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

Kory Priestley

CERES Instrument Working Group

CERES Fall Science Team Meeting
October 12, 2022

CERES Instrument Working Group

CERES Instrument Working Group

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CERES Instrument Status Summary

- **All CERES instruments continue to demonstrate stable performance.**
  - **NOAA-20/FM6 instrument continues to perform nominally.**
  - **SNPP/FM5 is currently operating in full biaxial mode.**
    - ***No evidence of deviation of instrument performance since transitioning to biaxial mode.***
  - **Terra/FM2, Aqua/FM4 currently operating in Biaxial mode.**
  - **Validations show that all instruments are performing consistently.**

- **Data products**
  - **NOAA-20/FM6 Edition 1 gains have been delivered through Aug 2022.**
  - **S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Aug 2022.**
  - **Terra and Aqua instruments' Edition 4 gains and SRFs have been delivered through Jul 2022.**

CERES Instrument Operations Summary

- **Operational Modes:**
  - **Terra/FM1, Aqua/FM3, NOAA-20/FM6 are operating in the Crosstrack mode.**
  - **Terra/FM2 operating in biaxial mode since November 1, 2021.**
  - **Aqua/FM4 is operating in biaxial mode since July 14, 2021.**
  - **S-NPP/FM5 is operating in biaxial mode since Oct 1, 2019; *Full* biaxial mode since Mar 23, 2020.**

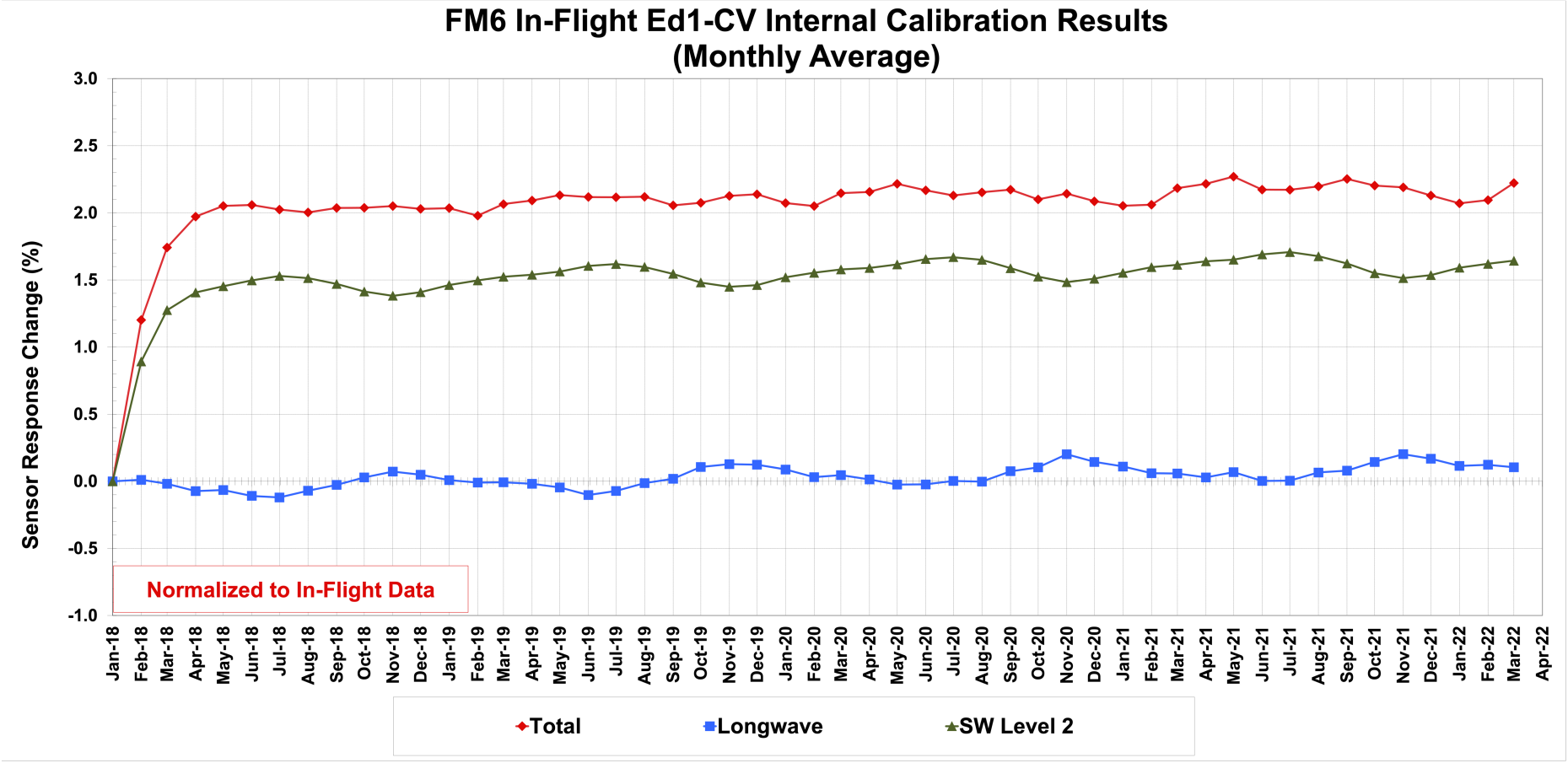
- **S-NPP had a spacecraft anomaly, likely due to solar weather event, on Jul 27, 2022.**
  - **S-NPP/FM5 instrument was SAFED and then powered off on Jul 29, 2022.**
  - **Instrument recovery completed and restored to normal ops on Sep 1, 2022.**

- **Inter-comparison operations completed 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

NOAA-20/FM6 Instrument Status

FM6 Internal Calibration

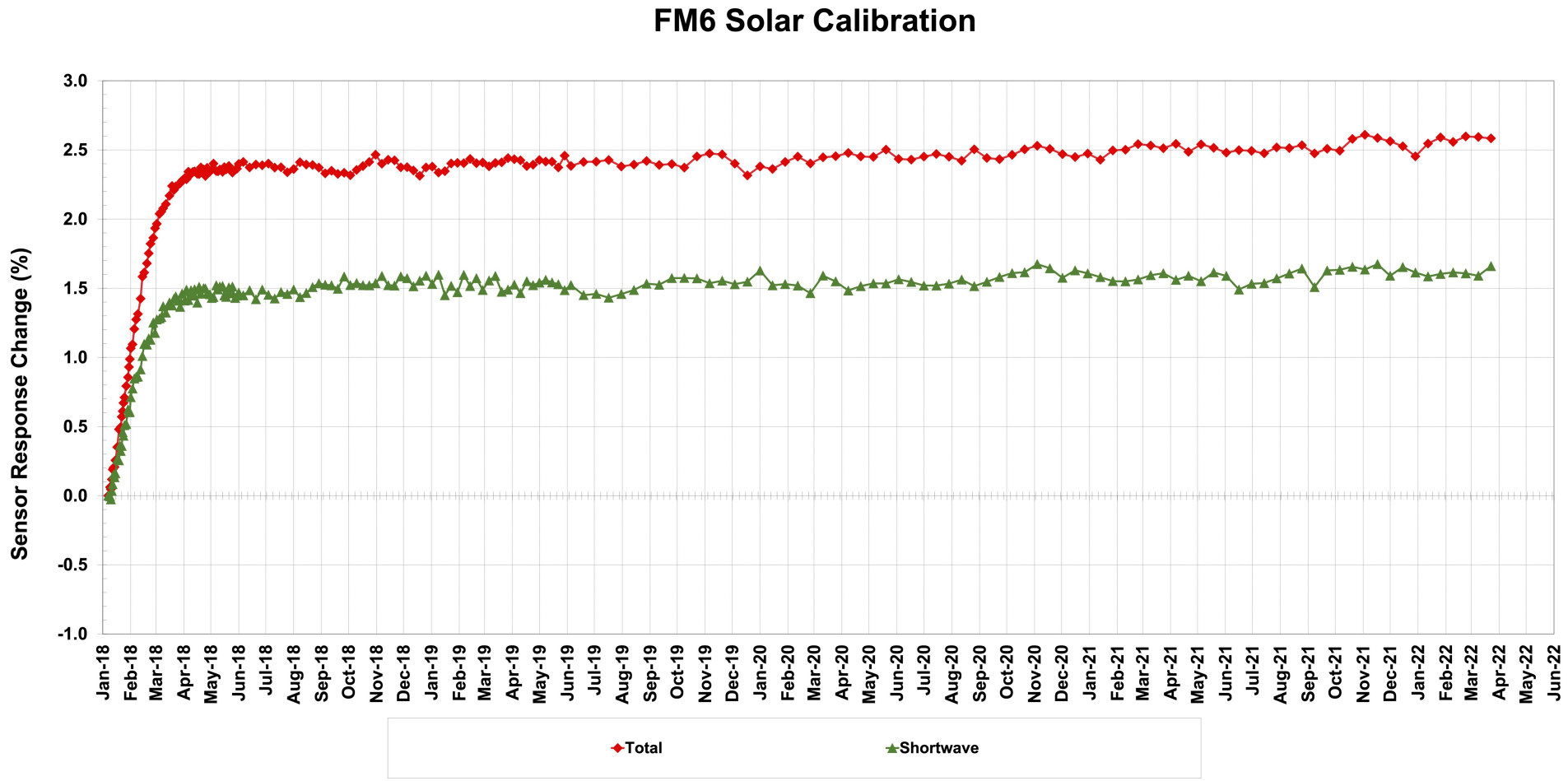
- **For SW and TOT channels, the responses to the on-board sources (SWICS lamp and Blackbodies) continue to be quite stable after the initial rise of ~1.5% (SW) and ~2% (TOT) since start of mission.**
- **LW Channel (calibrated using blackbody) continues to show very little change.**



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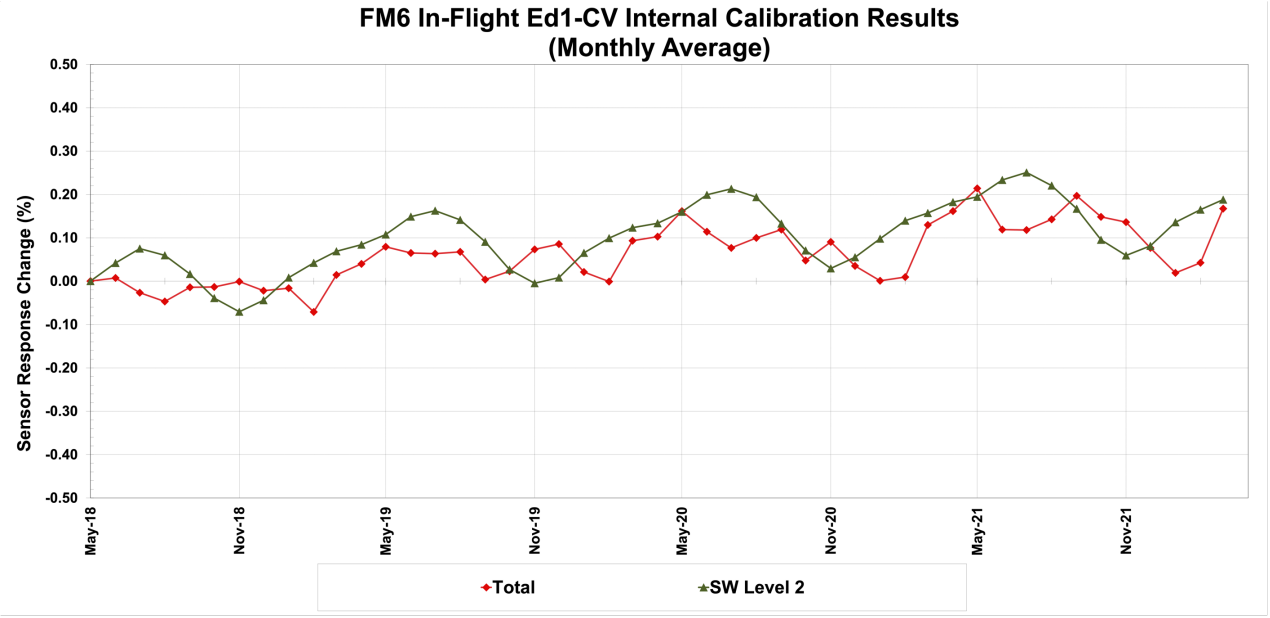
FM6 Solar Calibration

