CERES Instrument Status: Flight Models 1-6 (FM1-FM6)

Mohan Shankar

CERES Instrument Working Group

CERES Spring Science Team Meeting
May 12, 2026

CERES Instrument Working Group

Instrument Working Group

IWG Lead: Mohan Shankar
Technical Lead: Susan Thomas

Instrument Operations	**Data Management**	**Calibration/Validation**
B. Mike Tafazoli	Denise Cooper	Nathaniel Smith
Janet Daniels	A. Thomas Grepiotis	Nitchie Smith
Ethan Ames		Alexander Jarnot
		Daniel Goldin

CERES Instrument

- CERES measures the radiation at the Earth's top of atmosphere from the visible through the far IR wavelengths
  - Reflected Solar Radiances (SW channel: 0.3 - 5 microns)
  - Total Outgoing Radiances (TOT channel: 0.3 - 100 microns)
  - Outgoing Longwave Radiances (WN channel (FMs 1-5): 8 - 12 microns; LW channel (FM6): 5-35 microns)
- Three sensor assemblies contain Cassegrain telescopes and thermistor bolometer detectors.
- Sensor assemblies can be rotated in the elevation axis, and instrument can rotate about the azimuth axis.
  - Fixed Azimuth plane scan (Crosstrack)
  - Rotating Azimuth plane scan (RAPS, GEOSCAN)
- On-board Calibration:
  - Blackbodies: TOT and WN/LW channels
  - SWICS Lamp- SW channel
  - Mirror Attenuator Mosaic (MAM): Solar Calibration- SW and TOT channels

CERES Instrument Status Summary

- **NOAA-20/FM6** and **SNPP/FM5** instruments are operating in Crosstrack mode and are performing nominally.
  - *GEOSCANs are being conducted occasionally.*
- **Terra/FM1** and **Aqua/FM3** CERES instruments are primarily operating in RAPS mode.
  - *Terra/FM2 was turned off in Jan 2025 due to spacecraft power constraints.*
  - *GEOSCANs are conducted periodically.*

- **Level 1 Data products**
  - NOAA-20/FM6 Edition 1 gains have been delivered through Mar 2026.
  - S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Jul 2024.
  - Terra and Aqua instruments' Edition 4 gains and SRFs have been delivered through Feb 2026.

CERES Instrument Operations Summary

Spacecraft	Instrument	Operational Mode	Notes
NOAA20	FM6	XTK	GEOSCAN for specific targets started May 2025 (~ 2 x per month)
SNPP	FM5	XTK	GEOSCAN for specific targets started May 2025 (~ 2 x per month)
Aqua	FM4	XTK	Operated in RAPS from Jul 14, 2021, to Mar 22, 2023.
Aqua	FM3	RAPS + GEOSCAN	RAPS started on Mar 22, 2023. GEOSCAN started on Feb 1, 2023
Terra	FM2	-	Instrument Turned OFF on Jan 11, 2025
Terra	FM1	RAPS + GEOSCAN	RAPS started on Feb 14, 2025 GEOSCAN started on Feb 1, 2023

XTK: Cross-track

GEOSCAN on Terra and Aqua CERES instruments:

- For 5 days spaced evenly through the month, scan plane of CERES is aligned with a GEO imager for a few orbits.
- Target a different GEO imager each day.
- Instrument is operated in XTK for the rest of the day.

GEOSCAN on NOAA20 and S-NPP CERES instruments:

- FM5 and FM6, GEOSCAN conducted on 3 specific Earth targets for a single orbit.

CERES Instrument Operations Summary Cont'd

GEOSCAN for NOAA20/FM6 and SNPP/FM5:

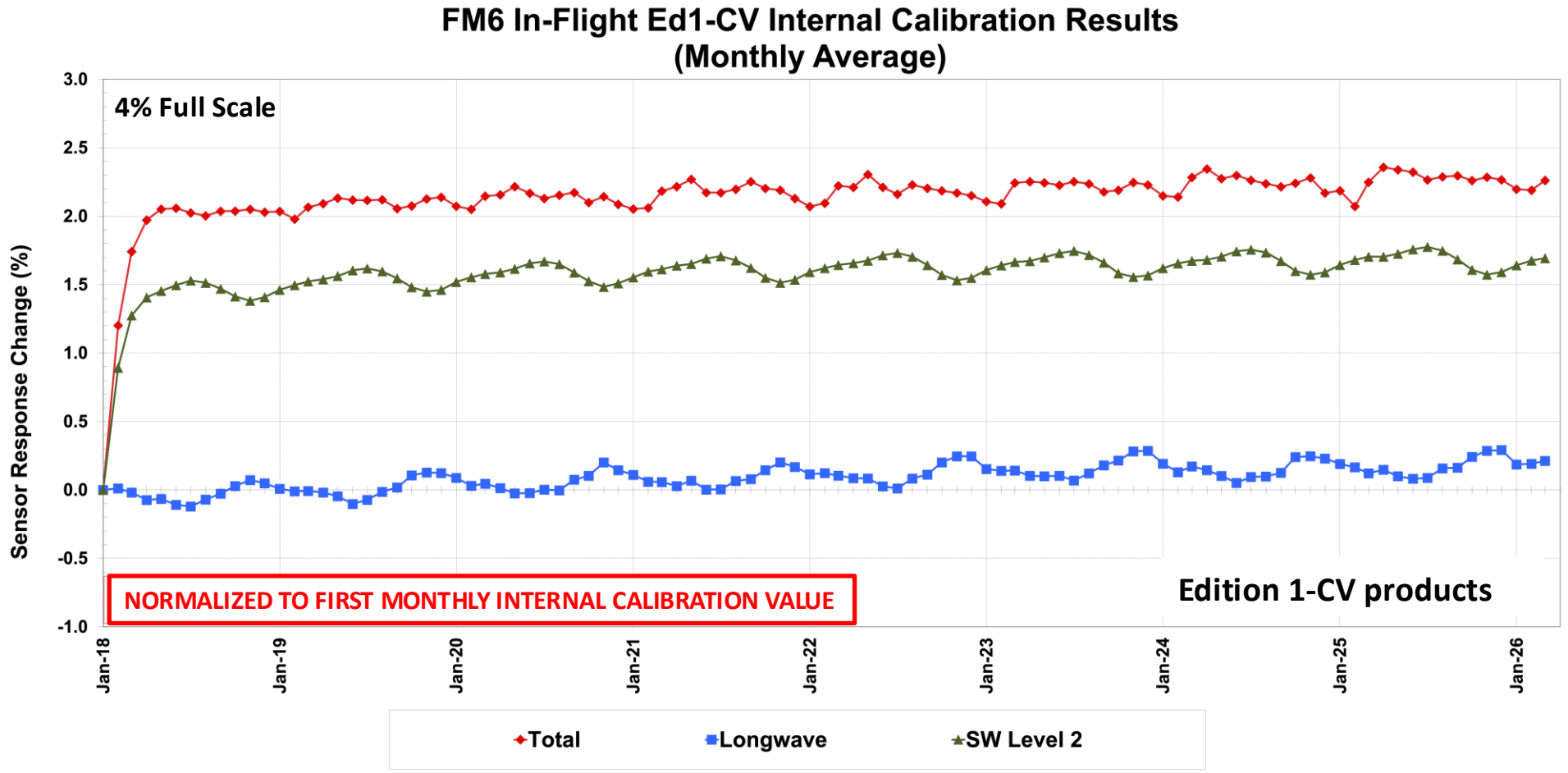
- Use GEOSCANS on specific Earth targets to place FM5 and FM6 on the same radiometric scale.
  - S-NPP and NOAA20 orbits don't cross over (no SNOs).
  - Involves aligning the scan planes of CERES instruments with GEO imagers.
- Conducted initial tests to validate operational planning in Apr 2025.
- Since May 2025, GEOSCANs are being collected from both instruments for 3 scene types, targeting the different CERES channels.
- GEOSCAN measurement approach leverages previously proven approaches with CERES instruments
  - For e.g., Comparisons between CERES and GERB, GEO imagers.

Kyle Itterly's talk on Thursday at 10am:
Using CERES GEOscan mode measurements to place instruments on same radiometric scale

NOAA-20/FM6 Instrument Status

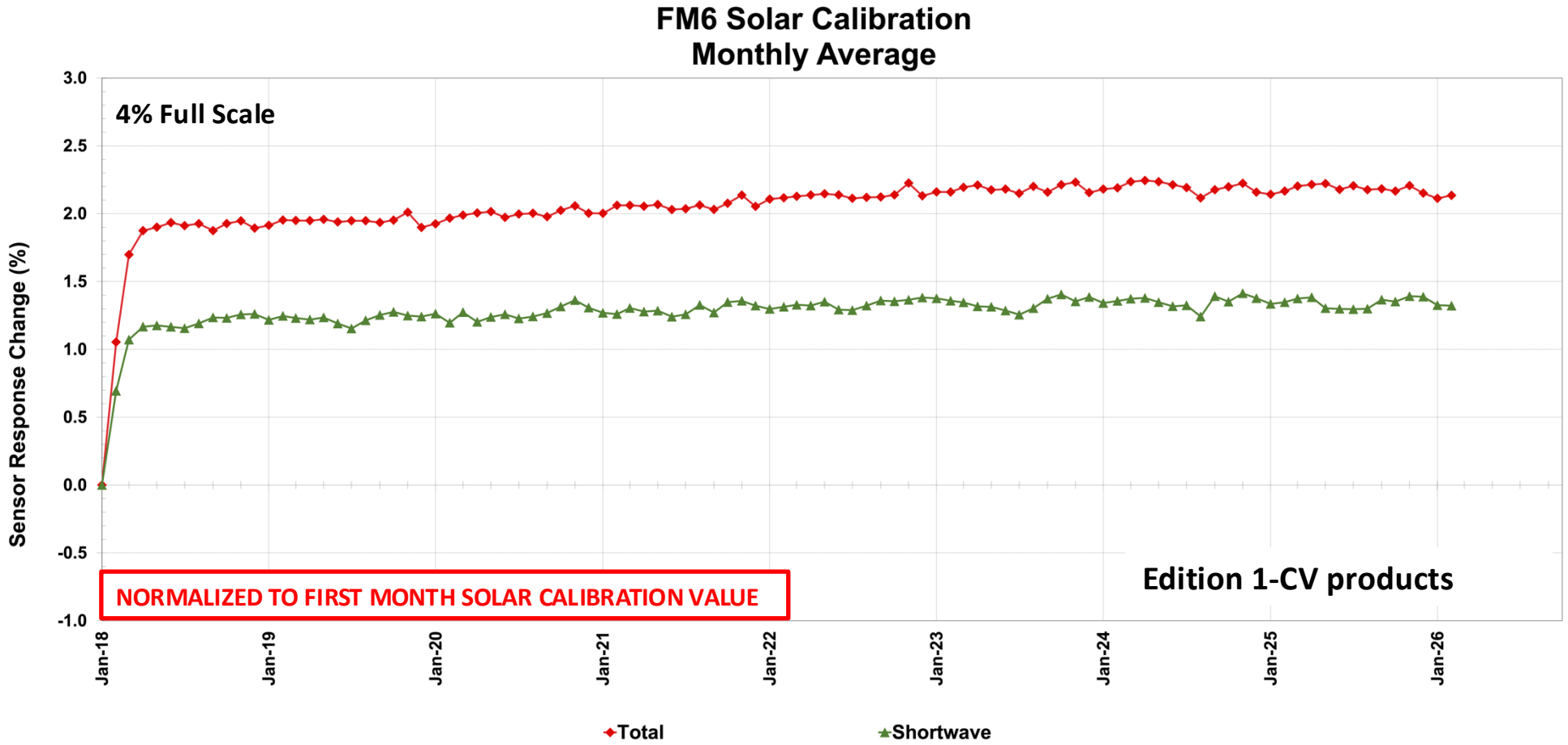
FM6 Internal Calibration

- For SW and TOT channels, the responses to the on-board sources show <0.3% change after the initial rise of ~1.5% (SW) and ~2% (TOT) since start of mission.
- LW Channel also shows ~0.2% since start of the mission.



