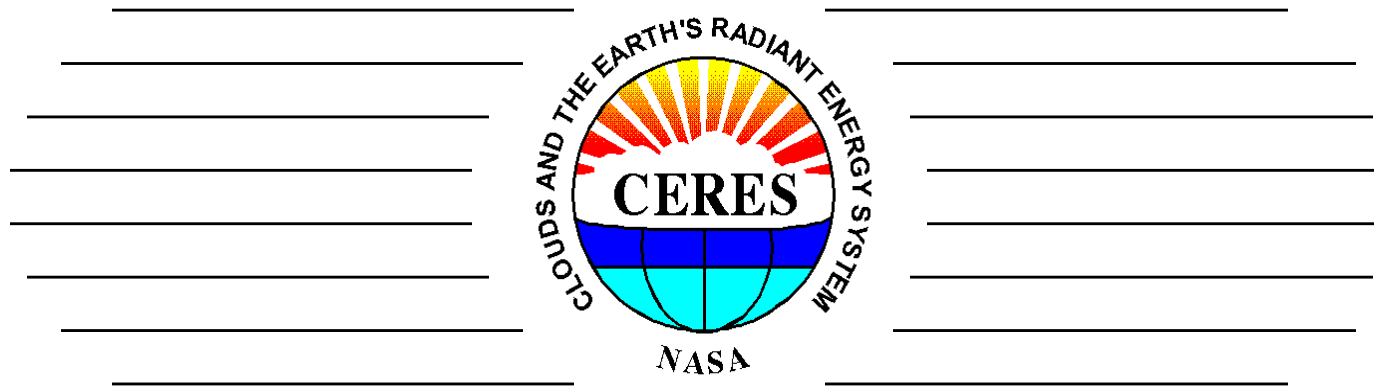


CERES Instrument Status Flight Models 1-6 (FM1-FM6)



Mohan Shankar

CERES Instrument Working Group

**CERES Spring Science Team Meeting
April 26, 2022**

CERES Instrument Working Group



CERES Instrument Working Group

PS: Kory Priestley
DPS: Mohan Shankar

Instrument Operations

- B. Mike Tafazoli -
Janet Daniels
Christopher Brown
Cian Branco
Carol Kelly
Ethan Ames

Data Management

- *Denise Cooper* -
- *Dale Walikainen* -
A. Thomas Grepiotis
Dianne Snyder

Cal/Val

-*Susan Thomas*-
Hyung Lee
Nathaniel Smith
Nitchie Smith
Z. Peter Szewczyk
Robert Wilson



CERES Instruments' Status Summary

- **All CERES instruments continue to perform nominally.**
 - NOAA-20/FM6 instrument continues to show stable performance after the initial sensor response rise.
 - SNPP/FM5 is currently operating in full biaxial mode, collecting ADM data.
 - *No evidence of change to SW channel performance since transitioning to biaxial mode.*
 - Terra/FM2, Aqua/FM4 operating in Biaxial mode.
 - Validations show that all instruments are performing consistently.
 - *Added a new validation tool using DCC: FM1-FM5 show consistent and stable performance.*
- **Data products**
 - NOAA-20/FM6 Edition 1 gains have been finalized and delivered through Mar 2022.
 - S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Mar 2022.
 - Terra and Aqua instruments' Edition 4 gains and SRFs have been delivered through Feb 2022.



CERES Instrument Operations

- **Flight Models (FM) 1, 3, 6 are operating in Crosstrack mode.**
 - FMs 2,4,5 are operating in biaxial mode.
- **Aqua successfully conducted a reset of the Solid state Recorder (SSR) on March 23, 2022 to fix an anomaly (occurred on Feb 22, 2022).**
 - CERES instruments were SAFED during the reset and then restored normal operations.
- **Aqua CERES instruments were SAFED on 3/31/22 due to spacecraft anomaly likely due to solar weather event.**
 - CERES instruments resumed normal operations on 4/14/22.
- **Inter-comparison operations planned in summer 2022:**
 - Terra/FM1 – S-NPP/FM5: May 1 – Jul 31, 2022
 - Terra/FM1 – NOAA-20/FM6: May 1 – Jul 31, 2022
 - Terra/FM1 – Aqua/FM3: Jun 1 – 30, 2022
 - Terra/FM2 – GERB: Jun 1 – 30, 2022

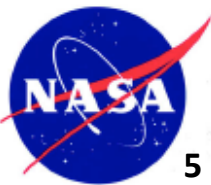
} Overpass region
around 70° N



NOAA-20/FM6 Instrument Status

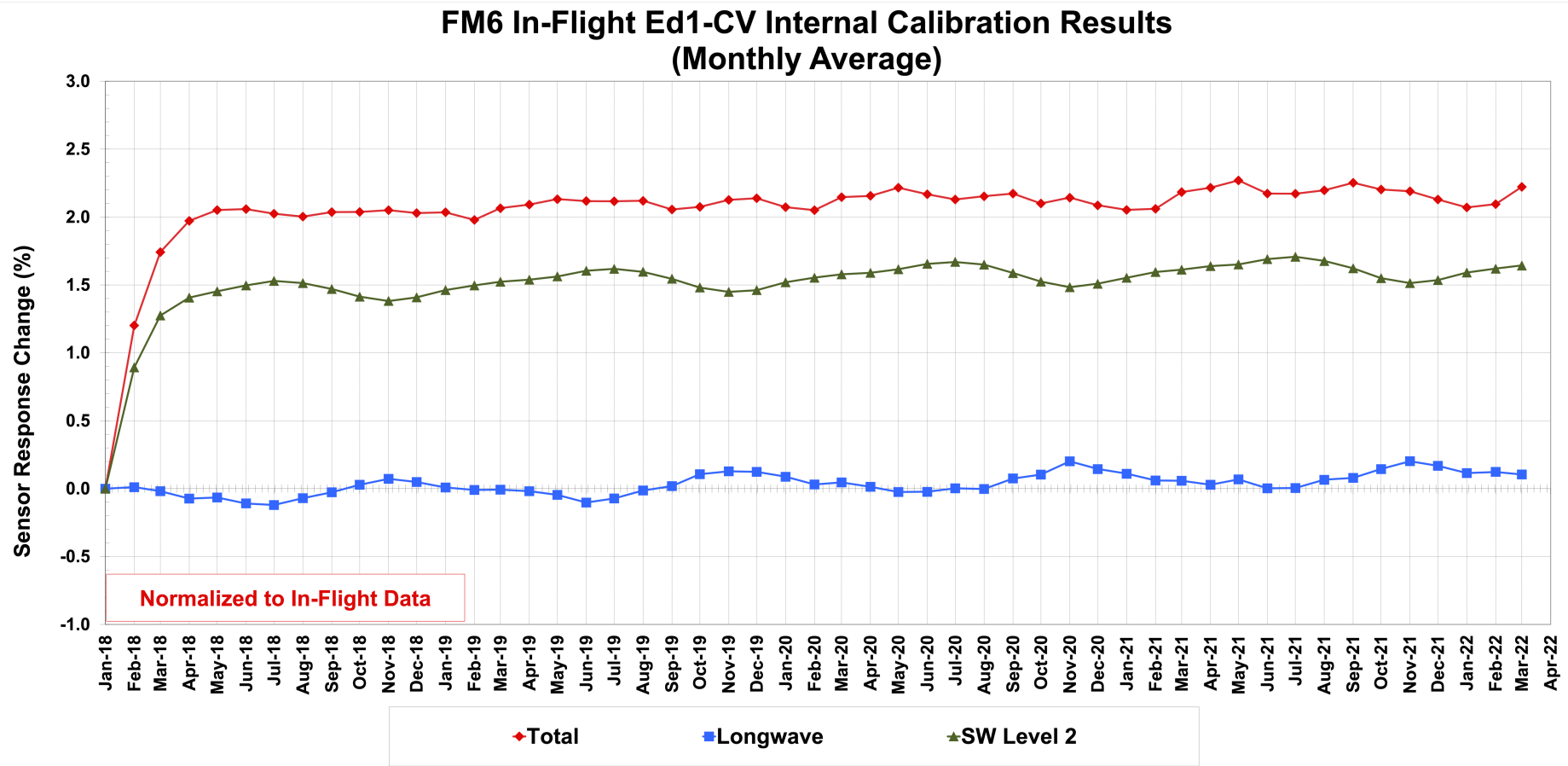


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FM6 Internal Calibration

- For SW and TOT channels, the responses to the on-board sources (SWICS lamp and Blackbodies) continue to be stable after the initial rise of ~1.5% (SW) and ~2% (TOT) since start of mission.
- LW Channel (calibrated using blackbody) continues to show very little change.

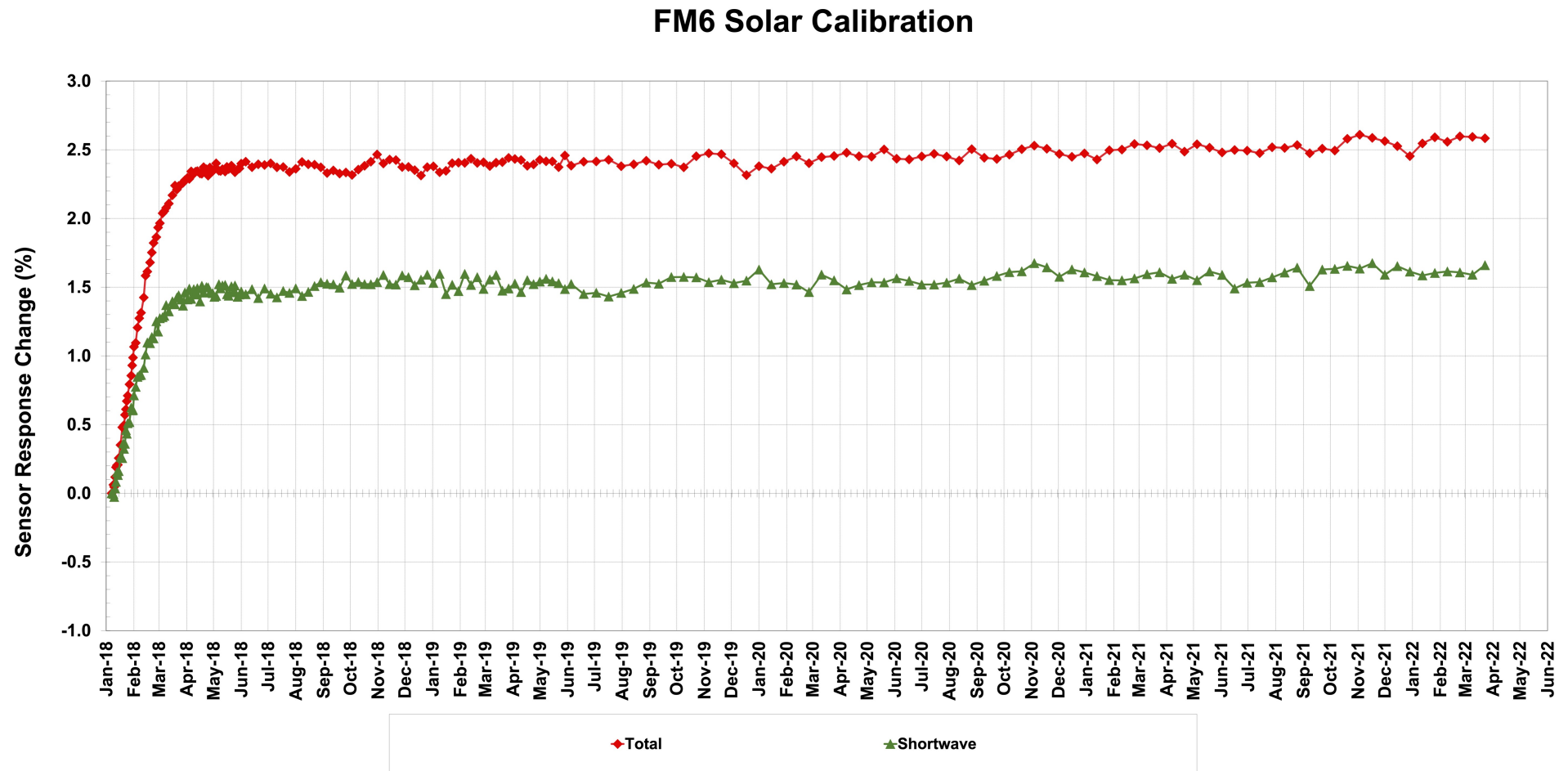


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FM6 Solar Calibration

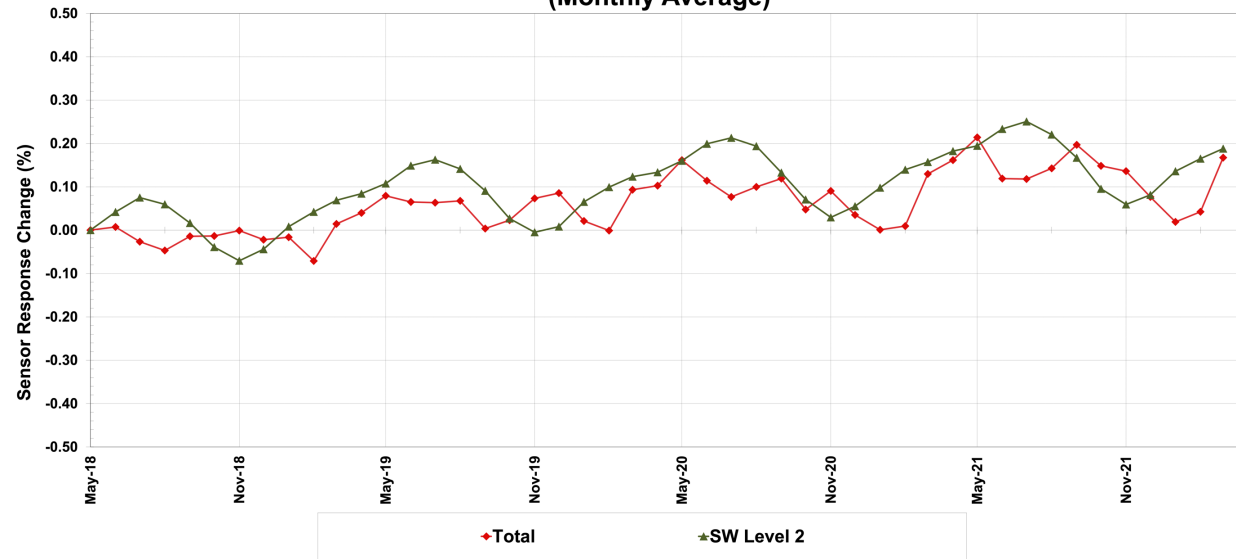
- Response of the SW and TOT channels while viewing the MAM that is illuminated by the sun.
- After the initial rise of $\sim 1.5\%$ for SW, and $\sim 2.3\%$ for TOT, the response is very stable.