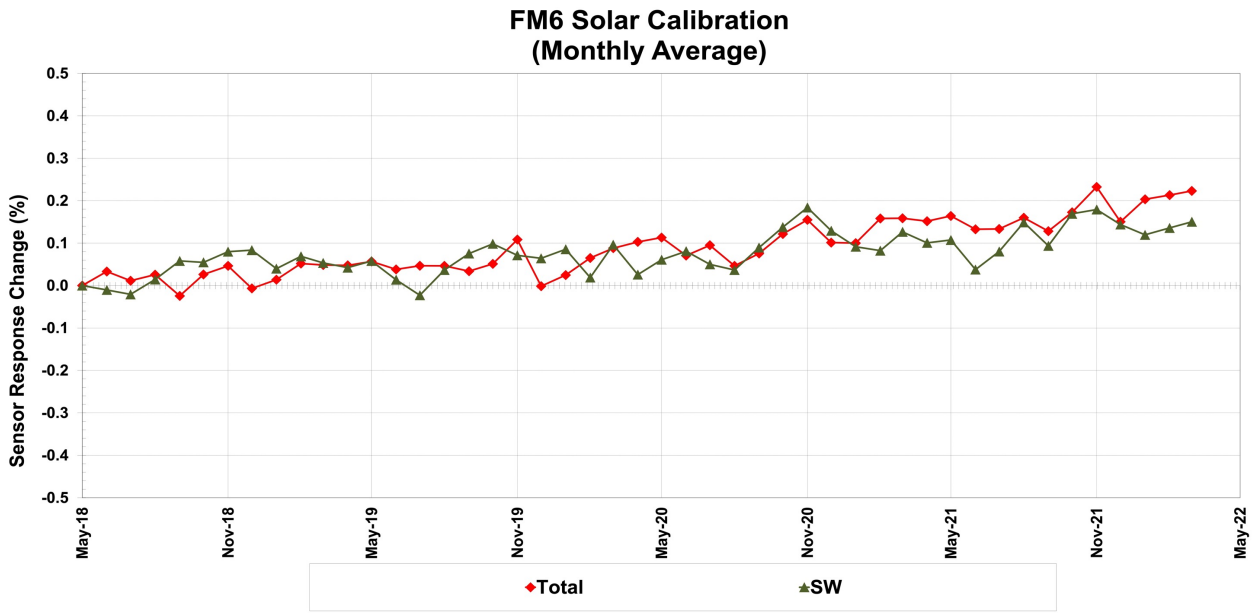
- **Response of the SW and TOT channels while viewing the MAM that is illuminated by the sun.**
- **After the initial rise of ~1.5% for SW, and ~2.3% for TOT, the response is quite stable.**



FM6 Calibration- Internal and Solar Cal Since May 2018

FM6 Internal and solar calibration results consistently show about 0.2% change since May 2018, demonstrating that the MAM is very stable.





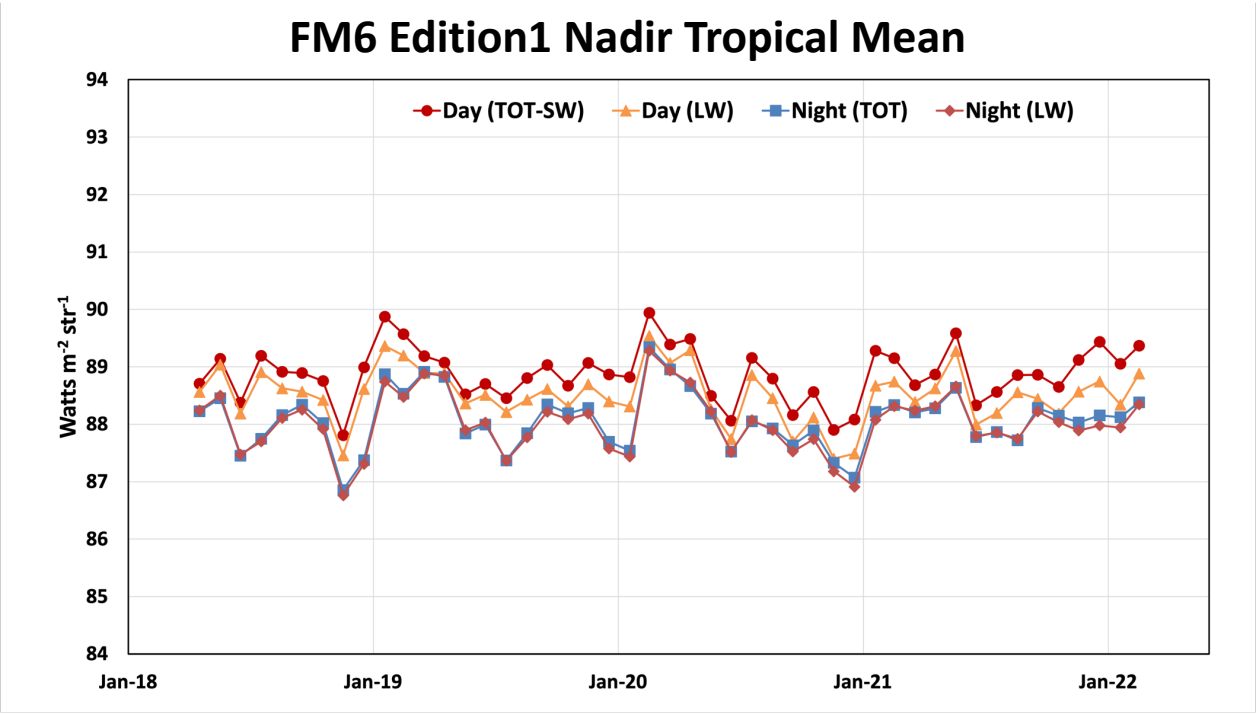
Validation – Tropical Mean

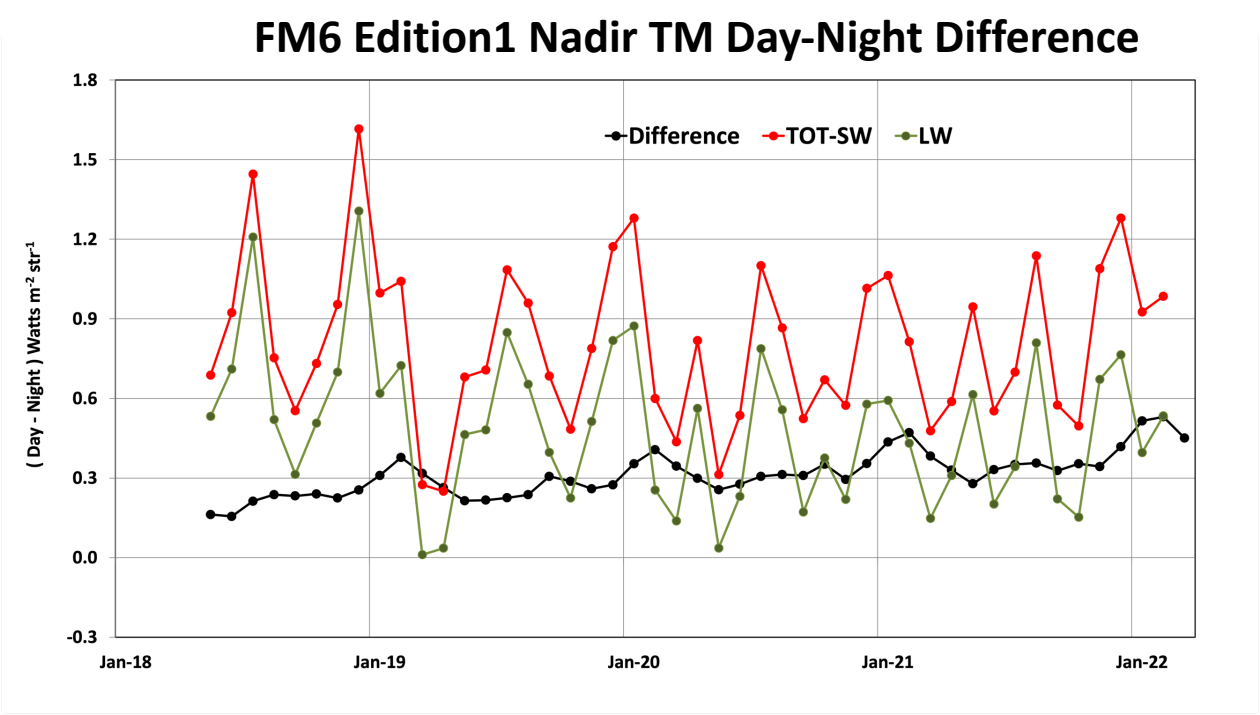
- Average of the ES-8 Nadir radiances over Tropical ocean (20^0N-20^0S) scenes under All-sky conditions.
- Two sets of TM Day-Night Differences (DN) are calculated:
  - TOT and SW sensors

    $DN = TM_D(TOT\text{-}SW) - TM_N(TOT)$
  - LW sensor

    $DN = TM_D(LW) - TM_N(LW)$
- Difference in the two DN values highlight any inconsistencies in the shortwave regions of the sensors.

