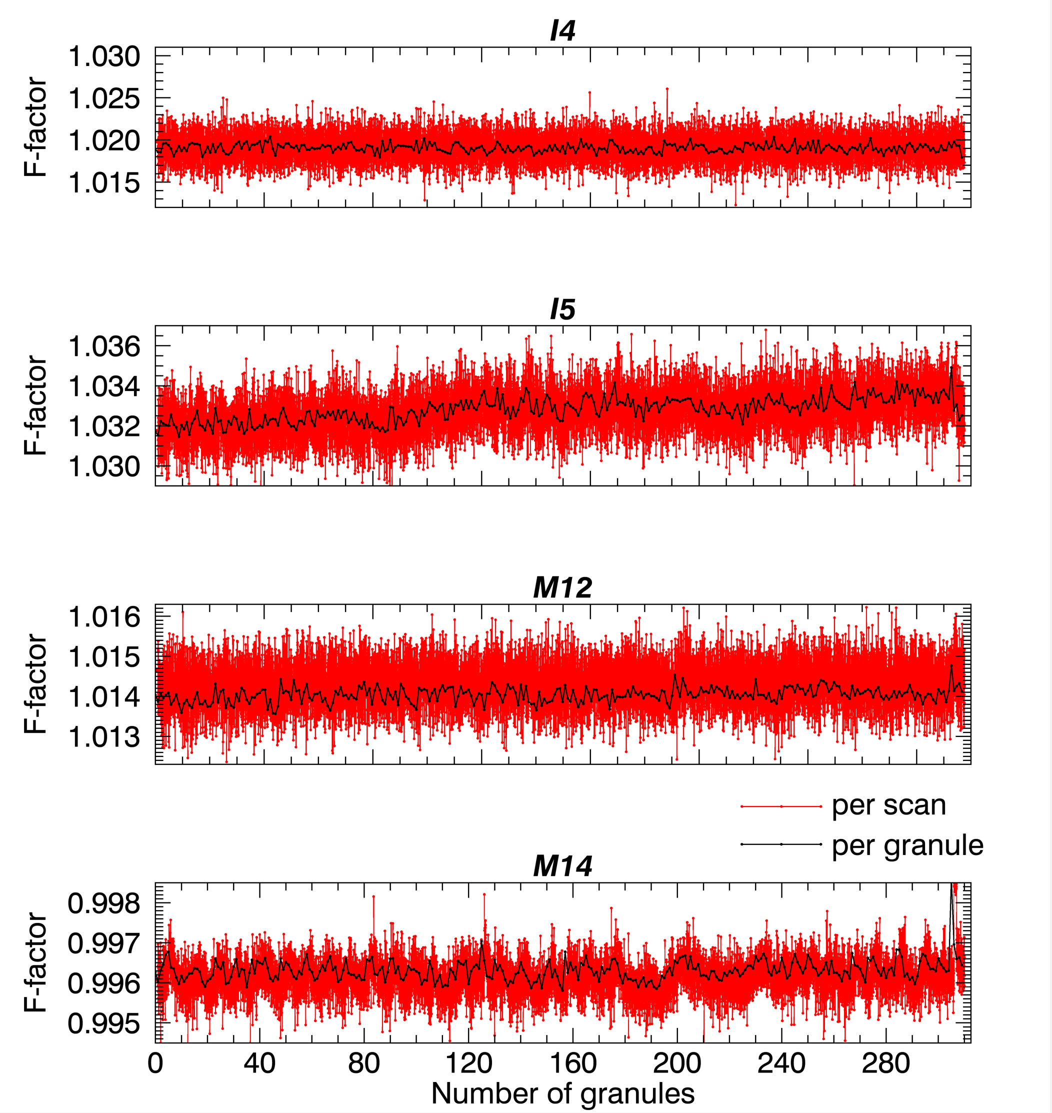




- Out-of-character features coincide with Earth passage through perihelion
- Small SMWIR focal plane temp. increasing trend that can be seen in MWIR TEBs (i.e. I4, M12, M13)