FM6 Solar Calibration

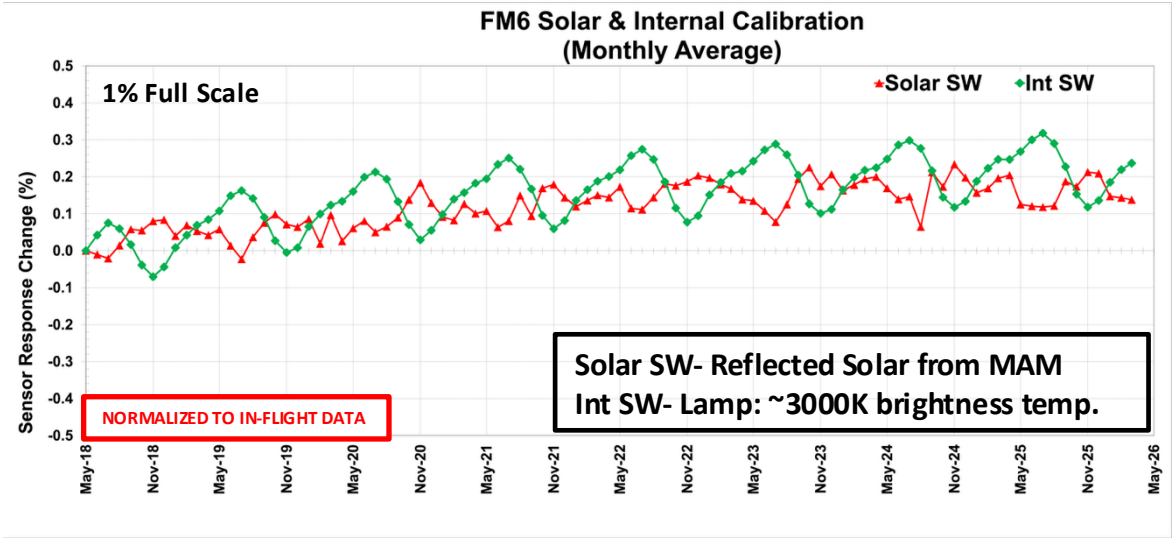
- Response of the SW and TOT channels while viewing the MAM that is illuminated by the sun.
- For SW, after the initial rise of ~1.2% for SW response shows very little change (<0.2%).
- For the TOT, after the initial rise of ~2% for TOT, the response shows ~ 0.3% change.



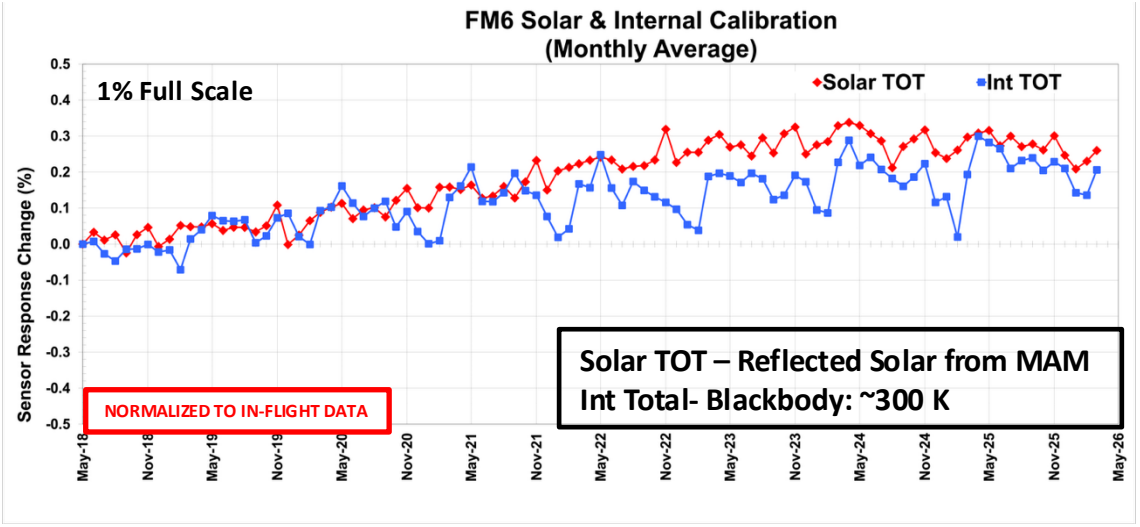
FM6 Calibration- Internal and Solar Cal Since May 2018

FM6 Internal and solar calibration results consistently show <0.4% change since May 2018, demonstrating that the MAM is very stable.

SW Channel

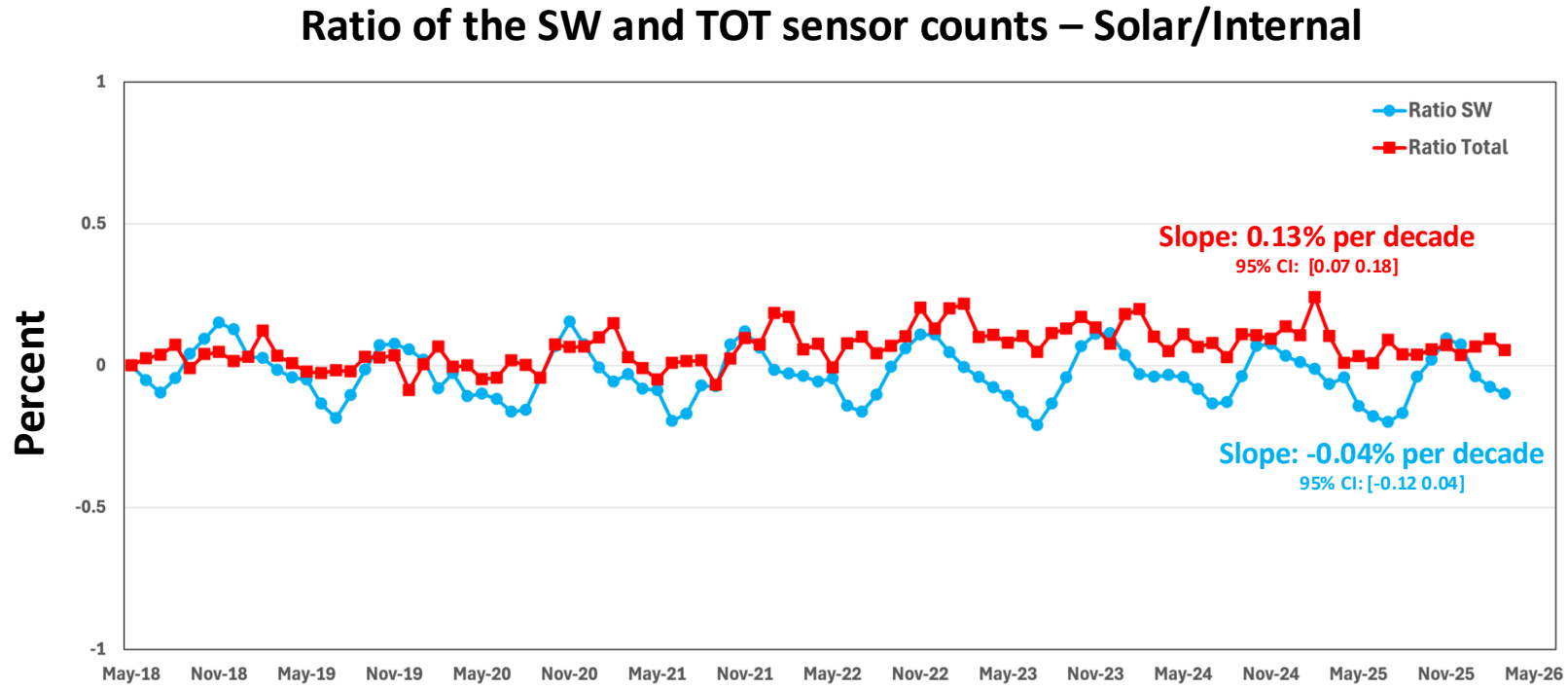


TOT Channel



Edition 1-CV products

FM6 Calibration- Solar vs. Internal- May 2018 to Mar 2026



SW Channel has excellent agreement between Internal and Solar calibrations

TOT Channel has a slight upward trend, indicating small change in the shortwave portion of the channel.

Validation – FM6 Tropical Mean (TM)

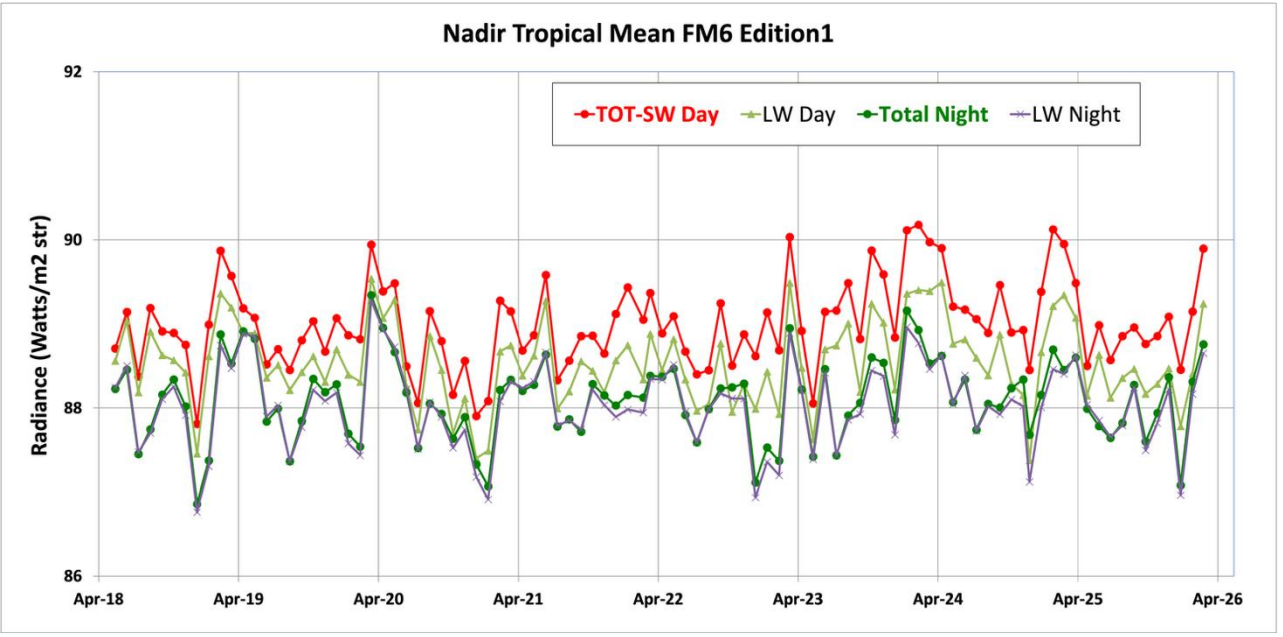
- Average of the Nadir radiances over Tropical ocean (20^0N-20^0S) scenes under All-sky conditions.
  - Uses latest version of ES-8 data products (Edition 1) - All calibration updates (gains) have been applied.
- Two sets of TM Day-Night Differences (DN) are calculated:
  - TOT and SW sensors

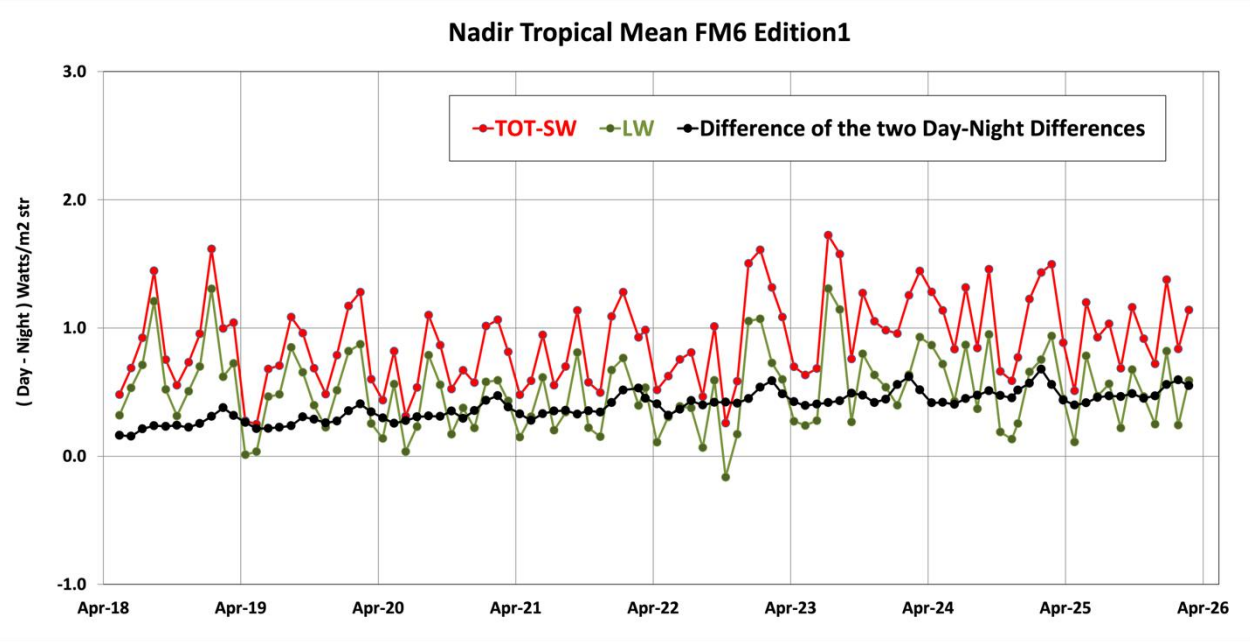
    $DN = TM_D(TOT\text{-}SW) - TM_N(TOT)$
  - LW sensor *(Observations from the LW channel)*

    $DN = TM_D(LW) - TM_N(LW)$
- Trends of the difference in the two DN values highlight any inconsistencies in the response between the three channels.

