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



Mohan Shankar

CERES Instrument Working Group

CERES Fall Science Team Meeting
Oct 27, 2026

CERES Instrument Working Group

Instrument Working Group

IWG Lead: Mohan Shankar
Deputy: Susan Thomas

Instrument Operations	Data Management	Calibration/Validation
Mike Tafazoli	Denise Cooper	Nathaniel Smith
Janet Daniels	A. Thomas Grepiotis	Nitchie Smith
Ethan Ames		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
  - QTH Lamp- SW channel
  - Mirror Attenuator Mosaic (MAM): Solar Calibration- SW and TOT channels



CERES Instrument Status Summary

- **NOAA-20/FM6** instrument is operating in Crosstrack mode and is performing nominally.
- **SNPP/FM5** instrument is currently operating primarily in Crosstrack mode.
  - End of Science scheduled for Nov. 1, 2026
  - IWG has conducted several calibration data collects.
- **Aqua**
  - FM3 instrument is primarily operating in RAPS mode; FM4 operating Crosstrack mode.
- **Terra**
  - FM1 primarily operating in RAPS mode; *FM2 was turned off in Jan 2025*.
  - End of Science scheduled for Dec 1, 2026.
  - IWG has scheduled several calibration data collects.

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

CERES Instrument Operations Summary

Spacecraft	Instrument	Operational Mode	Notes
NOAA20	FM6	XTK	GEOSCANs for specific targets May 2025-Oct 2026
SNPP	FM5	XTK	RAPS between Oct 2019- Oct 2023; GEOSCANs for specific targets May 2025-Oct 2026
Aqua	FM4	XTK	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: GEOSCAN

GEOSCAN for NOAA20/FM6 and SNPP/FM5:

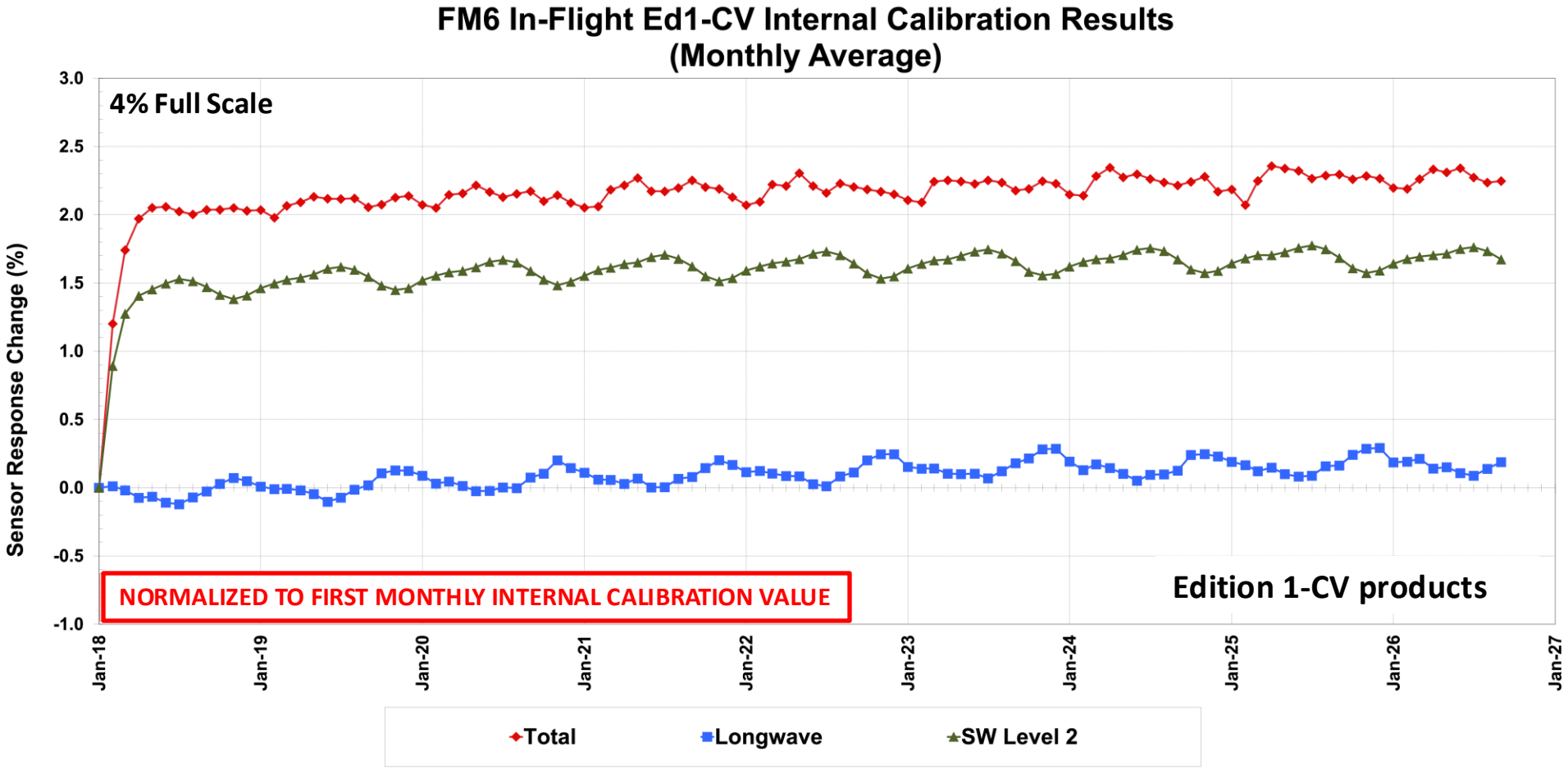
- Use GEOSCANS on specific Earth targets to place FM5 and FM6 on the same radiometric scale.
  - S-NPP and NOAA20 orbits don't cross over (no SNOs).
  - Involves aligning the scan planes of CERES instruments with GEO imagers.
- Since May 2025, GEOSCANs are being collected from both instruments for 3 scene types, targeting the different CERES channels.
- GEOSCANs concluded Oct 2026 ahead of End of Science for SNPP.

Dave Doelling's talk on Thursday at 9am:
On the Use of Geostationary Imagers as Transfer Radiometers to Inter-calibrate CERES Broadband Radiometers

NOAA-20/FM6 Instrument Status

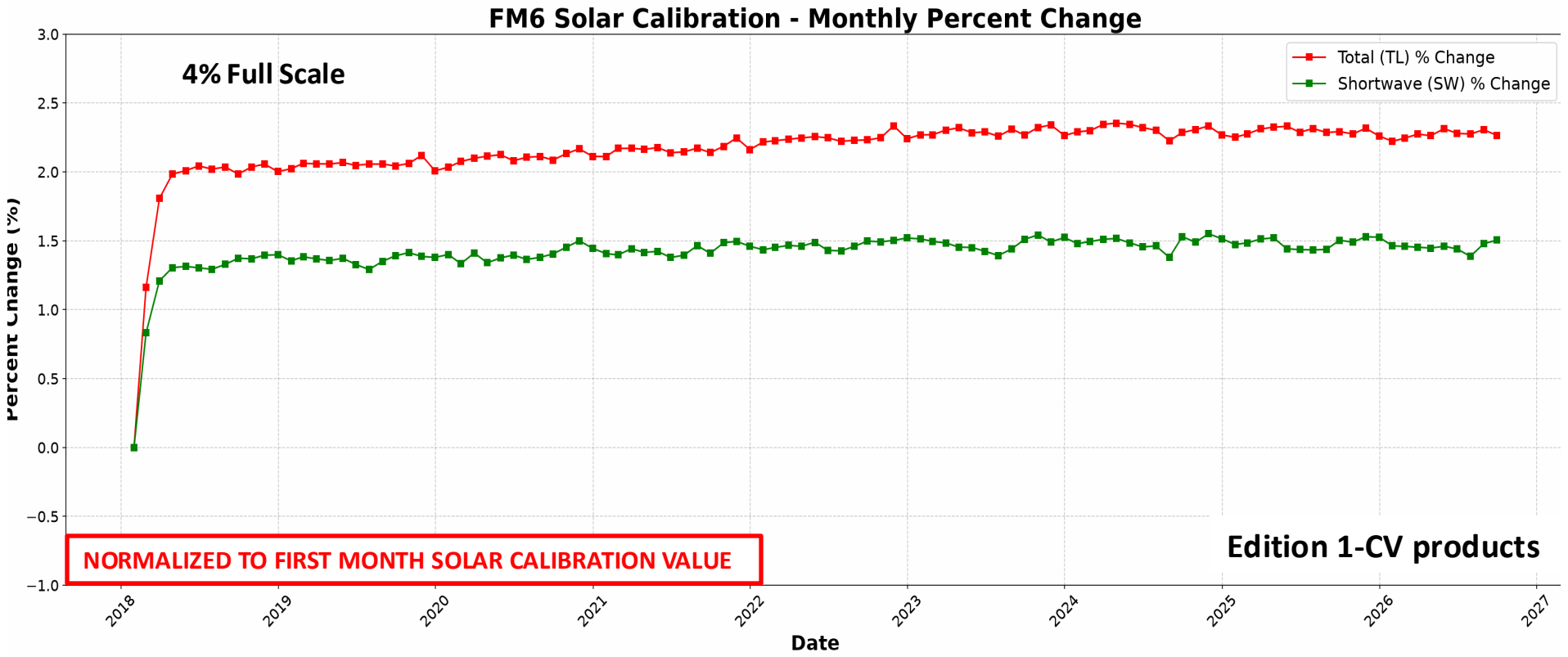
FM6 Internal Calibration

- 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 shows ~0.2% since start of the mission.



FM6 Solar Calibration

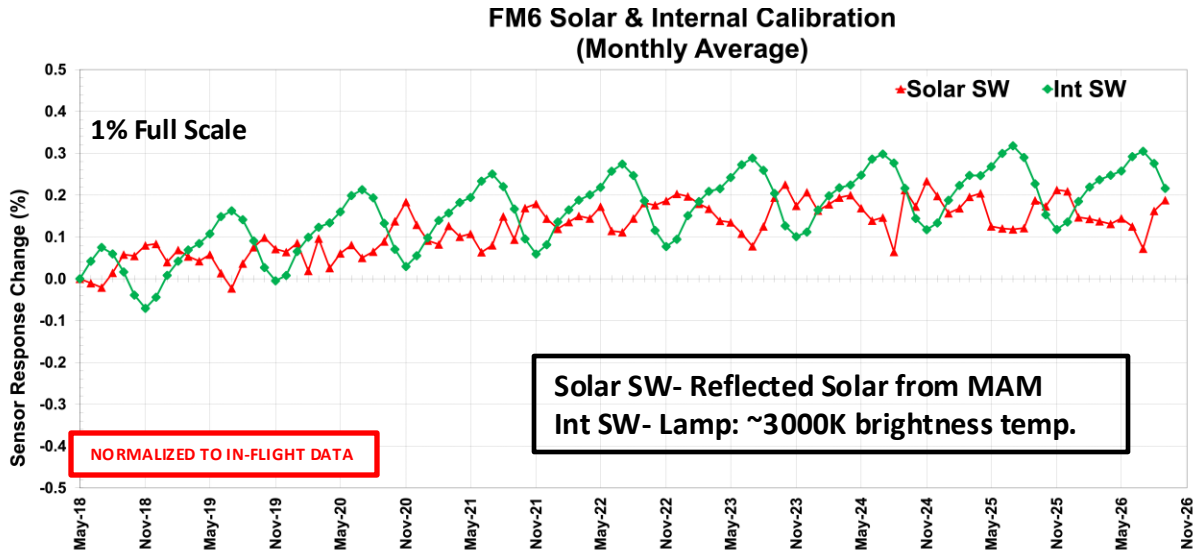
- Response of the SW and TOT channels while viewing the MAM that is illuminated by the sun.
- For SW, after the initial rise of ~1.2% for SW response shows very little change (<0.3%).
- For the TOT, after the initial rise of ~2% for TOT, the response shows ~ 0.3% change.