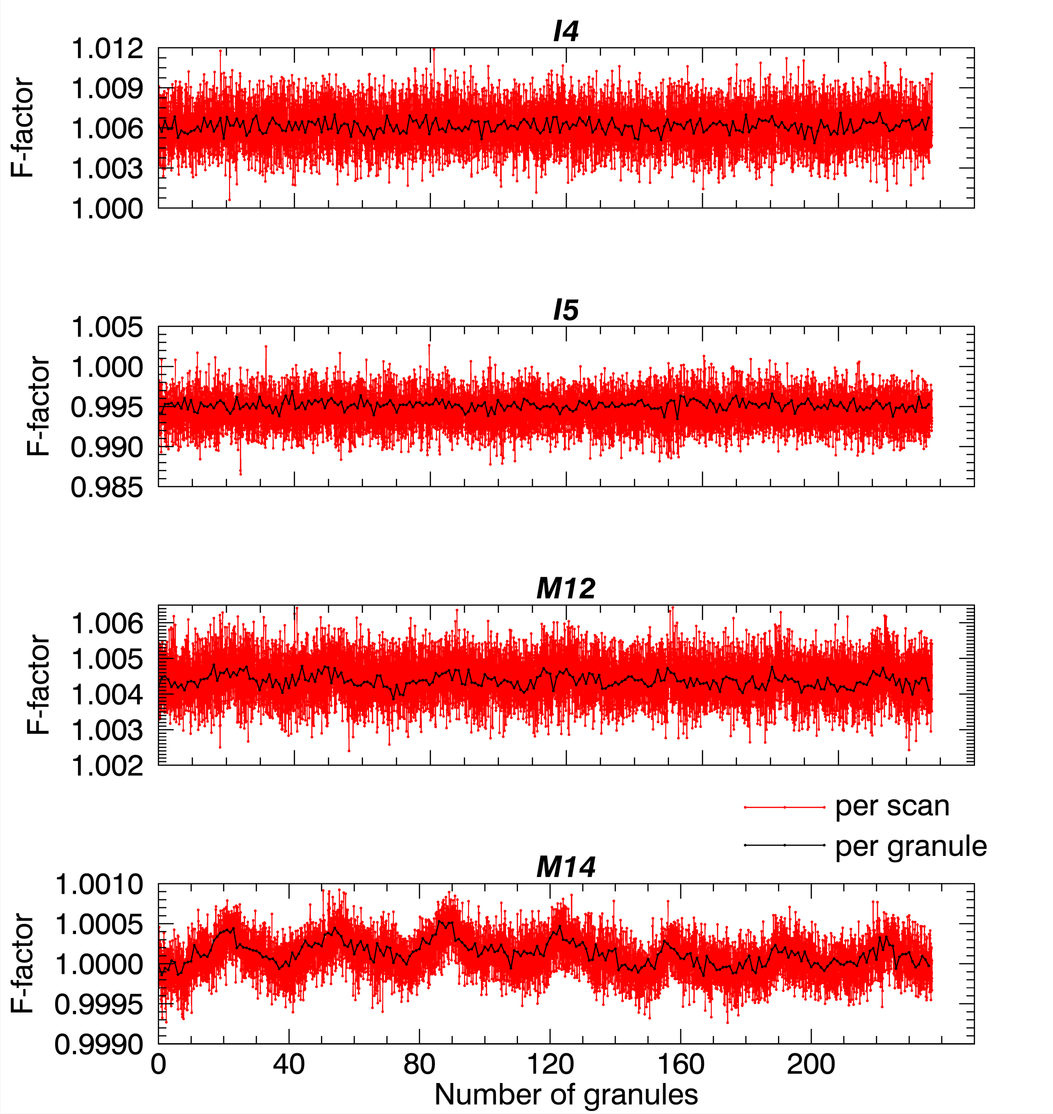
Short-term detector response (S-NPP)