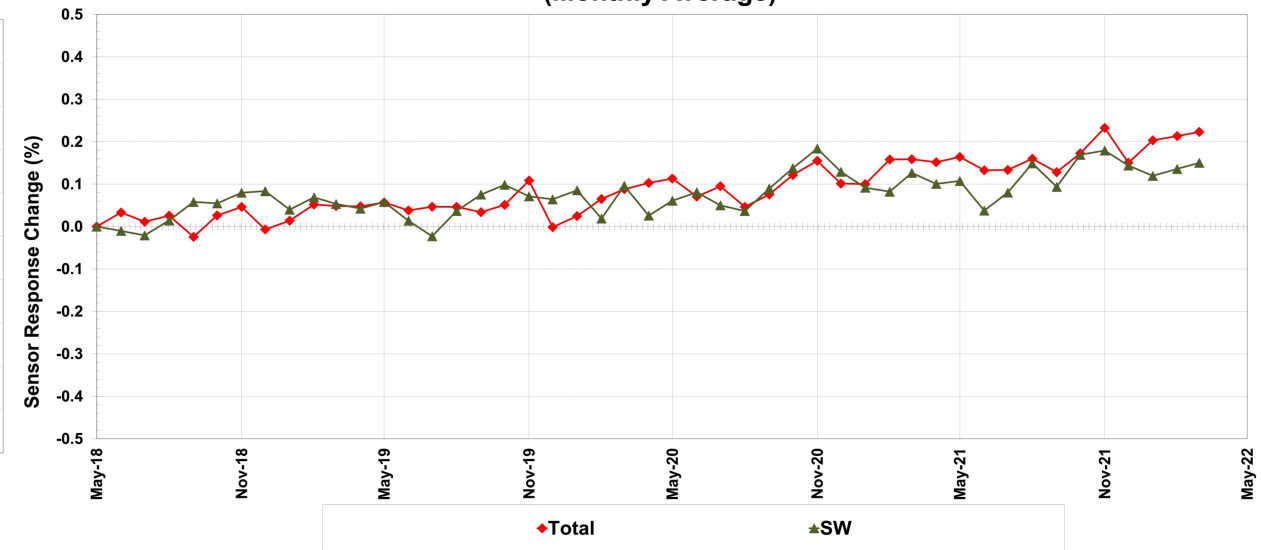
FM6 Calibration- Internal and Solar Cal Since May 2018

FM6 Internal and solar calibration results show consistently very little change ($\sim 0.2\%$) since May 2018.

FM6 In-Flight Ed1-CV Internal Calibration Results
(Monthly Average)



FM6 Solar Calibration
(Monthly Average)



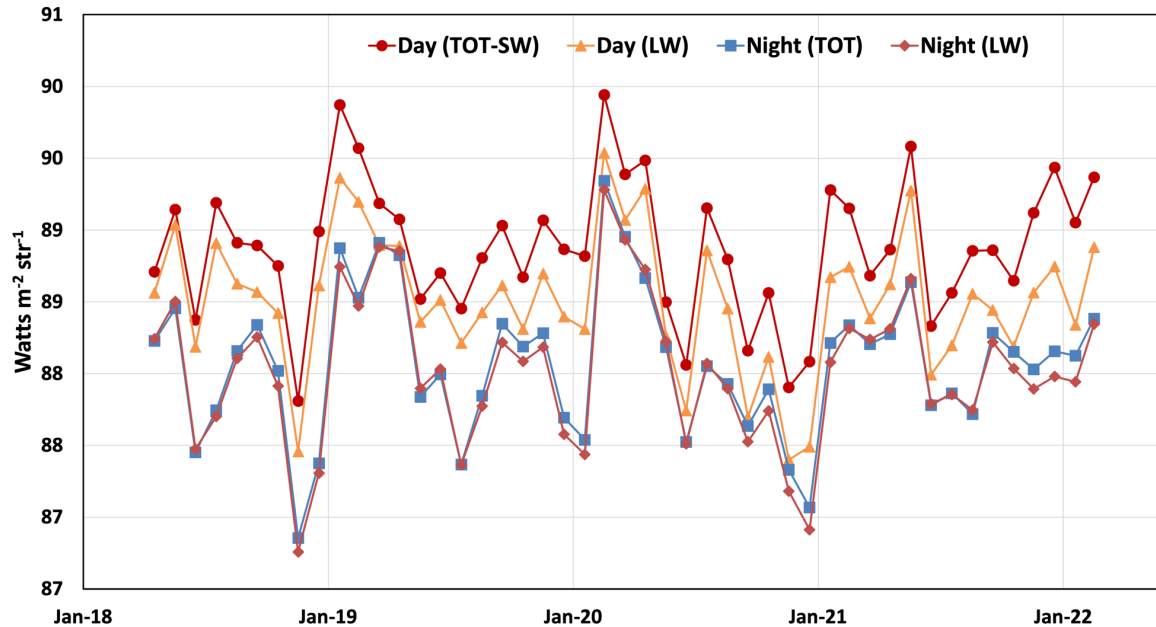
Validation – Tropical Mean

- Average of the ES-8 Nadir radiances over Tropical ocean (20°N-20°S) scenes under All-sky conditions.
- Two sets of TM Day-Night Differences (DN) are calculated:
 - TOT and SW sensors
 $DN = TM_D(TOT-SW) - TM_N(TOT)$
 - LW sensor
 $DN = TM_D(LW) - TM_N(LW)$
- Difference in the two DN values highlight any inconsistencies in the shortwave regions of the sensors.

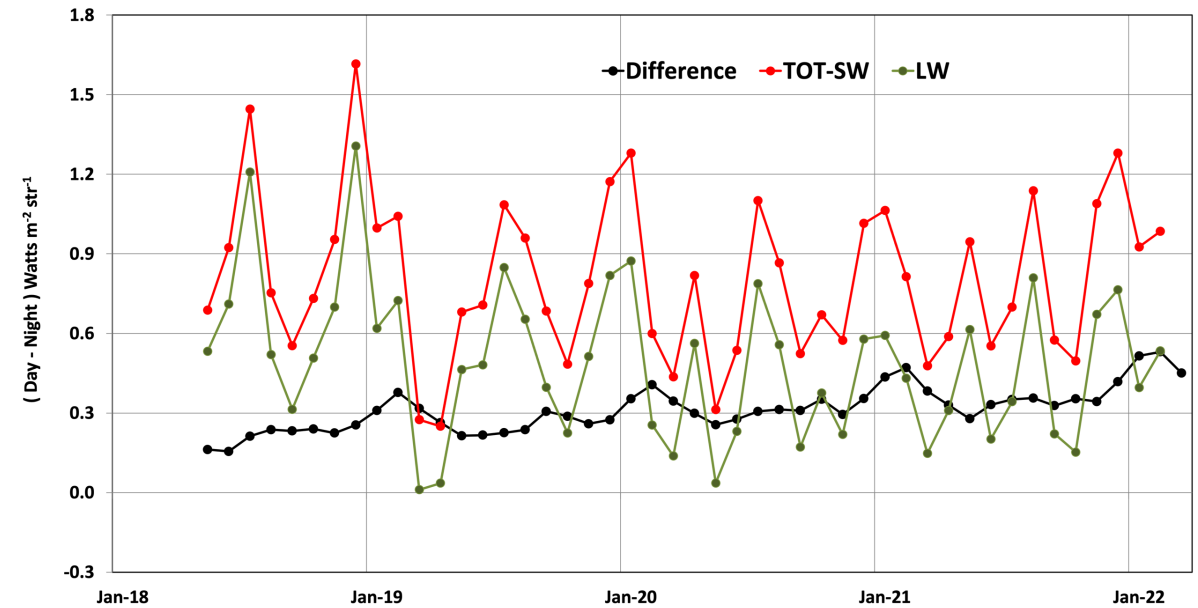


Validation- FM6 Tropical mean Day-Night

FM6 Edition1 Nadir Tropical Mean



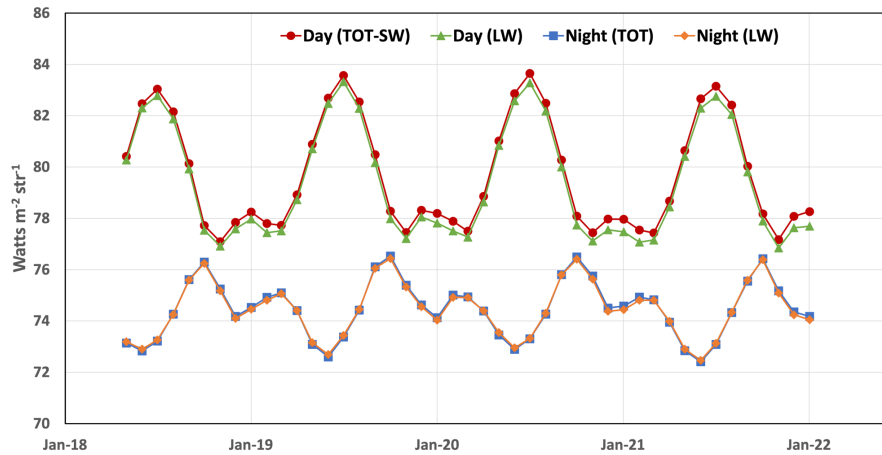
FM6 Edition1 Nadir TM Day-Night Difference



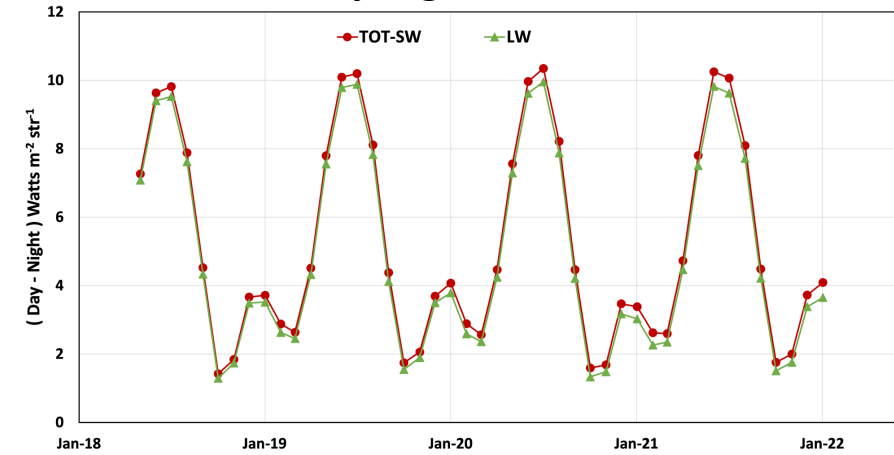
FM6 3-channel Consistency check- Global LW Day and Night

May 2018 - Jan 2022

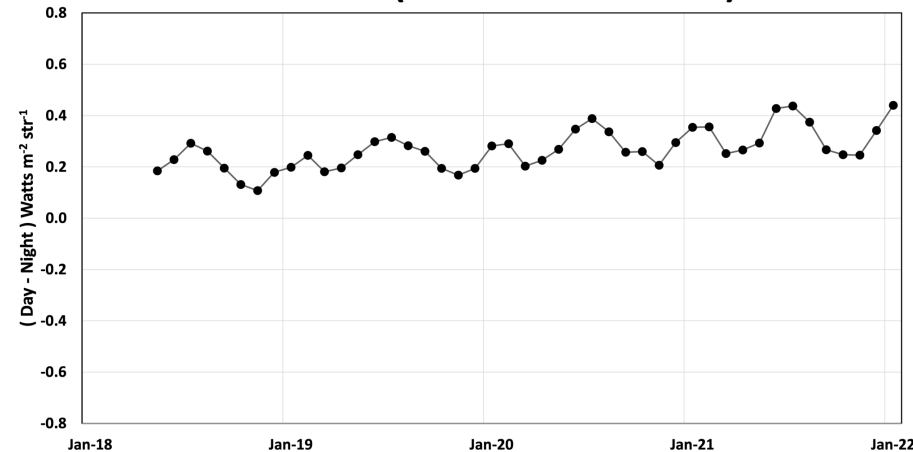
Global, Edition 1 ES-8 Nadir



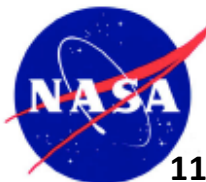
Day-Night Difference



Difference- (TOT-SW minus LW)



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Aqua/NOAA-20 Intercomparisons

- The orbital geometries for Aqua and NOAA-20 are such that orbital overlaps occur every ~64 hours.
- Obtain spatially and temporally matched observations during every crossover.
- Use matching criteria to subset the data:
 - SZA, VZA difference < **2.0°**
 - RAZ difference < **5°**
 - Distance between centroid of footprints < **7km**
- Obtain monthly all-sky SW reflectance and daytime LW radiance differences using the matched footprints.