Validation- FM6 Tropical mean Day-Night

Day-Night Differences





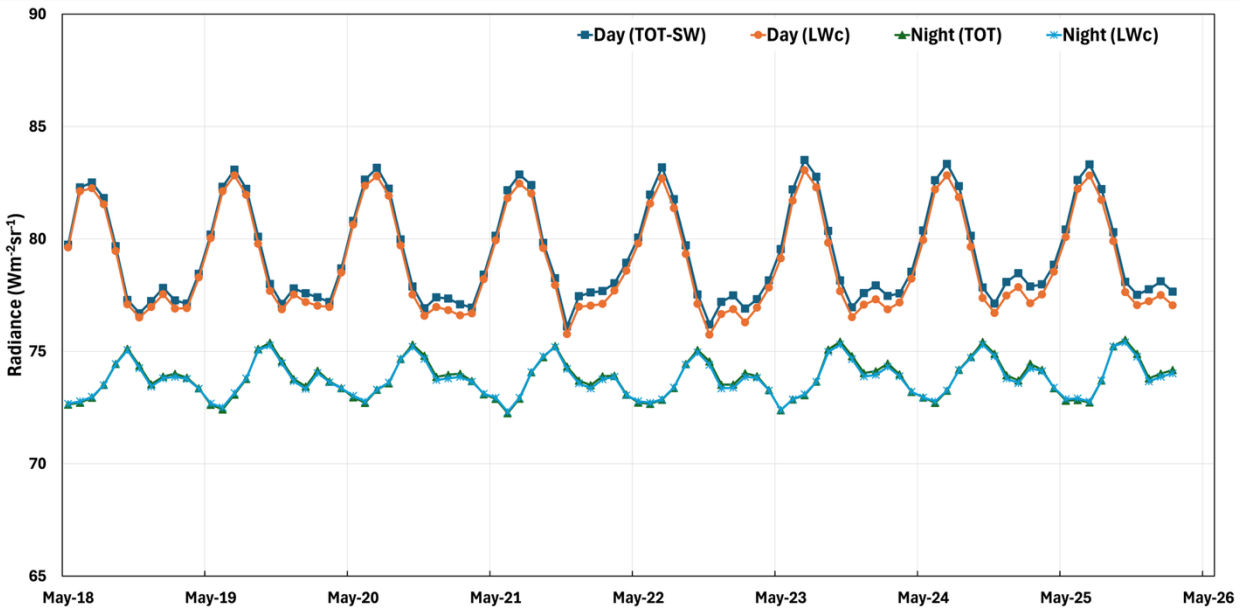
Edition 1 ES-8 products

FM6 3-channel Consistency check- SSF All-sky Global Day-Night Differences

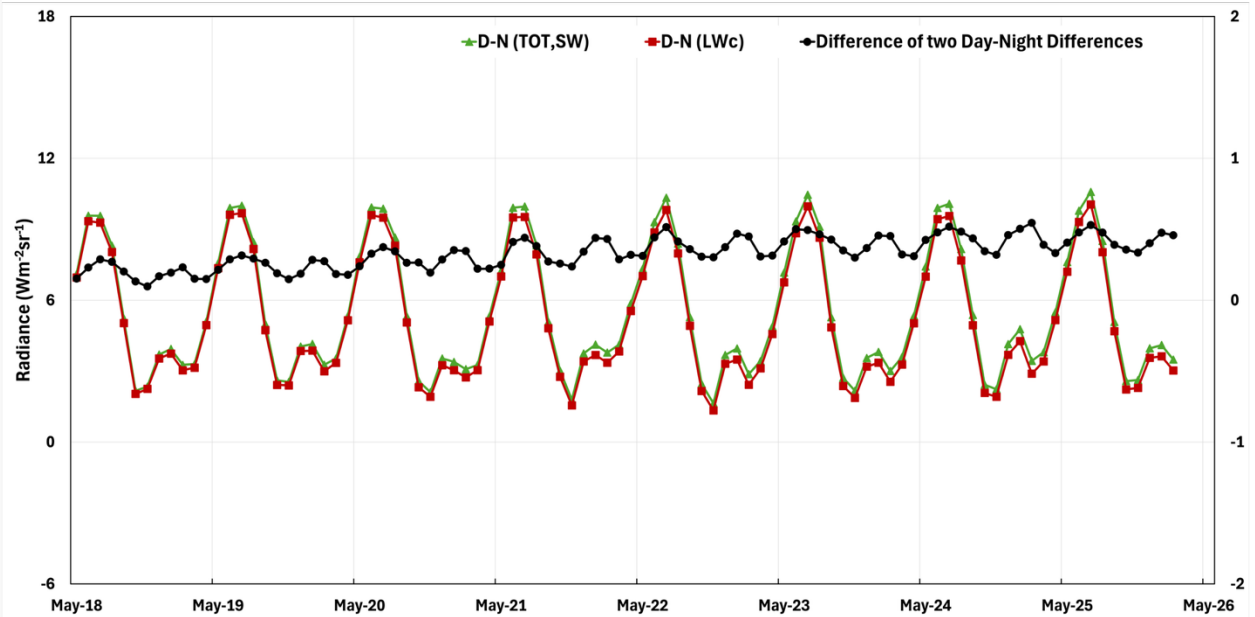
May 2018 - Feb 2026

Edition 1 SSF, Global, All-sky, Nadir Radiance

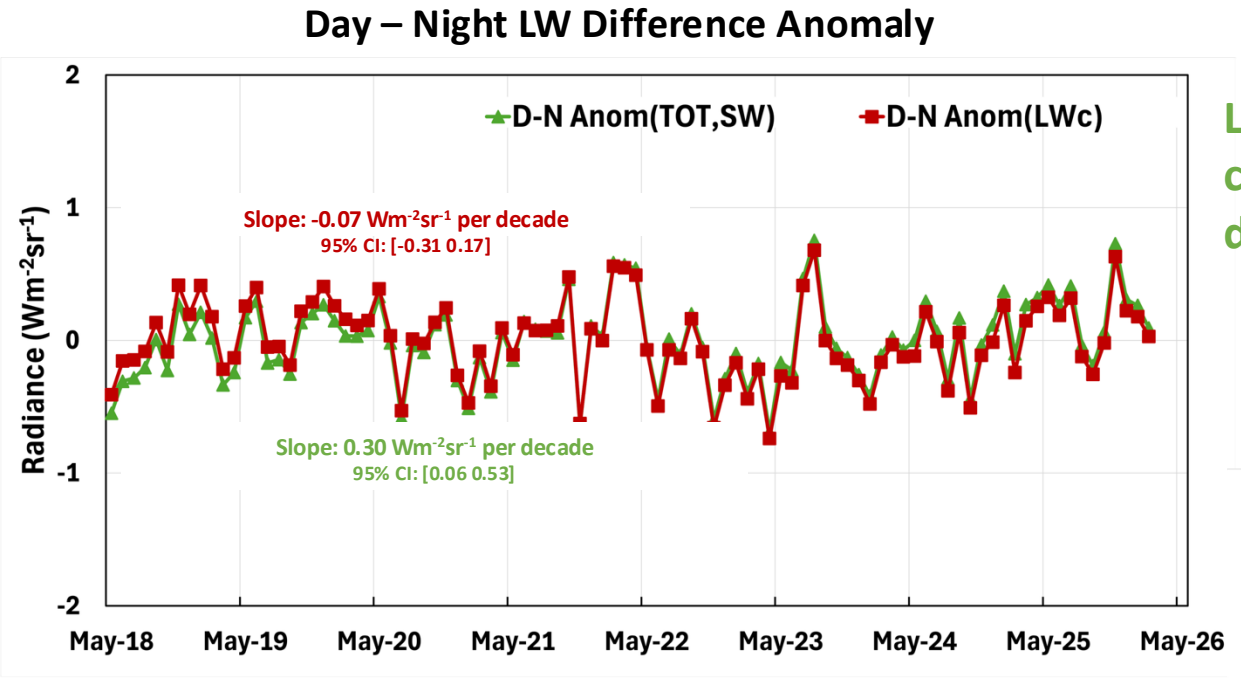
FM6 Edition 1 Global Mean LW radiance



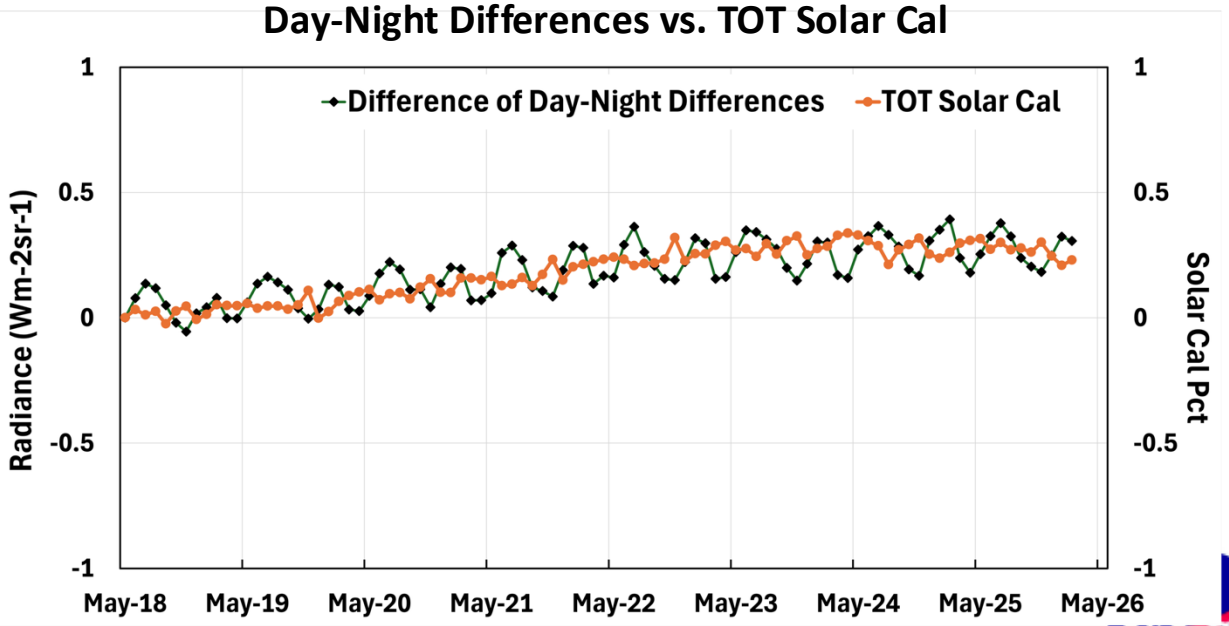
Day-Night Difference



FM6 3-channel Consistency check- SSF All-sky Global Day-Night Differences



LW Channel has consistent Day-Night difference

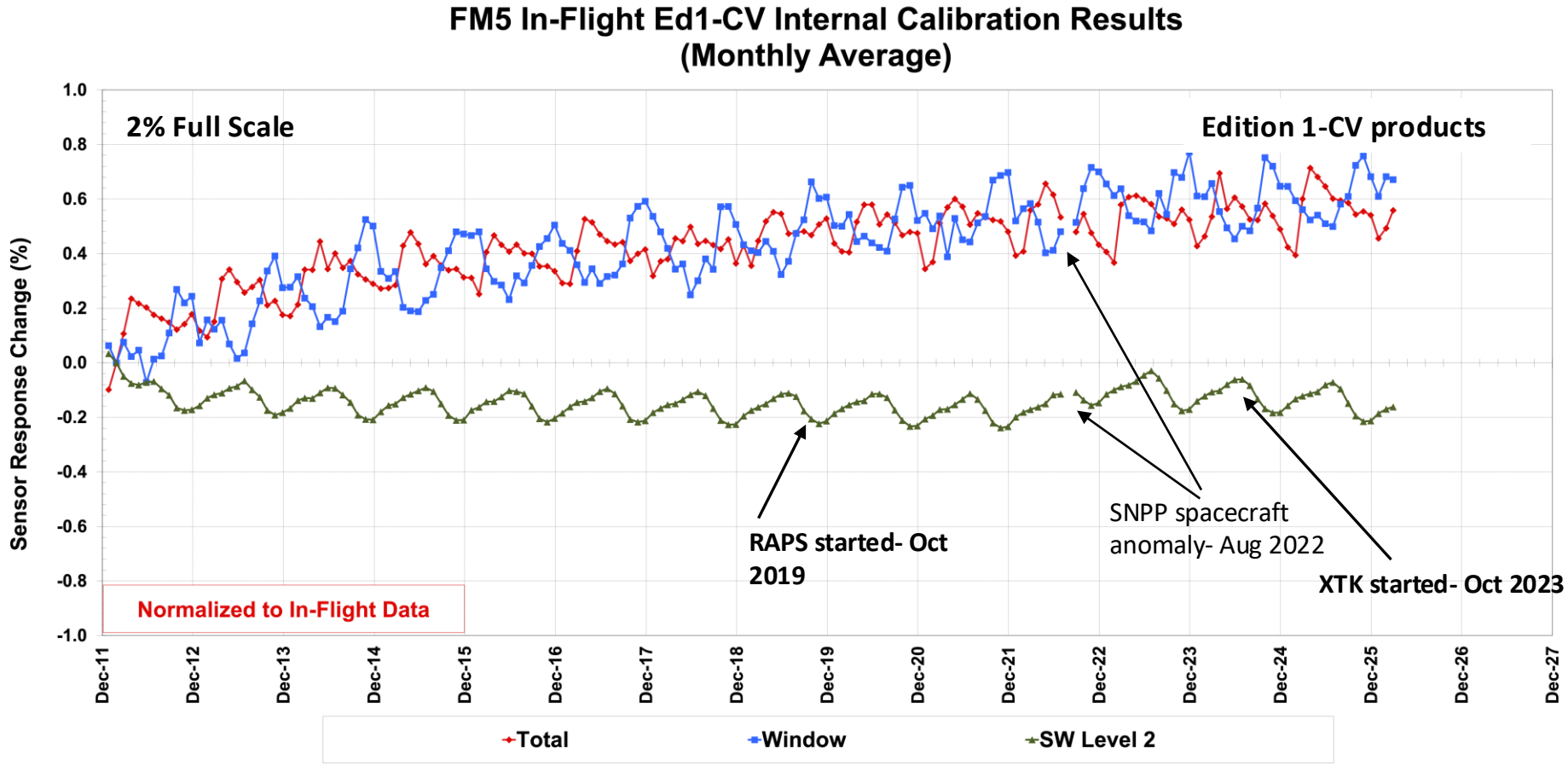


Shortwave portion of TOT Channel performance can be tracked with Solar Calibration on FM6

S-NPP/FM5 Instrument Status