- 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
- Orbits 41375-41394

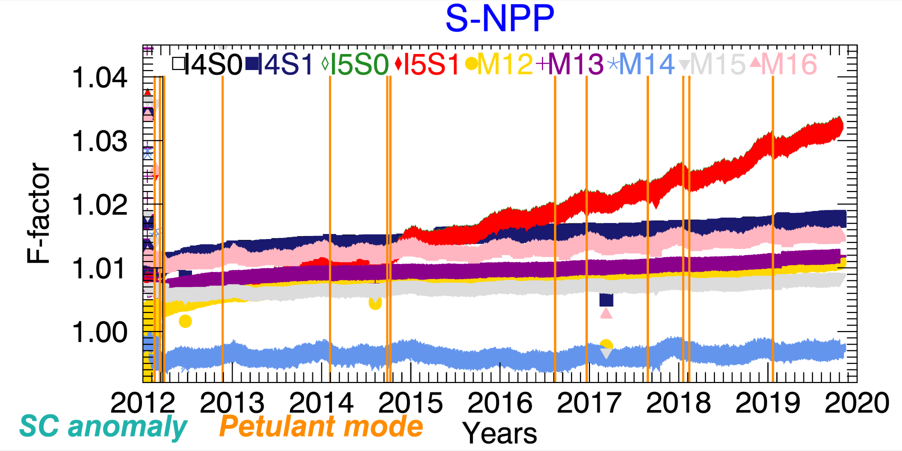


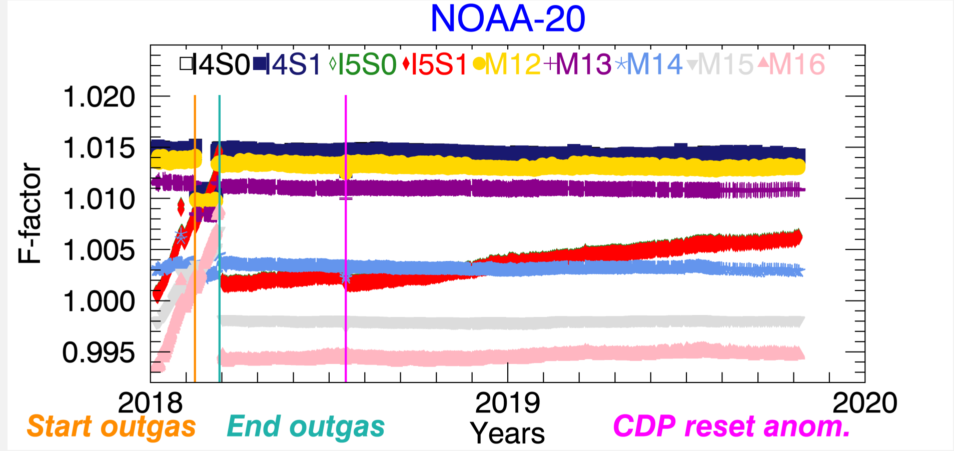
Short-term detector response (N20)

- 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
- Orbits 10000-10012



Long-term detector response



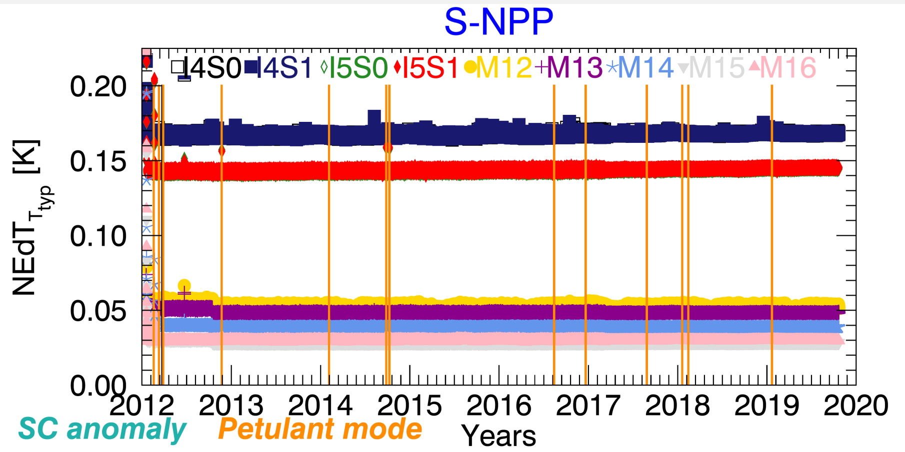


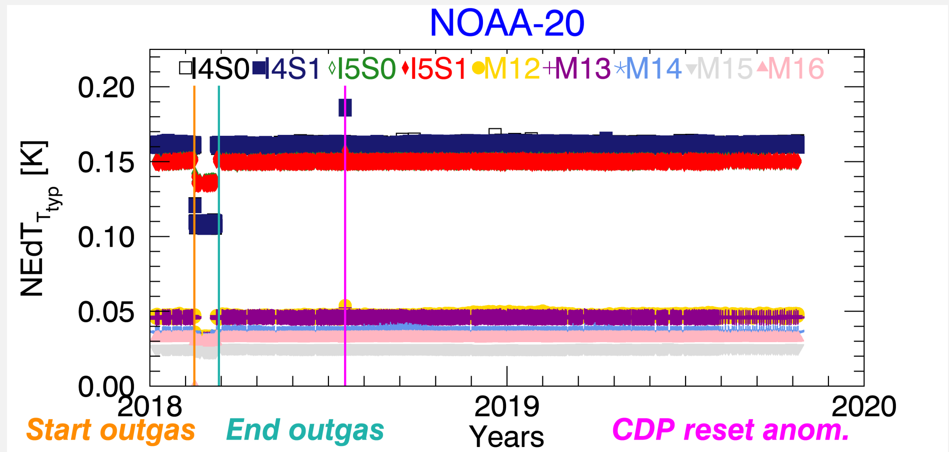
Satellite	TEB	I4	I5	M12	M13	M14	M15	M16
S-NPP	Avg. F-factor 03-26-2012	1.0105	1.0040	1.0035	1.0070	0.9946	1.0056	1.0101
	Avg. F-factor 10-22-2019	1.0176	1.0323	1.0110	1.0119	0.9972	1.0084	1.0152
N20	Avg. F-factor 04-17-2018	1.0145	1.0018	1.0134	1.0112	1.0035	0.9981	0.9942
	Avg. F-factor 10-25-2019	1.0139	1.0062	1.0130	1.0109	1.0029	0.9981	0.9948