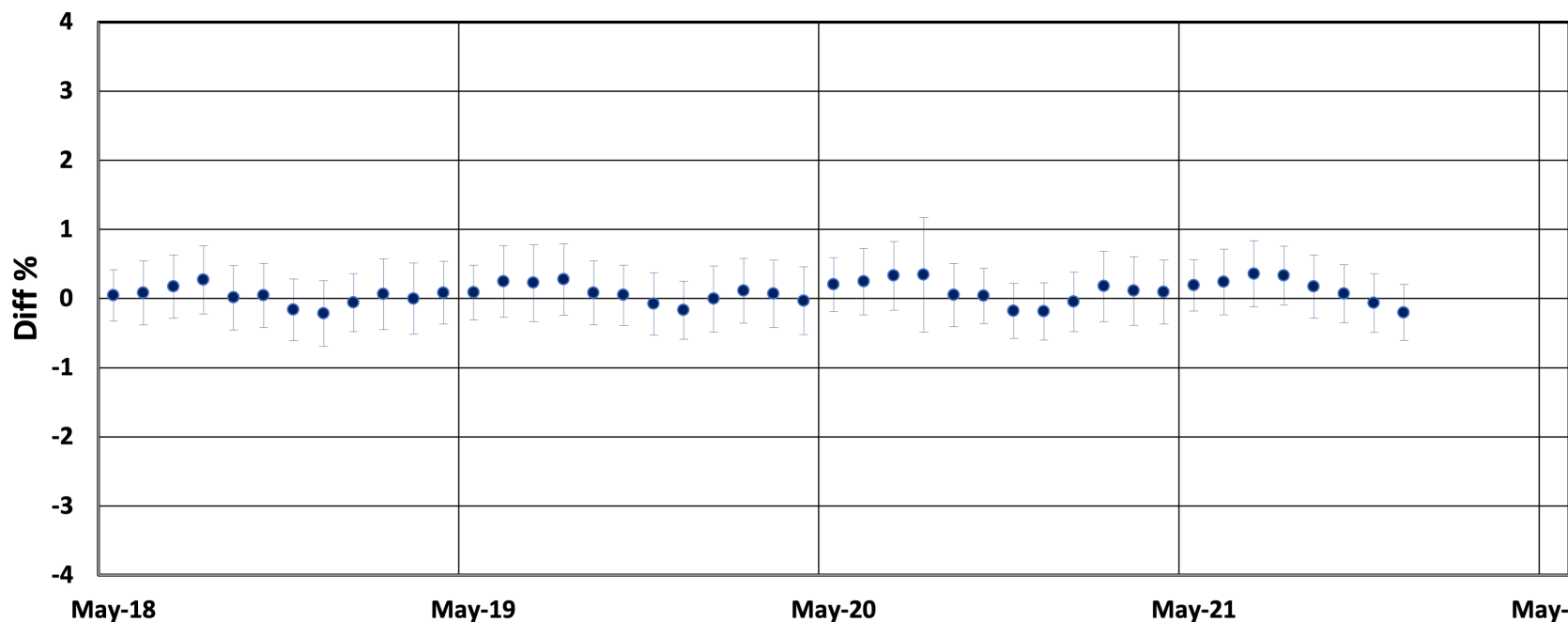


FM3/FM6 SW All-sky Inter-comparisons: May 2018- Dec 2021

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

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

Aqua (Ed4)/NOAA-20 (Ed1) SW Intercomparison



Data:

CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1B

Radiometric scaling of FM6 to FM3 done in May 2018.

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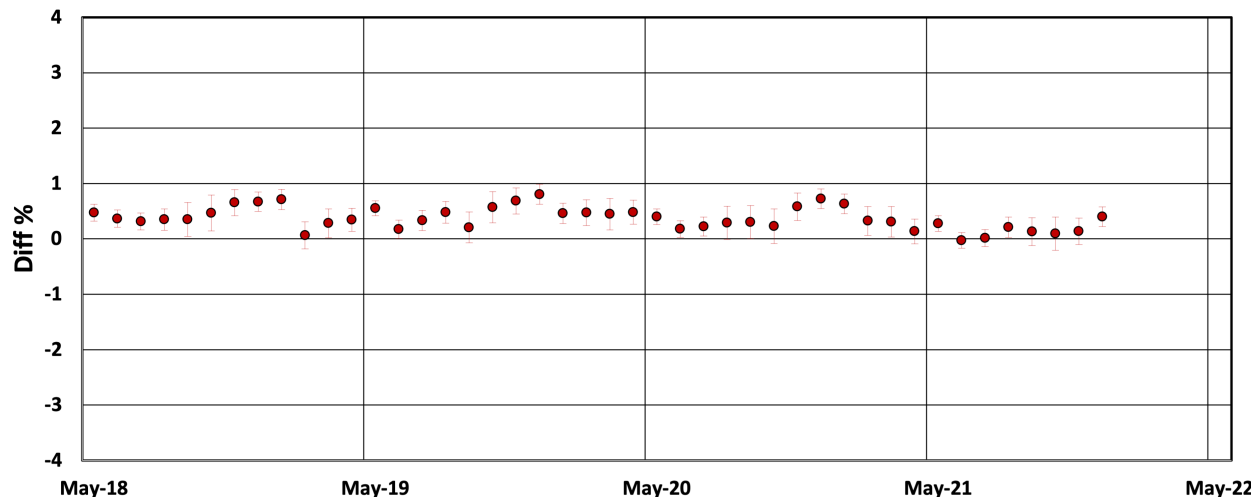


FM3/FM6 LW All-sky Inter-comparisons: May 2018-Dec 2021

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

Daytime LW for FM6 obtained from TOT -SW

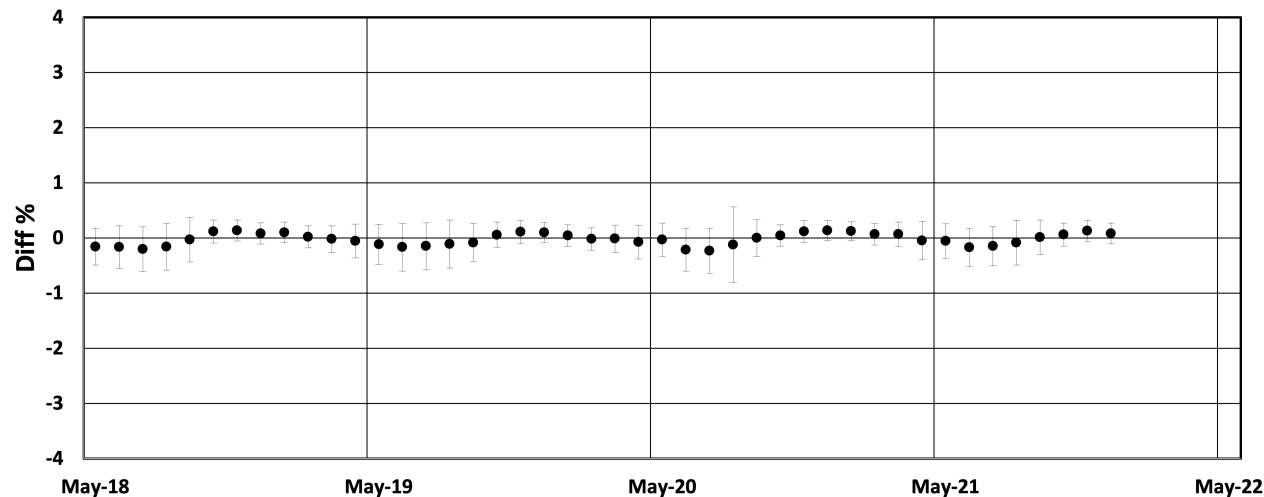
Aqua (Ed4)/NOAA-20 (Ed1) Daytime LW Intercomparison



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

Nighttime LW for FM6 obtained from TOT

Aqua (Ed4)/NOAA-20 (Ed1) Nighttime LW Intercomparison



Radiometric scaling of FM6 to FM3 done in May 2018.

Data:

CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1B



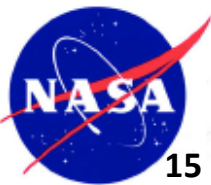
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S-NPP/FM5 Instrument Status



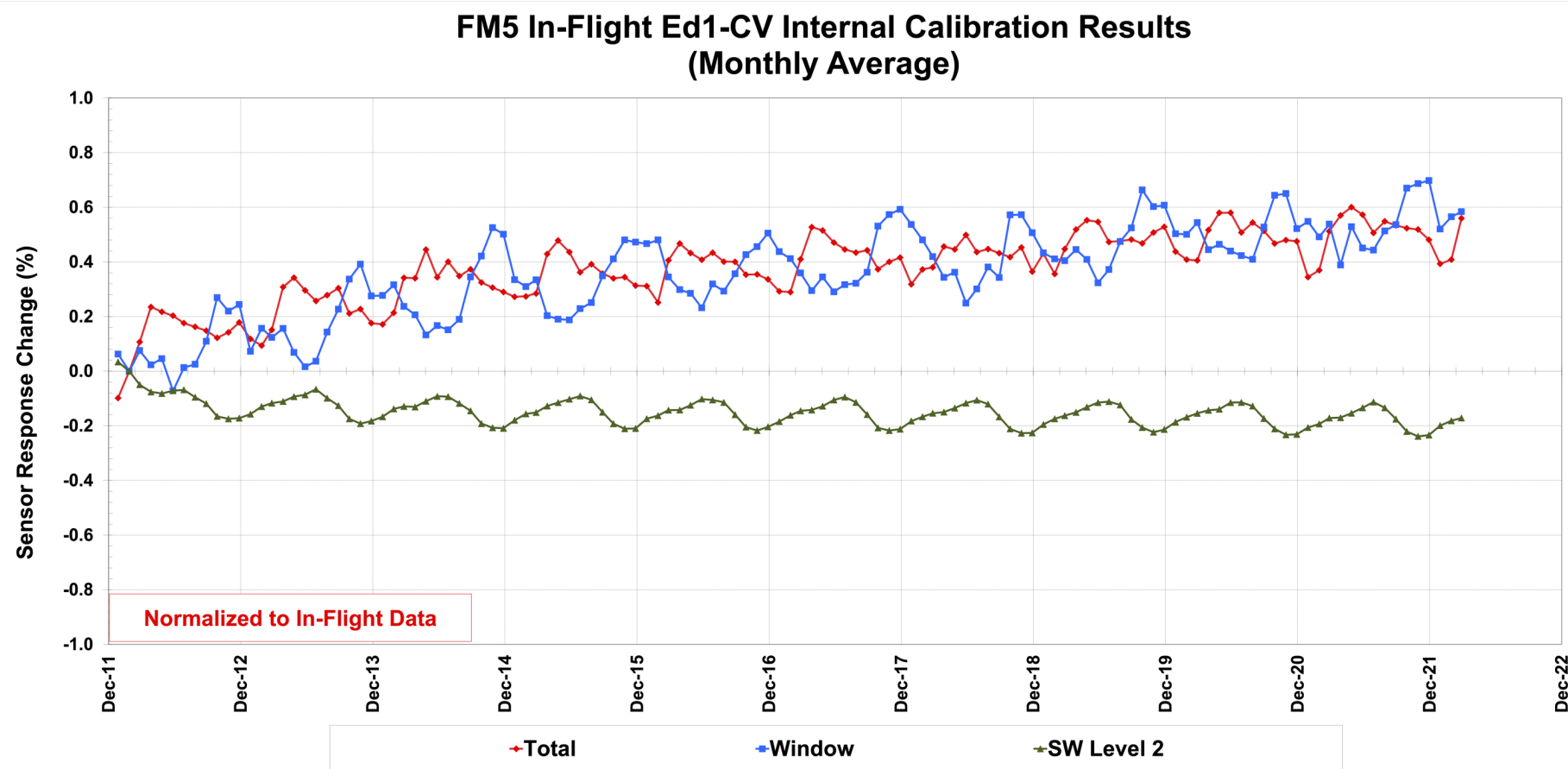
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FM5 Internal Calibration

In response to the blackbodies, the FM5 TOT and WN sensors show a $\sim 0.5\%$ rise since start of mission.

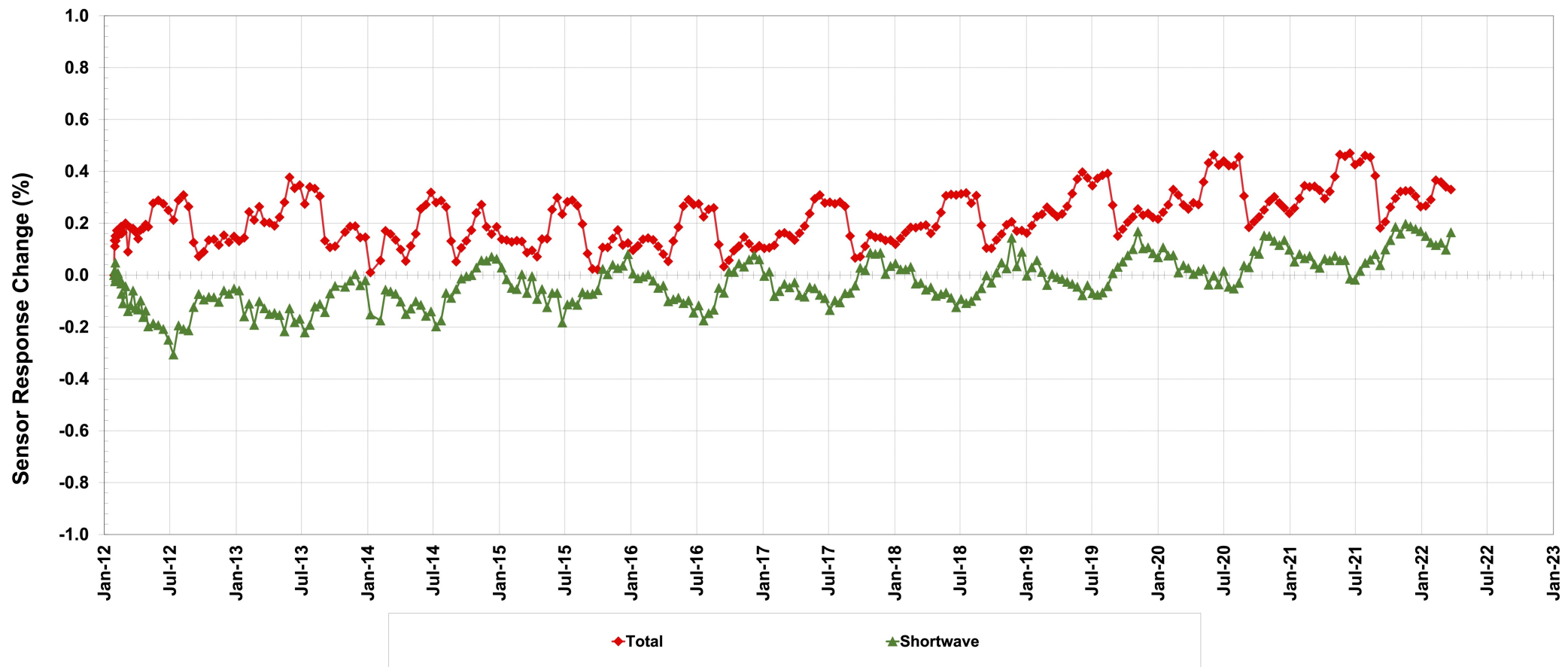
SW channel's response to the SWICS has settled at $\sim -0.2\%$ since start of mission.