Validation- FM6 Tropical mean Day-Night

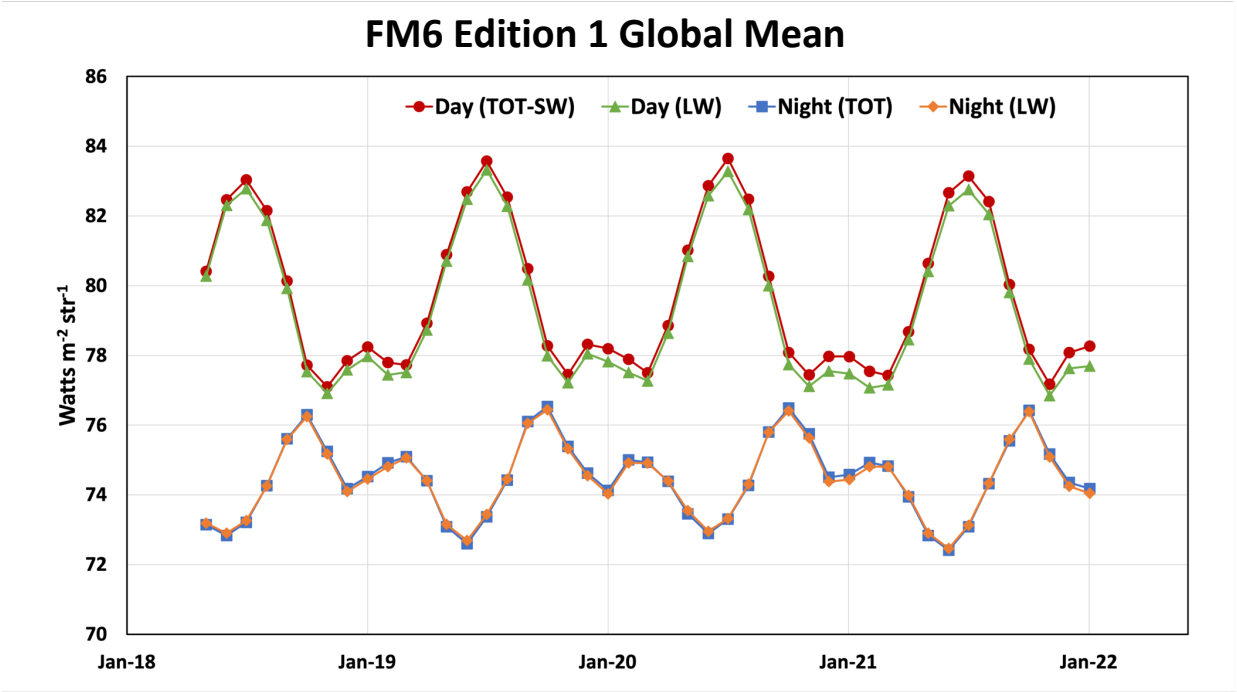


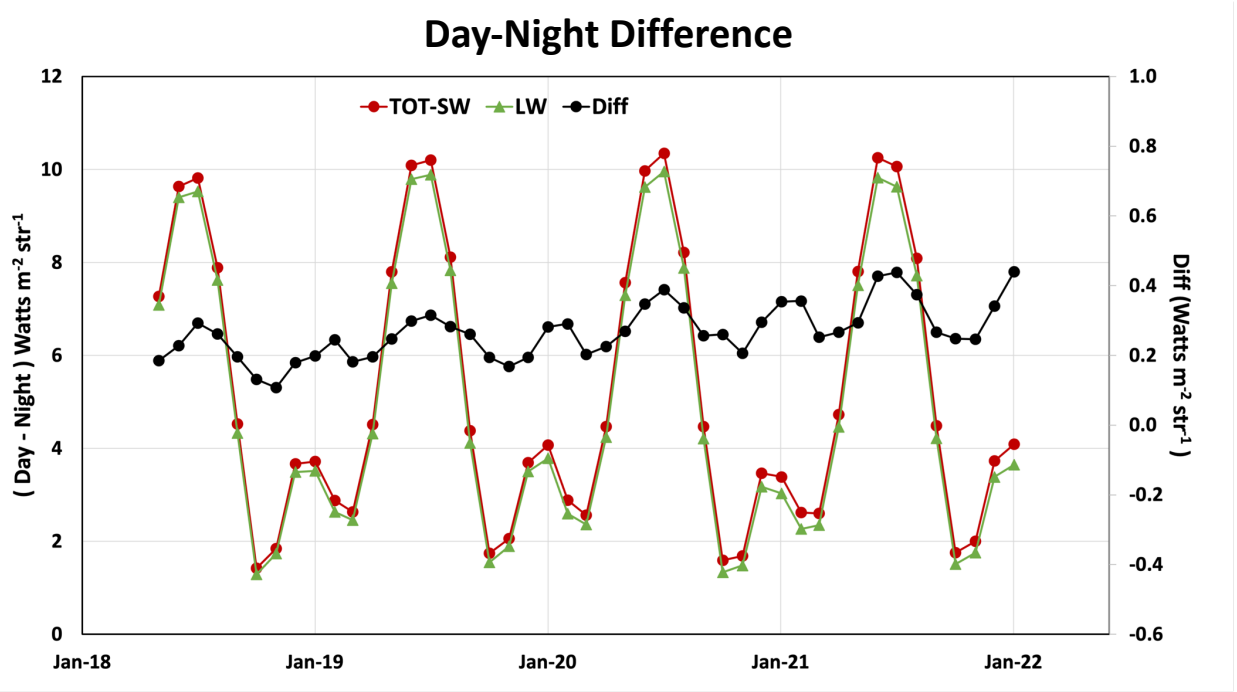


FM6 3-channel Consistency check- Global Day-Night Differences

May 2018 - Jan 2022

Edition 1 ES-8, Global, All-sky, Nadir Radiance





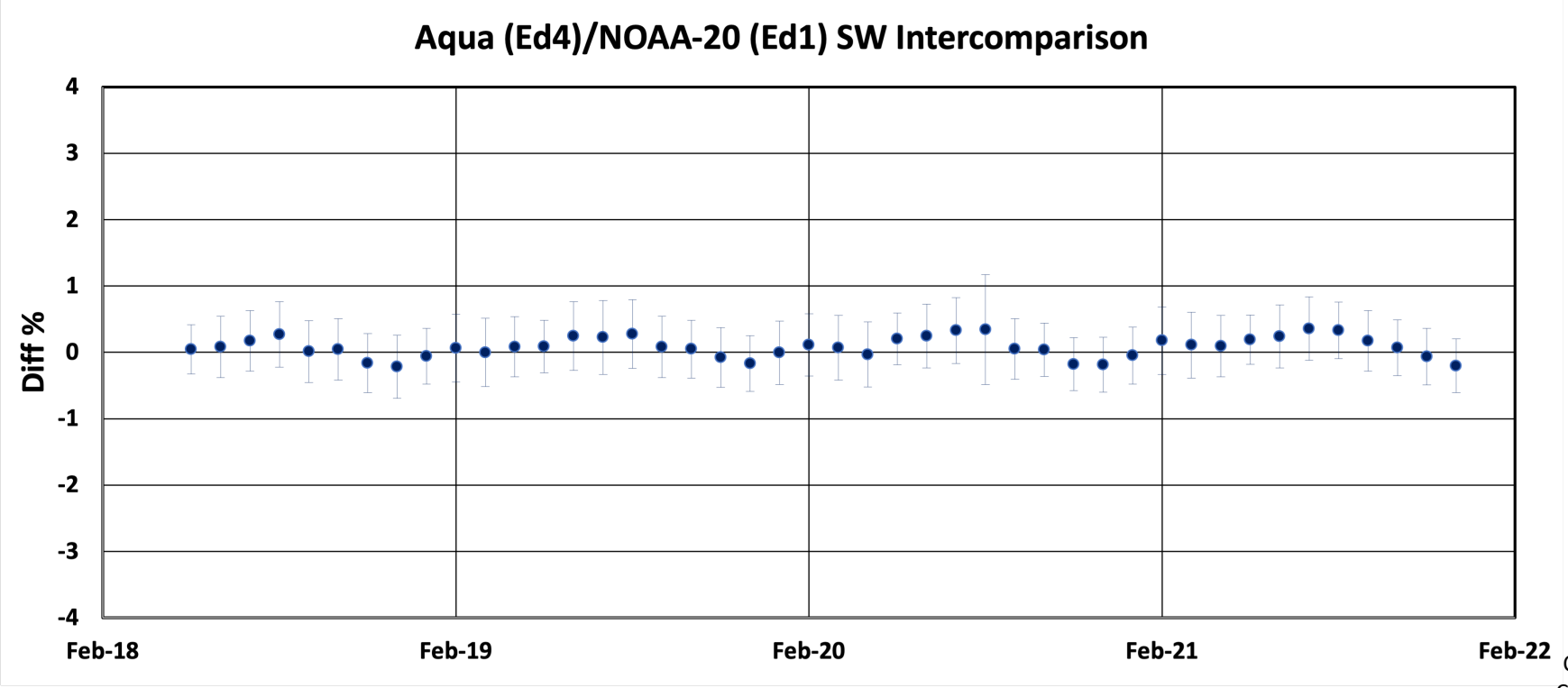
Aqua/NOAA-20 Intercomparisons

- 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.
- No special operations are conducted to match viewing geometries; Both instruments continue operating in cross-track mode.
- 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 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

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



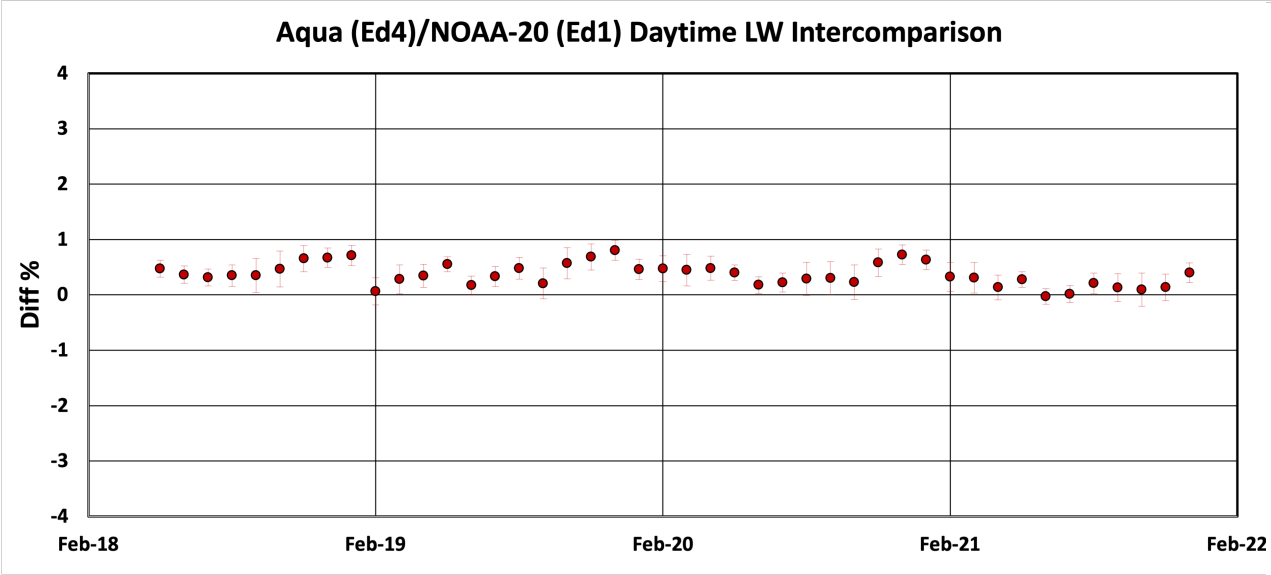
Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1B

Radiometric scaling of FM6 to FM3 done in May 2018.