TEB I5 upward trend is approximately 0.35 % / yr for both VIIRS instruments. All other TEBs exhibit relatively stable trends.

✭ Band- and daily-averaged

Noise characterization (NEdT)





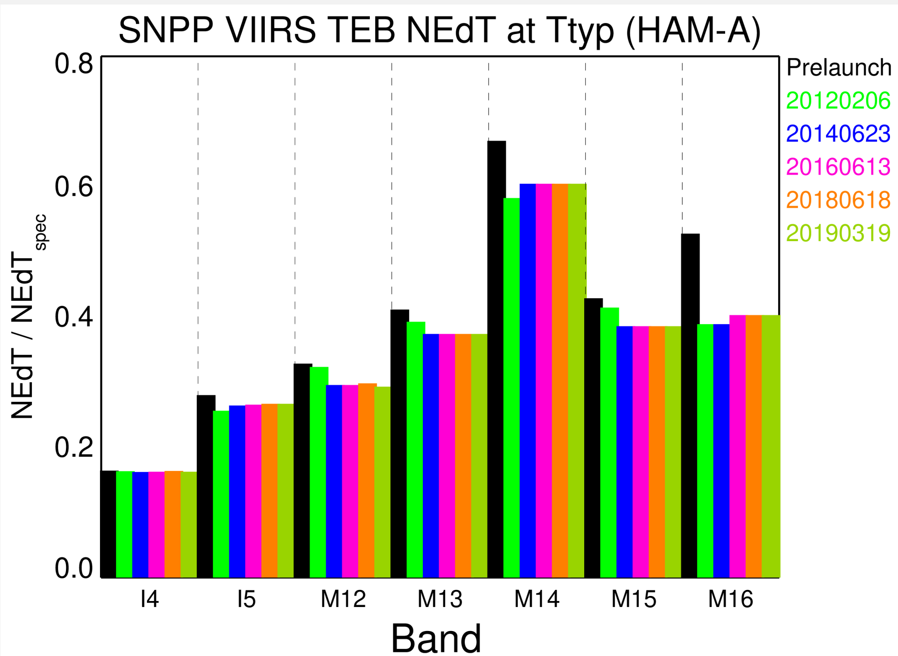
$$NEdT = \frac{NEdL}{\partial L / \partial T}$$

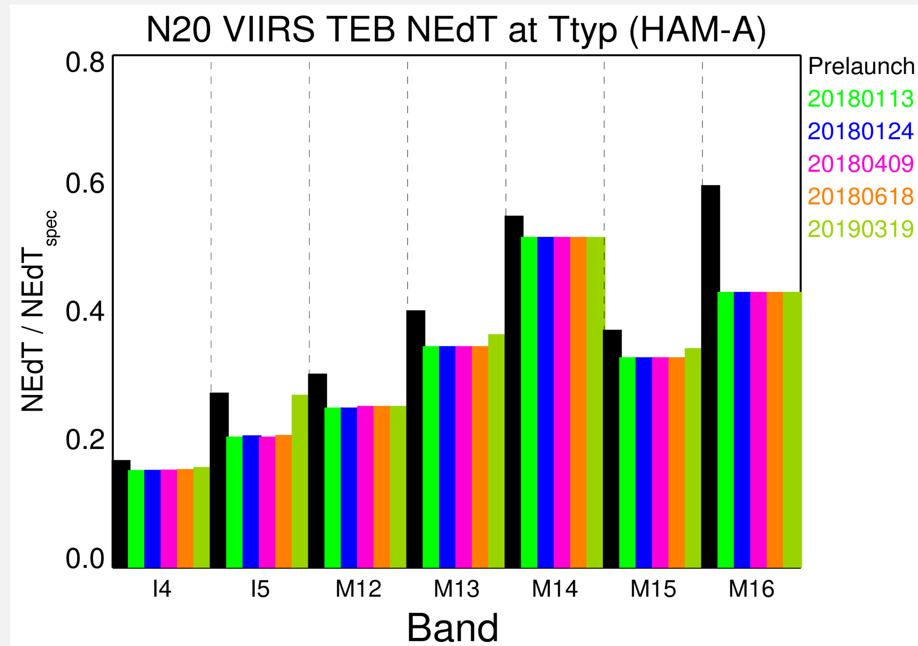
- NEdT trended routinely at 292.5 K
- Stable for both instruments
- Band-averaged values
  - - I-bands: ~ 0.2 K
  - - M-bands: ~ 0.07 K