FM5 Solar Calibration

- FM5 Solar calibration results show the MAMs are very stable.
- TOT and SW responses show a slight upward trend in latter part of mission.

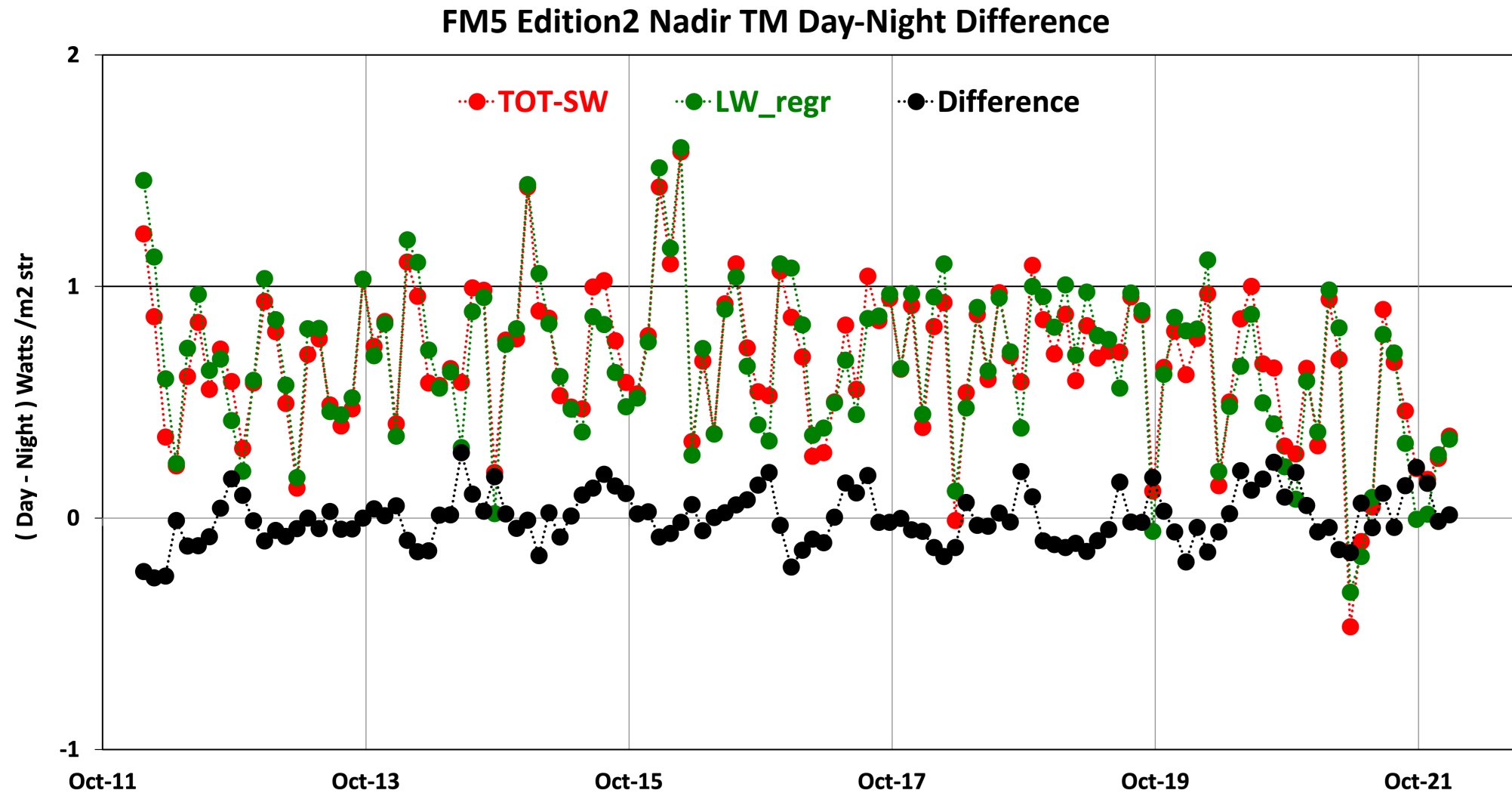
FM5 Solar Calibration



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Validation- FM5 Tropical Mean

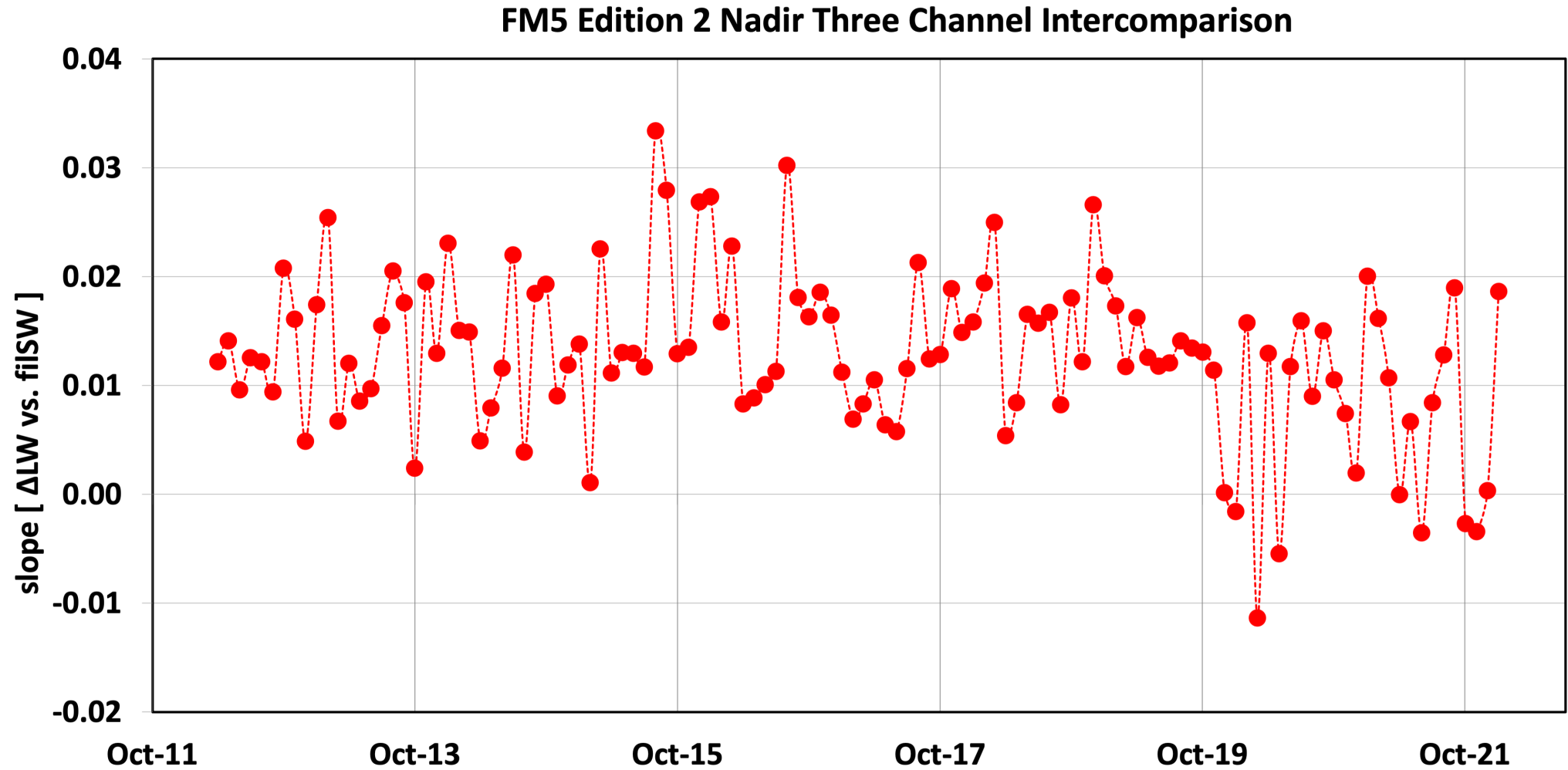


Validation: DCC 3-Channel Inter-comparison

- Compare the radiances from the three sensors of the instrument when viewing Deep Convective Clouds (DCC).
- Two sets of longwave (LW) radiances obtained:
 - TOT and SW sensors
 - Trained WN sensor
- Monitor the trend between the difference of the two LW radiances in relation to the SW radiance.
- Highlights any inconsistencies in the SW sensor or the shortwave part of the TOT sensor.



FM5 DCC 3-Channel Intercomparison



Aqua/S-NPP Intercomparisons

- The orbital geometries for Aqua and S-NPP are such that orbital overlaps occur every ~64 hours.
- Obtain spatially and temporally matched observations during every crossover.
- Use matching criteria to subset the data:
 - SZA, VZA difference < 2.0°
 - RAZ difference < 5°
 - Distance between footprints < 7km
- Obtain monthly all-sky SW reflectance and daytime LW radiance differences using the matched footprints.
- *Since FM5 is operating in biaxial mode, the number of matched footprints has drastically reduced.*

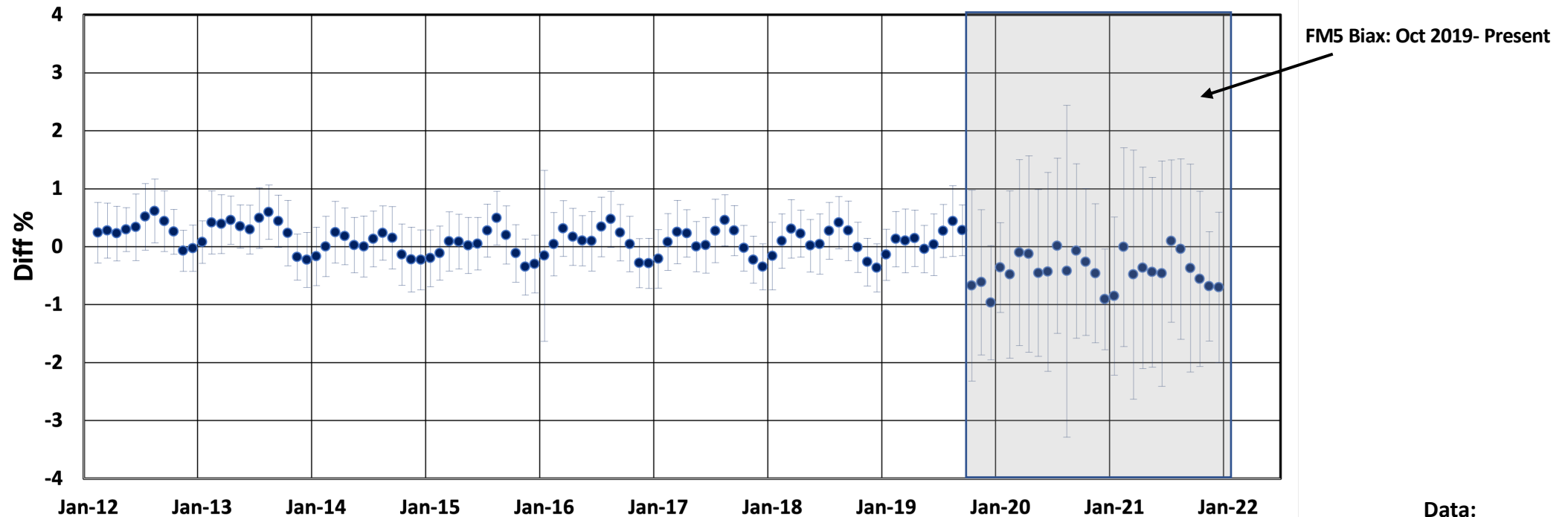


FM3/FM5 SW All-sky Inter-comparisons: Feb 2012- Dec 2021

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

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

Aqua (Ed4)/S-NPP (Ed2) SW Intercomparison



2014 data used for the radiometric scaling FM5 to FM3.

Data:

CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM5-VIIRS_Edition2A

Larger differences observed after FM5 switched to biaxial mode are driven by the drastic reduction in number of spatially and temporally matched observations.

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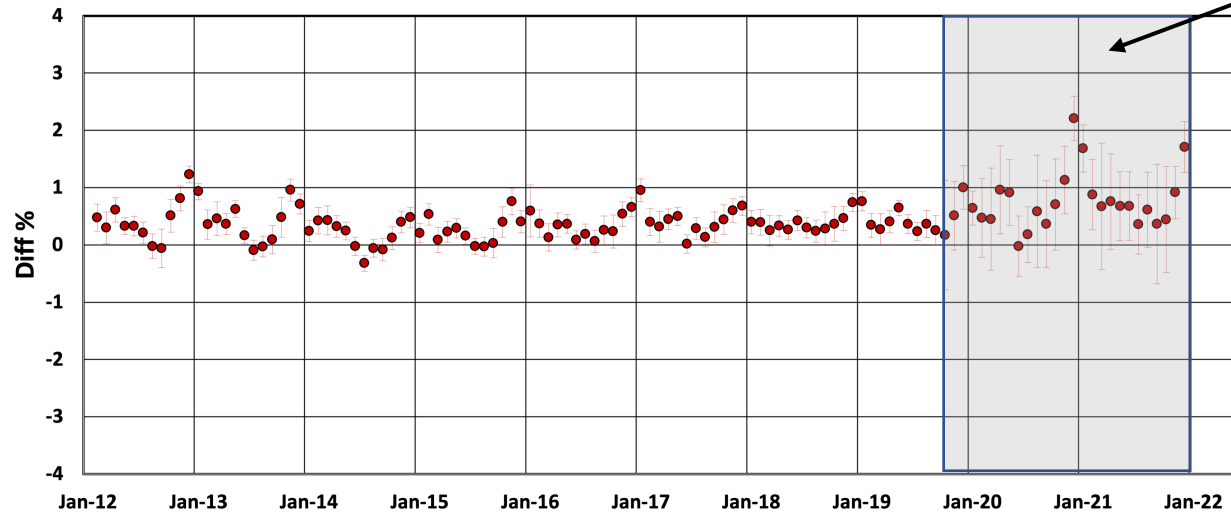
FM3/FM5 LW All-sky Inter-comparisons: Feb 2012- Dec 2021