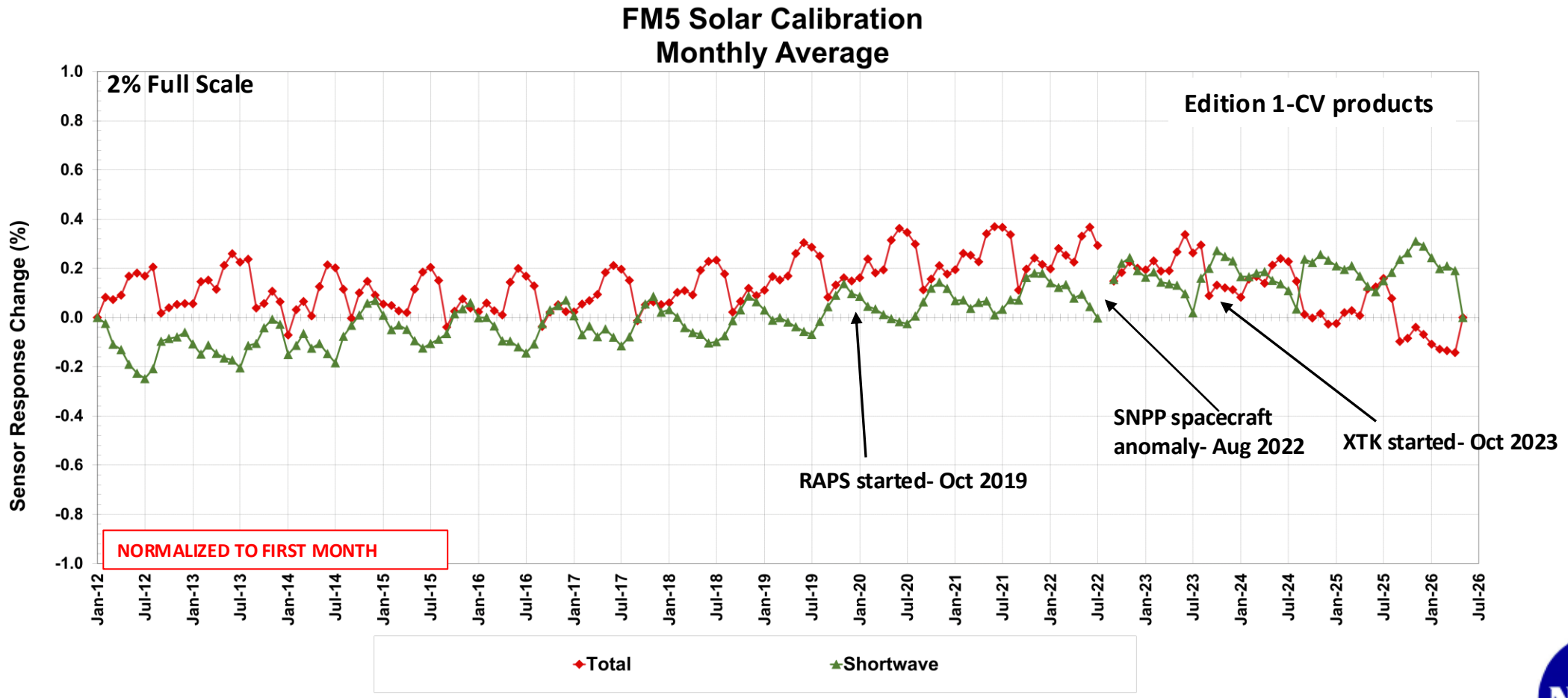
FM5 Internal Calibration

- In response to the blackbodies, the FM5 TOT and WN sensors settled at 0.6% since start of mission.
- SW channel's response to the SWICS is stable at ~0.2% since start of mission.



FM5 Solar Calibration

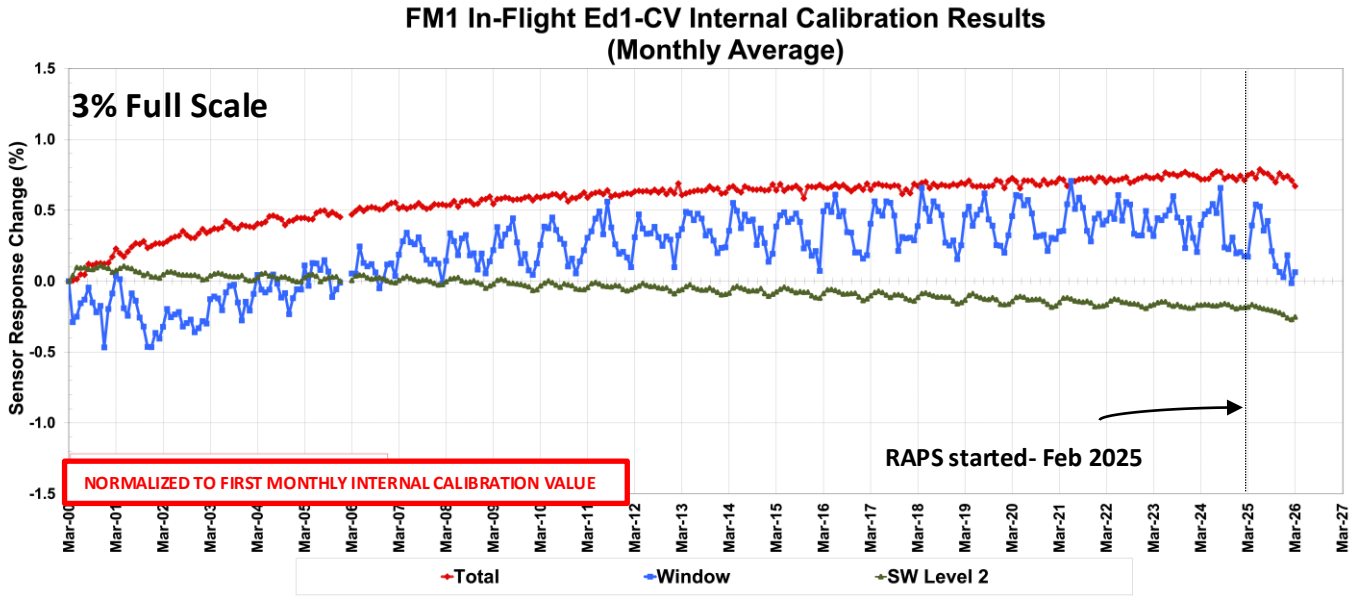
FM5 Solar calibration results show <0.3% change since start of mission for both SW and TOT channels.



Terra & Aqua
FM1-FM4 Instruments' Status

Terra- FM1 & FM2 Internal Calibration

- For FM1, TOT channel shows ~0.7% rise, SW channel shows ~0.2% drop, and WN channel shows a rise of ~0.3% since start of mission. **FM1 operating in RAPS mode since Feb 2025.**
- **FM2 Instrument was turned off in Jan 2025.**



Total, WN- Blackbody: ~300 K
SW- Lamp: ~3000K brightness temp.