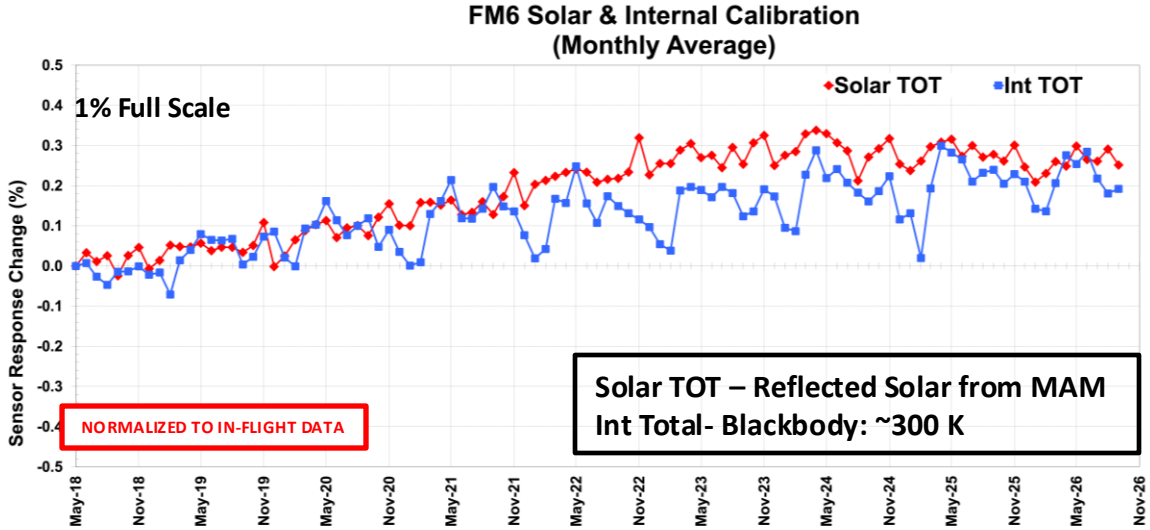
FM6 Calibration- Internal and Solar Cal Since May 2018

FM6 Internal and solar calibration results consistently show <0.3% change since May 2018, demonstrating that the MAM is very stable.

SW Channel



TOT Channel



Edition 1-CV products

Validation – FM6 Tropical Mean (TM)

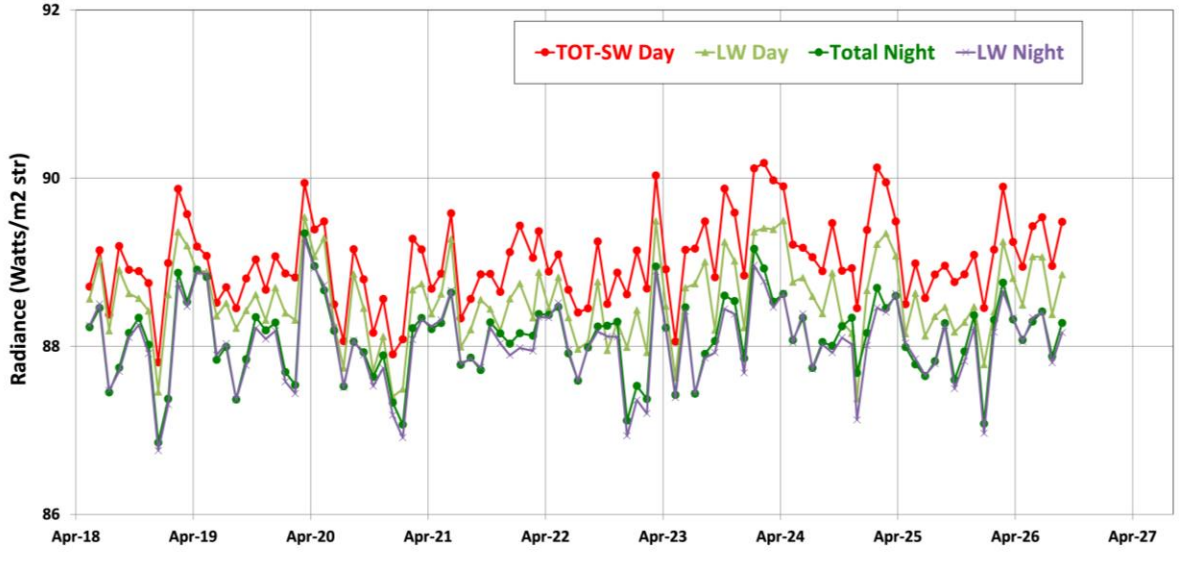
- Average of the Nadir radiances over Tropical ocean (20^0N-20^0S) scenes under All-sky conditions.
  - Uses latest version of ES-8 data products (Edition 1) - All calibration updates (gains) have been applied.
- Two sets of TM Day-Night Differences (DN) are calculated:
  - TOT and SW sensors

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

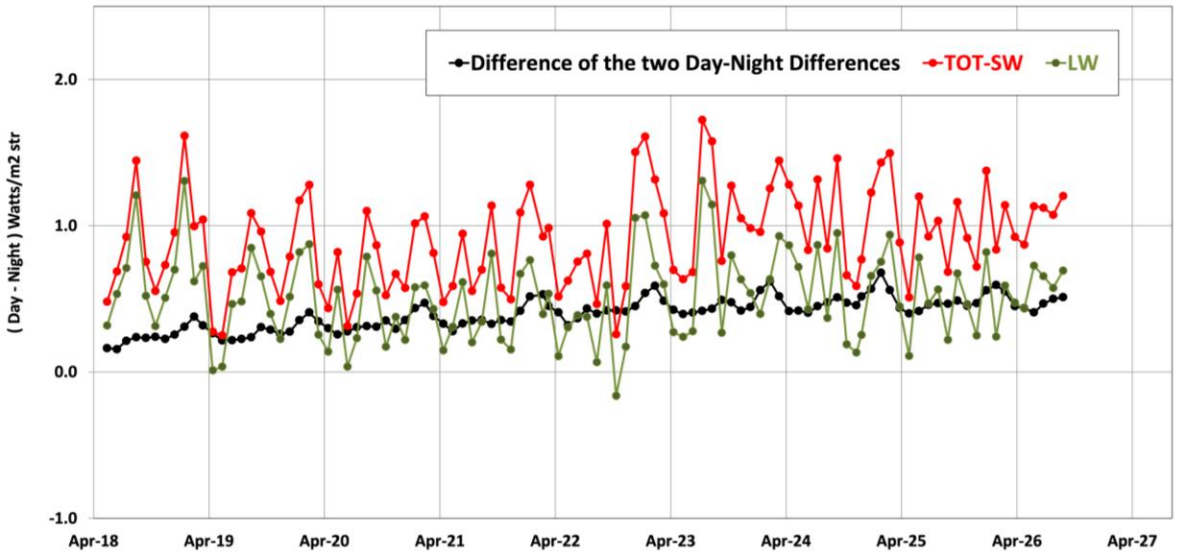
    $DN = TM_D(LW) - TM_N(LW)$
- Trends of the difference in the two DN values highlight any inconsistencies in the response between the three channels.