TEB	T_{typ} (K)	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

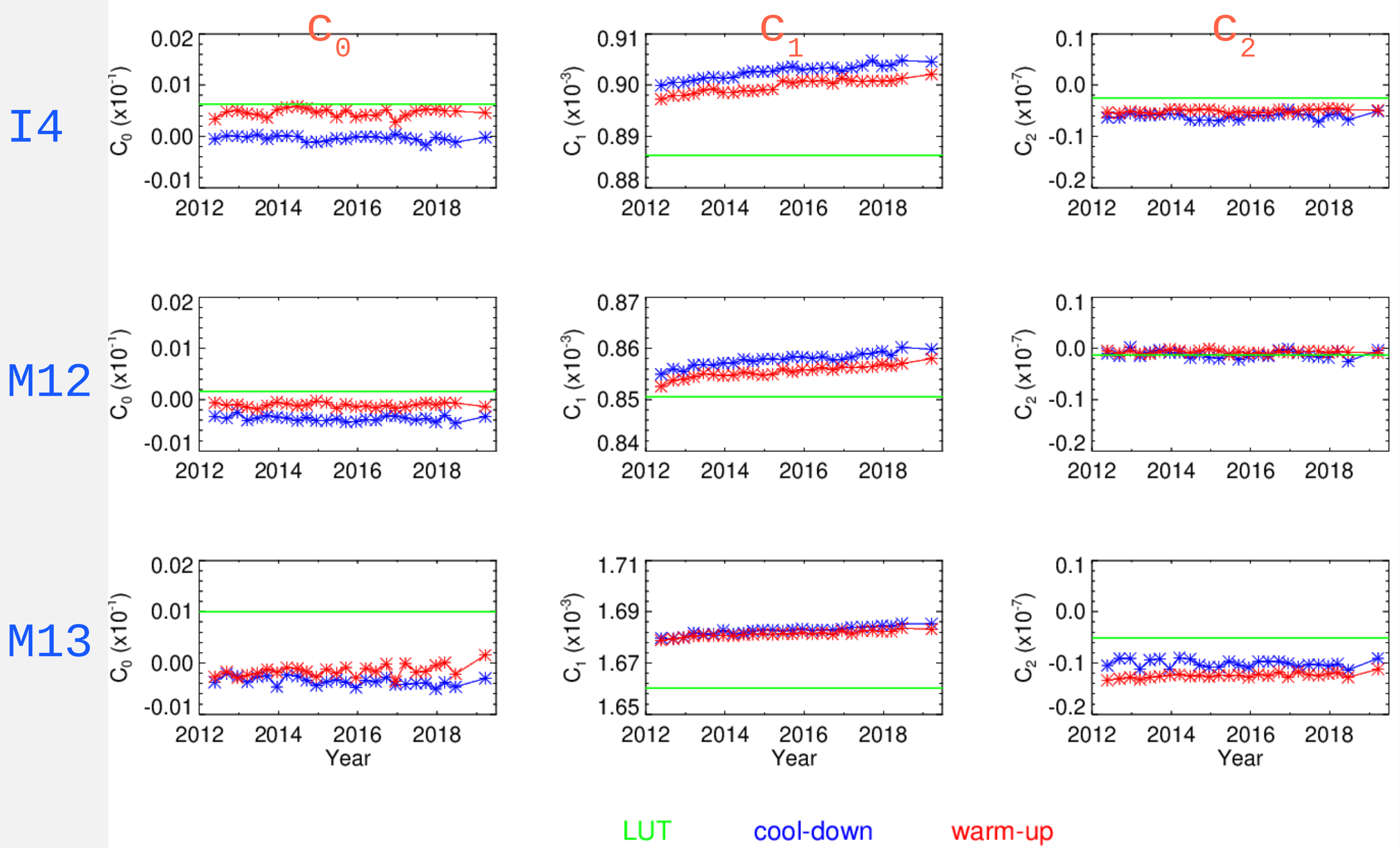
Noise characterization (NEdT)