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

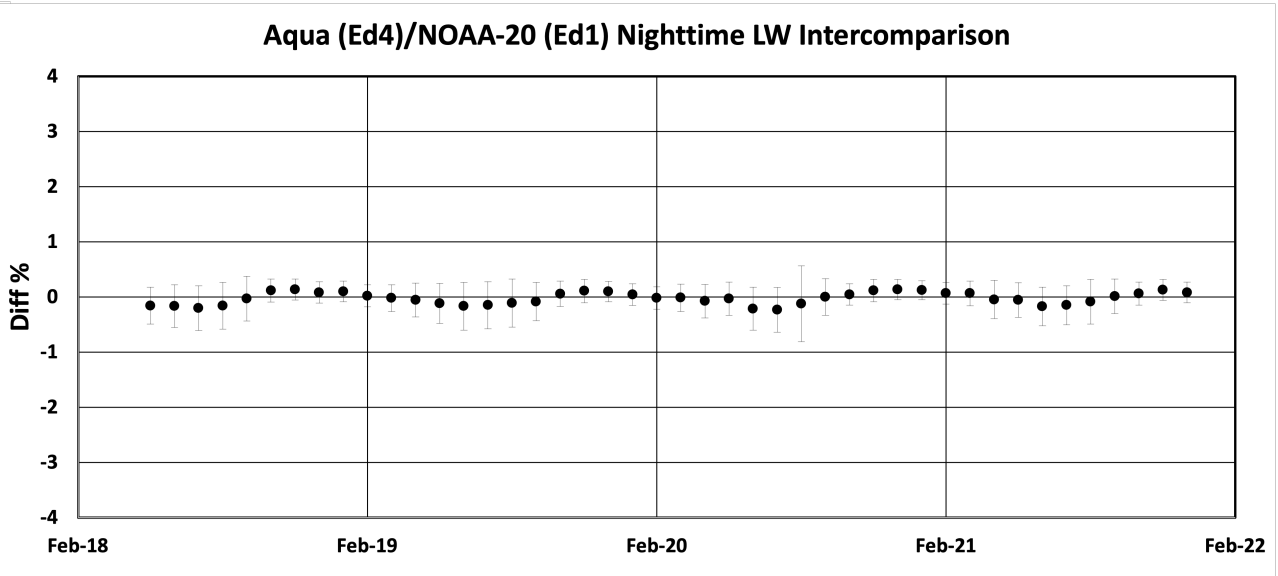
Difference of Daytime Radiance: FM3-FM6 %, 95% CI

Daytime LW for FM6 obtained from TOT-SW



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

Nighttime LW for FM6 obtained from TOT



Radiometric scaling of FM6 to FM3 done in May 2018.

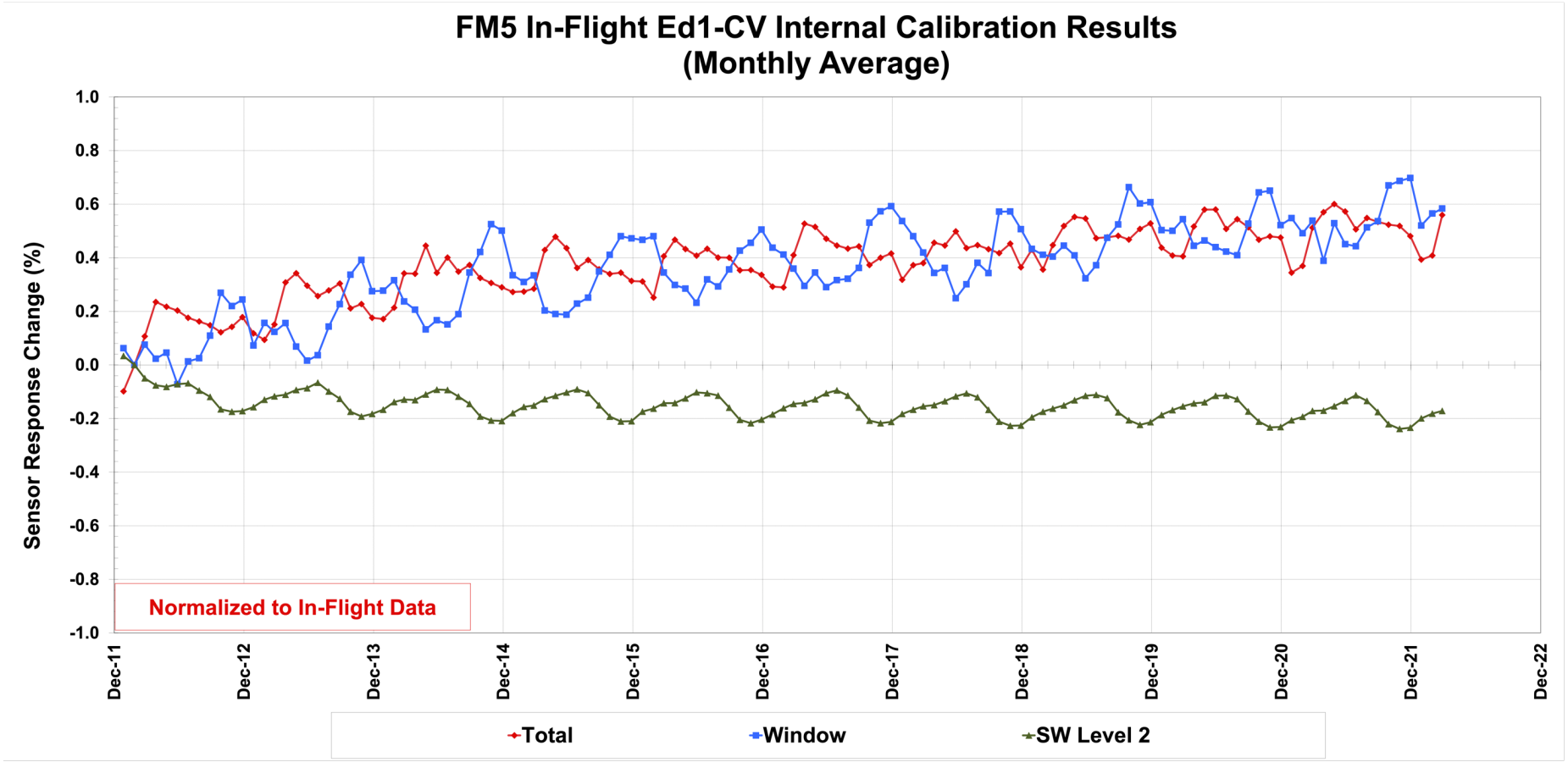
Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1B

S-NPP/FM5 Instrument Status

FM5 Internal Calibration

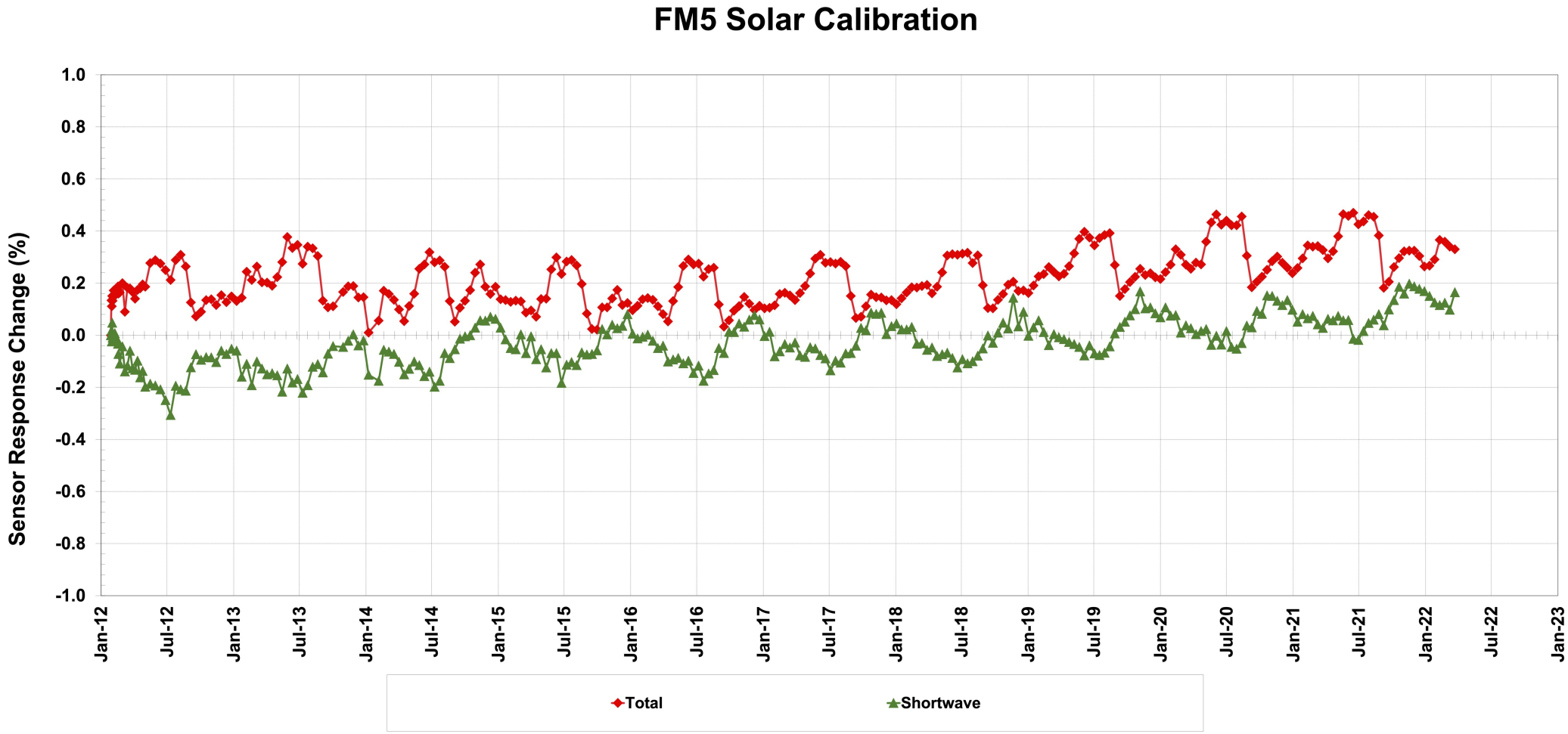
In response to the blackbodies, the FM5 TOT and WN sensors show a ~0.6% rise since start of mission.

SW channel's response to the SWICS is stable at ~-0.2% since start of mission.