Validation- FM6 Tropical mean Day-Night

FM6 Tropical Mean



FM6 Tropical Mean D-N Differences



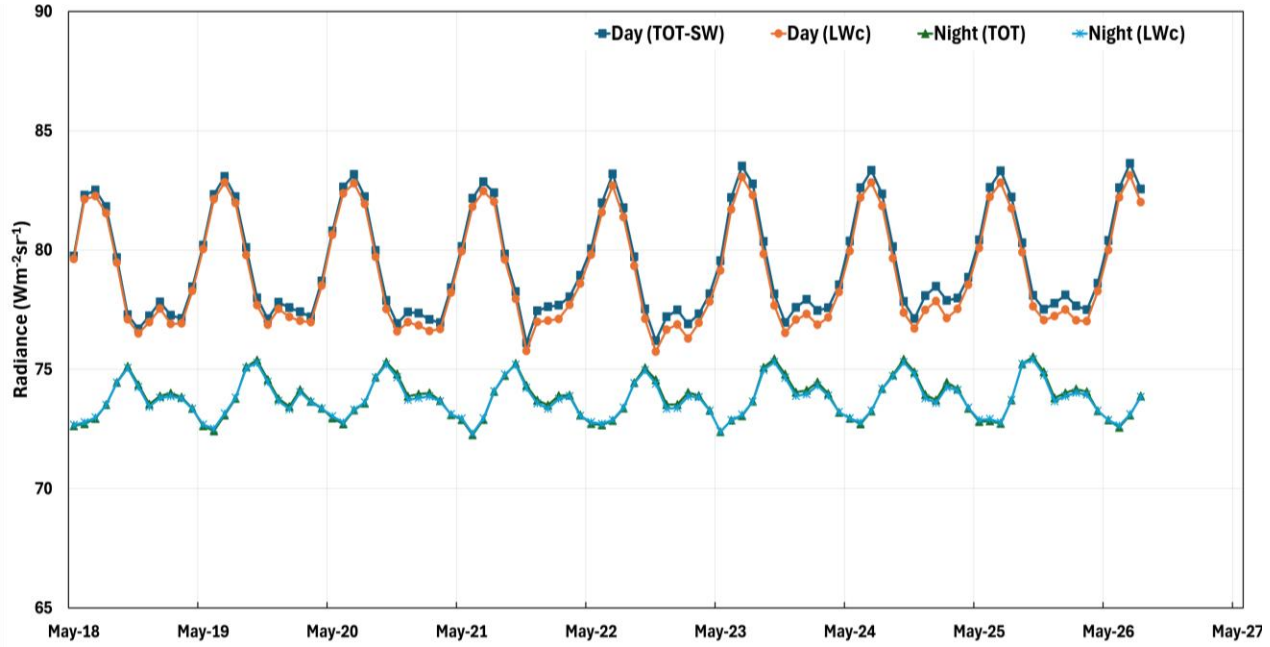
Edition 1 ES-8 products

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

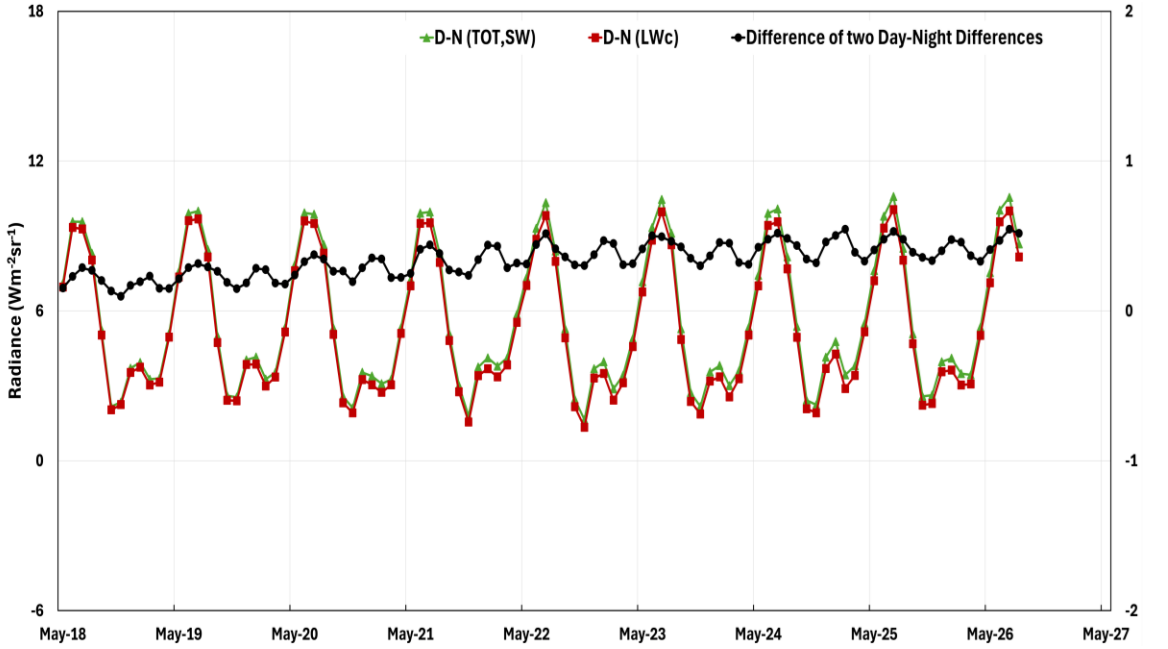
May 2018 - Aug 2026

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

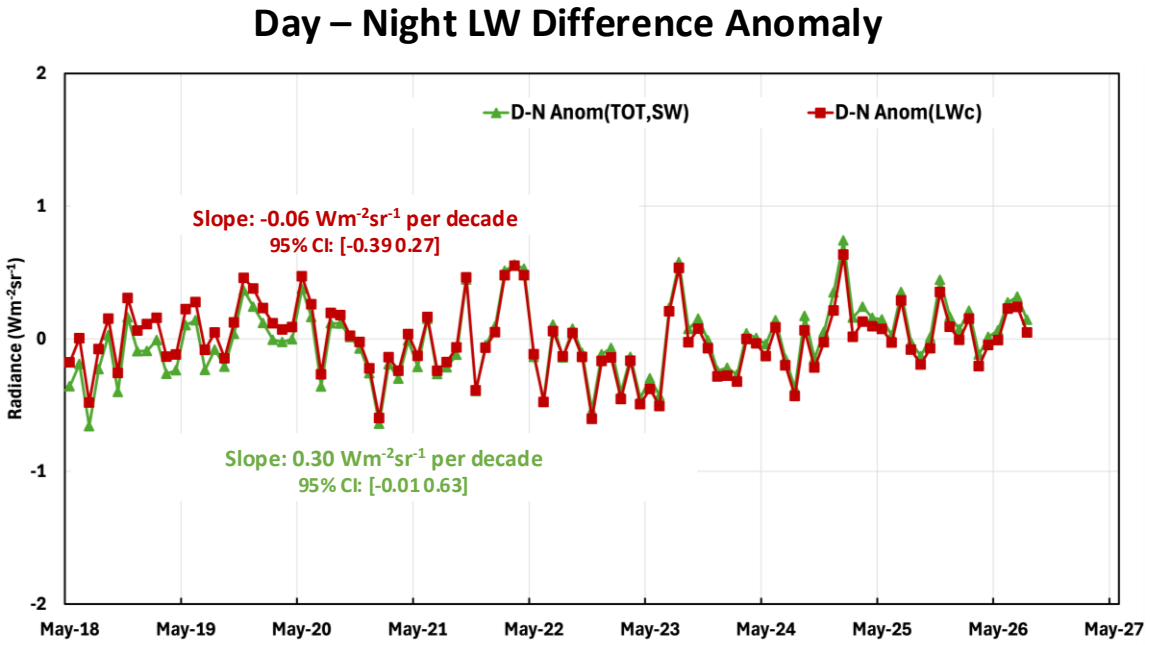
FM6 Edition 1 Global Mean LW radiance



Day-Night Difference

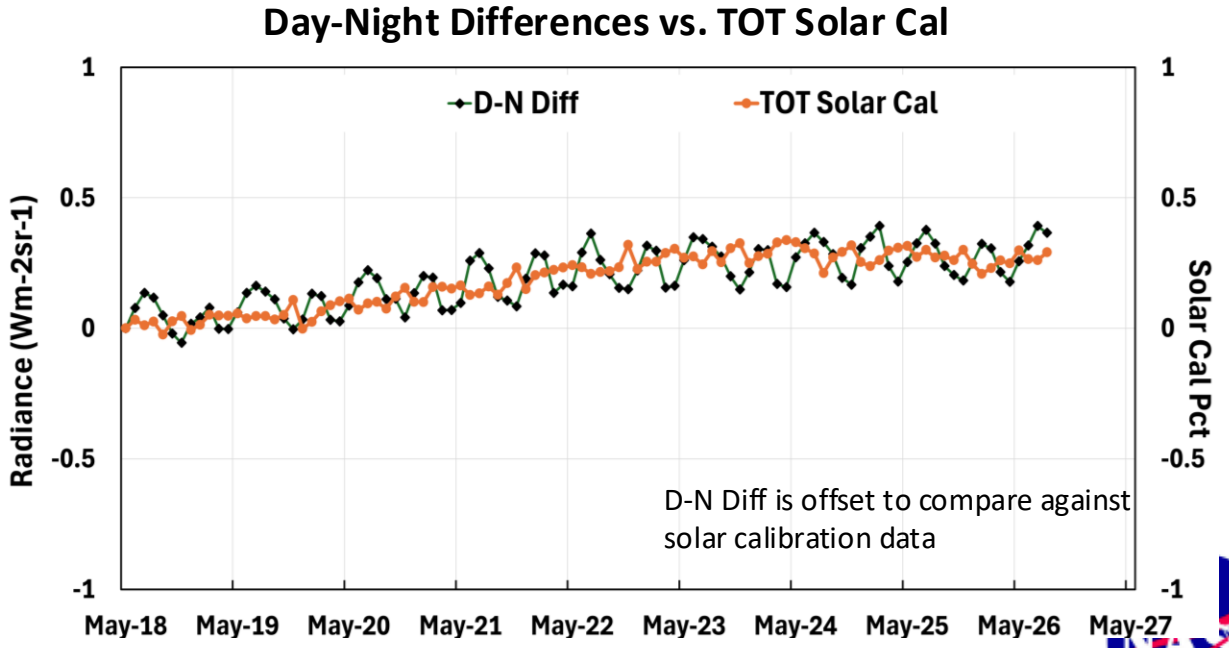


FM6 3-channel Consistency check- SSF All-sky Global Day-Night Differences



LW Channel has consistent Day-Night difference

D-N Diff: Difference of Day-Night differences: LW (TOT-SW) – LW(LW channel)

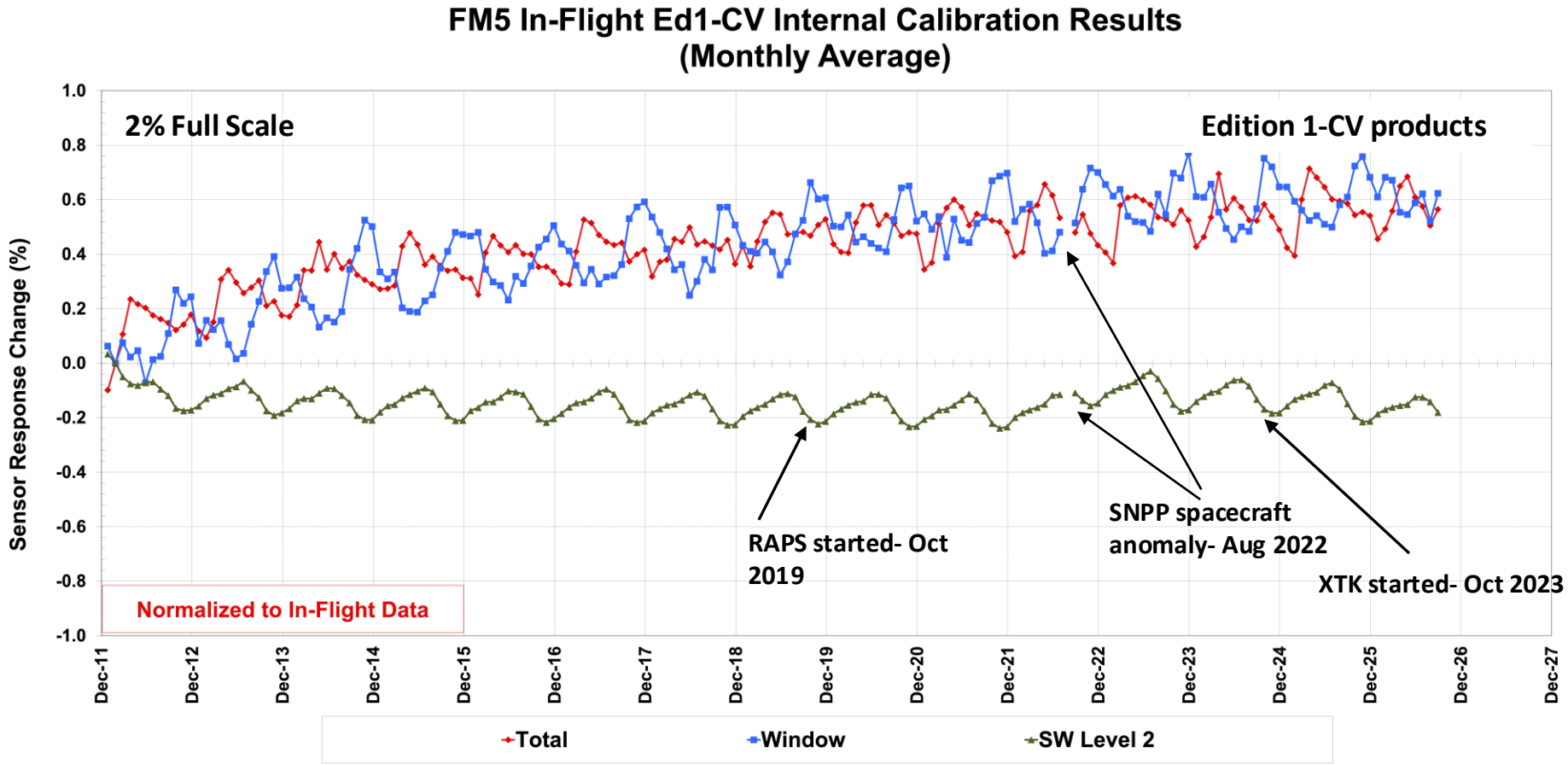


Shortwave portion of TOT Channel performance can be tracked with Solar Calibration

S-NPP/FM5 Instrument Status

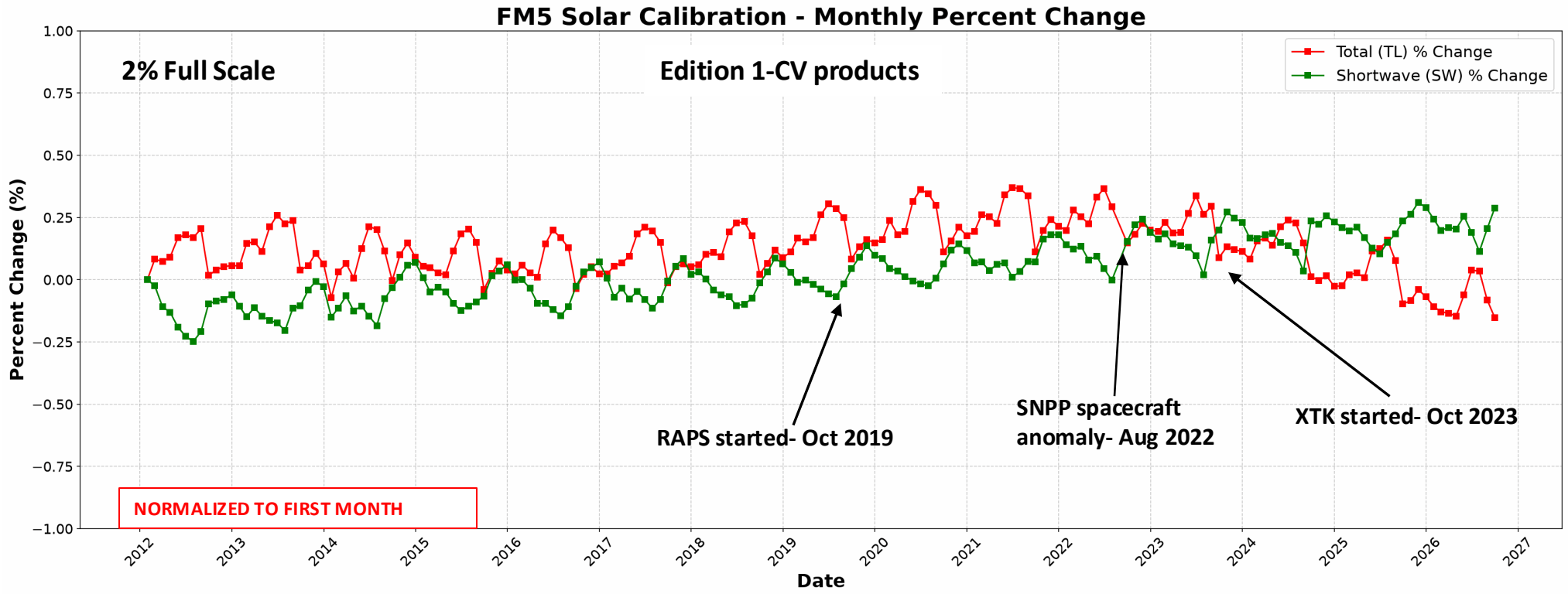
FM5 Internal Calibration

- 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.