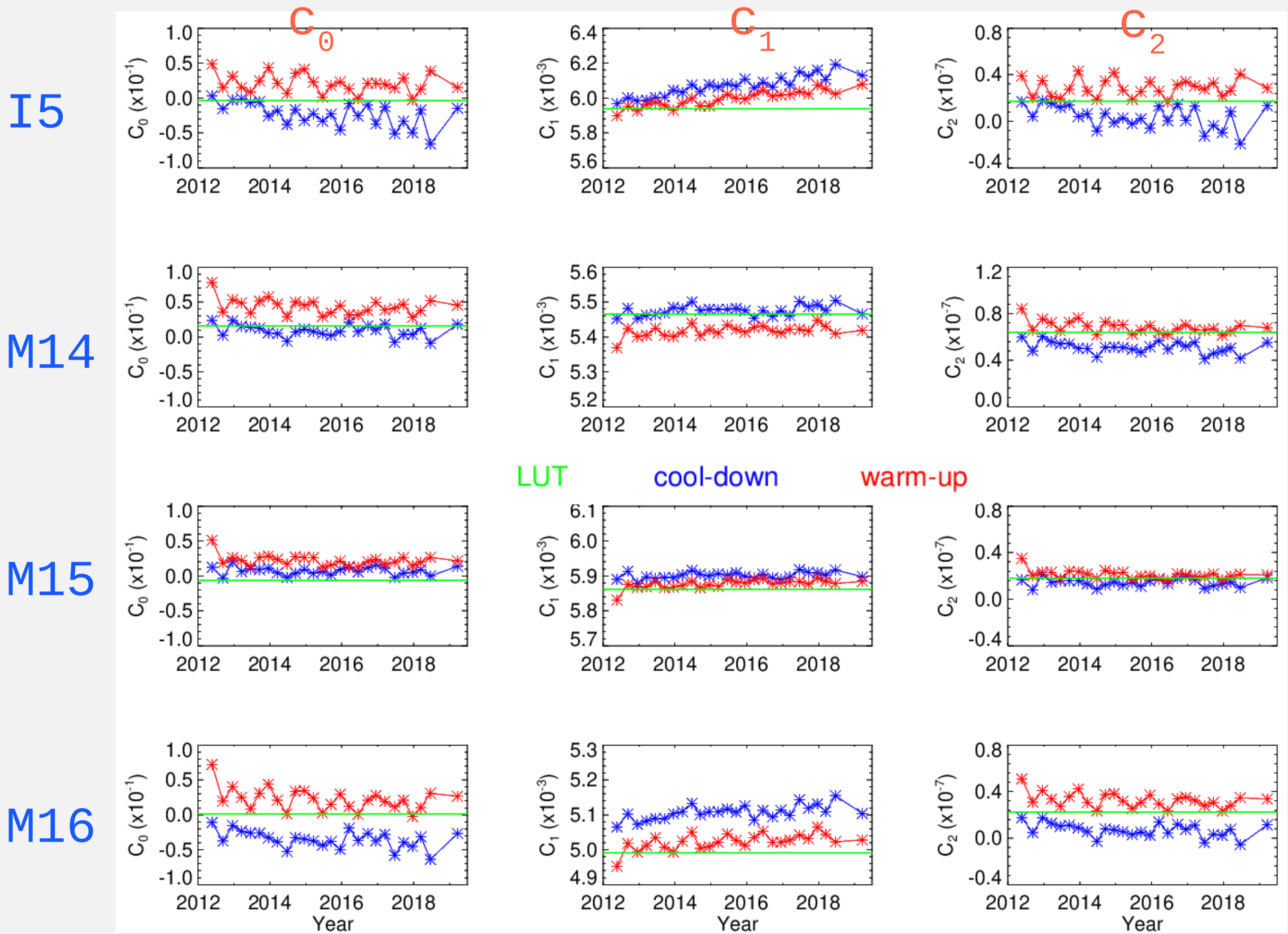
- $NEdT_{Ttyp}$ derived from BB CD data – TEBs meet sensor design req.