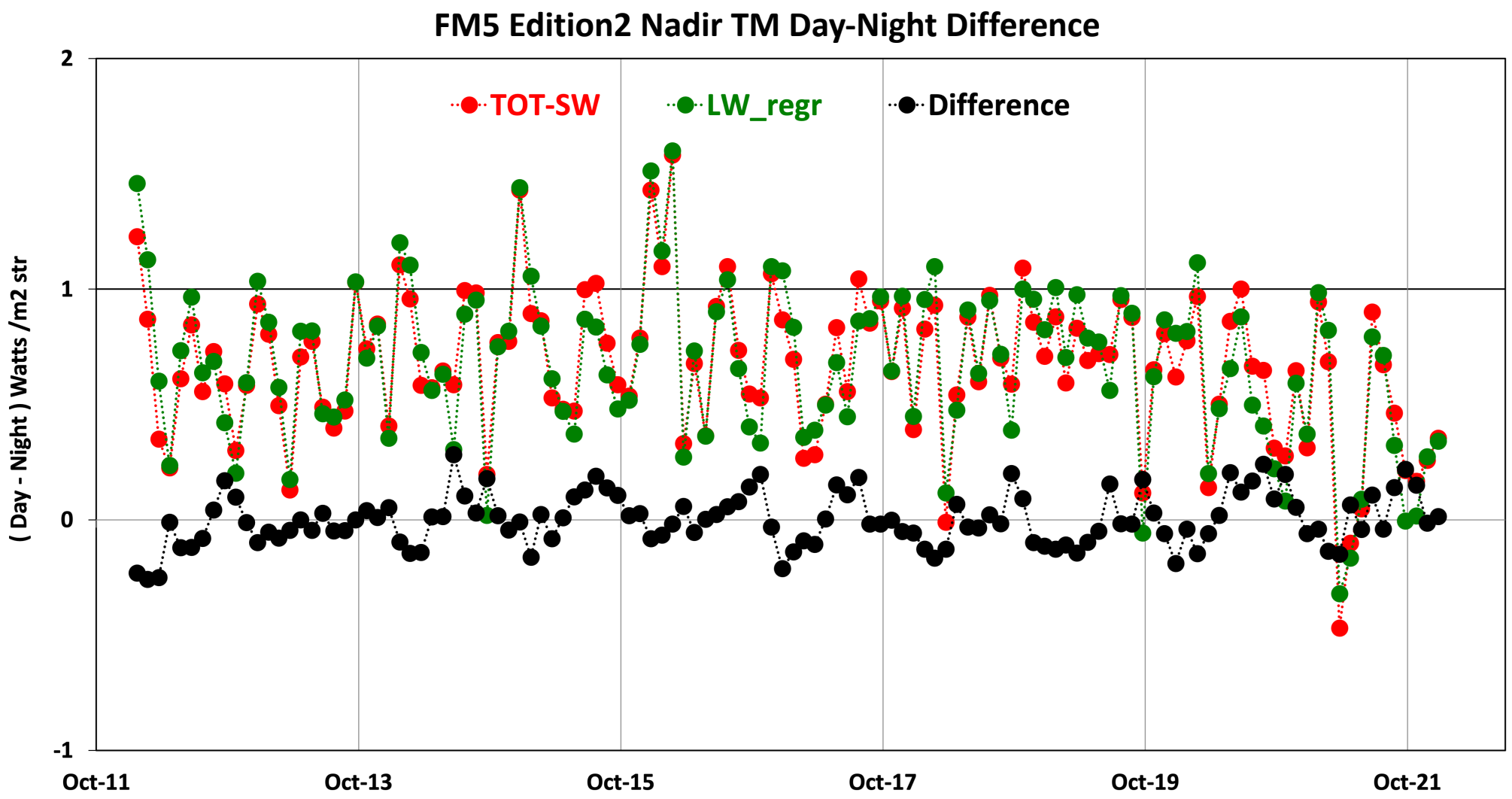


FM5 Solar Calibration

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



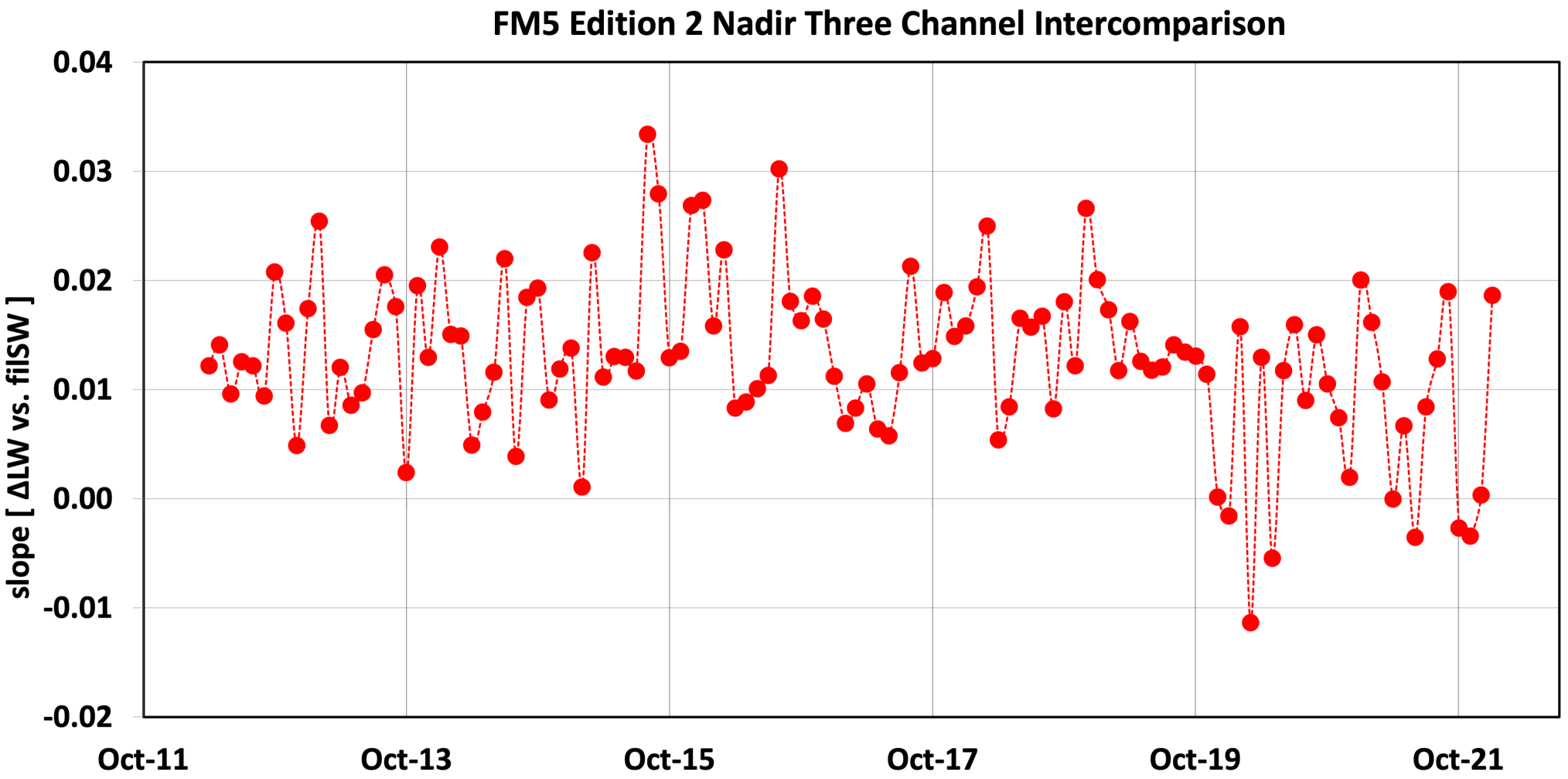
Validation- FM5 Tropical Mean



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

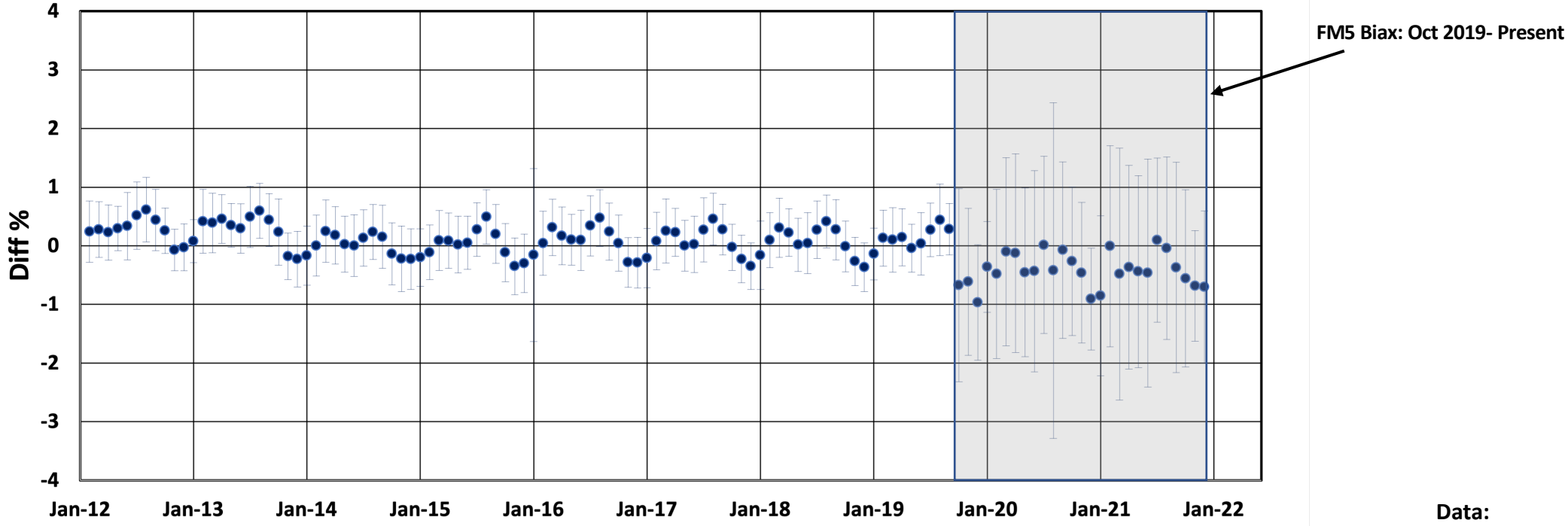
- The orbital geometries for Aqua and S-NPP are such that orbital overlaps occur every ~64 hours.
- Obtain spatially and temporally matched observations during every crossover.
- No special operations conducted; FM5 continues operating in biaxial mode.
- Use matching criteria to subset the data:
  - SZA, VZA difference < **2.0^0**
  - RAZ difference < **5^0**
  - Distance between footprints **< 7 km**
- 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

$$Reflectance = \frac{SW_{rad} * \pi}{F * \cos(SZA)}$$ F=1361 W/m²

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



2014 data used for the radiometric scaling FM5 to FM3.

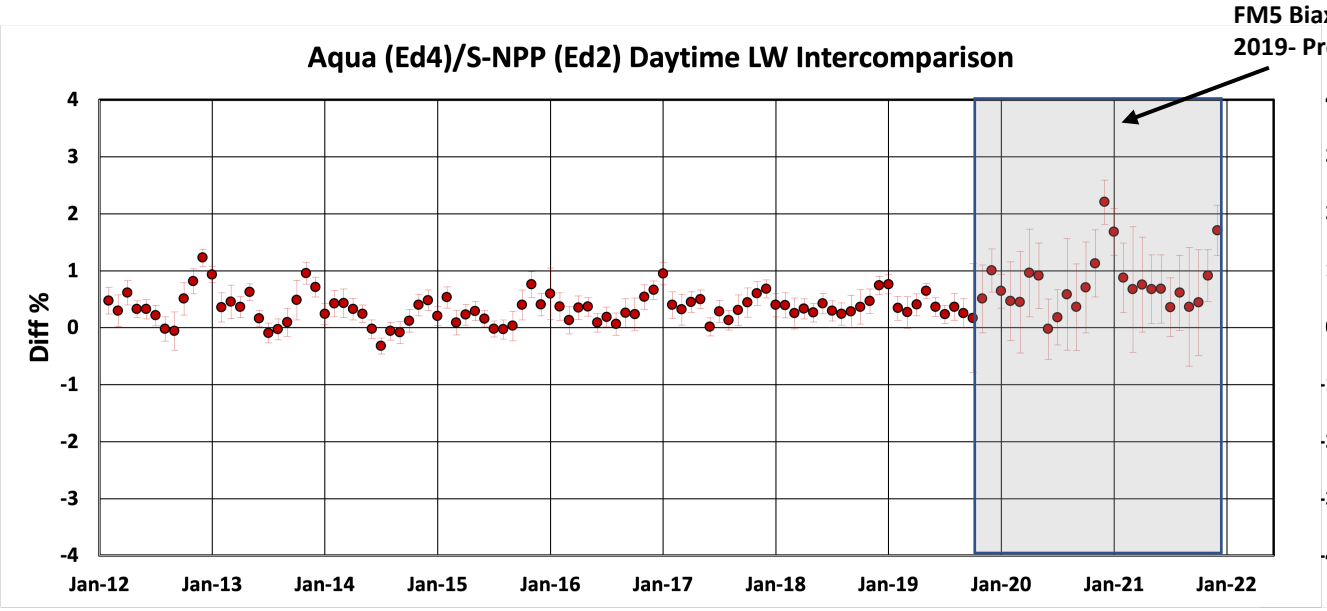
Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM5-VIIRS_Edition2A