Validation – Tropical Mean (FMs 1-5)

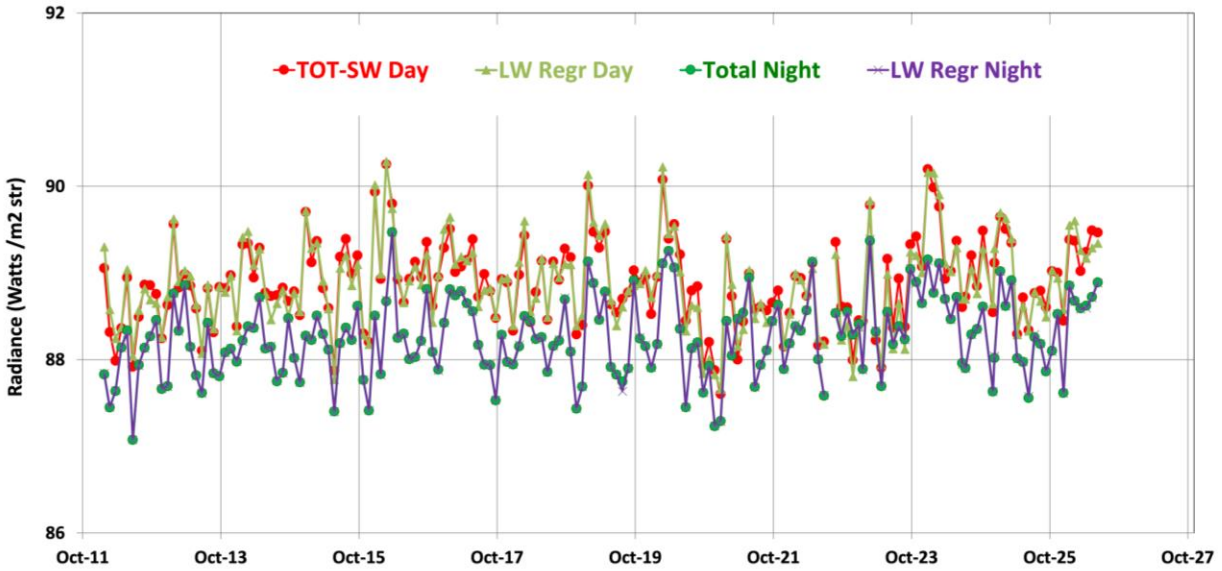
- Average of the ES-8 Nadir radiances over Tropical ocean (20^0N-20^0S) scenes under All-sky conditions.
  - Uses latest version of data products- All calibration updates have been applied.
- Two sets of TM Day-Night Differences (DN) are calculated:
  - TOT and SW sensors

    $DN = TM_D(TOT\text{-}SW) - TM_N(TOT)$
  - LW_r *(FMs 1-5 use a 'trained' WN- Narrow to BB regression)*

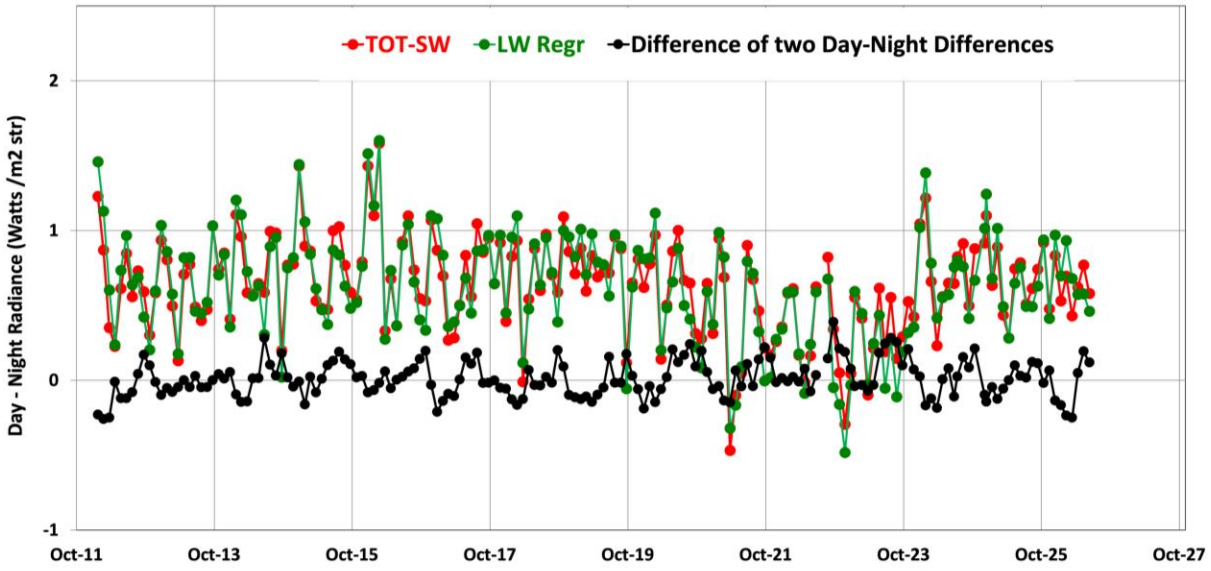
    $DN = TM_D(LW) - TM_N(LW_r)$
- Trends of the difference in the two DN values highlight any inconsistencies in the Reflected Solar wavelengths of the TOT and SW sensors.

Validation- FM5 Tropical Mean

FM5 Tropical Mean



FM5 Tropical Mean D-N Differences

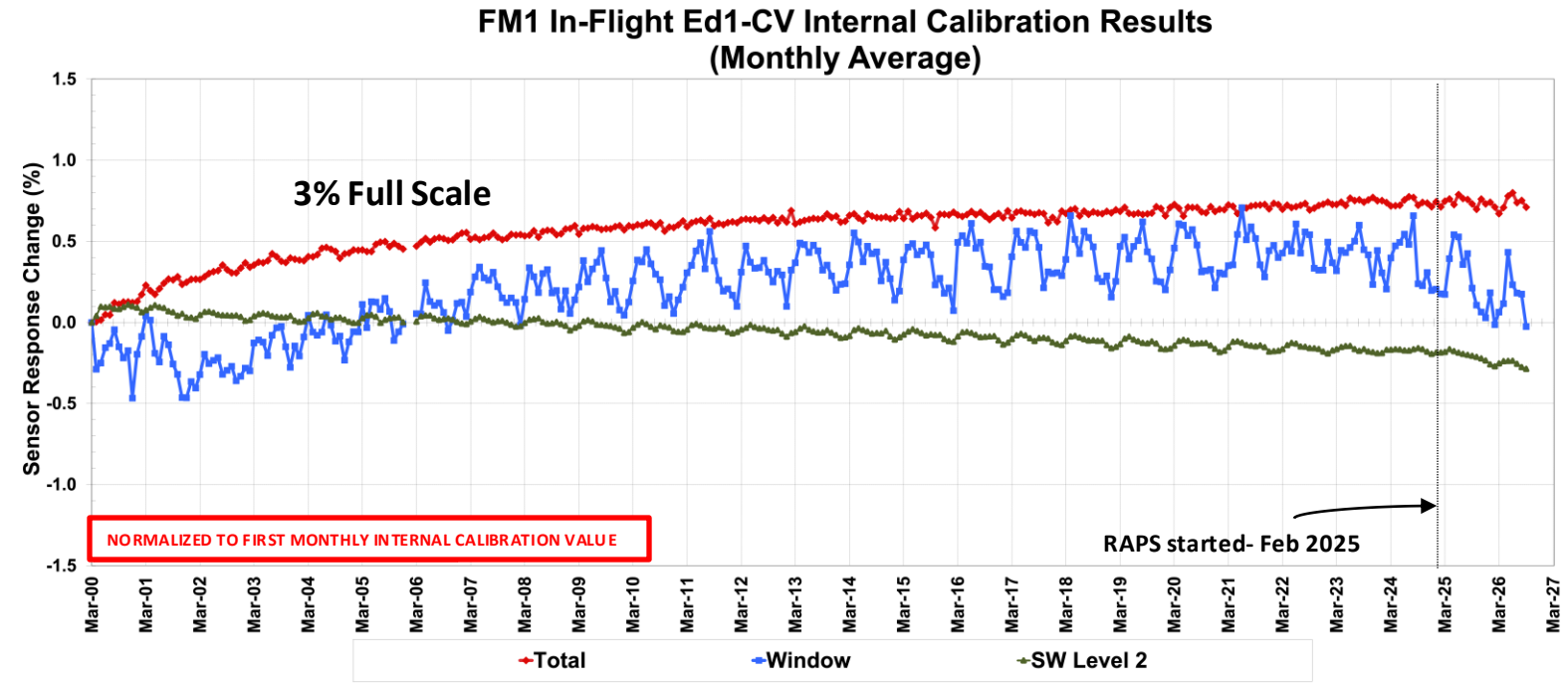


Edition 2 ES-8 products

Terra & Aqua
FM1-FM4 Instruments' Status

Terra- Internal Calibration

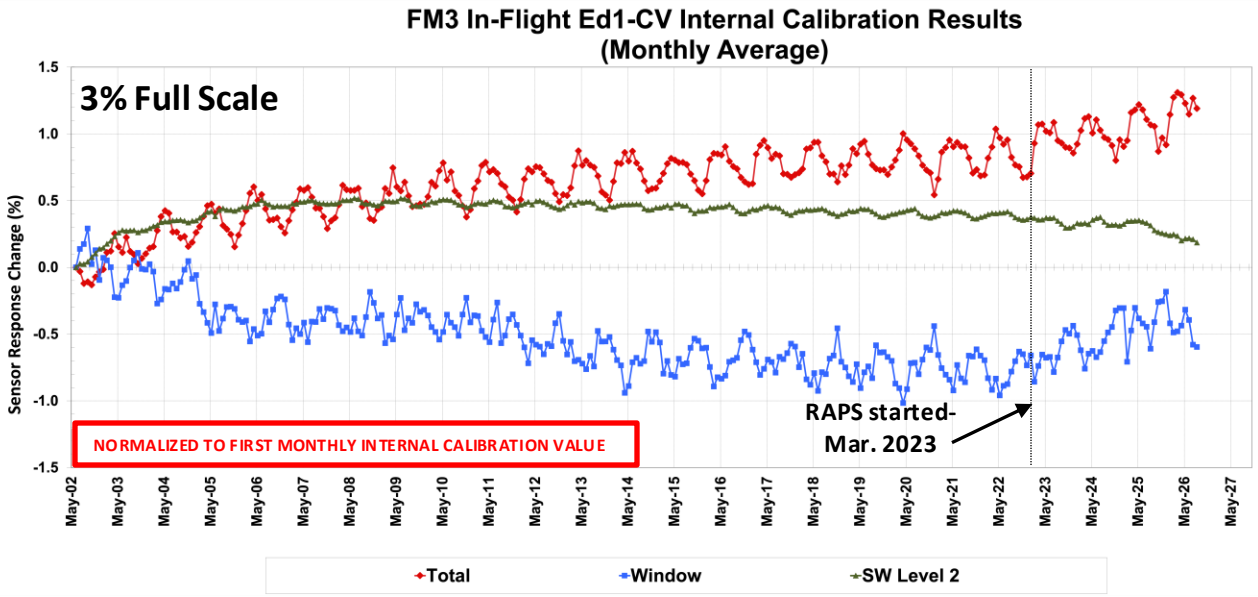
- For FM1, TOT channel shows ~0.7% rise, SW channel shows ~0.2% drop, and WN channel shows a rise of ~0.3% since start of mission
- **FM2 Instrument was turned off in Jan 2025.**

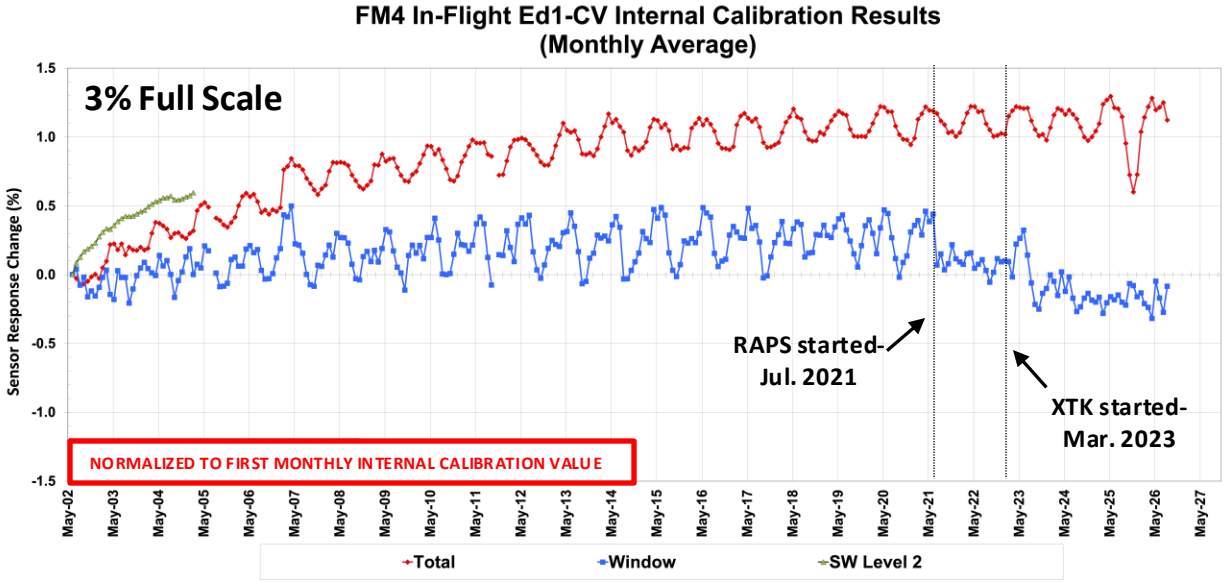


Total, WN- Blackbody: ~300 K
SW- Lamp: ~3000K brightness temp.

Aqua- Internal Calibration

- For FM3, TOT channel shows ~1.2% 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.