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

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

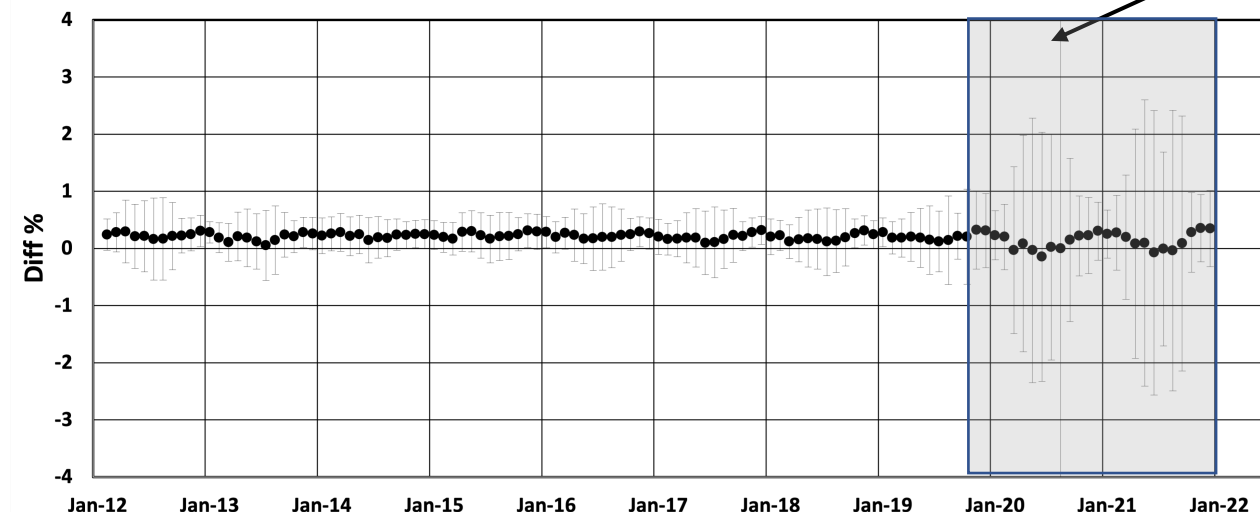
Aqua (Ed4)/S-NPP (Ed2) Daytime LW Intercomparison

FM5 Biax- Oct
2019- Present



Aqua (Ed4)/S-NPP (Ed2) Nighttime LW Intercomparison

FM5 Biax- Oct
2019- Present



2014 data used for the radiometric scaling FM5 to FM3.

Data:

CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM5-VIIRS_Edition2A

Larger differences observed after FM5 switched to biaxial mode are driven by the drastic reduction in number of spatially and temporally matched observations.

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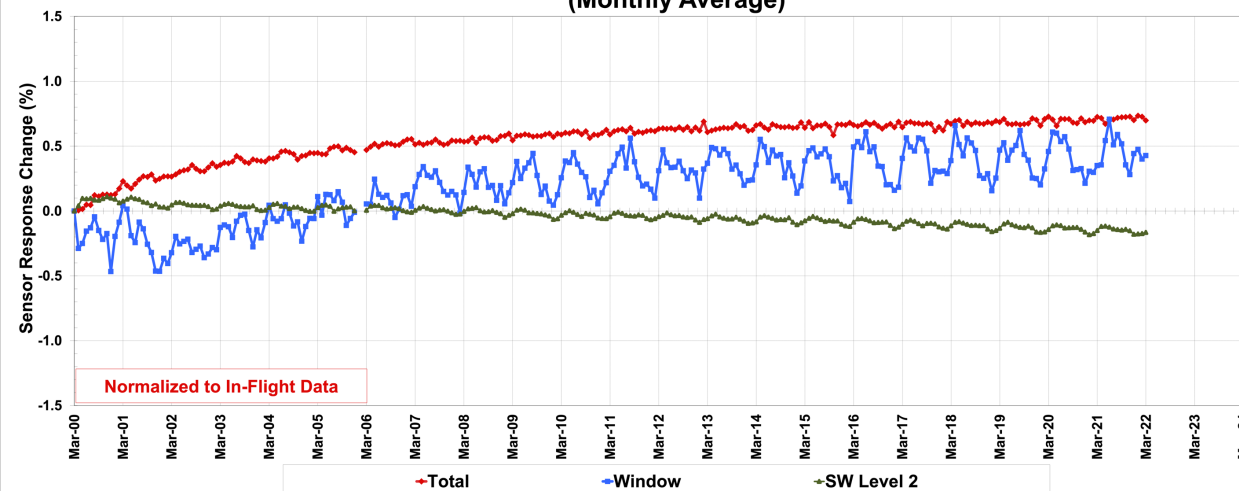
Terra & Aqua FM1-FM4 Instruments' Status



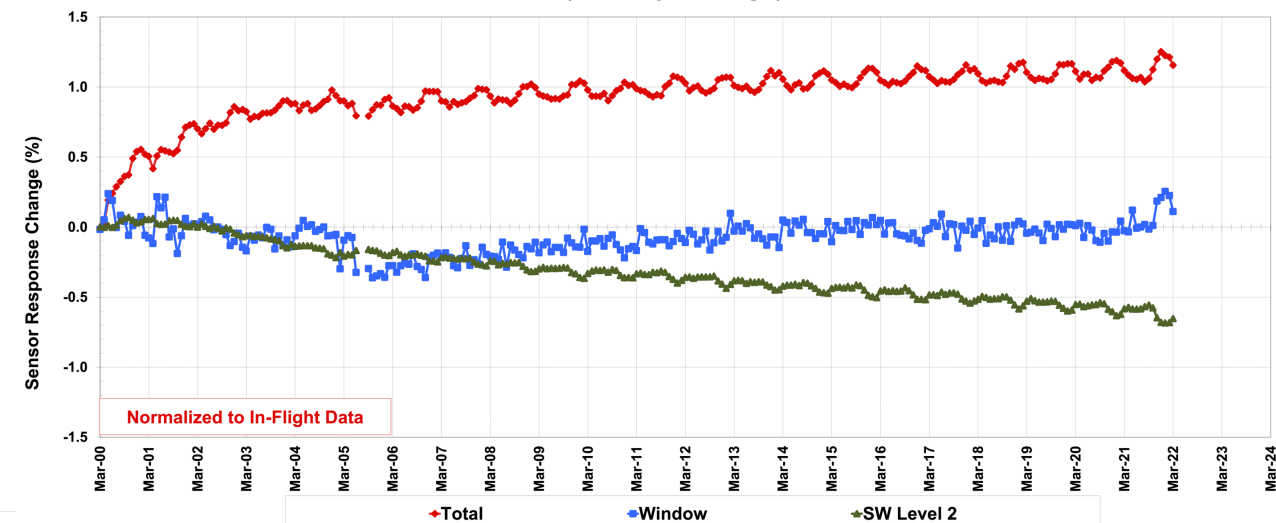
Terra- FM1 & FM2 Internal Calibration Results

- For FM1, TOT channel shows ~0.7% rise, SW channel shows ~0.1% drop, and WN channel shows a rise of ~0.4% since start of mission.
- For FM2, TOT channel shows ~1.2% rise, SW channel shows ~0.6% drop, while WN channel shows ~0% change since start of mission.

FM1 In-Flight Ed1-CV Internal Calibration Results
(Monthly Average)



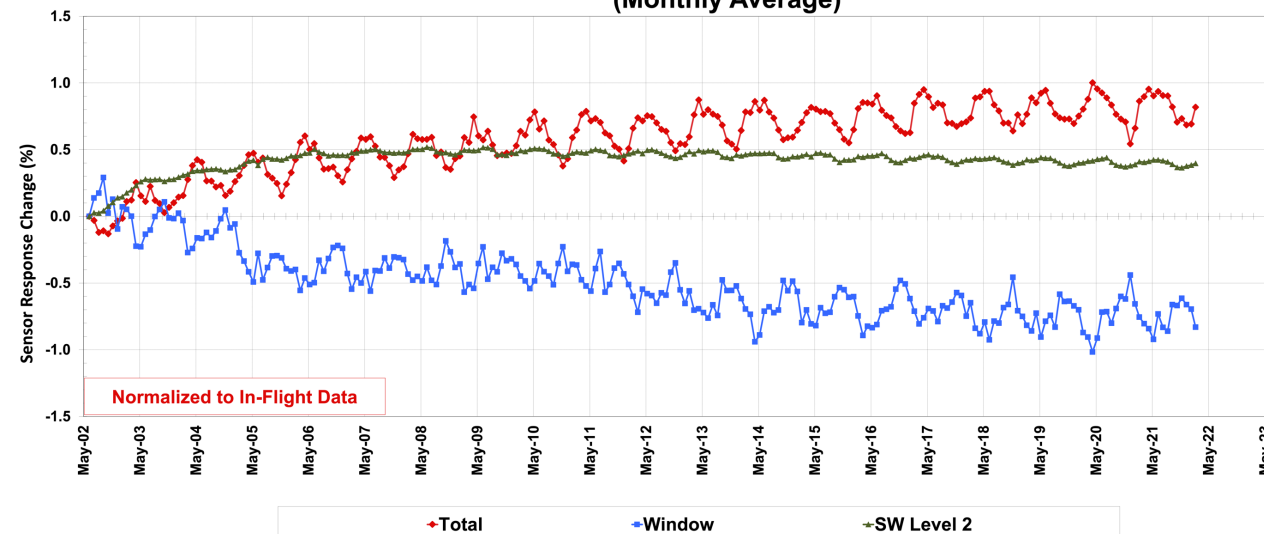
FM2 In-Flight Ed1-CV Internal Calibration Results
(Monthly Average)



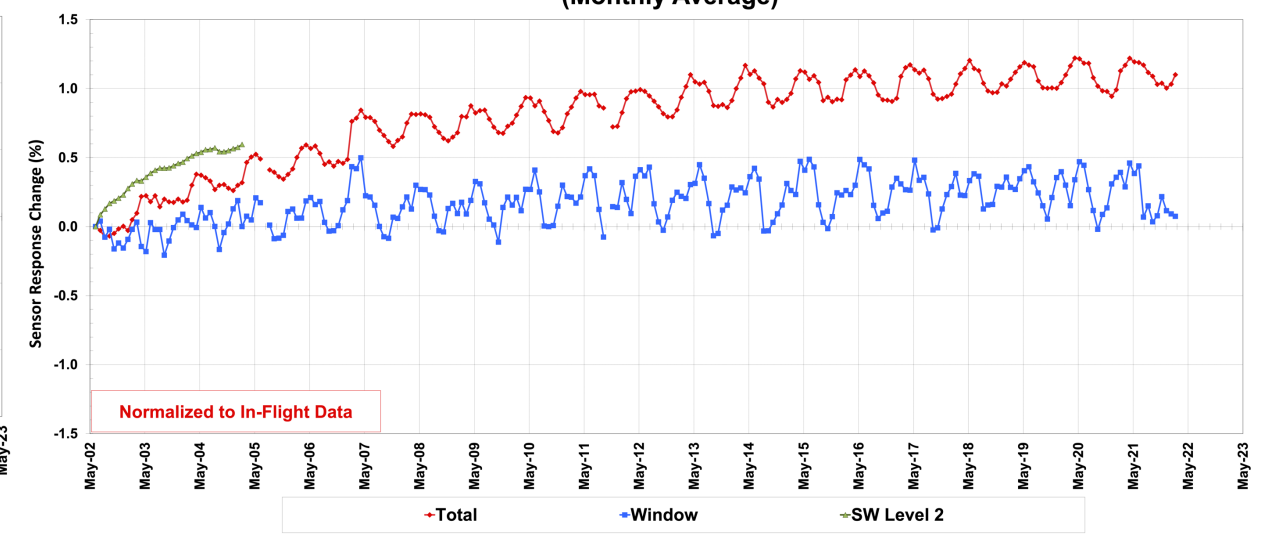
Aqua- FM3 and FM4 Internal Calibration Results

- For FM3, TOT channel shows $\sim 0.8\%$ rise, SW channel shows $\sim 0.4\%$ rise, and WN channel shows $\sim 0.8\%$ drop since start of mission.
- For FM4, TOT channel shows $\sim 1\%$ rise, while WN channel shows $\sim 0.25\%$ rise since start of mission.

FM3 In-Flight Ed1-CV Internal Calibration Results
(Monthly Average)



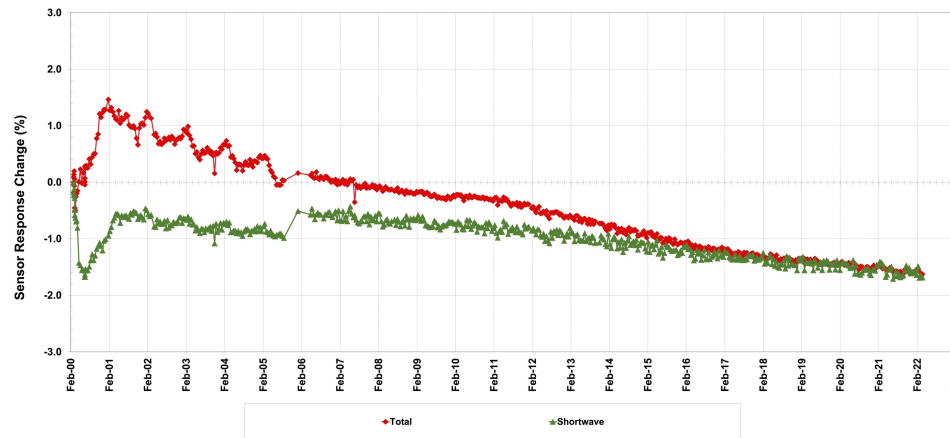
FM4 In-Flight Ed1-CV Internal Calibration Results
(Monthly Average)



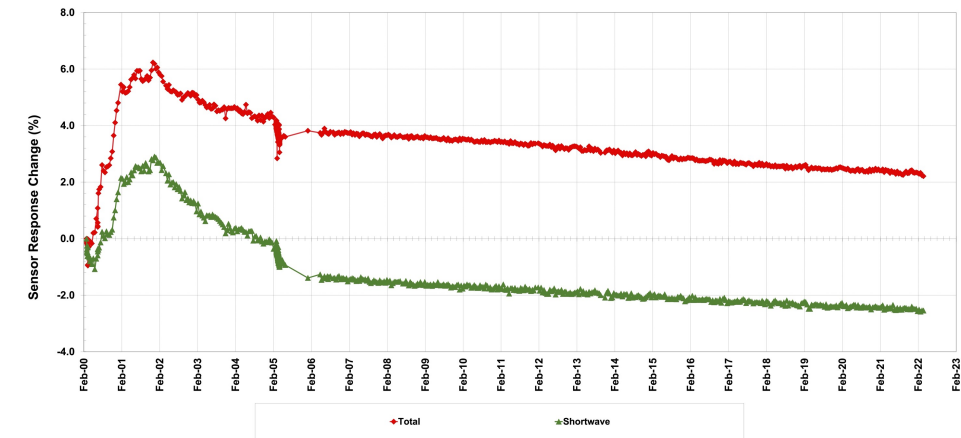
Terra & Aqua Solar Calibration

Since the start of raster scan for solar calibration, SW channel data shows a drop of response of $\sim 1\%$ and TOT channel shows a drop of 1.5%-2% for all instruments.