Calibration coefficients (S-NPP)



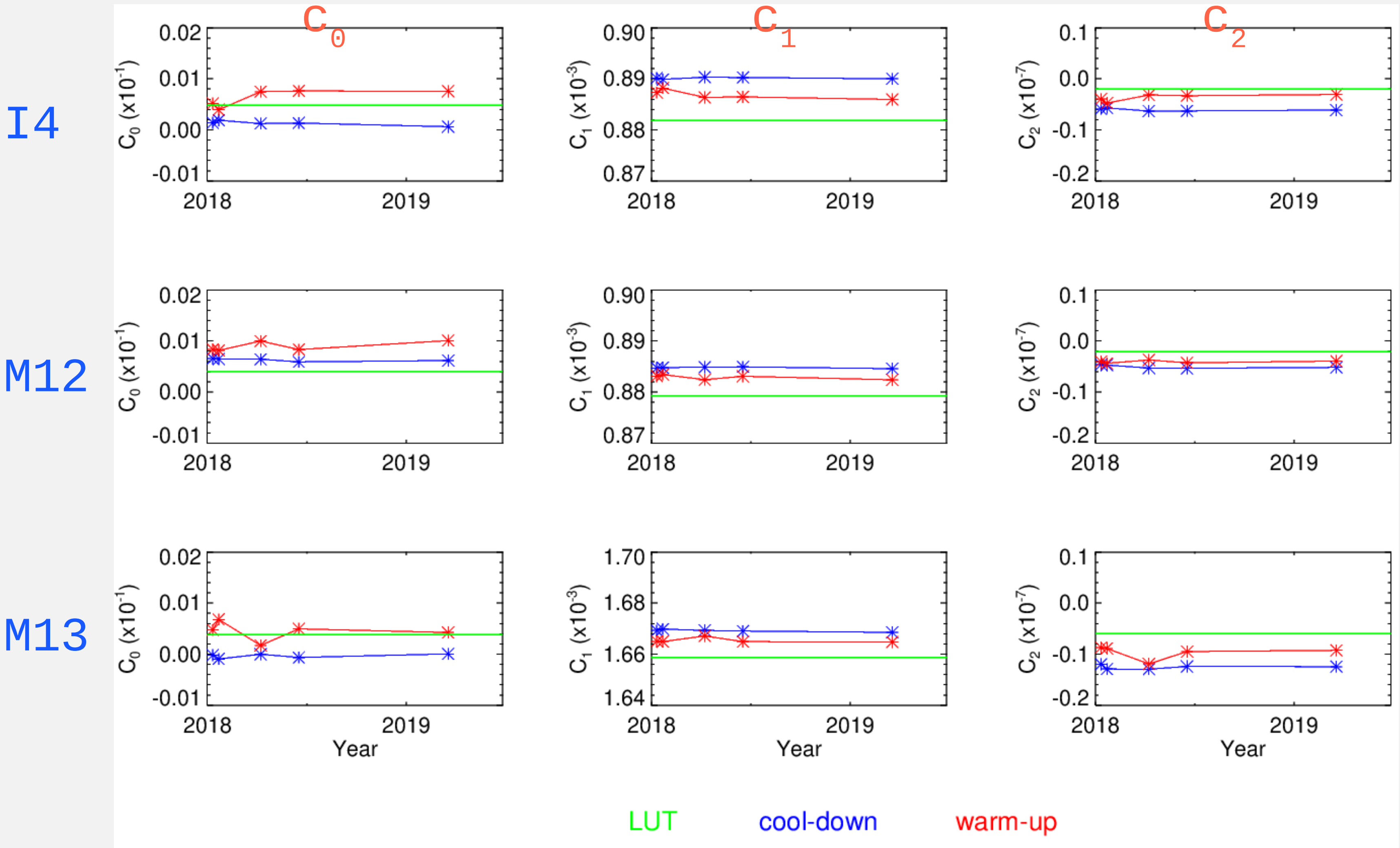
- Band-avg. c_0, c_1, and c_2 calibration coeffs. Derived from 27 WUCD through November 2019.
- Band-avg. c_1 coeffs. are within 1.9 % from pre-launch

Calibration coefficients (S-NPP)



- C_{0LUT} ± 0.002 (MWIR), ± 0.01 (LWIR) C_{2LUT} ± 3*C_{2LUT}

Calibration coefficients (N20)



- Band-avg. c_0, c_1, and c_2 calibration coeffs. Derived from 5 WUCD through November 2019.
- Band-avg. c_1 coeffs. are within 3.0 % from pre-launch