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

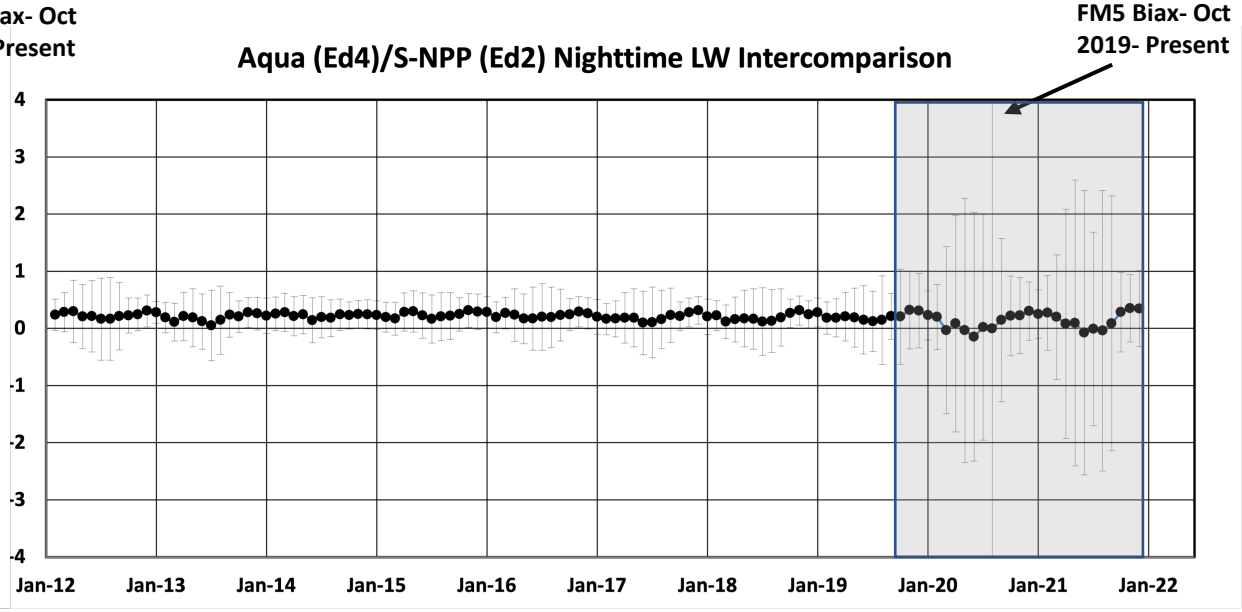
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FM3/FM5 LW All-sky Inter-comparisons: Feb 2012- Dec 2021

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



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



2014 data used for the radiometric scaling FM5 to FM3.

Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM5-VIIRS_Edition2A

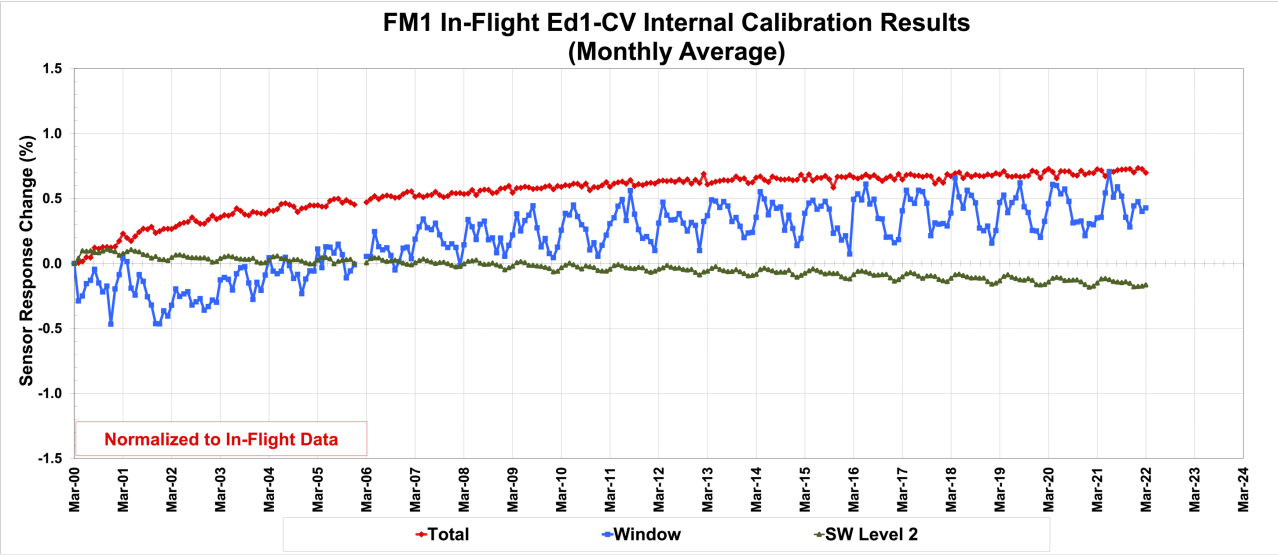
Larger differences observed after FM5 switched to biaxial mode are driven by the drastic reduction in number of spatially and temporally matched observations.

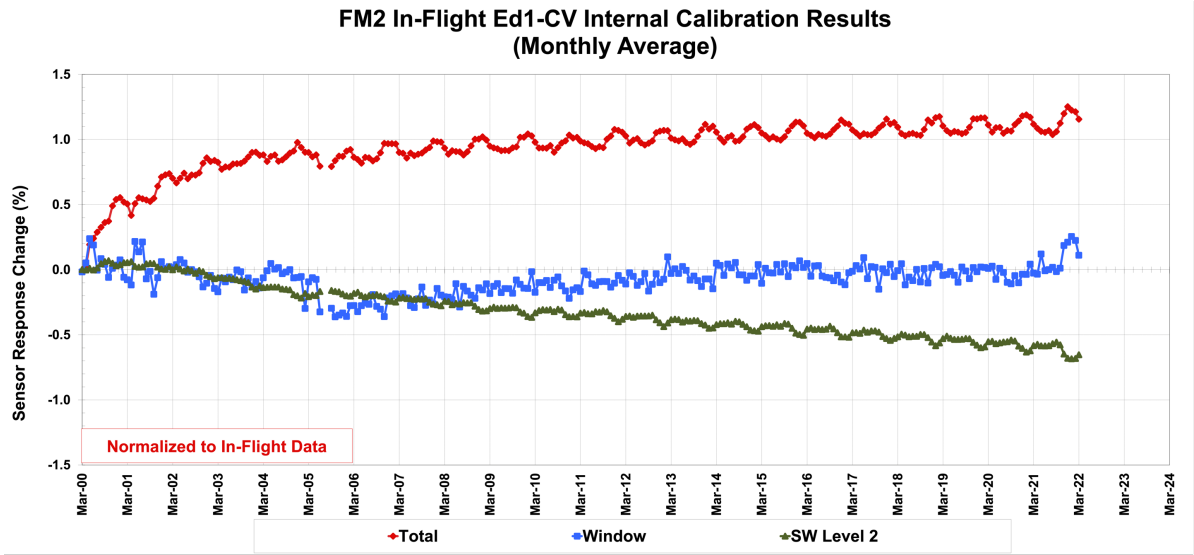
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Terra & Aqua
FM1-FM4 Instruments' Status

Terra- FM1 & FM2 Internal Calibration

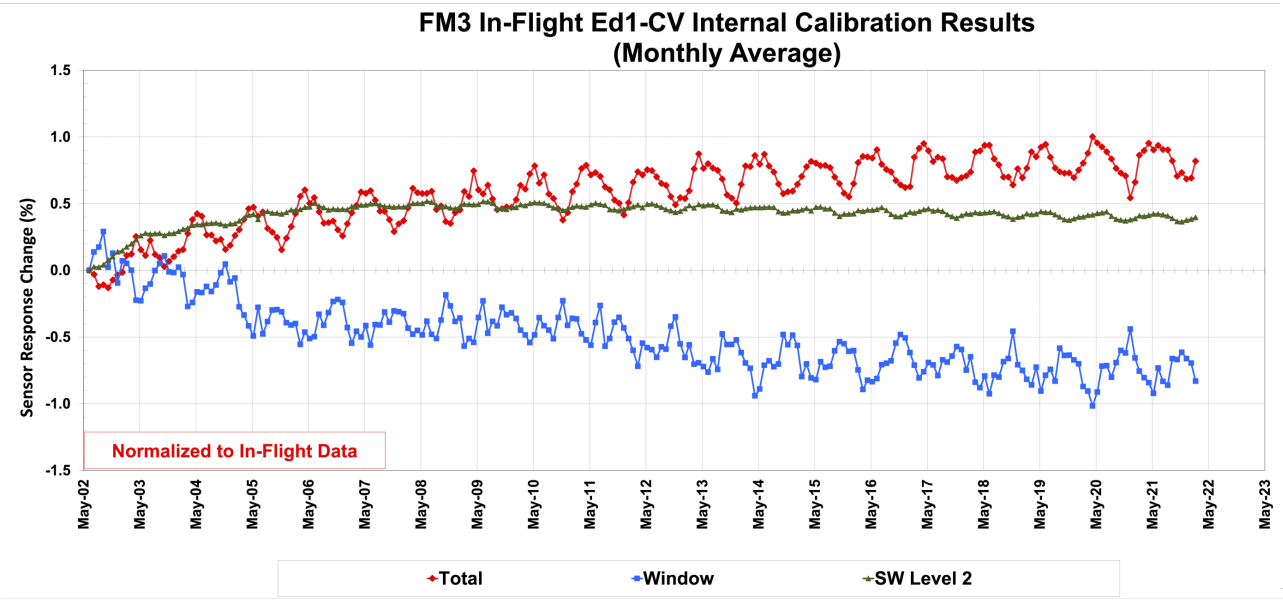
- **For FM1, TOT channel shows ~0.7% rise, SW channel shows ~0.1% drop, and WN channel shows a rise of ~0.4% since start of mission.**
- **For FM2, TOT channel shows ~1.2% rise, SW channel shows ~0.6% drop, while WN channel shows ~0% change since start of mission.**