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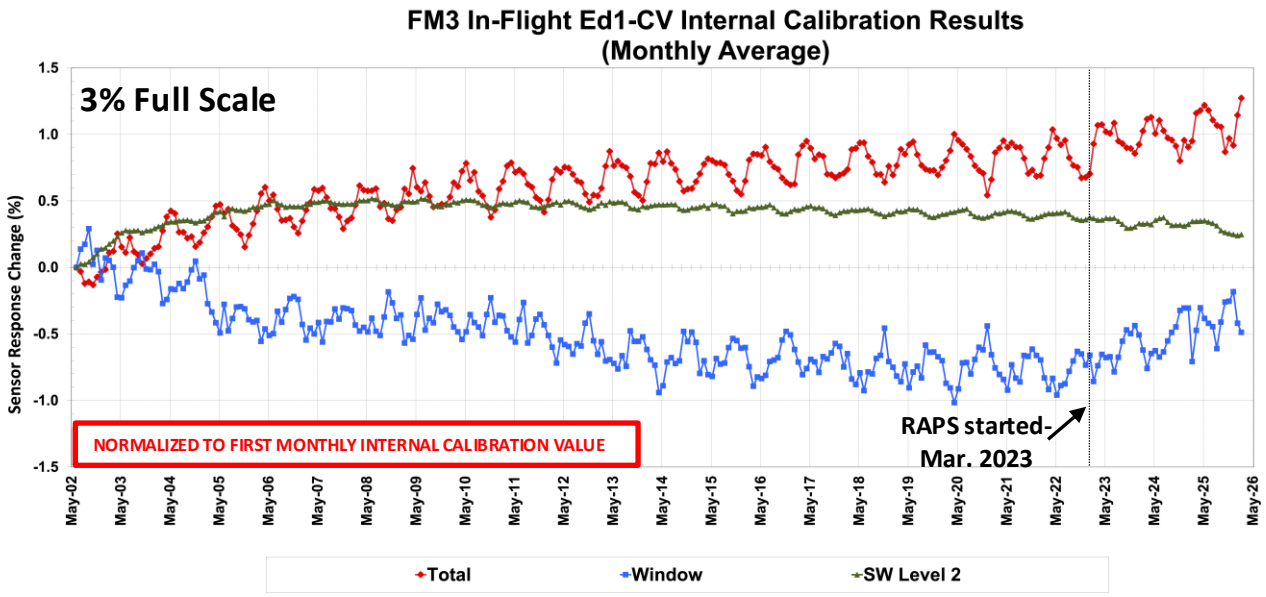
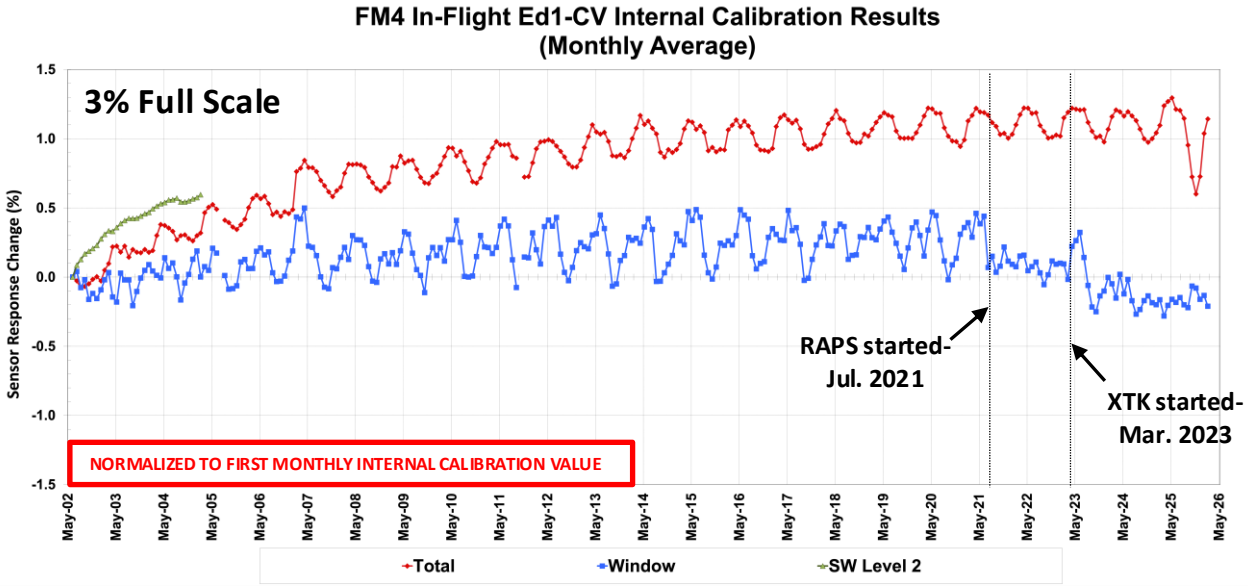
Aqua- FM3 and FM4 Internal Calibration

- For FM3, TOT channel shows ~1% rise, SW channel shows ~0.2% rise, and WN channel shows mode dependent behavior and is currently ~0.5% below start of mission.
- For FM4, TOT channel shows ~1.1% rise, while WN channel shows ~0.25% rise since start of mission till the transition of operational modes in 2021. SW Channel anomaly in Mar 2005.

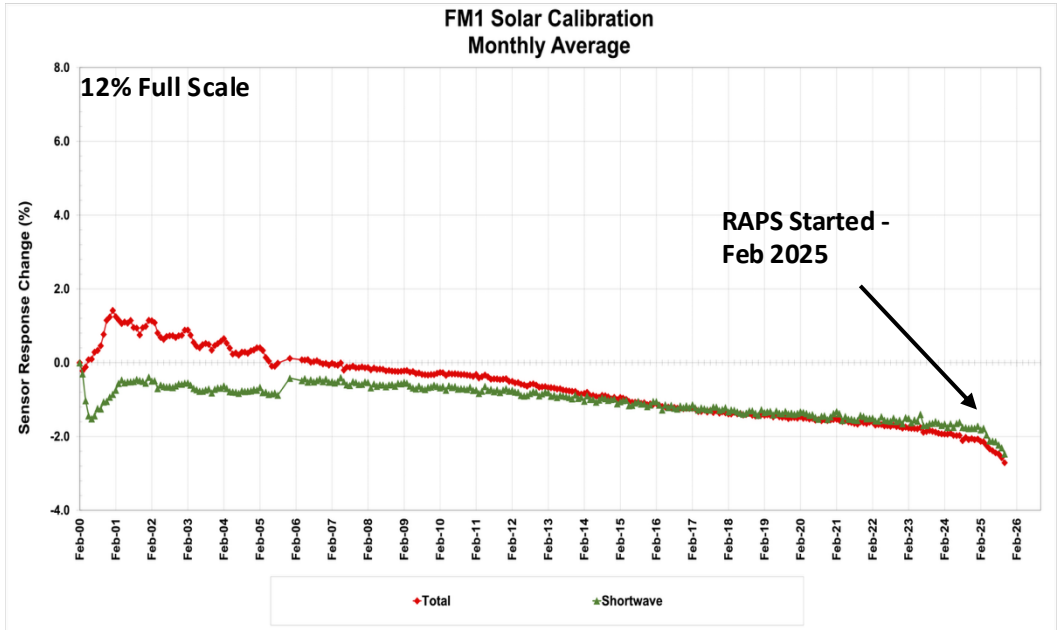


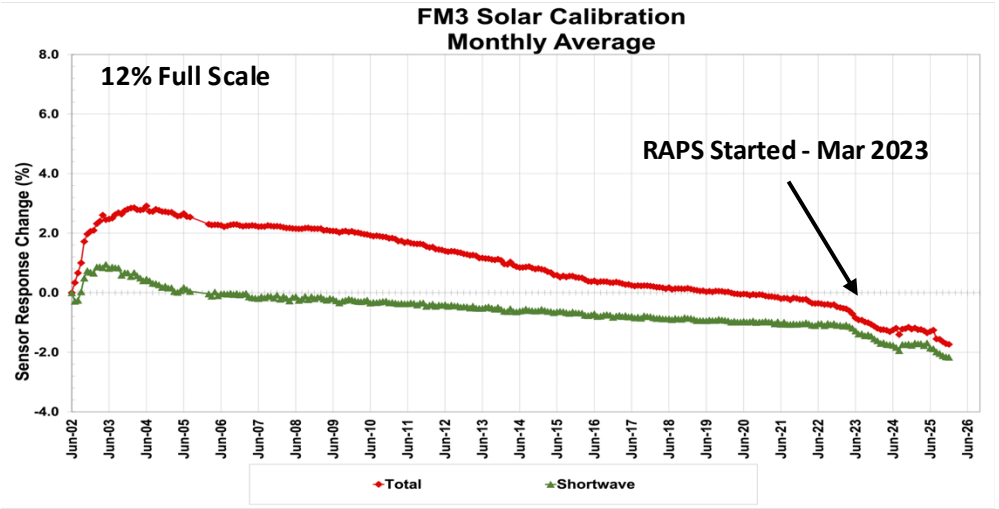


Total, WN- Blackbody: ~300 K
SW- Lamp: ~3000K brightness temp.

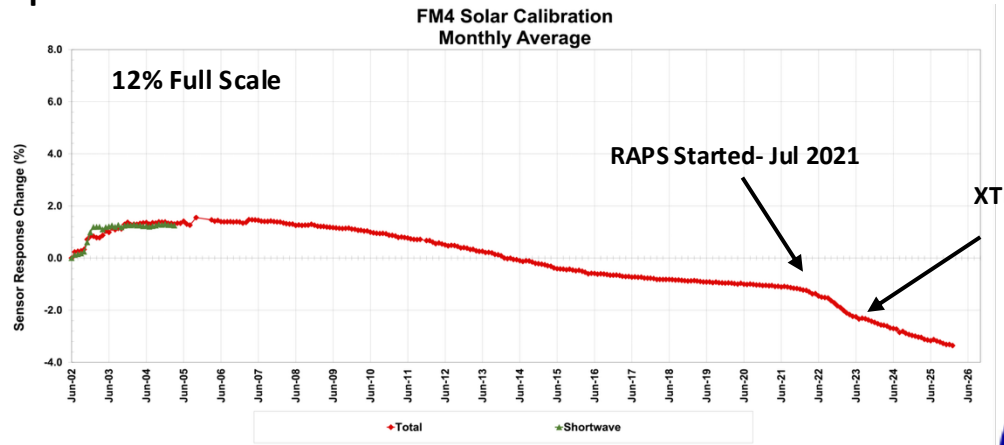
Terra & Aqua Solar Calibration

Since the start of BIAX, the TOT and SW channels on FM1 and FM3 showed a drop in response of ~1%.
TOT channel on FM4 showed a drop of ~1.2% while in BIAX, and ~1% since then.





Edition 1-CV data products



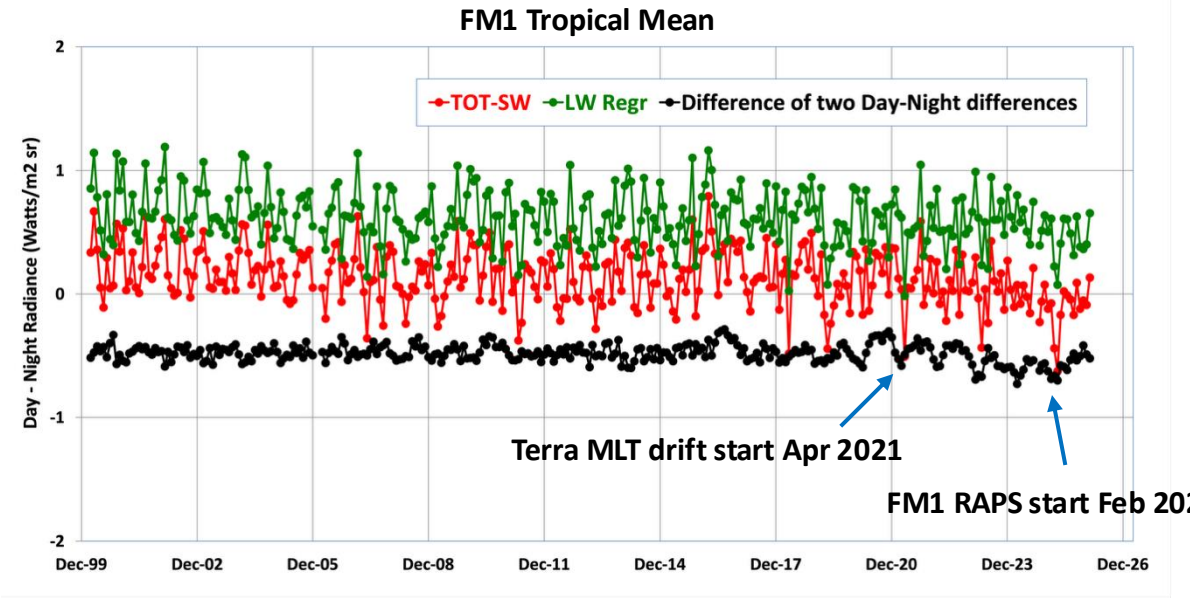
Validation – Tropical Mean (TM)