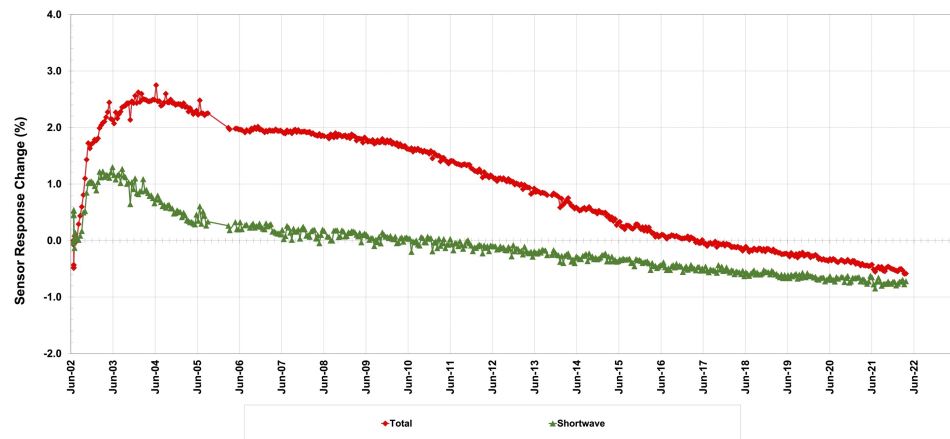
FM1 Solar Calibration



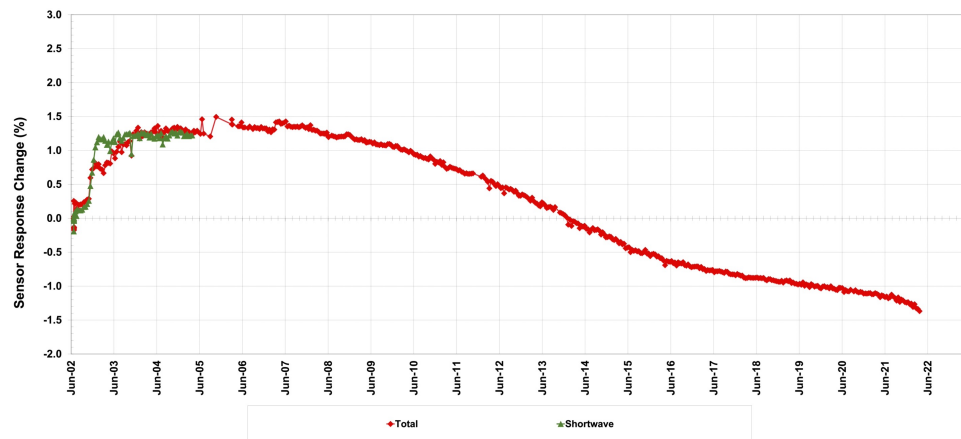
FM2 Solar Calibration



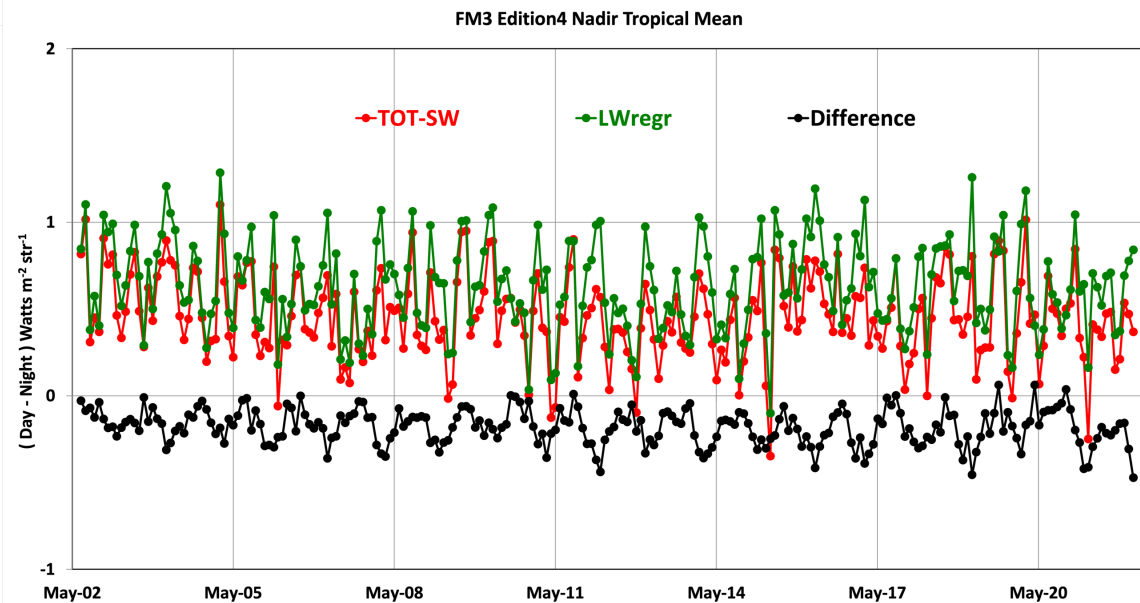
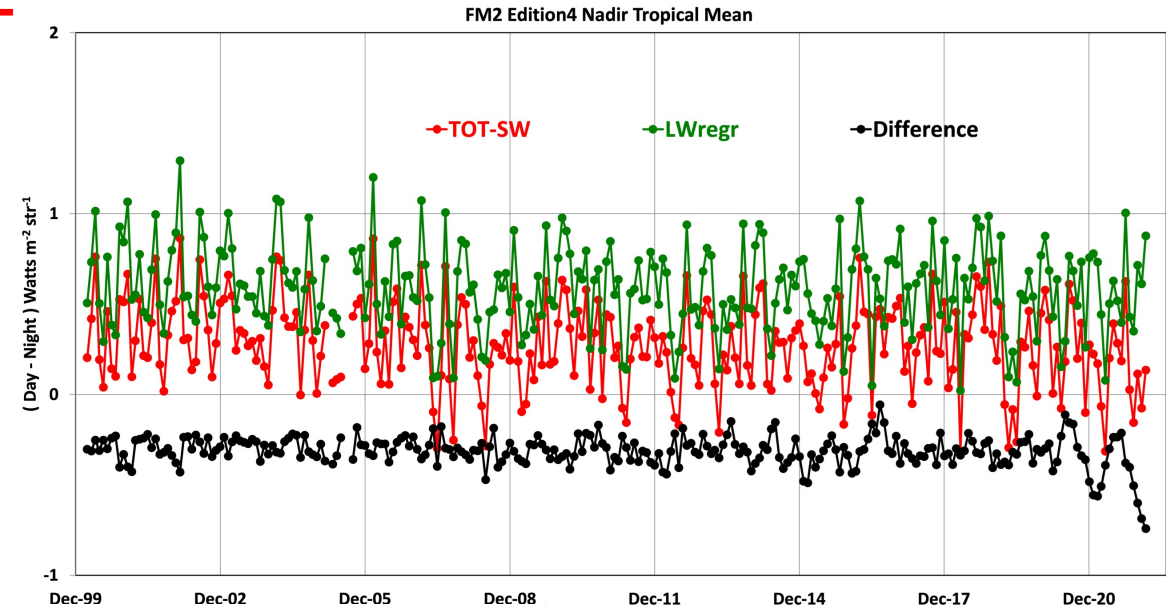
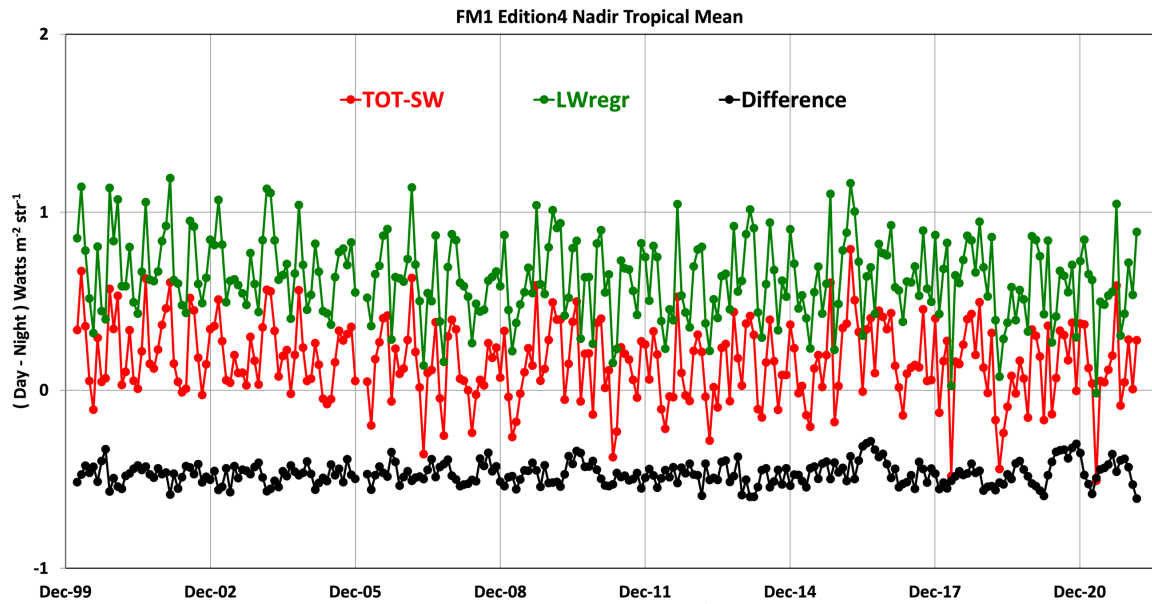
FM3 Solar Calibration