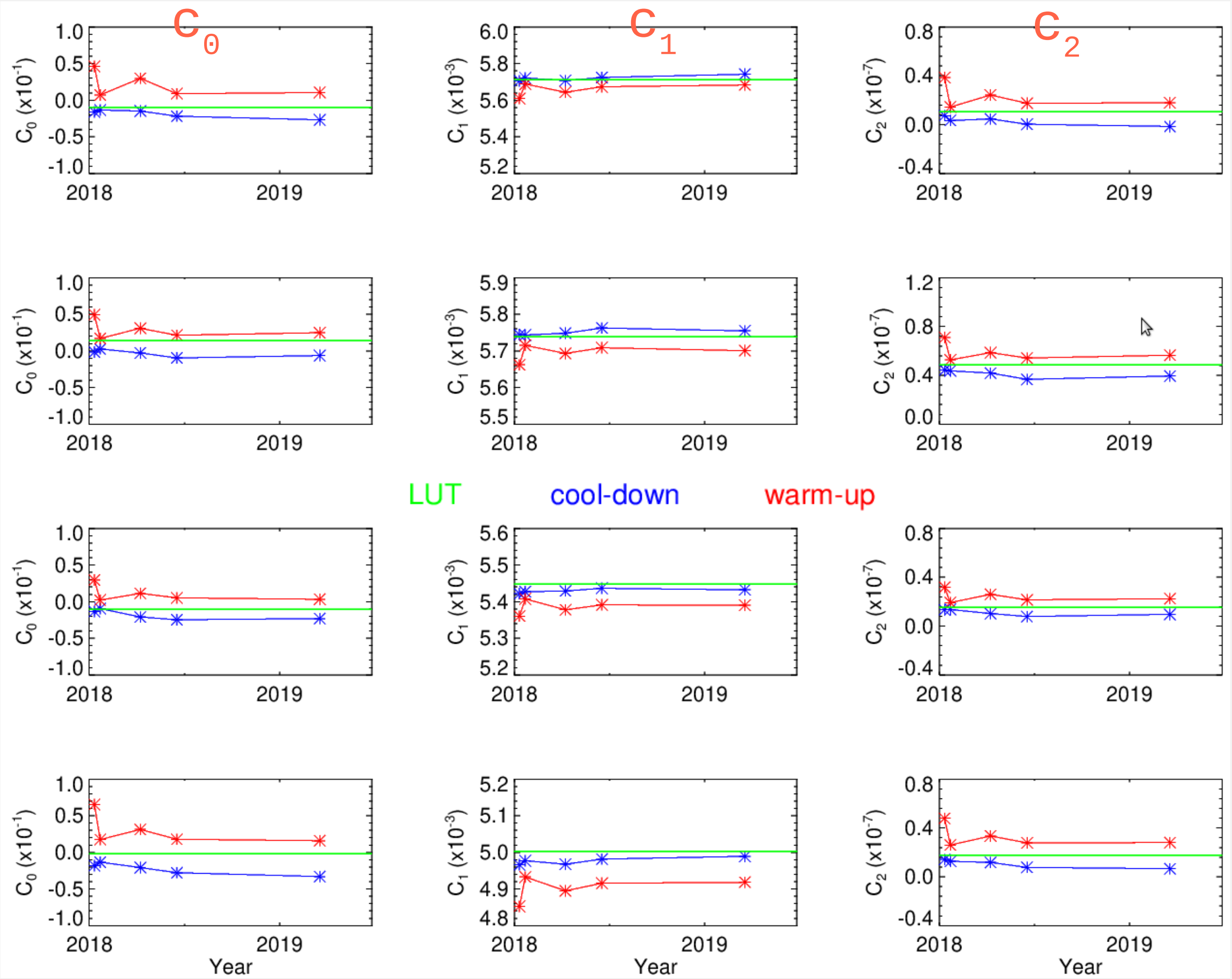
Calibration coefficients (N20)

I5

M14

M15

M16



- C_{0LUT} ± 0.002 (MWIR), ± 0.01 (LWIR) C_{2LUT} ± 5*C_{2LUT}

NASA L1B TEBs improvements

- **NASA L1B TEBs improvements**
  - **Modified scaled integer table for M13 to increase radiometric resolution at low radiance / BT**
  - **Updated S-NPP VIIRS Delta-C LUT with correct temperature dependence to reprocess**

- **NASA L1B TEBs improvements in progress**
  - **Uncertainty algorithm in the L1B products**
  - **N20 pre-launch RVS LUT update**

Summary

- On-orbit BB long-term performances for S-NPP (~8 years) and JPSS-1 (~2 years) VIIRS are quite stable. Short-term (orbital) temperature variations are present, but generally within the uniformity requirement of 30 mK.
- Detector response (F-factor) trending is stable for both S-NPP and JPSS-1 VIIRS. S-NPP VIIRS TEB I5 shows the maximum band-average trend of 2.8 %, followed by M12 and I4. JPSS-1 VIIRS TEB I5 shows a maximum trend of 0.5 %. Small orbital variations (± 0.05 – 0.1 %) are present for both instruments.
- The TEBs detector noise characteristics are stable for both instruments. The NEdT at T_{TYP} is compliant with the requirements.