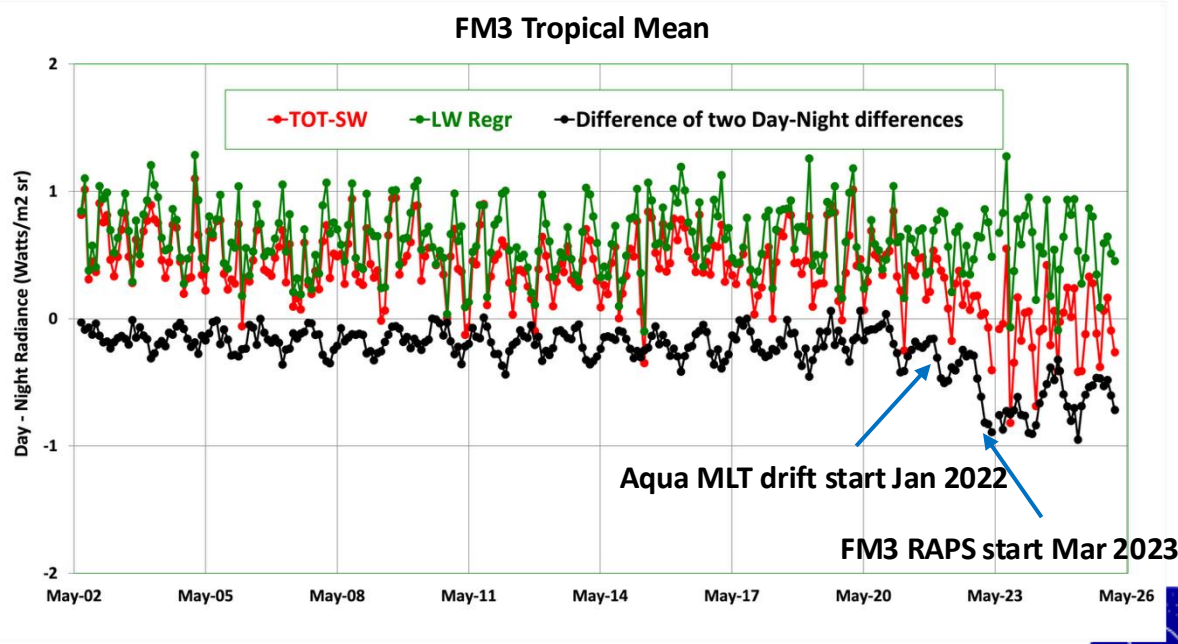
- Average of the ES-8 Nadir radiances over Tropical ocean (20^0N-20^0S) scenes under All-sky conditions.
  - Uses latest version of data products - All calibration updates have been applied.
- Two sets of TM Day-Night Differences (DN) are calculated:
  - TOT and SW sensors

    $DN = TM_D(TOT\text{-}SW) - TM_N(TOT)$
  - LW_r *(Uses a 'trained' WN- Narrow to BB regression)*

    $DN = TM_D(LW) - TM_N(LW_r)$
- Trends of the difference in the two DN values highlight any inconsistencies in the Reflected Solar wavelengths of the TOT and SW sensors.

Validation- Terra and Aqua Tropical Mean





Uses Edition 4 ES-8 data products

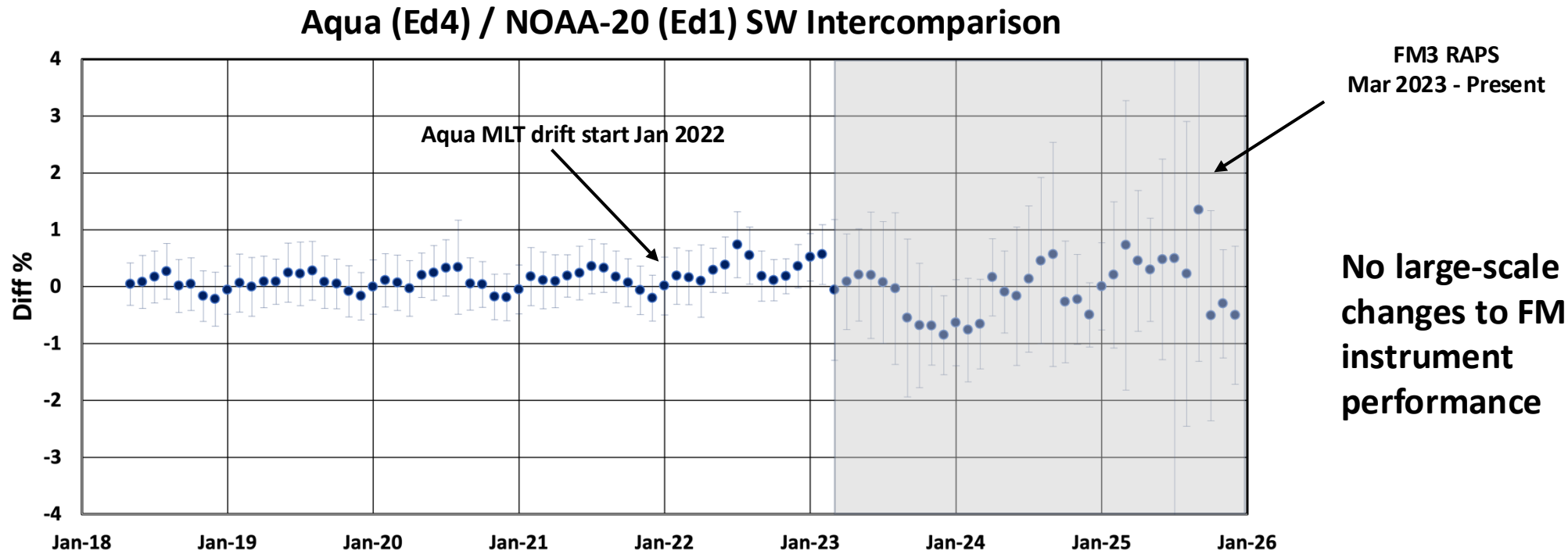
Aqua/NOAA-20 Intercomparisons

- Obtain spatially and temporally matched observations on days with orbital crossovers.
- No special operations are conducted to match viewing geometries; Instruments continue operating in their nominal mode:
  - *FM6 in Crosstrack scan mode, FM3 in RAPS scan mode since Mar 2023.*
- Use matching criteria to subset the data:
  - SZA, VZA difference < **2.0^0**
  - RAZ difference < **5^0**
  - Distance between centroid of footprints **< 7 km**
- Obtain monthly all-sky SW reflectance and LW radiance differences using the matched footprints.
- *Note:*
  - *Original analysis considered samples in the two-hour window around the orbital crossover times.*
  - *Since FM3 started operating in biaxial scan mode, the number of matched footprints drastically reduced.*
  - *To counteract the reduced sampling, footprint matches for a full day considered (during the RAPS period) instead of just around the cross-over times on the days that crossovers occur.*

FM3/FM6 SW All-sky Inter-comparisons: May 2018 – Dec 2025

Difference of Reflectance:
(FM3-FM6) %, 95% CI

$$Reflectance = \frac{SW_{rad} * \pi}{F * \cos(SZA)}$$ F=1361 W/m^2



No large-scale changes to FM3 instrument performance

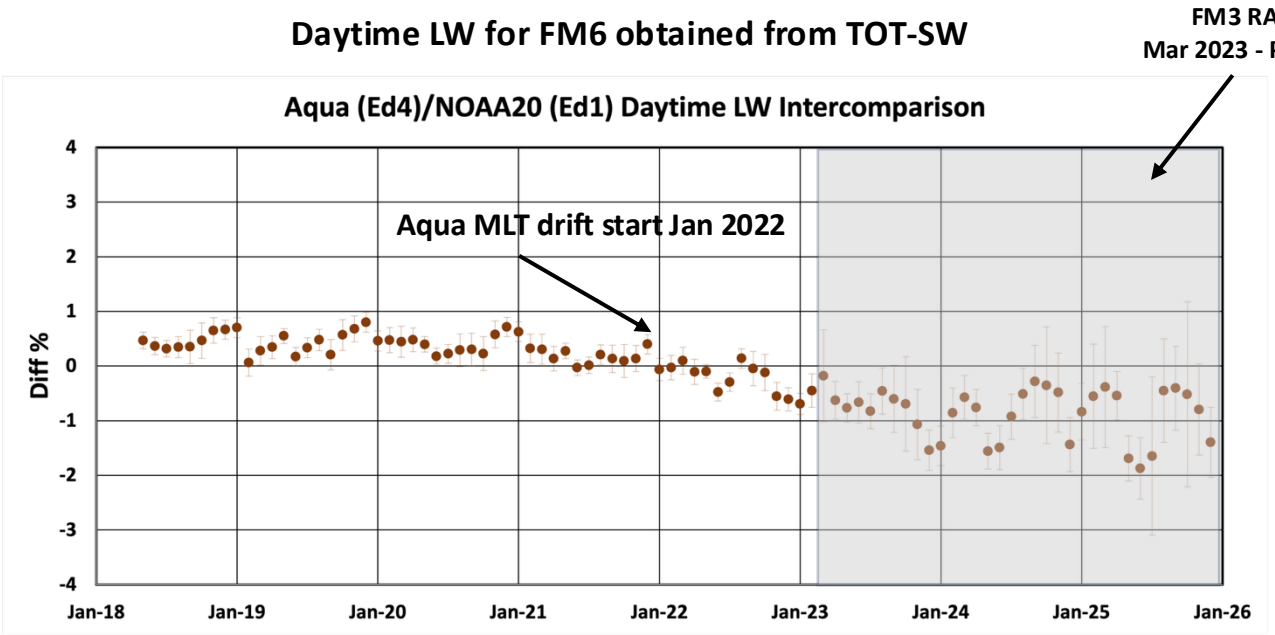
Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1B

Deviation from the long-term trend in the later years due to the impact on the sampling caused by Aqua's orbital drift and FM3 operating in RAPS mode.

FM3/FM6 LW All-sky Inter-comparisons: May 2018 - Dec 2025

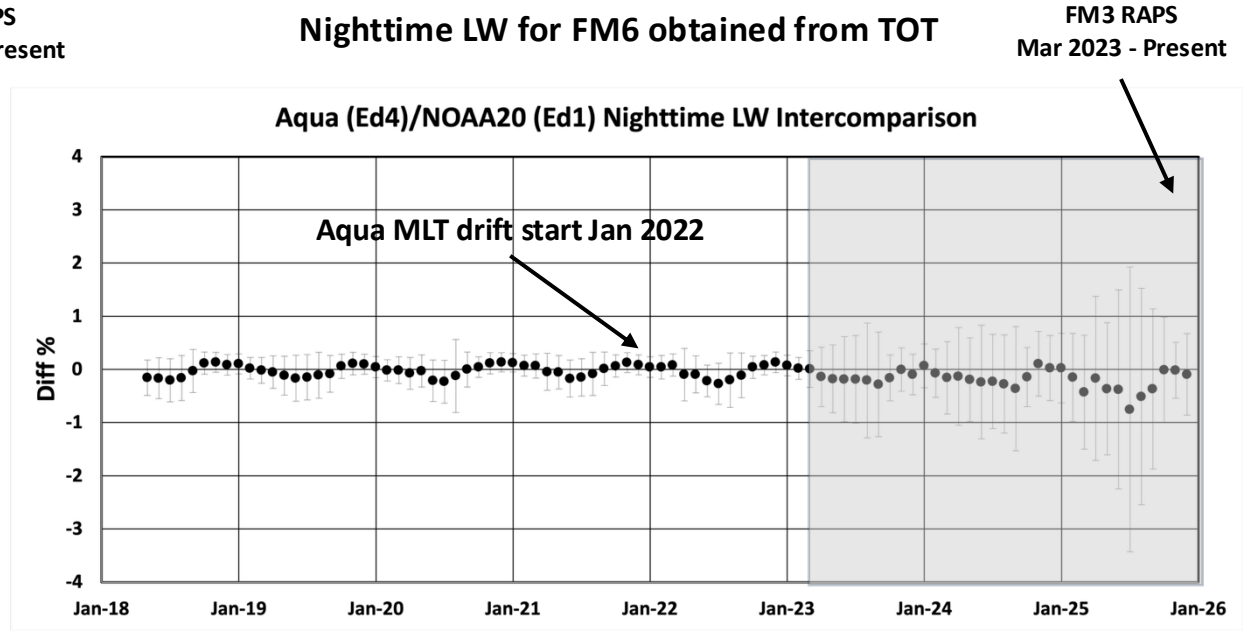
Difference of Daytime Radiance: (FM3-FM6) %, 95% CI

Daytime LW for FM6 obtained from TOT-SW



Difference of Nighttime Radiance: (FM3-FM6) %, 95% CI

Nighttime LW for FM6 obtained from TOT



No large-scale changes to FM3 instrument performance

Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1B

Deviation from the long-term trend in the later years due to the impact on the sampling caused by Aqua's orbital drift and FM3 operating in RAPS mode.