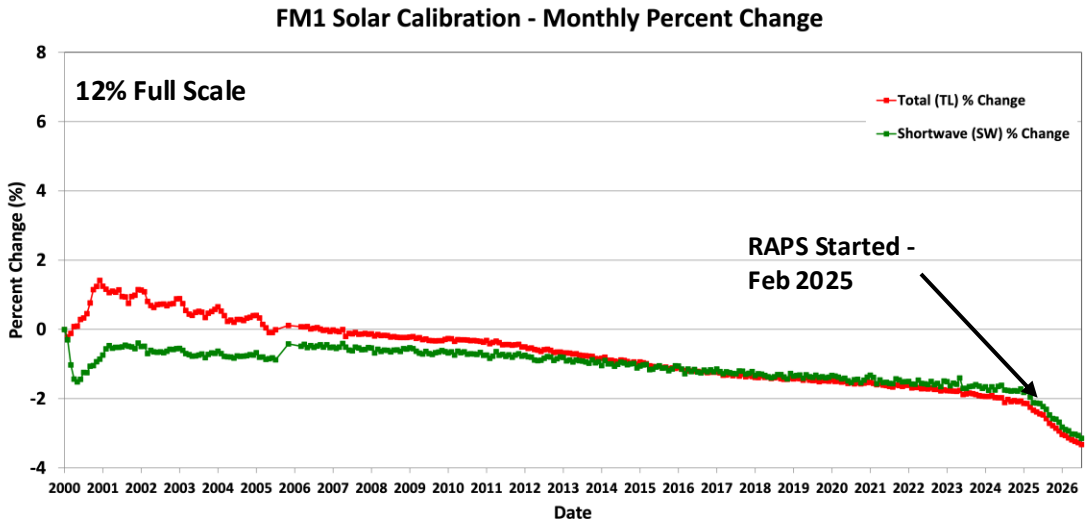


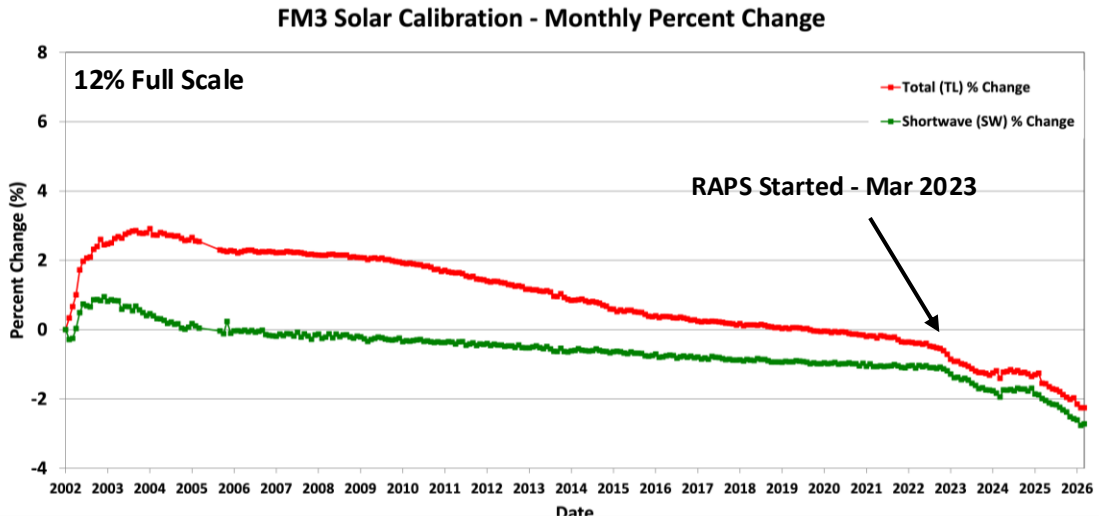


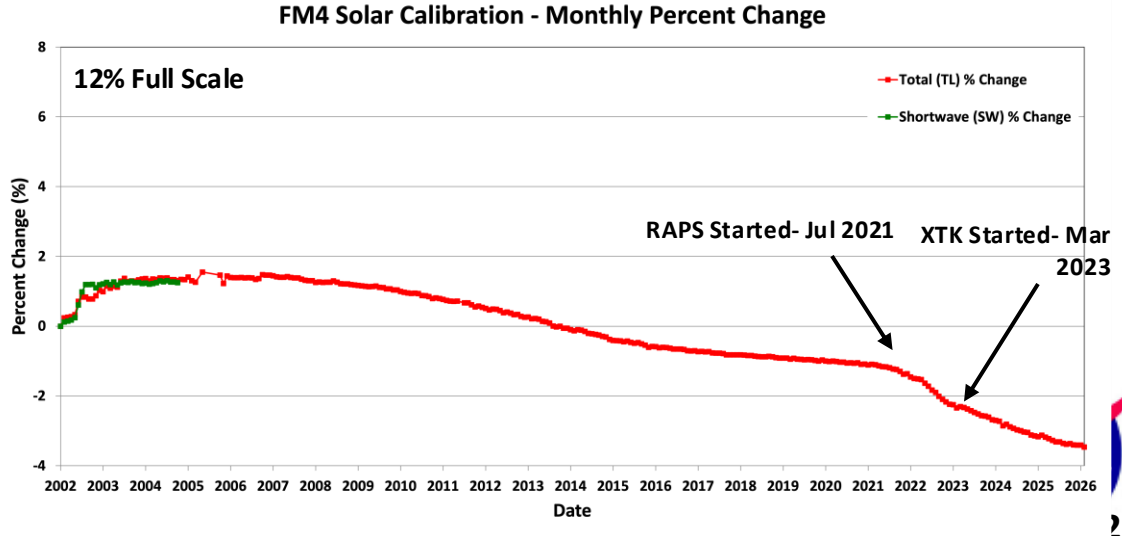
Total, WN- Blackbody: ~300 K
SW- Lamp: ~3000K brightness temp.

Terra & Aqua Solar Calibration

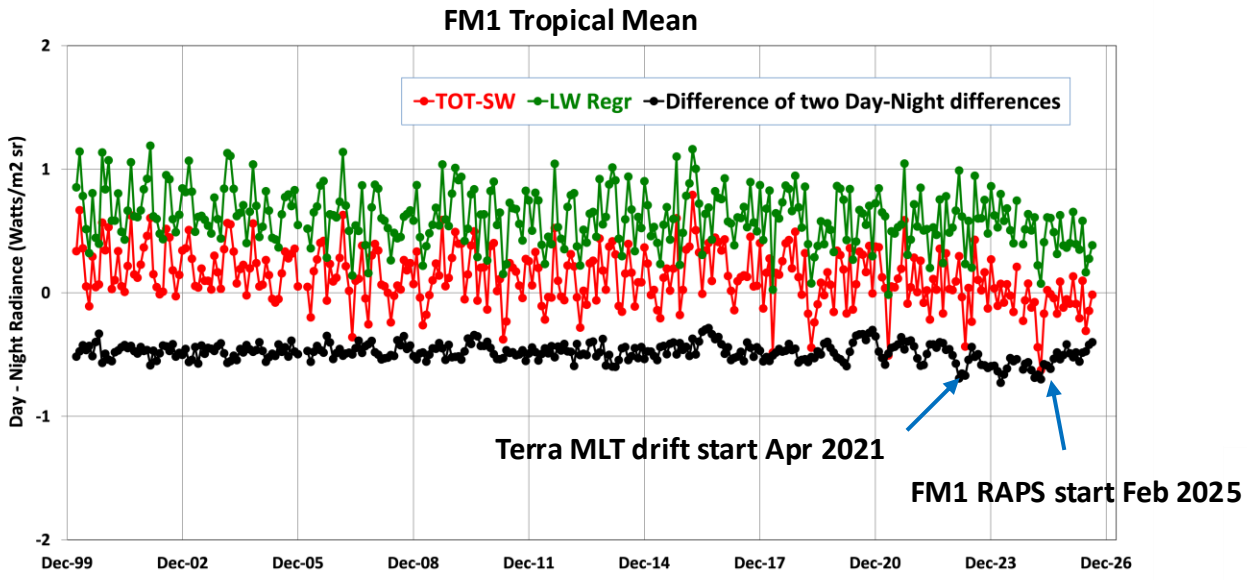
Since the start of BIAX, the TOT and SW channels on FM1 and FM3 showed a drop in response of ~1%.
TOT channel on FM4 showed a drop of ~1.2% while in BIAX, and ~1% since then.

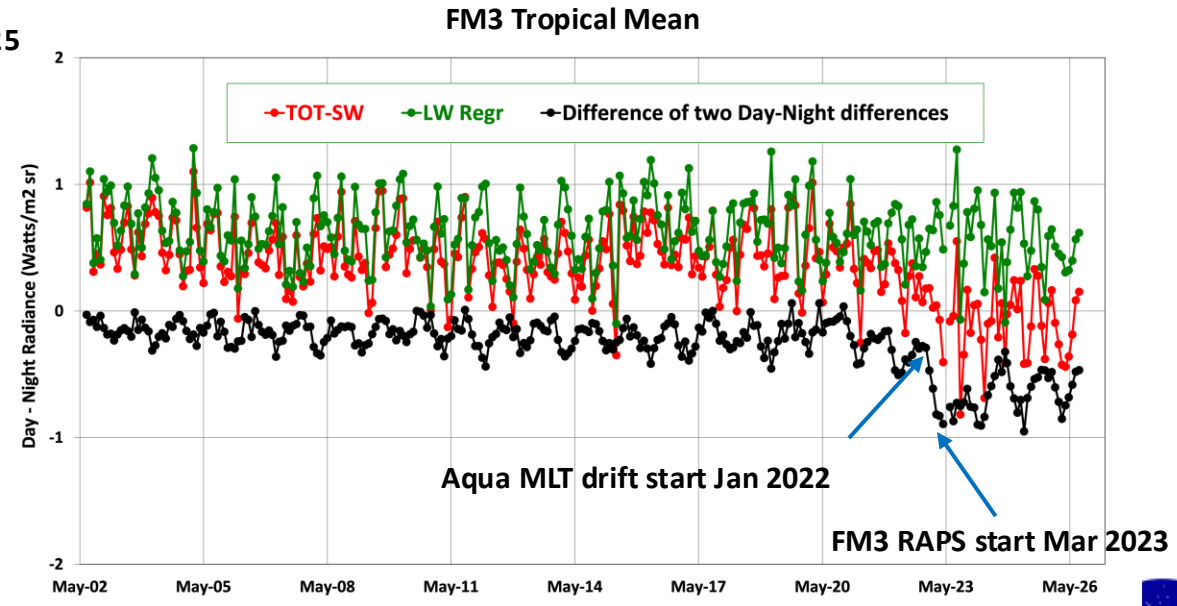






Validation- Terra and Aqua Tropical Mean





Uses Edition 4 ES-8 data products

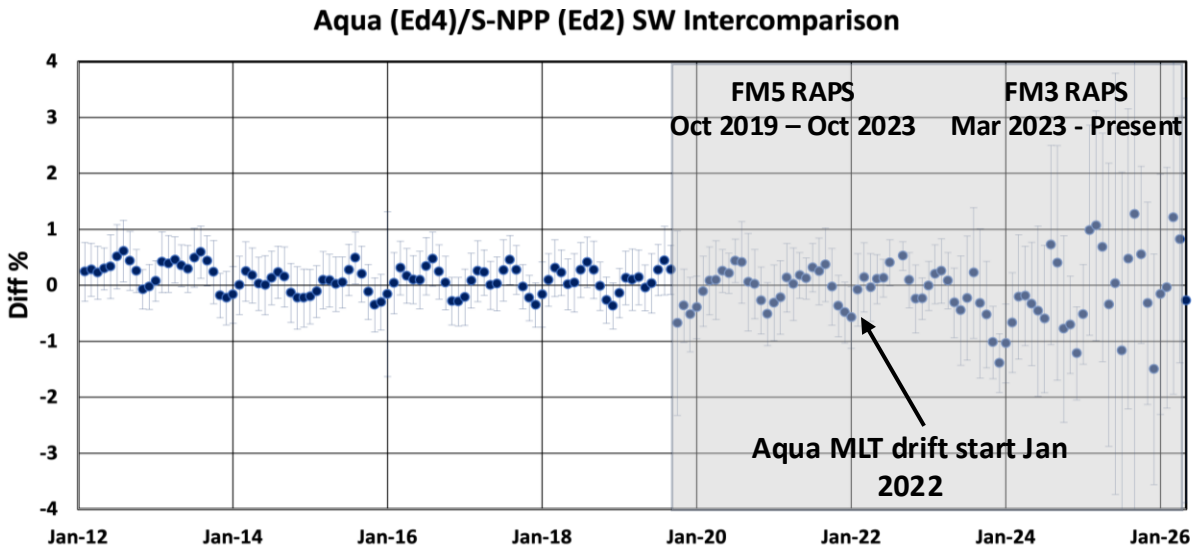
Aqua-NOAA20/SNPP Intercomparisons

- 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/FM5 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.*