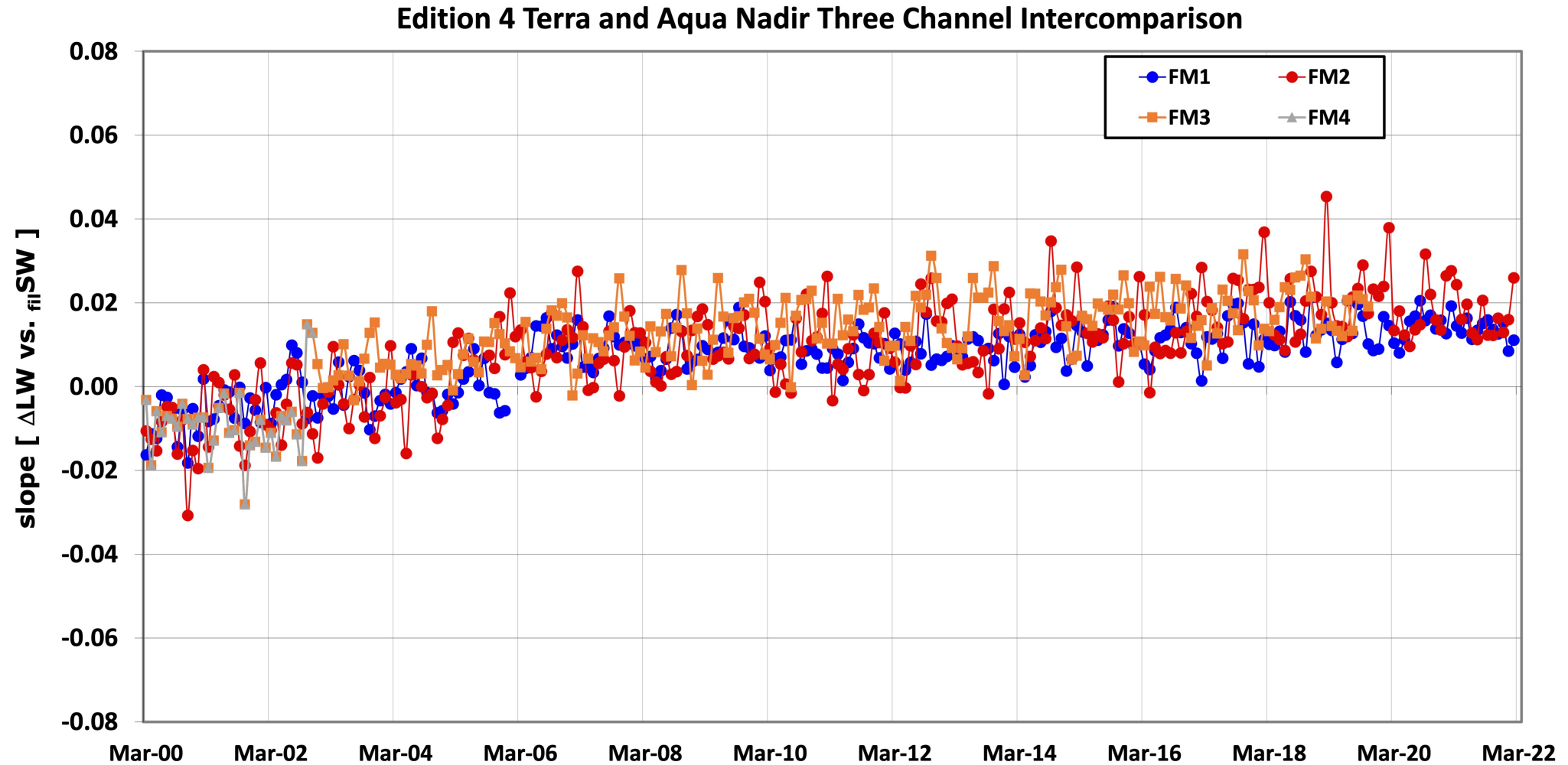
FM4 Solar Calibration



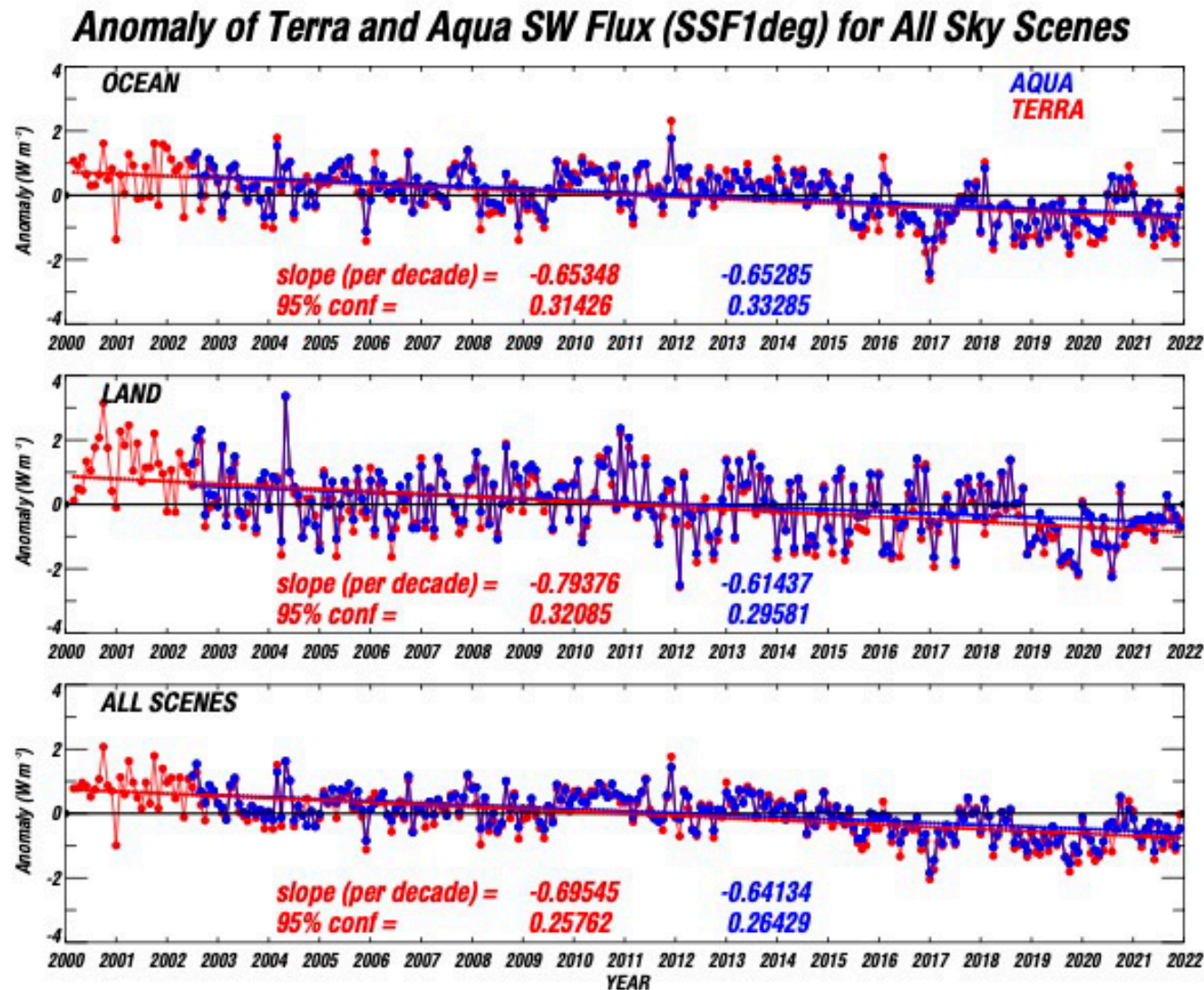
Validation- Terra and Aqua Tropical Mean



Validation- DCC 3-Channel Intercomparison

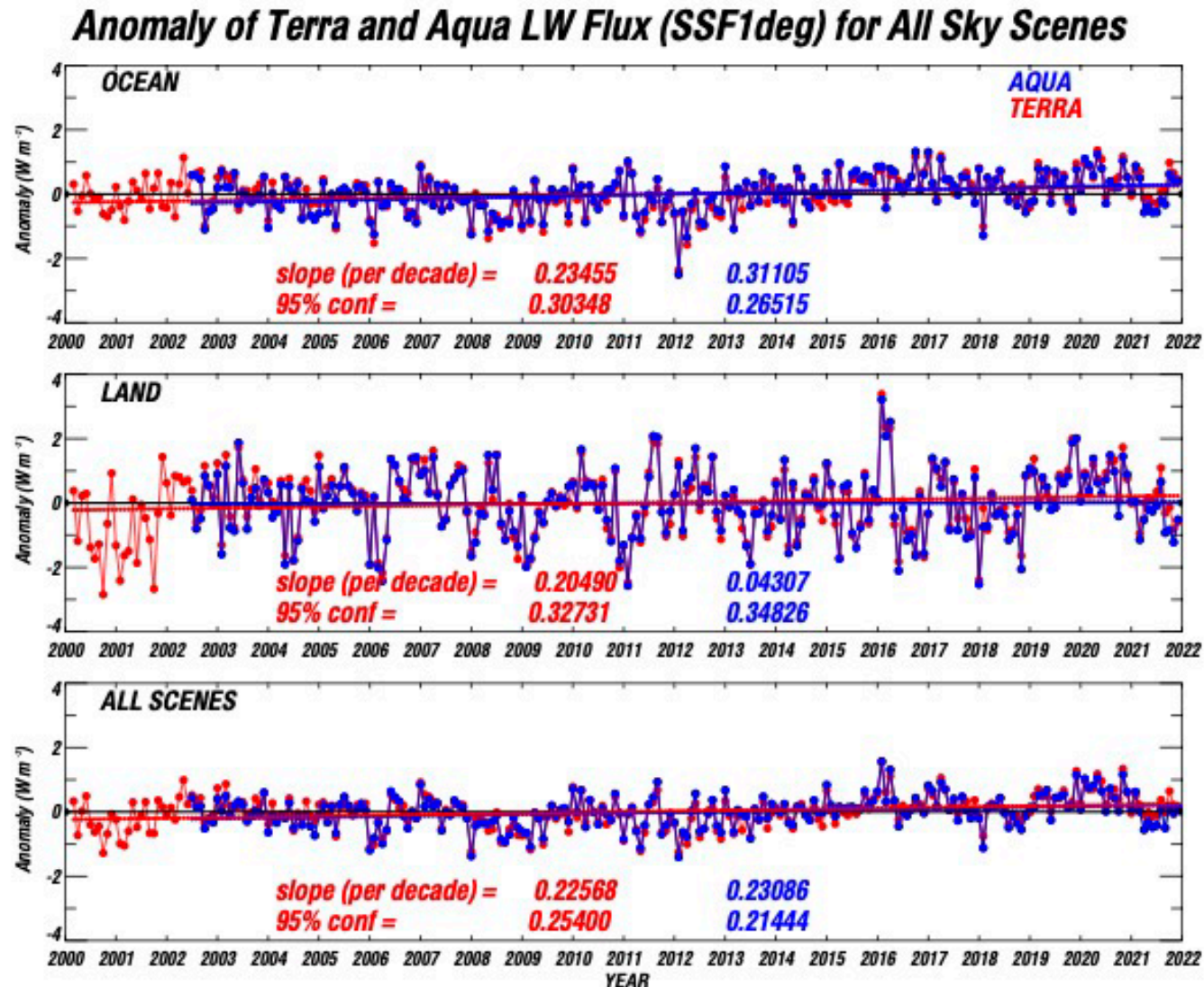


Validation: Terra and Aqua Ed-4 SW Flux Anomalies



SW flux anomalies show similar trends for Terra and Aqua

Validation: Terra and Aqua Ed-4 LW Flux Anomalies



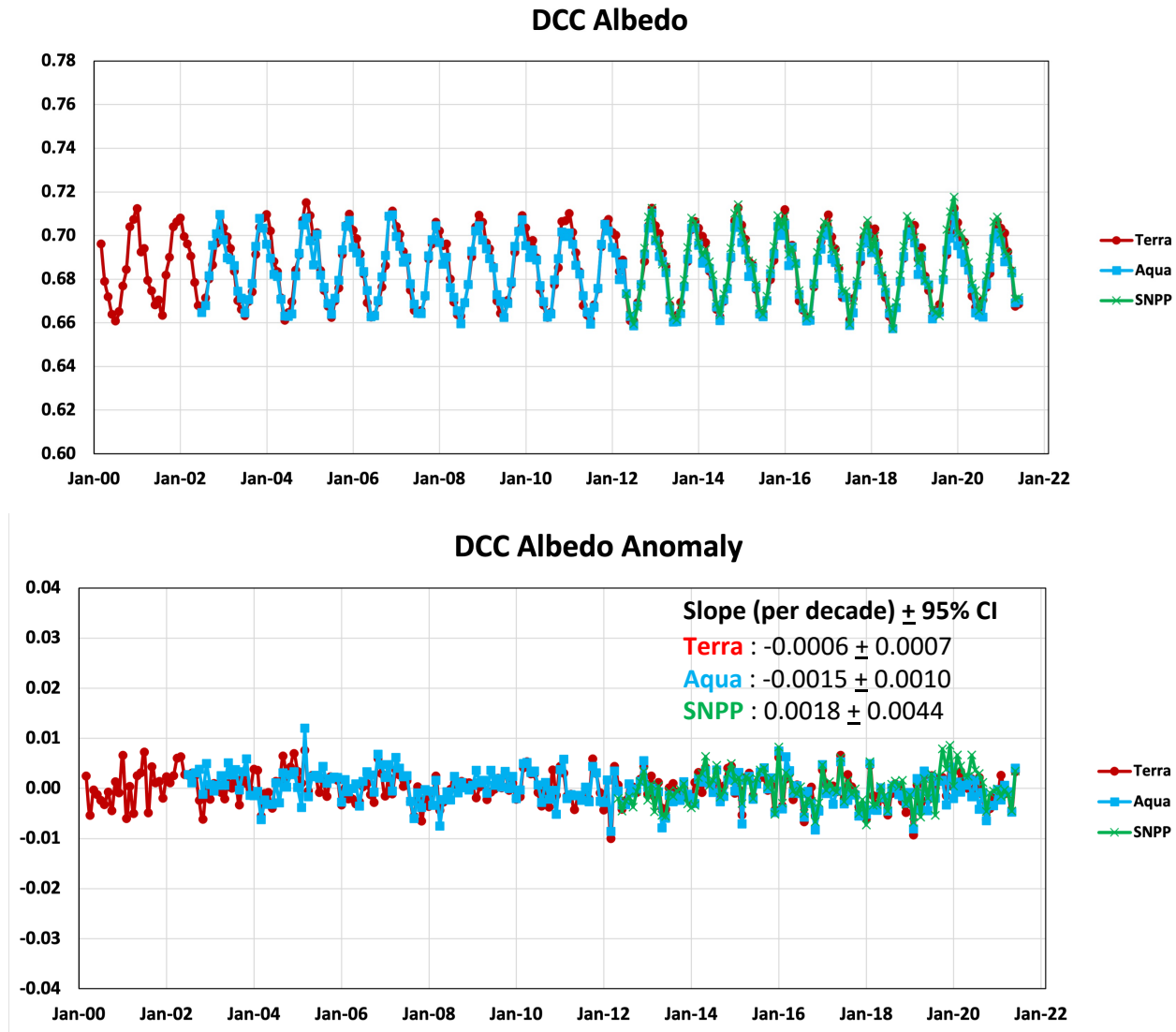
LW flux anomalies show similar trends for Terra and Aqua.

Validation: DCC Albedo

- Observe the long-term trends of DCC albedo.
 - Uses Level-2 products (SSF), calculate monthly means of DCC footprints.
 - Trends observed for instruments on Terra, Aqua, S-NPP.
- For Terra and Aqua, consider data from instruments operating in crosstrack mode.
- Criteria for selecting DCC:
 - Consider all footprints with VZA, SZA < 40 deg.
 - Latitude bands: 30 N-S, Over Ocean.
 - Cloud Fraction= 100%.
 - Use MODIS/VIIRS 11um channel to identify footprints with brightness temperature <210K.
 - WN channel filtered radiance < $1 \text{ Wm}^{-2}\text{sr}^{-1}\text{um}^{-1}$.



Validation: DCC Albedo



Data Series:

Terra: Mar 2000- Jun 2021

Aqua: Jul 2002- Jun 2021

SNPP: May 2012- Jun 2021

DCC trends show that CERES instruments on Terra, Aqua and SNPP are very consistent with each other.

Slope (per decade) $\pm$ 95% CI

Aqua-Terra: -0.0007 ± 0.0012

SNPP-Aqua: 0.0034 ± 0.0028

SNPP-Terra: 0.0025 ± 0.0028

Data:

CER_SSF_Terra-FM1-MODIS_Edition4A
CER_SSF_Terra-FM2-MODIS_Edition4A
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_Aqua-FM4-MODIS_Edition4A
CER_SSF_NOAA20-FM5-VIIRS_Edition2A



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SUMMARY

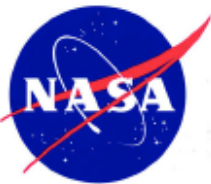
- **All CERES instruments continue to perform nominally.**
 - NOAA-20/FM6 instrument continues to show stable performance after the initial sensor response rise.
 - SNPP/FM5 is currently operating in full biaxial mode, collecting ADM data.
 - *No evidence of change to SW channel performance since transitioning to biaxial mode.*
 - Terra/FM2, Aqua/FM4 operating in Biaxial mode.
 - Validations show that all instruments are performing consistently.
 - *Added a new validation tool using DCC: FM1-FM5 show consistent and stable performance.*
- **Data products**
 - NOAA-20/FM6 Edition 1 gains have been finalized and delivered through Mar 2022.
 - S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Mar 2022.
 - Terra and Aqua instruments' Edition 4 gains and SRFs have been delivered through Feb 2022.



Backup



CERES Instrument Working Group



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.