CERES Instrument Working Group

Edition 5 Instrument Updates- Terra and Aqua

- Gains for Terra and Aqua have been updated.

- Time-varying SRFs are currently being validated
  - Edition 5 uses a more robust approach to determine the shortwave portion of Total Channel SRFs.
  - SW channel and WN channel SRFs are unchanged from Edition 4.

Edition 5 Instrument Updates for Terra and Aqua

- Update and validate Edition 5 gains. ✅
- Terra/FM1 and FM2 radiometric scaling at Start of Mission (Mar 2000). ✅
- Terra TOT channel SRF selection and validation. ⬅
- Aqua/FM3 and FM4 radiometric scaling at Start of Mission (Jul 2002). ✅
- Terra/Aqua Radiometric Scaling. ✅
- Aqua TOT channel SRF selection and Validation. ⬅

SUMMARY

- **NOAA-20/FM6 and SNPP/FM5 instruments are performing nominally.**
  - **FM6 instrument is very stable; Onboard calibration sources track instrument performance.**
  - **FM6 MAMs are performing extremely well.**
  - **GEOSCANs being conducted on both FM5 and FM6 on specific Earth targets.**
- **Terra and Aqua instruments' performance continue to be monitored with on-board calibration as their orbits drift.**
  - **Terra/FM2 instrument turned off in Jan 2025; FM1 was placed primarily in RAPS mode in Feb 2025.**
  - **Aqua/FM3 instrument continues to primarily operate in RAPS mode.**
  - **GEOSCANs continue to be conducted periodically.**
- **Edition 5 instrument updates (Gains, SRFs) for Terra and Aqua are currently being validated.**
- **Level 1 Data products**
  - **NOAA-20/FM6 Edition 1 gains have been delivered through Mar 2026.**
  - **S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Jul 2024.**
  - **Terra and Aqua instruments' Edition 4 gains and SRFs have been delivered through Feb 2026.**
- **Libera: IWG continues to support Cal-Val meetings**
  - **Bi-weekly meeting with Libera instrument team covering instrument calibration and related topics.**

Backup

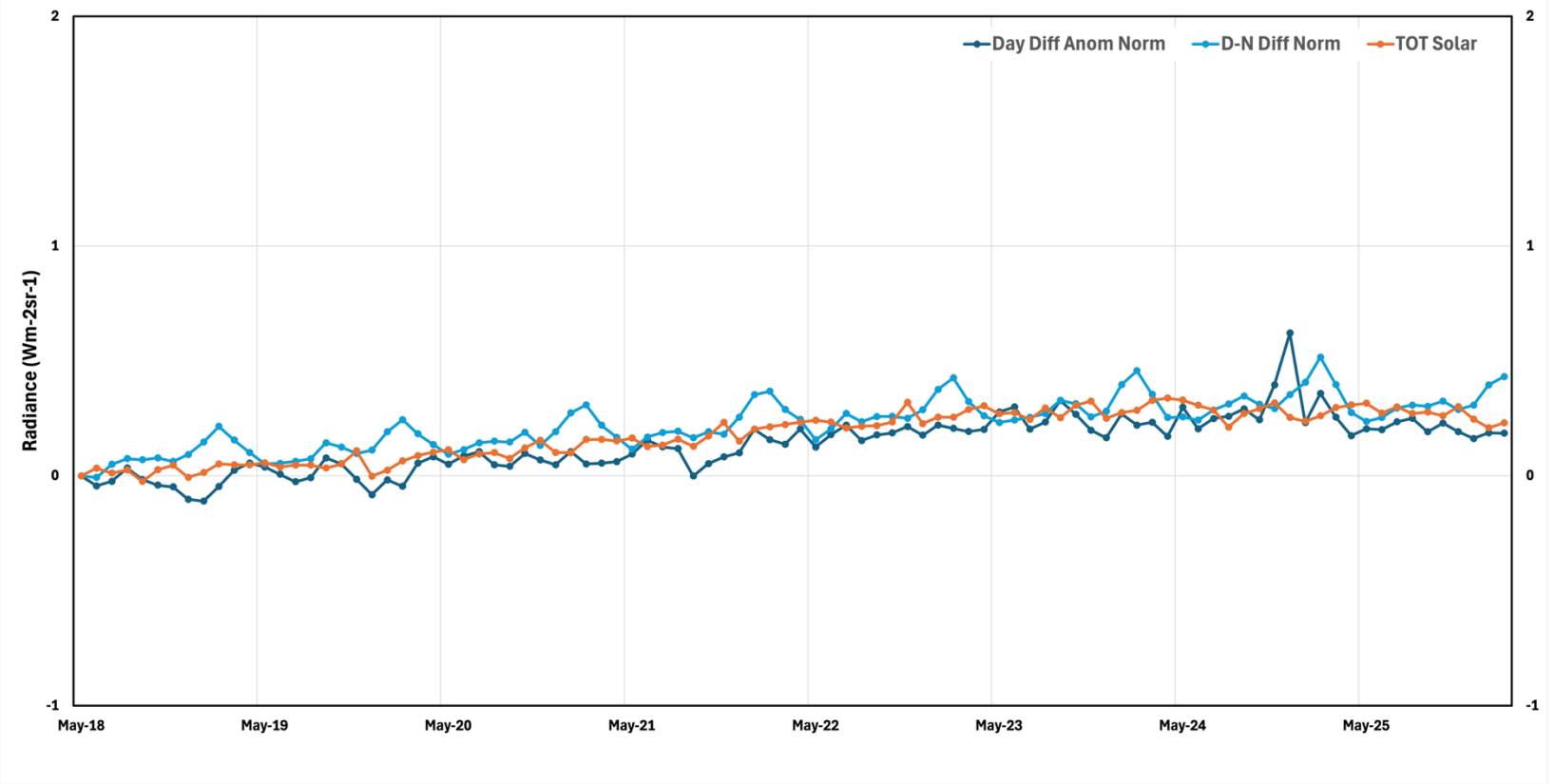
Instrument Product-line definitions

- **NOAA-20**
  - *Edition1-CV*: Products without any on-orbit instrument calibration corrections applied.
  - *Edition 1*: Incorporates the most up-to-date calibration corrections, radiometric scaling to Aqua.

- **S-NPP**:
  - *Edition 1-CV*: Products without any on-orbit instrument calibration corrections applied.
  - *Edition 2*: Incorporates the most up-to-date calibration corrections, radiometric scaling to Aqua, and time varying SRF adjustments to TOT channel.

- **Terra/Aqua**:
  - *Edition 1-CV*: Products without any on-orbit instrument calibration corrections applied.
  - *Edition 4*: Incorporates the most up-to-date calibration corrections, radiometric scaling and time varying SRF adjustments to SW and TOT channels.

FM6 Tropical mean Day-Night vs. Solar Cal



Day Diff: LW- LWc
D-N Diff: Diff of two Day-Night Diffs
TOT Solar: Pct Change in TOT Solar Cal

Edition 1 ES-8 products

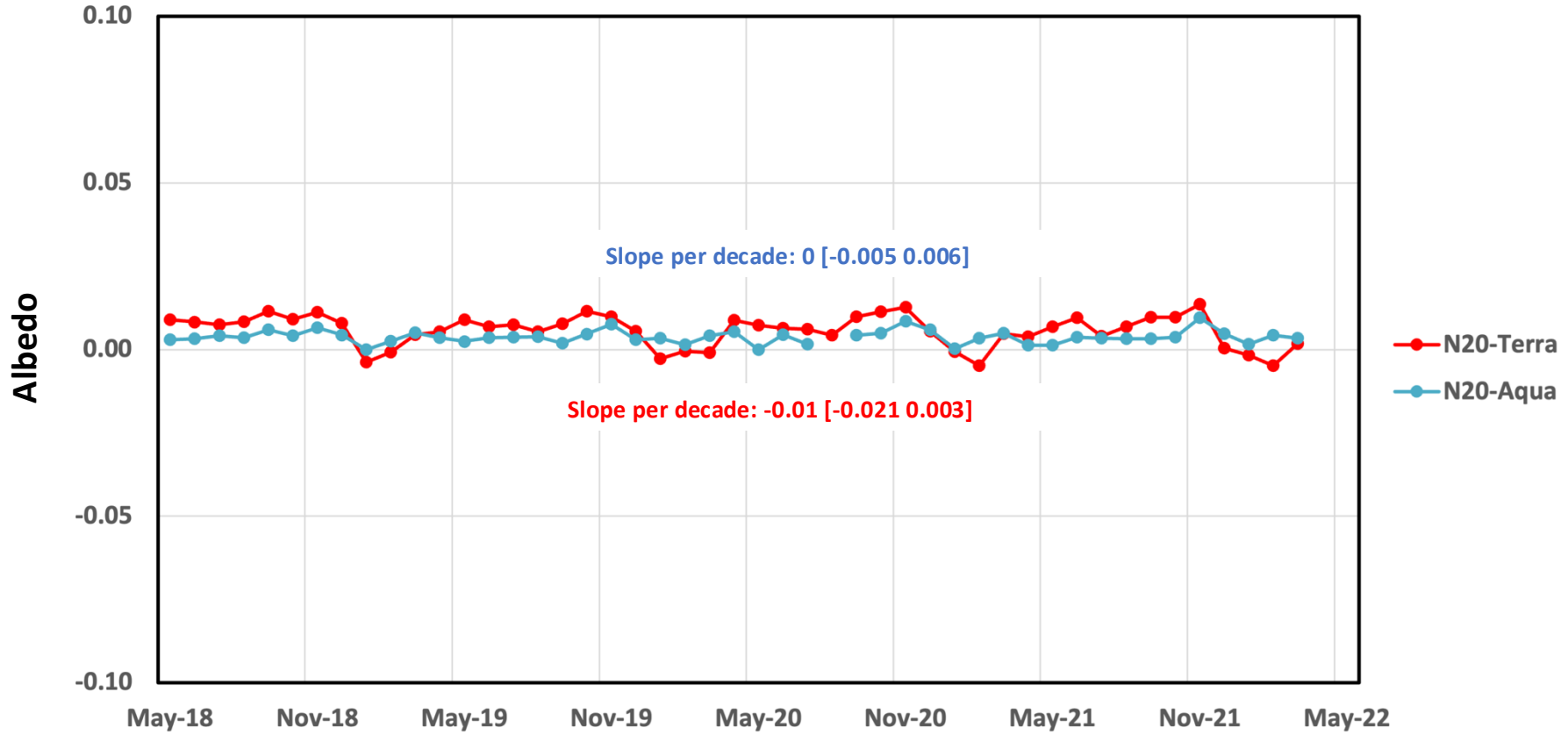
CERES Instrument Working Group

Deep Convective Cloud (DCC) Albedo

- Observe the relative differences of DCC albedo from NOAA-20 and Terra, Aqua.
  - Uses Level-2 products (SSF), calculate monthly means of DCC footprints.
  - Uses instruments operated in cross-track.
  - Period: May 2018- Feb 2022

- Criteria for selecting DCC:
  - Consider all footprints with VZA, SZA < 40 deg.
  - Latitude bands: 30^0 N-S.
  - Cloud Fraction= 100%.
  - Use MODIS/VIIRS 11um channel to identify footprints with brightness temperature <220K.
  - Use Filtered radiance thresholds:
    - WN channel filtered radiance (Terra, Aqua) < 1 $Wm^{-2}sr^{-1}um^{-1}$.
    - LW channel filtered radiance (NOAA-20) < 19 $Wm^{-2}sr^{-1}um^{-1}$.