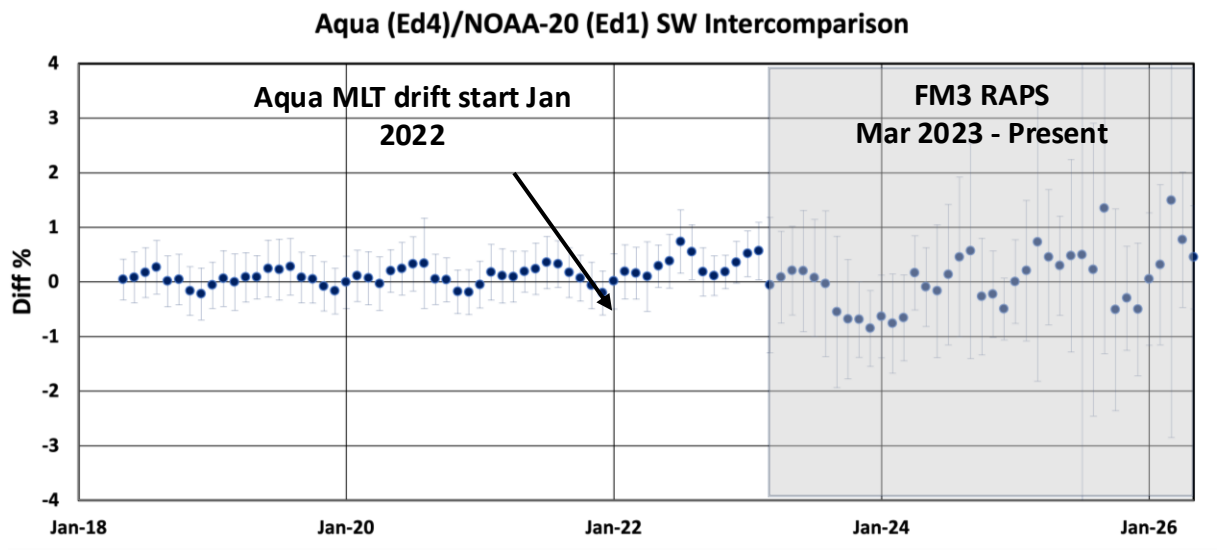
FM3-FM6/FM5 SW All-sky Inter-comparisons: May 2018 – May 2026

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

Difference of Reflectance: (FM3-FM5) %, 95% CI



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



Both FM5 and FM6 comparisons with FM3 show similar behavior

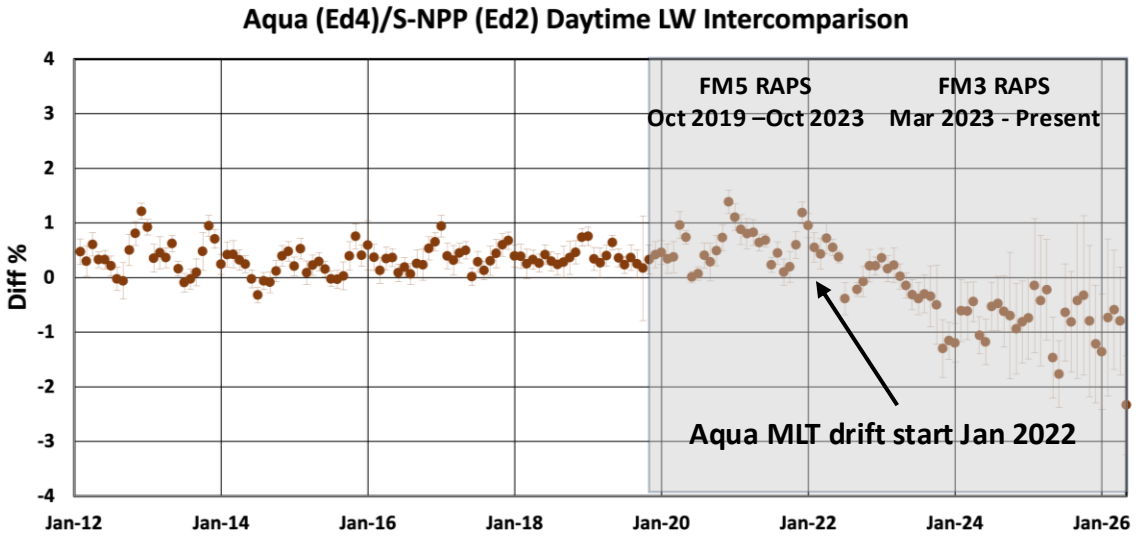
Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1B
CER_SSF_NPP-FM5-VIIRS_Edition2A

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

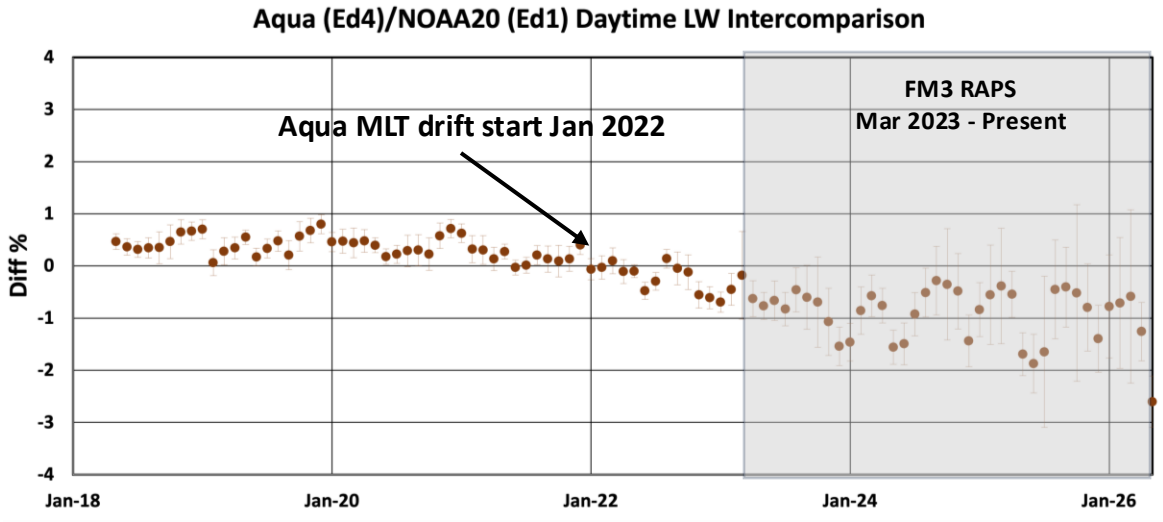
FM3-FM6/FM5 Daytime LW All-sky Inter-comparisons: May 2018 - May 2026

Difference of Daytime Radiance: (FM3-FM5) %, 95% CI



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

Daytime LW for FM6 obtained from TOT, SW



Both FM5 and FM6 comparisons with FM3 show similar behavior

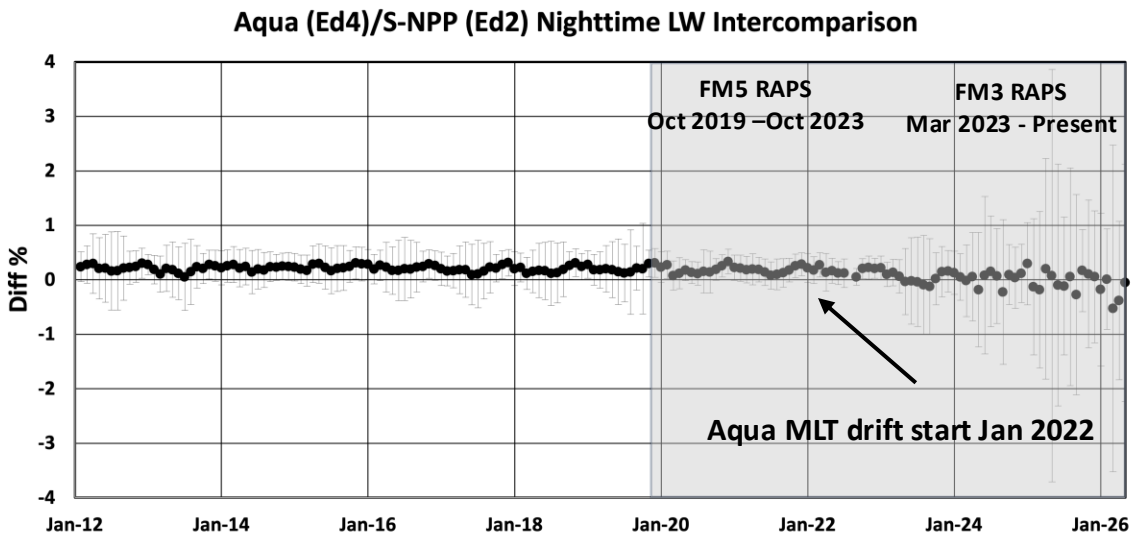
Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1B
CER_SSF_NPP-FM5-VIIRS_Edition2A

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.

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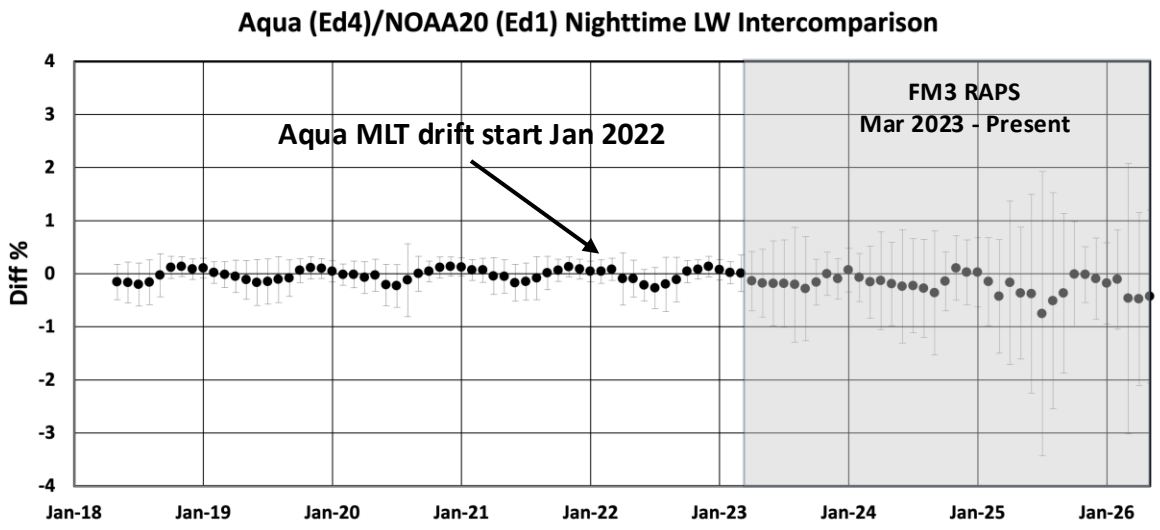
FM3-FM6/FM5 Nighttime LW All-sky Inter-comparisons: May 2018 - May 2026

Difference of Nighttime Radiance: (FM3-FM5) %, 95% CI



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

Nighttime LW for FM6 obtained from TOT



Both FM5 and FM6 comparisons with FM3 show similar behavior

Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1B
CER_SSF_NPP-FM5-VIIRS_Edition2A

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.