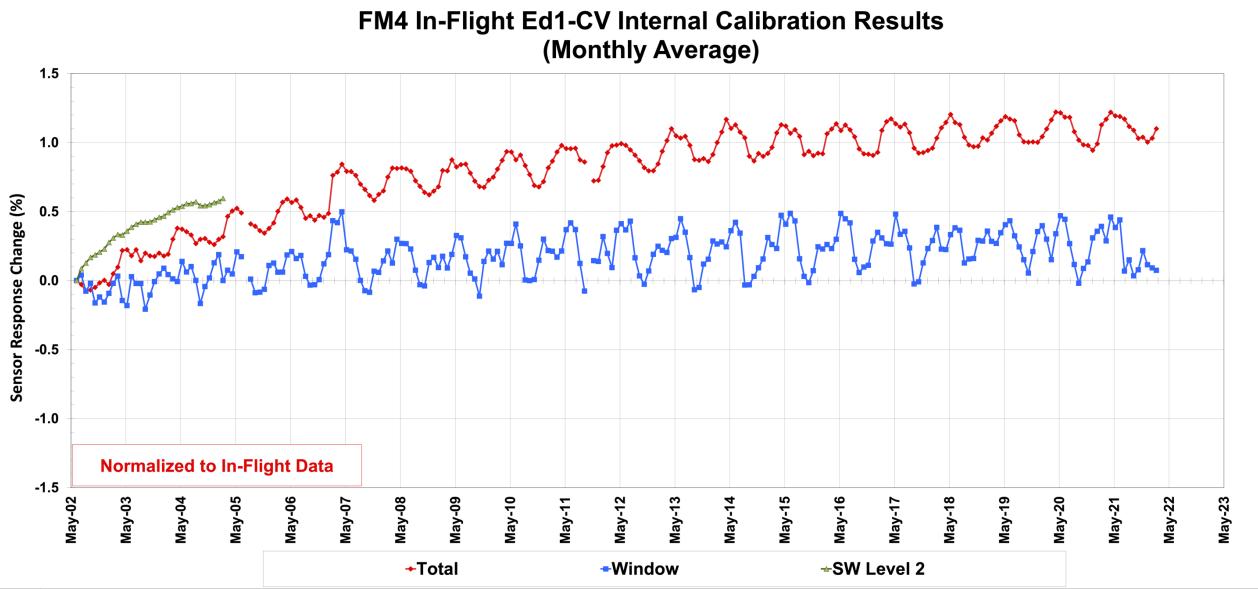




Aqua- FM3 and FM4 Internal Calibration

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

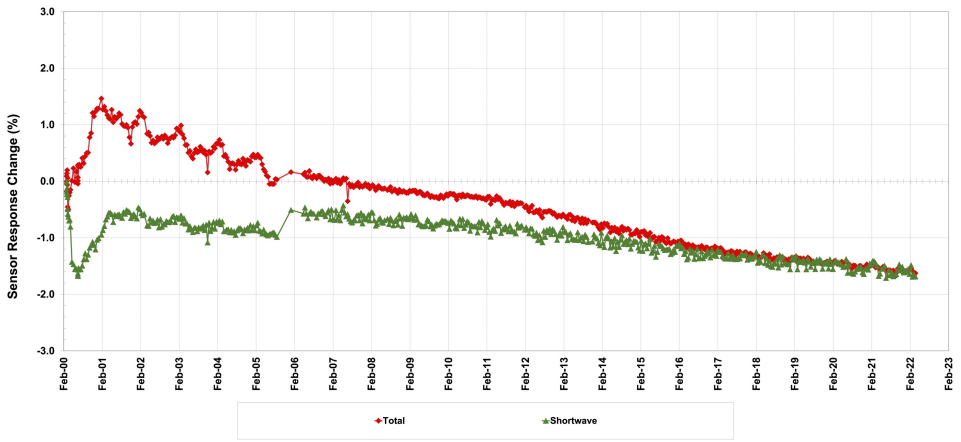




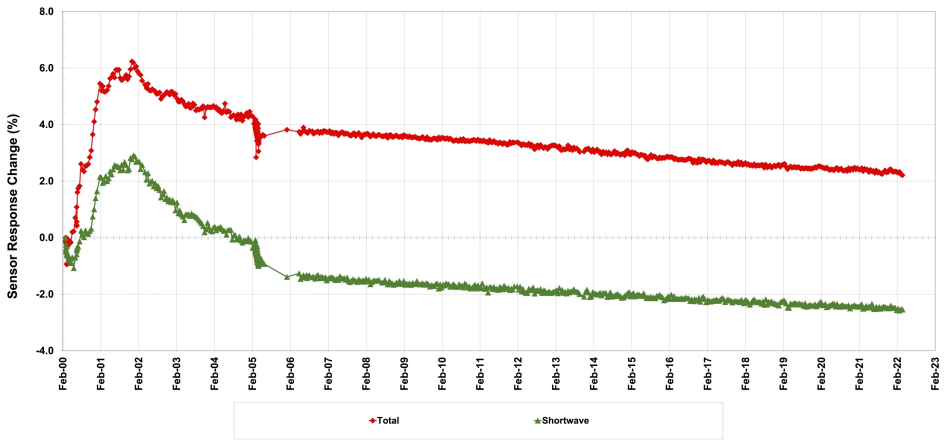
Terra & Aqua Solar Calibration

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

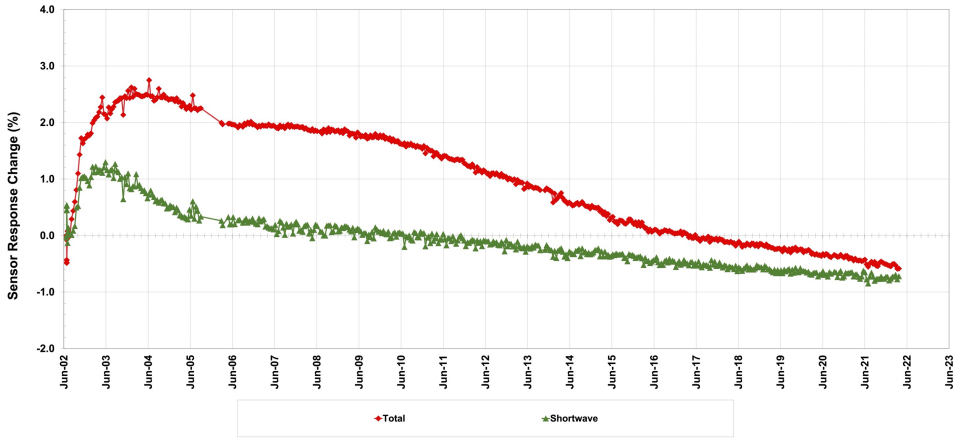
FM1 Solar Calibration