NOAA-20- Aqua DCC Albedo Difference

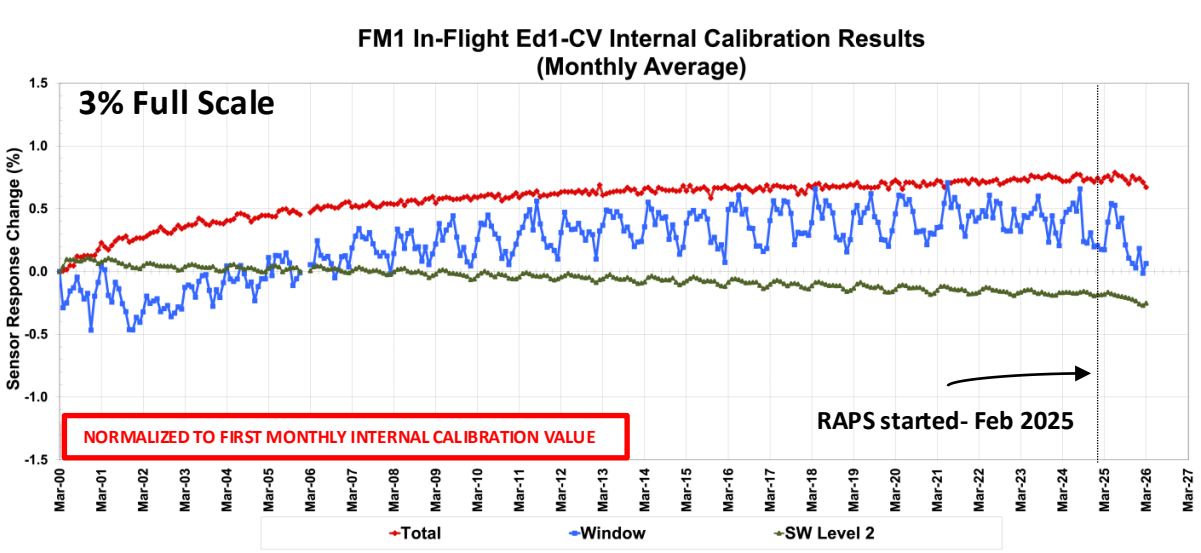


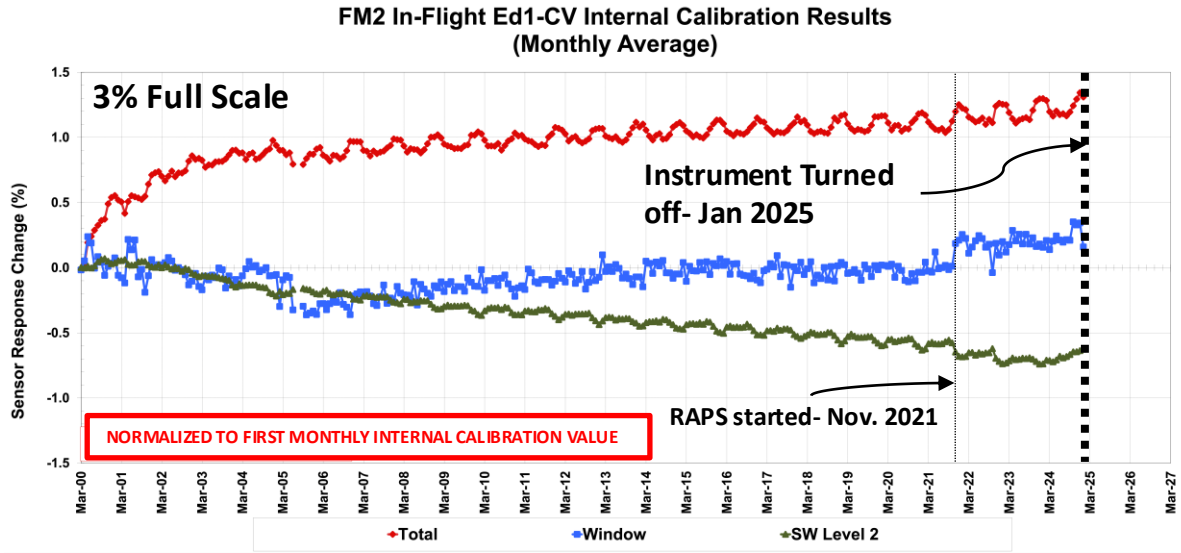
Relative difference of Albedo shows consistency between the two instrument pairs

Terra- FM1 & FM2 Internal Calibration

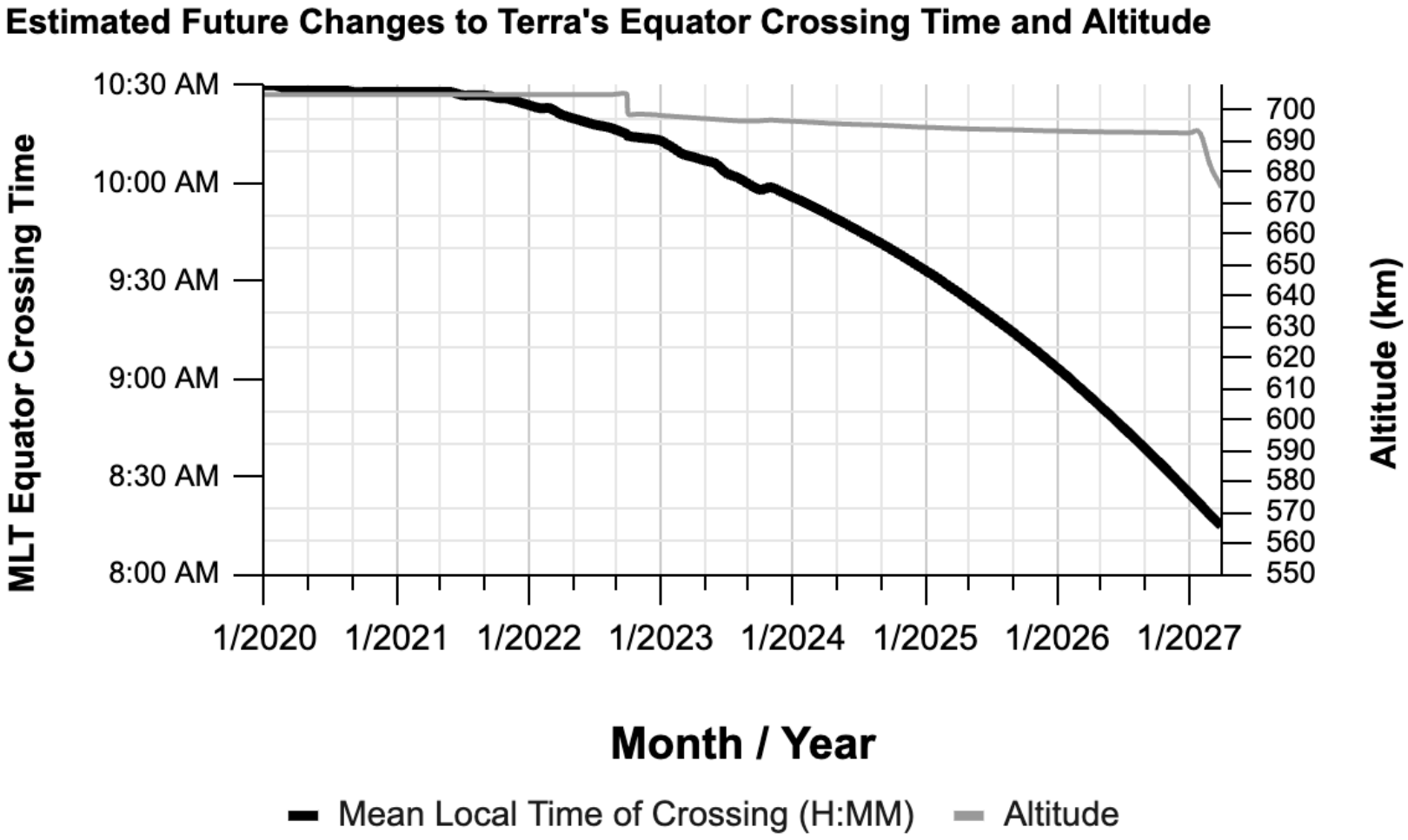
- For FM1, TOT channel shows ~0.7% rise, SW channel shows ~0.2% drop, and WN channel shows a rise of ~0.3% since start of mission. **FM1 operating in RAPS mode since Feb 2025.**
- **FM2 Instrument was turned off in Jan 2025.**

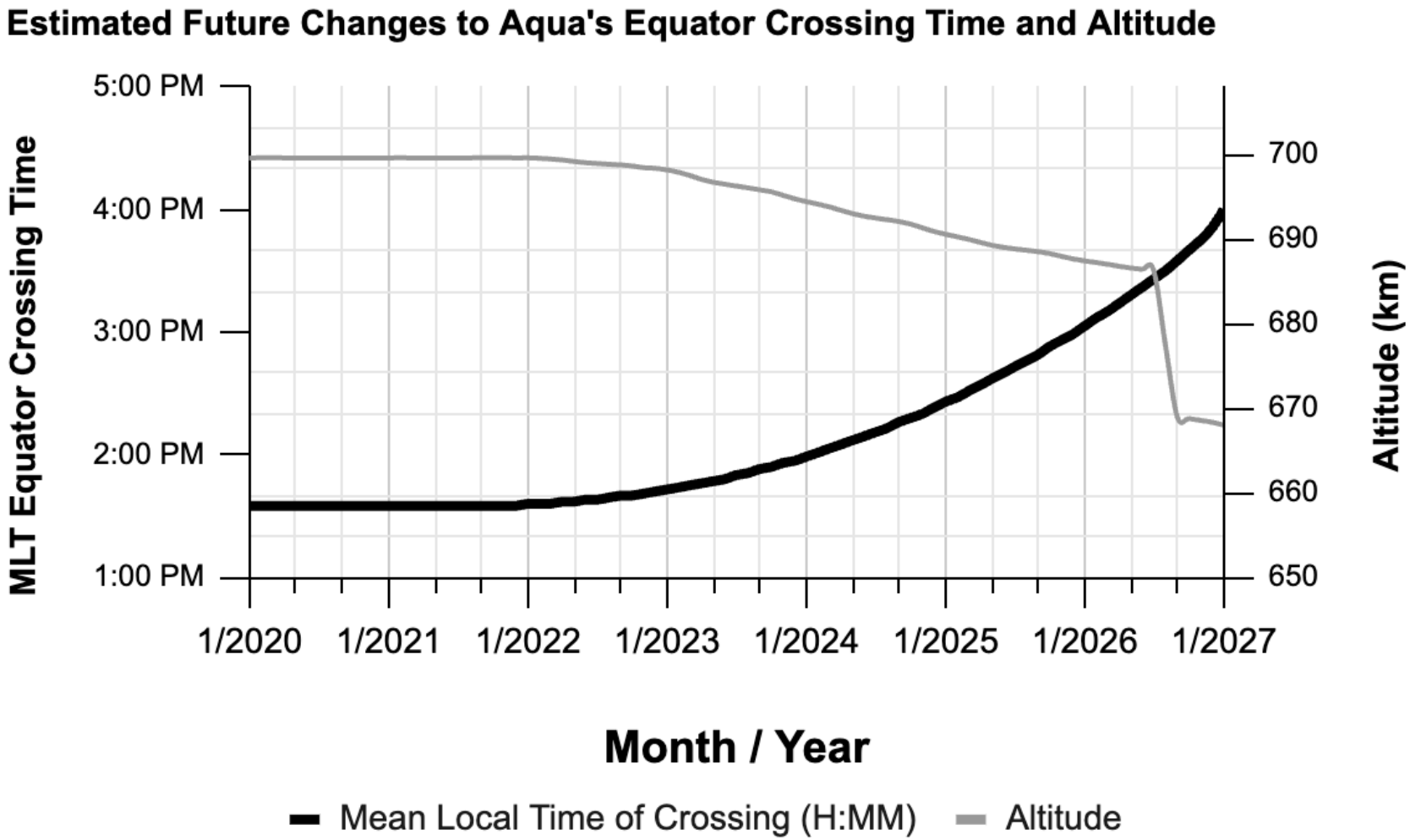
Edition 1-CV products





Total, WN- Blackbody: ~300 K
SW- Lamp: ~3000K brightness temp.


Estimated Future Changes to Terra's Equator Crossing Time and Altitude
MLT Equator Crossing Time
10:30 AM
10:00 AM
9:30 AM
9:00 AM
8:30 AM
8:00 AM
1/2020
1/2021
1/2022
1/2023
1/2024
1/2025
1/2026
1/2027
Month / Year
Altitude (km)
700
690
680
670
660
650
640
630
620
610
600
590
580
570
560
550
Mean Local Time of Crossing (H:MM)
Altitude


Estimated Future Changes to Aqua's Equator Crossing Time and Altitude
MLT Equator Crossing Time
5:00 PM
4:00 PM
3:00 PM
2:00 PM
1:00 PM
Altitude (km)
700
690
680
670
660
650
1/2020
1/2021
1/2022
1/2023
1/2024
1/2025
1/2026
1/2027
Month / Year
Mean Local Time of Crossing (H:MM)
Altitude