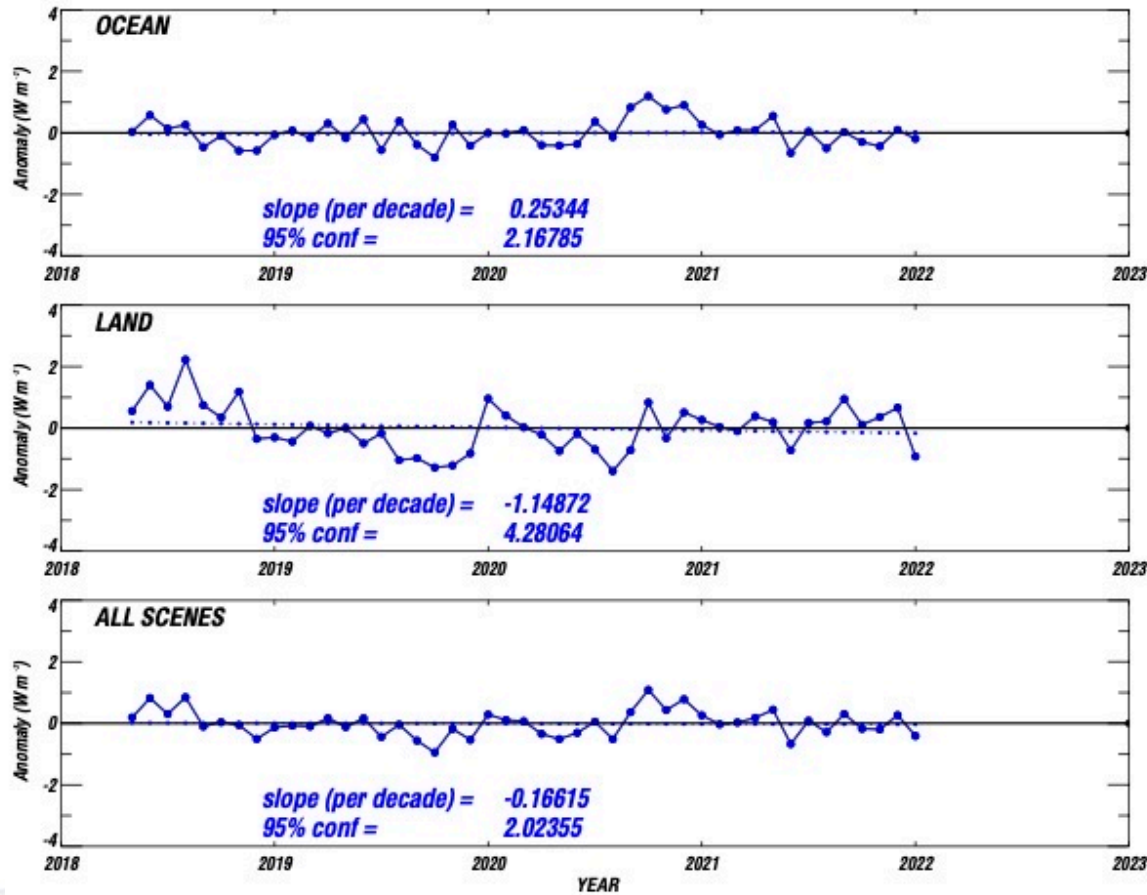
- **Terra/Aqua:**

- *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.

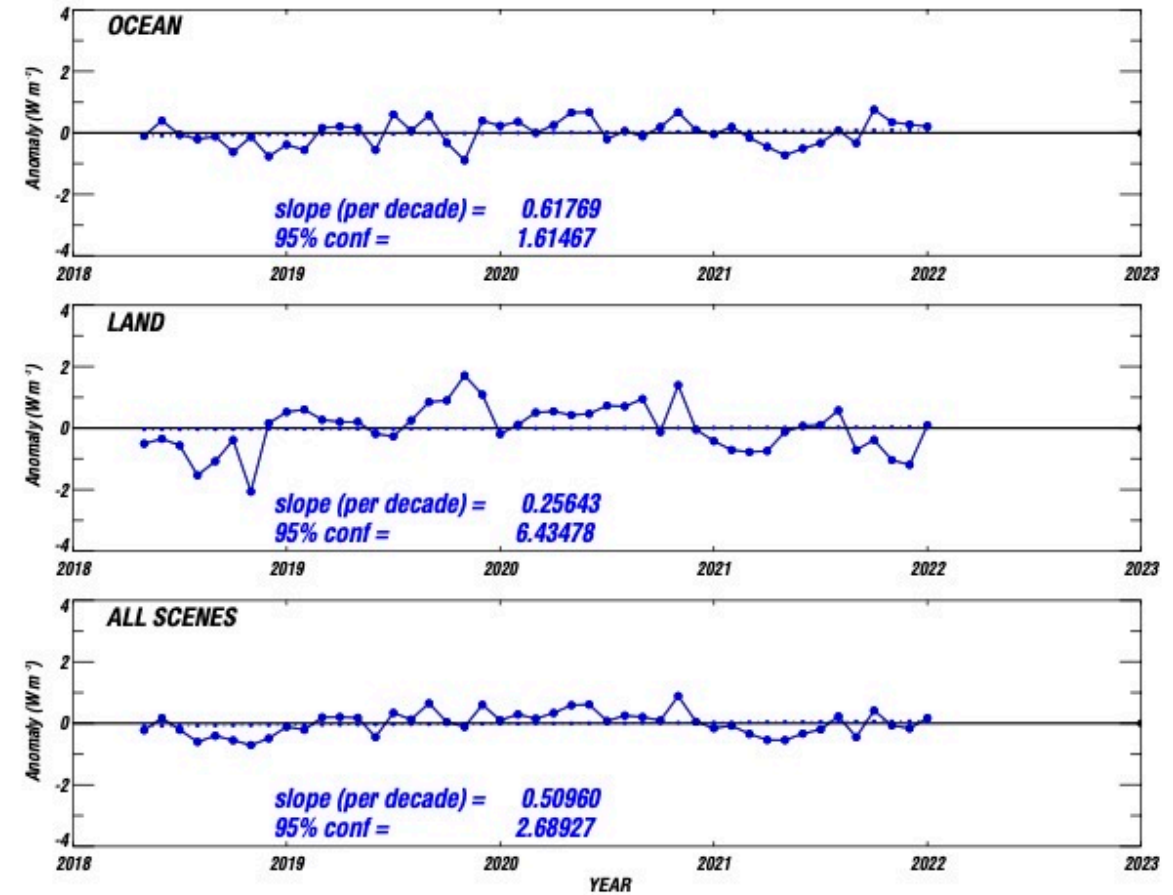


FM6 Edition 1 SW and LW Flux Anomaly

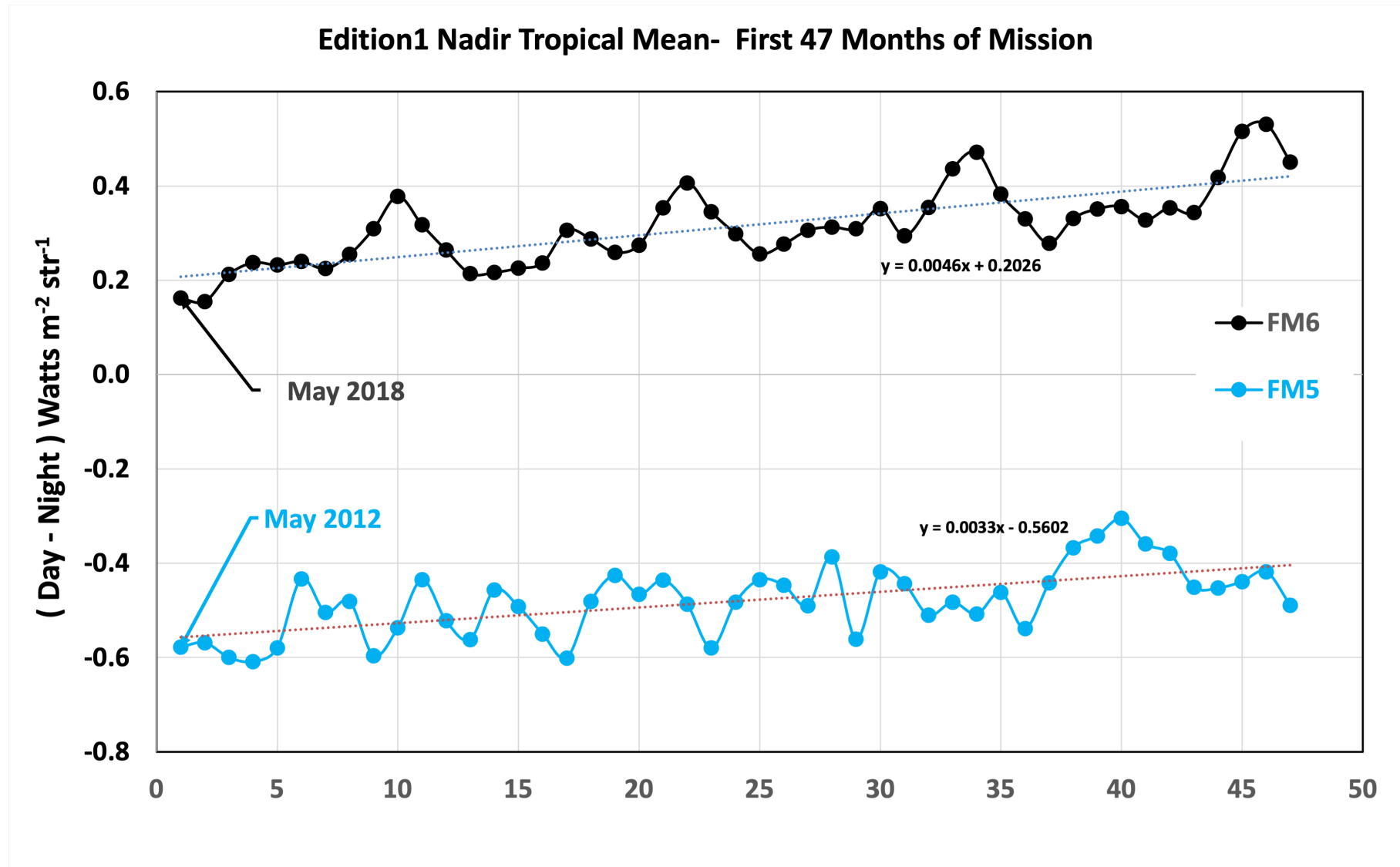
Anomaly of NOAA20 SW Flux (SSF1deg) for All Sky Scenes



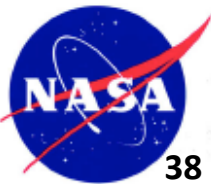
Anomaly of NOAA20 LW Flux (SSF1deg) for All Sky Scenes



FM5 and FM6 Tropical Mean- First 47 months



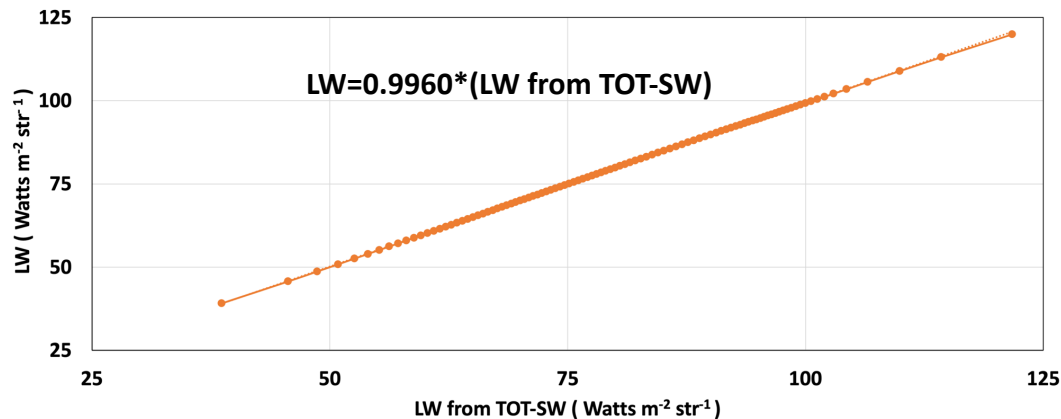
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FM6 3-channel Consistency check- Global LW Day and Night

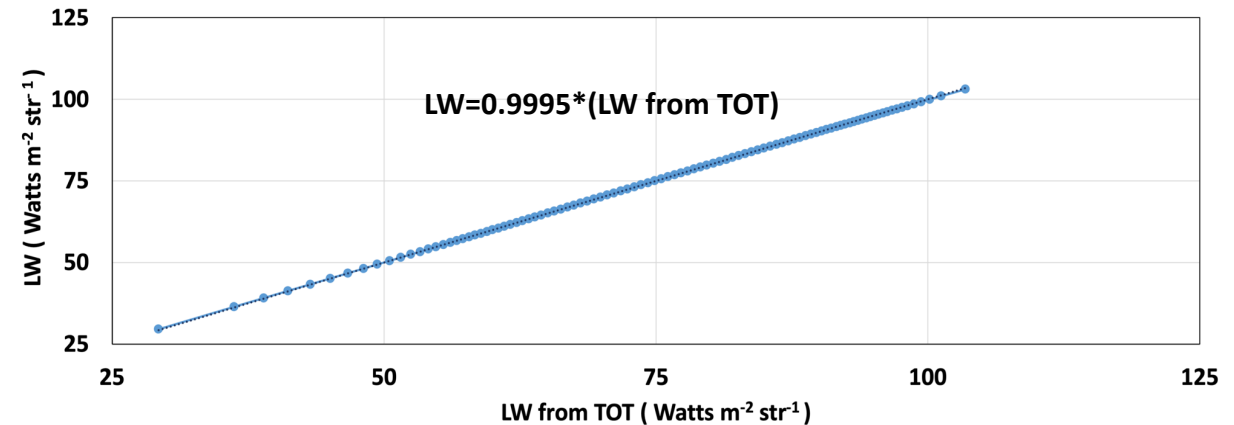
May 2018 - Jan 2022

Daytime Global Edition 1 ES-8 Nadir
TOT- SW vs. LW sensor



Daytime
 $LW_{TOT-SW} - LW_{LWC} = 0.4\%$

Nighttime Global Edition 1 ES-8 Nadir
LW from TOT vs. LW sensor



Nighttime
 $LW_{TOT} - LW_{LWC} = 0.05\%$