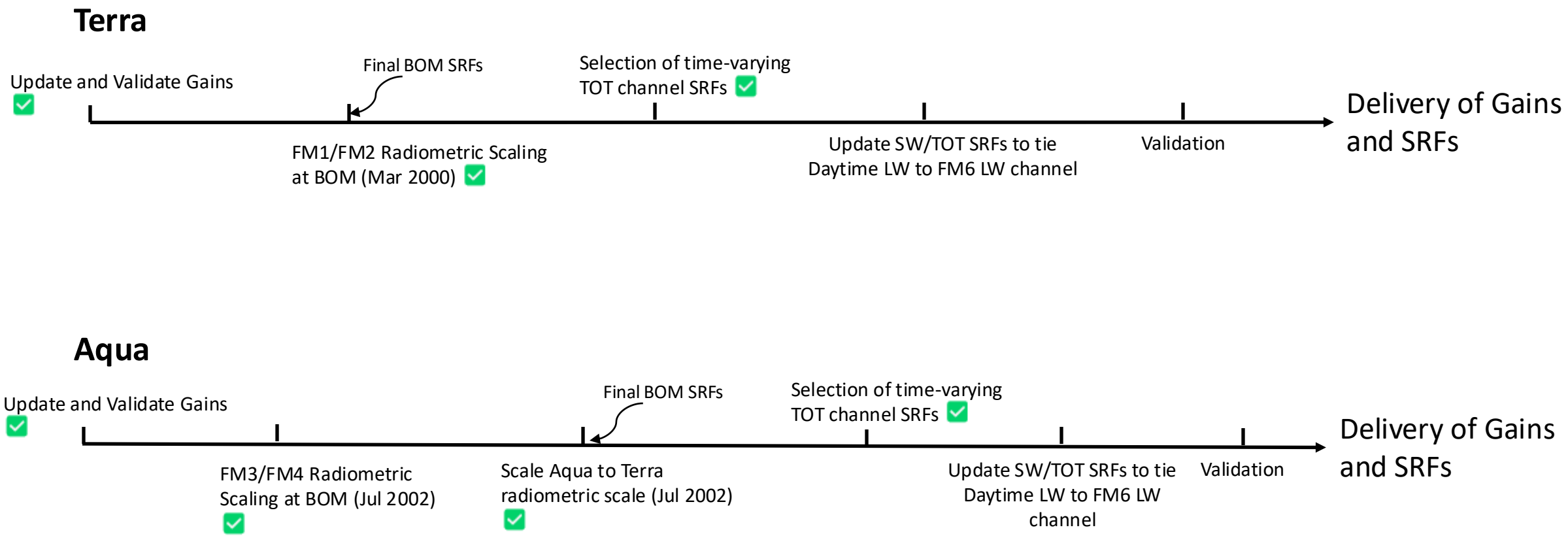
Edition 5 Status

Edition 5 Updates- Terra and Aqua

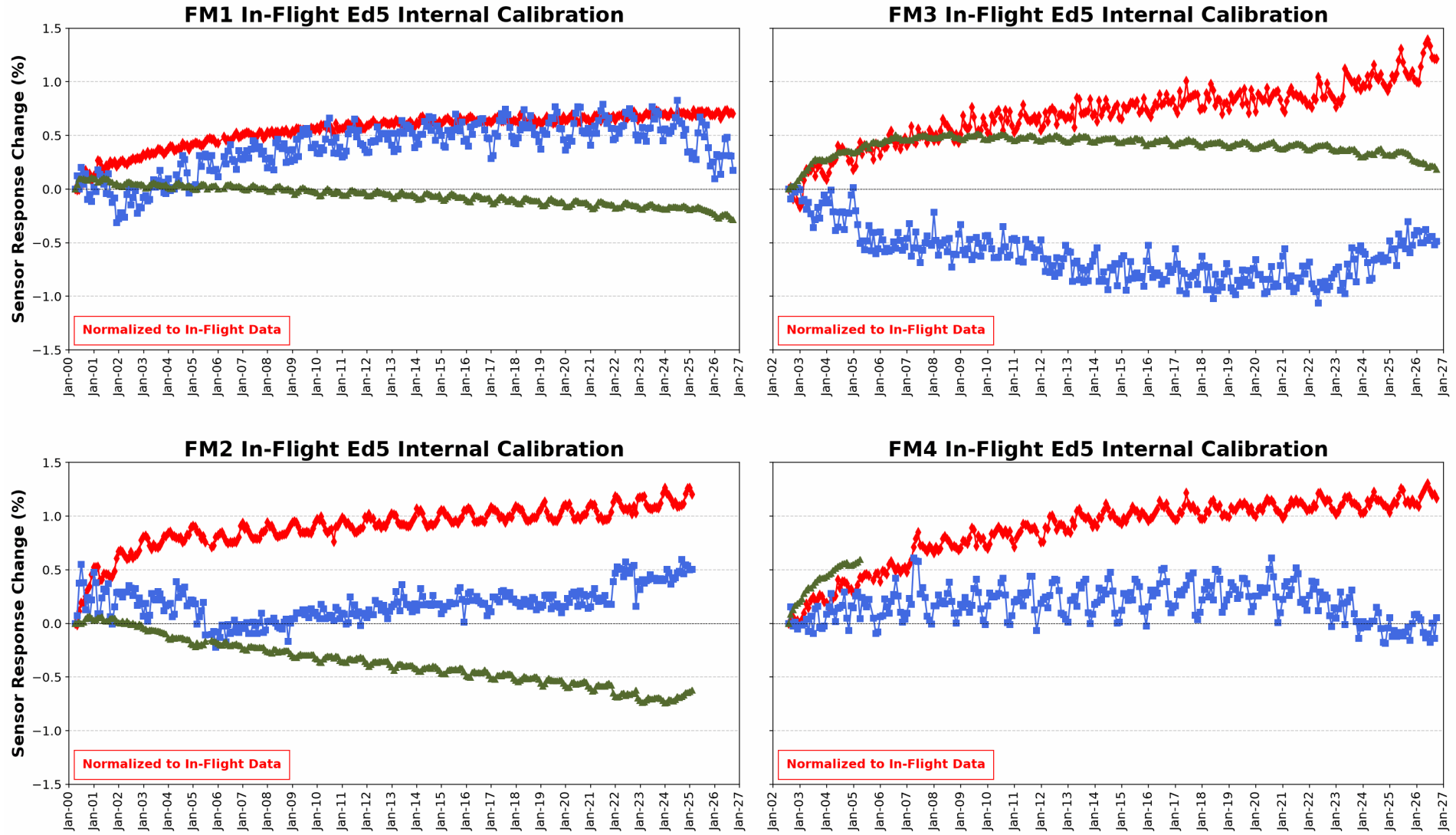
- Gains
  - TOT and WN channel gains have been updated from Edition 4.
  - SW channel gain has no change.

- Spectral Response Functions
  - TOT channel time-varying SRFs have been updated from Edition 4.

Edition 5 Steps- Terra and Aqua



Edition 5 Gains- Terra and Aqua



Edition 5 TOT SRF Selection approach (Terra, Aqua, SNPP)

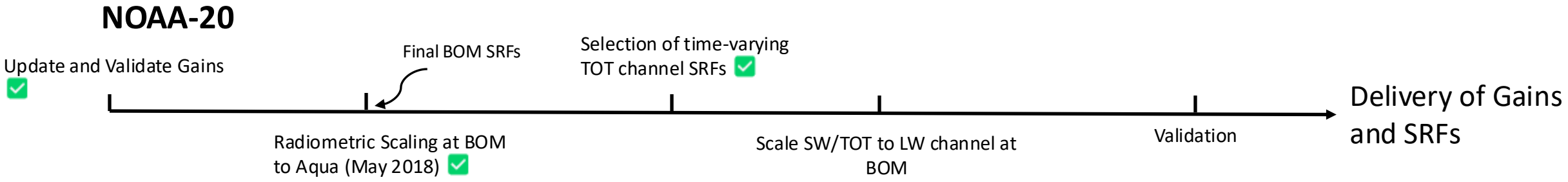
- Leverages the stability of the WN channel Day-Night radiance difference.
- **Calculate Target Day-Night LW radiance (dLW)**
  - Establish linear relationship between LW (computed from TOT and SW) Day-Night radiance difference (dLW) and WN Day-night radiance difference (dWN) for first month of mission (nadir only).
  - Compute and Detrend dWN anomalies- to account for any long-term sensor drift from the anomalies, add back the climatology to obtain drift-free dWN time series.
  - Calculate the Target dLW time series using dWN and linear fit.
- **Select Best fit SRF (Nominal orbit- Terra, Aqua, SNPP)**
  - For each month and for each SRF candidate, compute the dLW for 45N-45S region across Ocean, Land, Desert and All scenes.
  - Find SRF that has smallest weighted RMS error in dLW against Target dLW (weighted by geographic percentage of scene type).
- **Select Best fit SRF (Orbit Drift period- Terra, Aqua)**
  - For every month post Mar 2022, the target dLW is computed using the slope of dLW vs. dWN from the previous month.

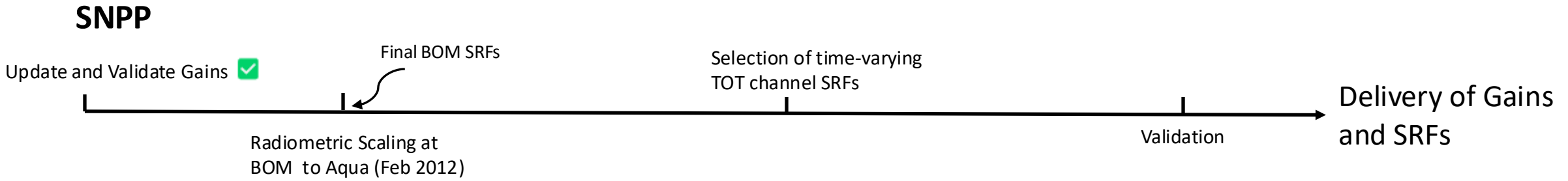
Edition 5 Updates: NOAA-20

- Gains:
  - TOT and WN channel gains have been updated from Edition 1.
  - SW channel gain has no change.

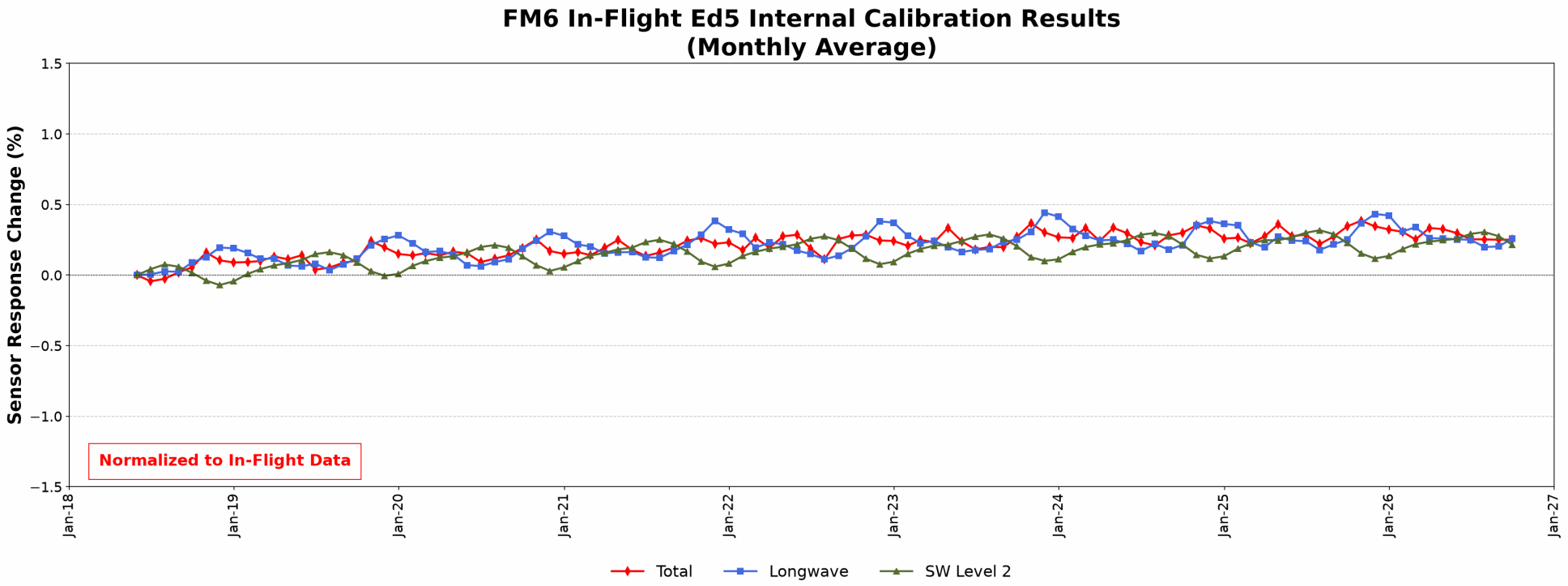
- Spectral Response functions
  - Time varying TOT channel SRFs are updated using solar calibration.
  - Uses a wavelength dependent correction in the SW portion of the TOT channel.

Edition 5 Steps- SNPP and NOAA-20



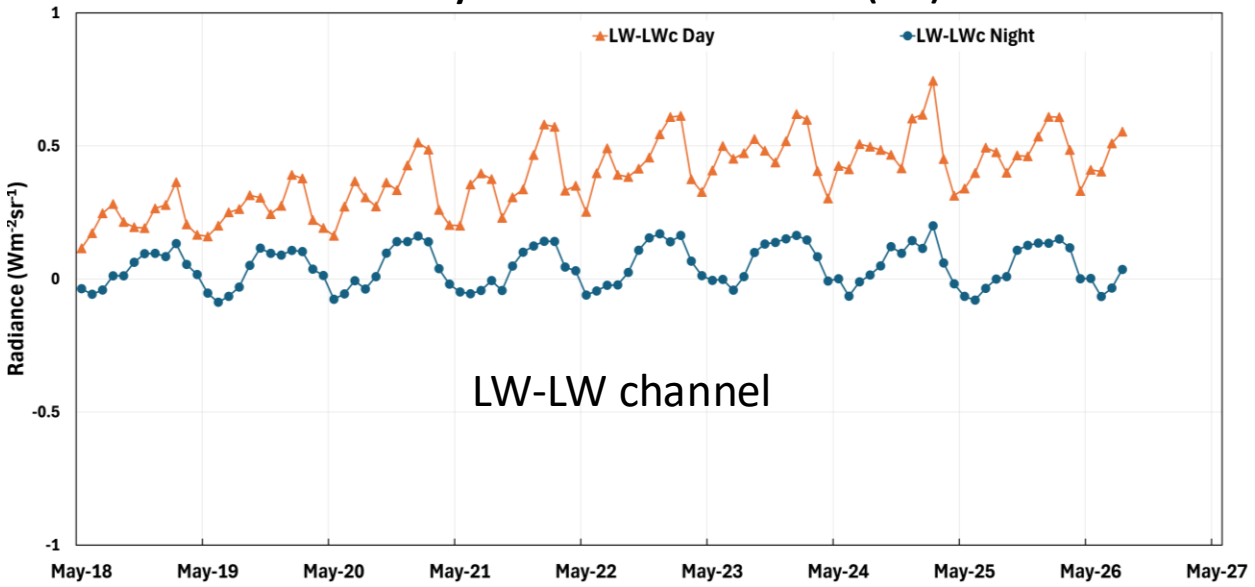


Edition 5 Gains: NOAA20/FM6

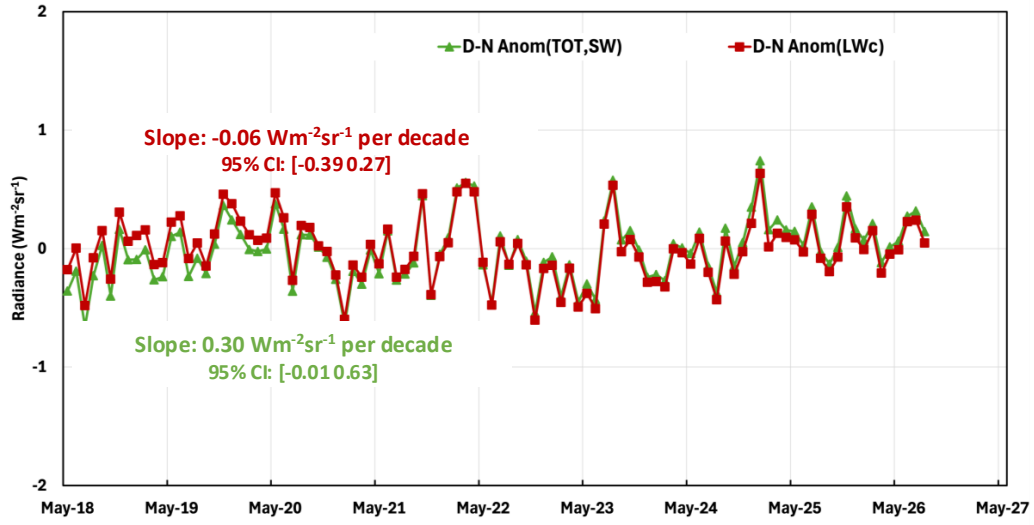


Edition 5: NOAA20/FM6 Time Varying TOT Channel SRFs

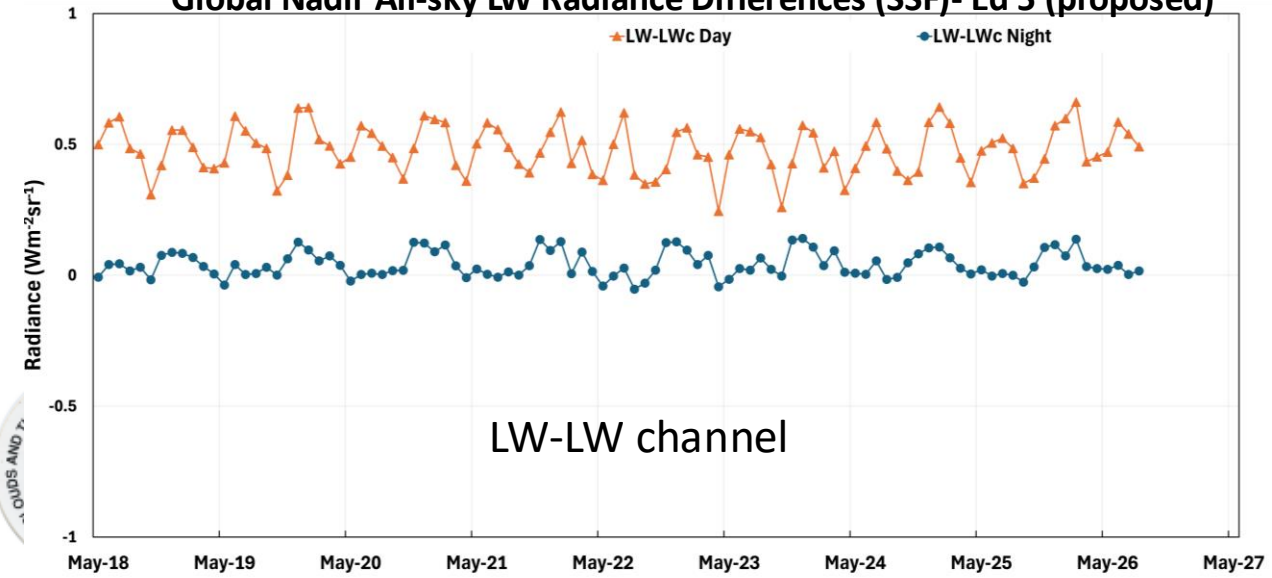
Global Nadir All-sky LW Radiance Differences (SSF)- Ed 1



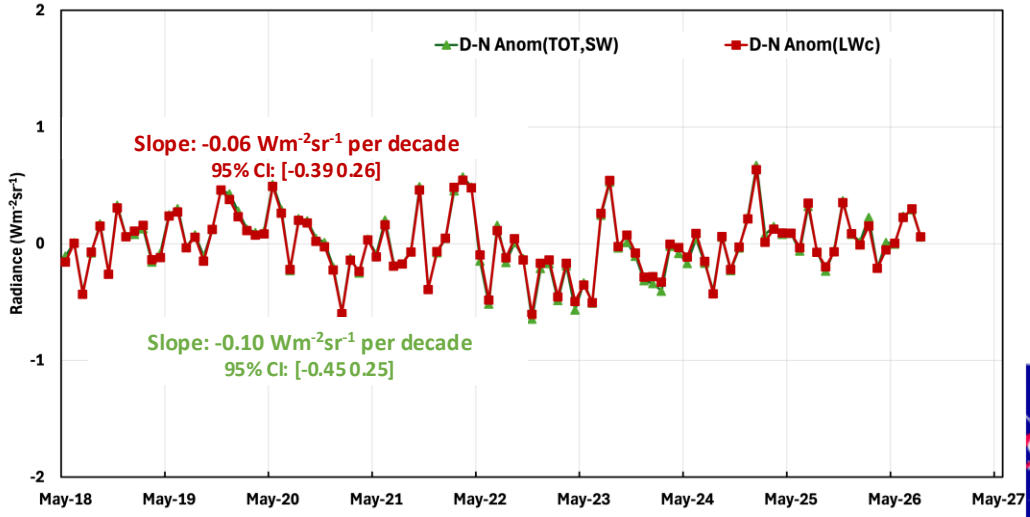
Global Day – Night Nadir LW Difference Anomaly- Ed 1



Global Nadir All-sky LW Radiance Differences (SSF)- Ed 5 (proposed)



Global Day – Night Nadir LW Difference Anomaly- Ed 5 (proposed)



t Work

Libera Support

- Key members of IWG participated in face-to-face meetings with Libera team focused on instrument calibration and operations.
- IWG received a subset of Libera pre-launch test data, performed quick-look and validated analysis methodology.
- Reviewed and provided feedback about key instrument related documents to Libera team.
- Conducted operations related discussions particularly regarding GEOSCANs.

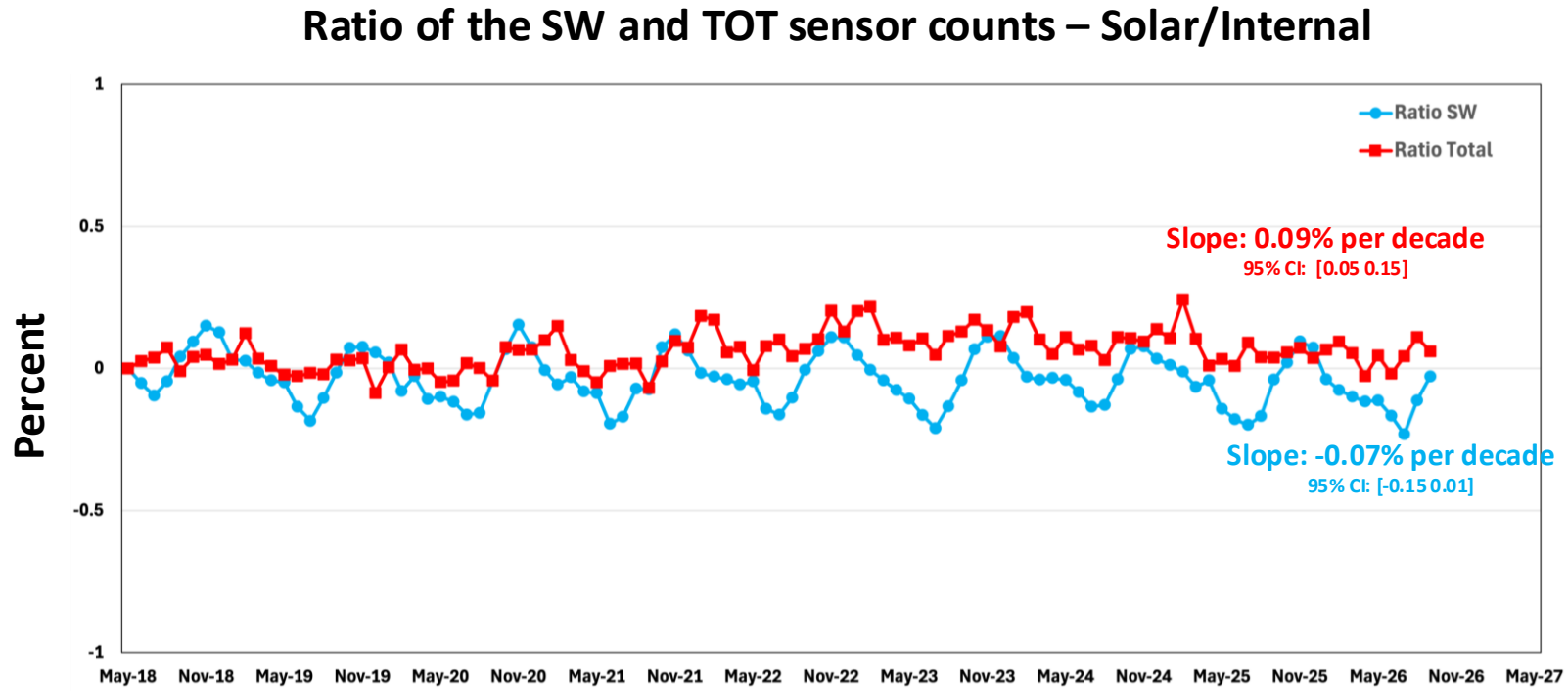
SUMMARY

- **NOAA-20/FM6 and SNPP/FM5 instruments are performing nominally.**
  - **FM6 instrument is very stable as tracked by onboard calibration sources.**
  - **GEOSCANs being conducted on both FM5 and FM6 on specific Earth targets.**
  - **Preparing for End of Science on SNPP on November 1, 2026; instrument performance tests being conducted.**
- **Terra and Aqua instruments' performance are monitored as their orbits drift.**
  - **GEOSCANs continue to be conducted periodically.**
  - **Preparing for End of Science on Terra on December 1, 2026; instrument performance tests being conducted.**
- **Edition 5 instrument updates**
  - **Terra and Aqua Gains and SRFs are being finalized and validated.**
  - **NOAA20 Gains and SRFs are currently being validated.**
- **Level 1 Data products**
  - **NOAA-20/FM6 Edition 1 gains have been delivered through September 2026.**
  - **S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Jul 2026.**
  - **Terra and Aqua instruments' Edition 4 gains and SRFs have been delivered through August 2026.**

- **Libera: IWG continues to support Cal-Val and ops meetings**
  - **Supported several meetings with Libera team covering instrument calibration and operations related topics.**

Backup

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



Both SW and TOT channels have excellent agreement between Internal and Solar calibrations

Edition 5 Gains- NPP

Updated NPS