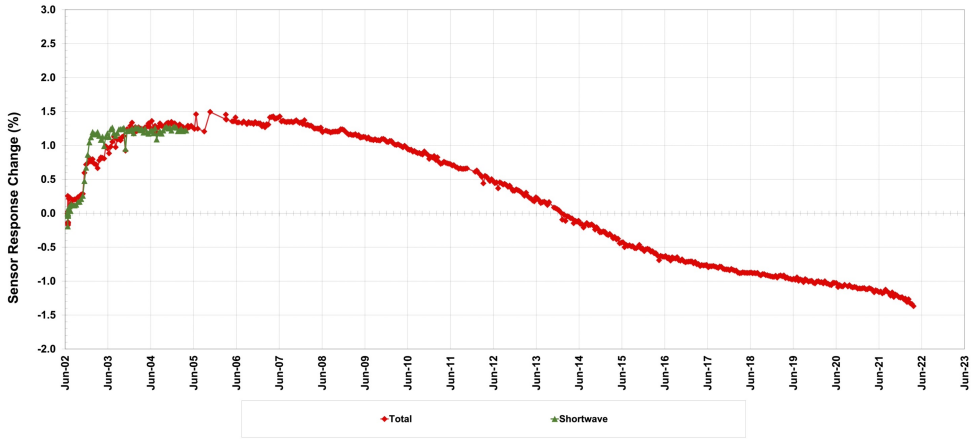
FM2 Solar Calibration



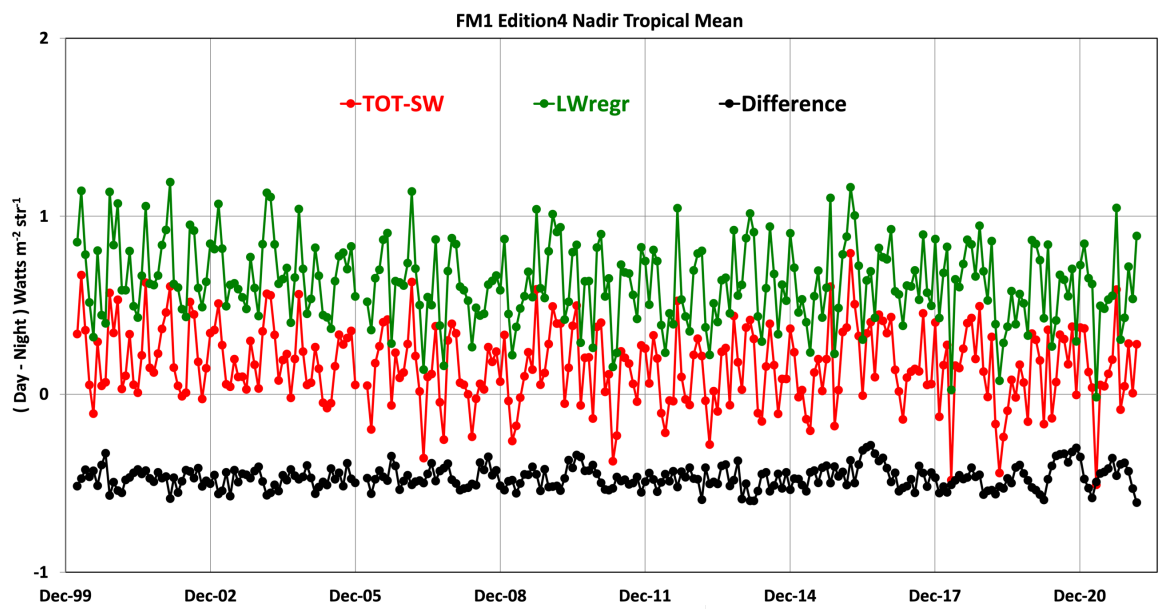
FM3 Solar Calibration

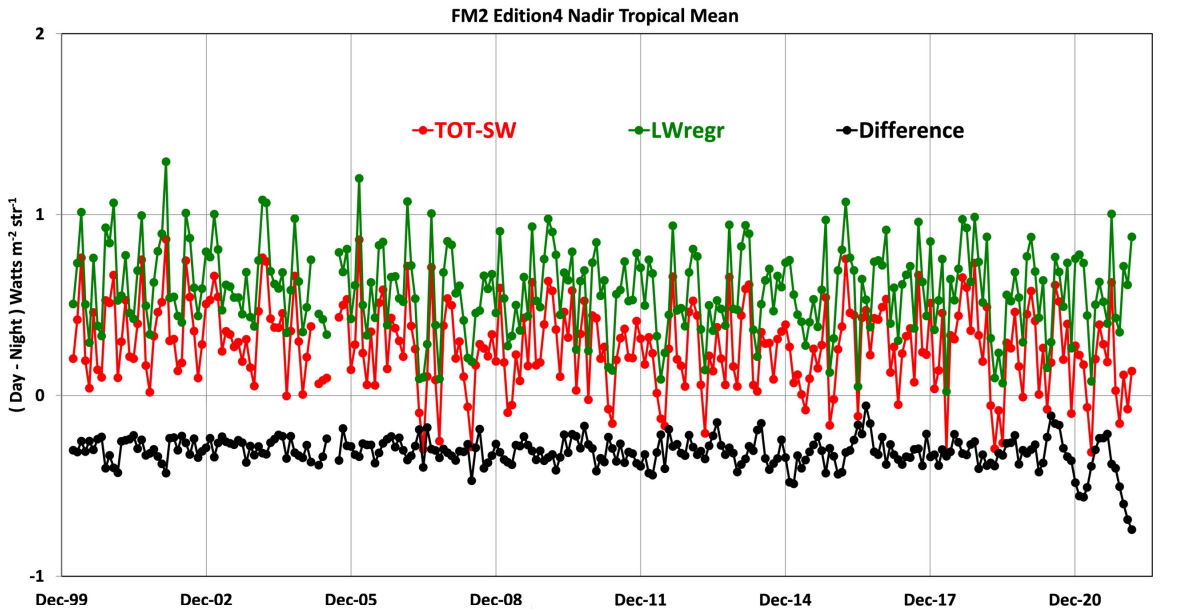


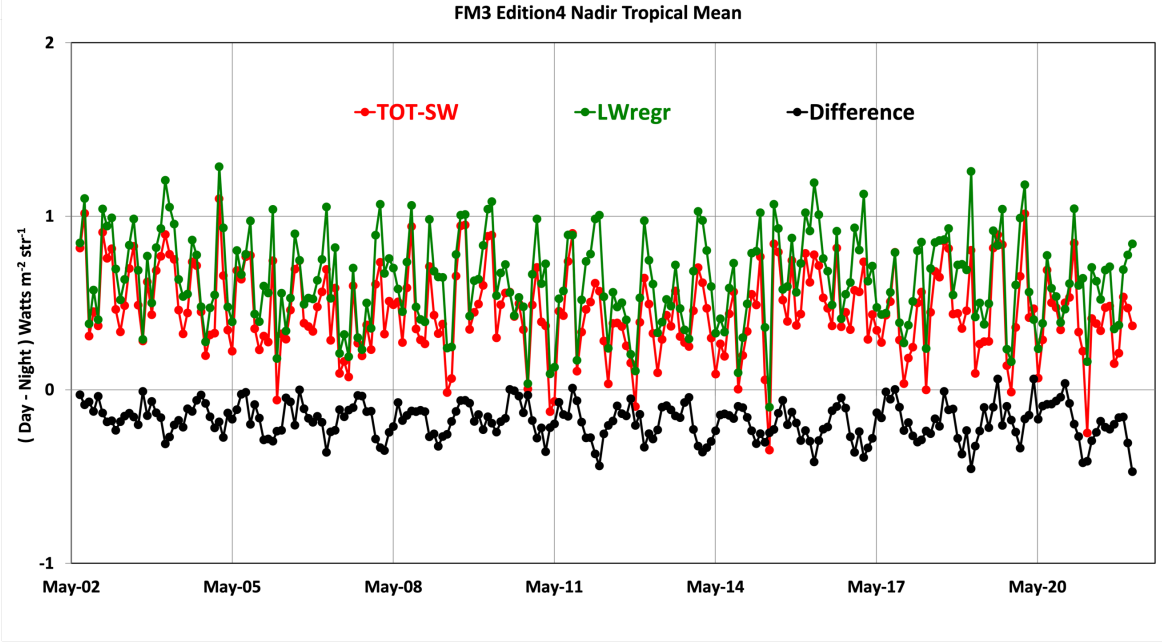
FM4 Solar Calibration



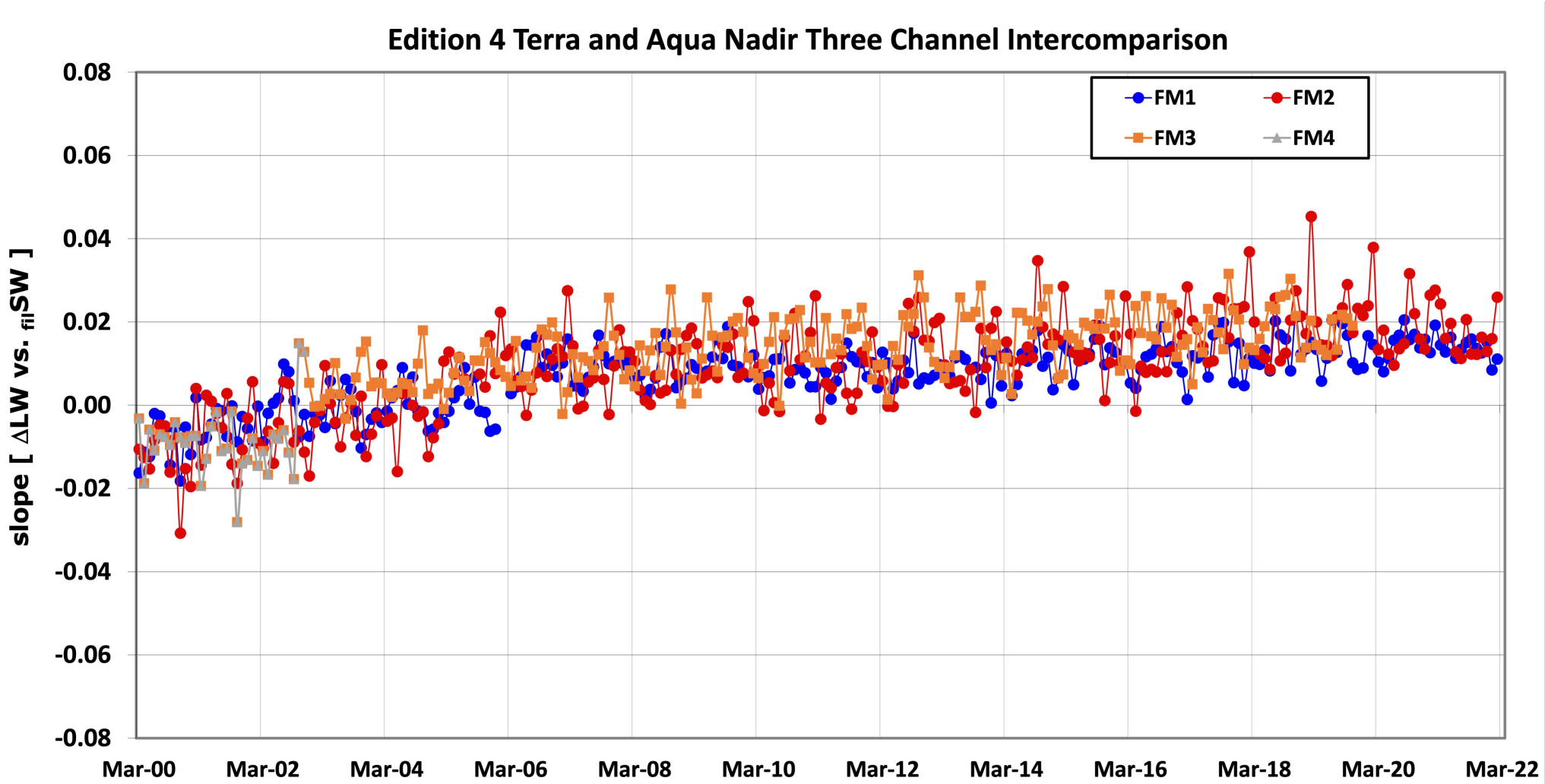
Validation- Terra and Aqua Tropical Mean



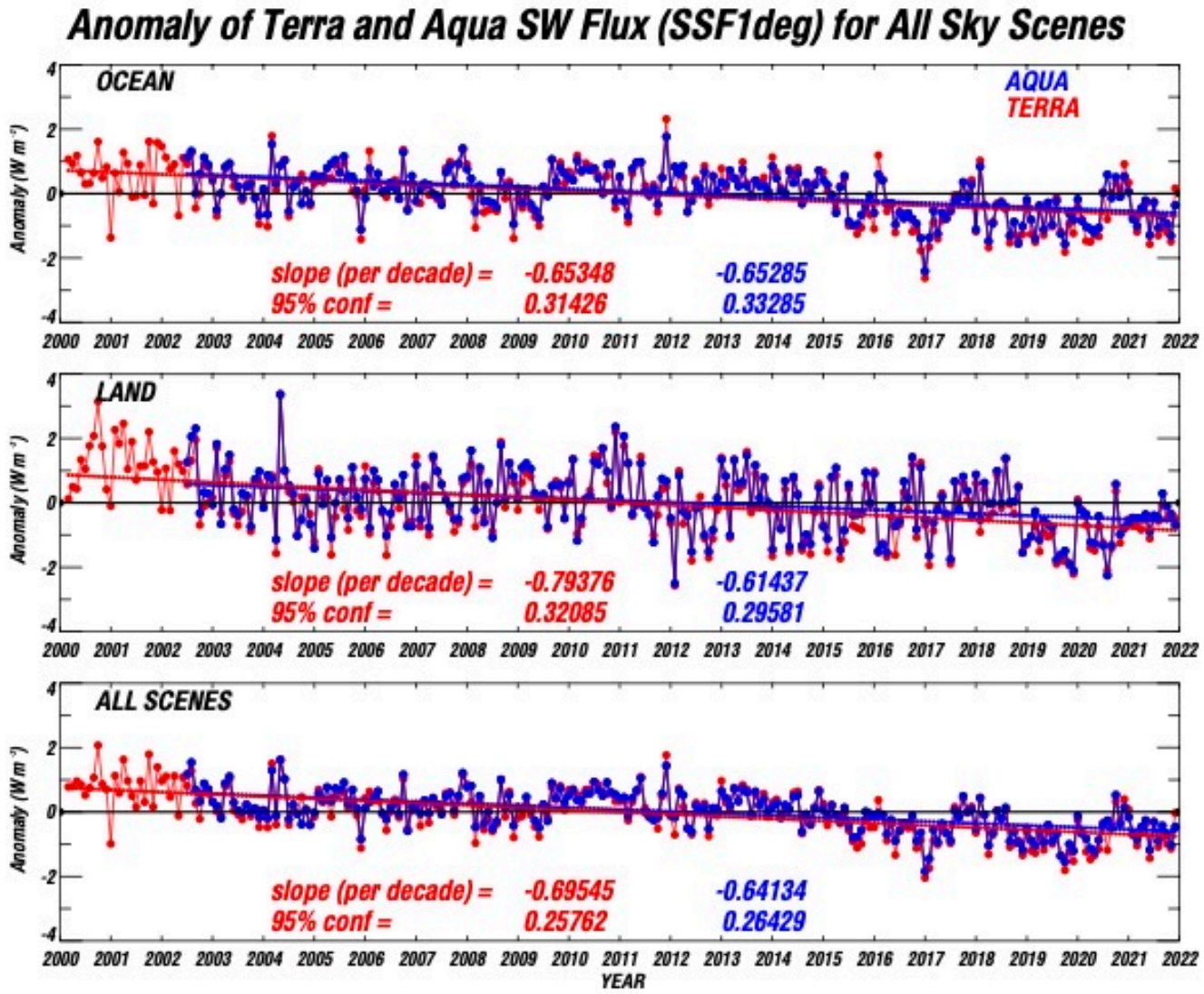




Validation- DCC 3-Channel Intercomparison



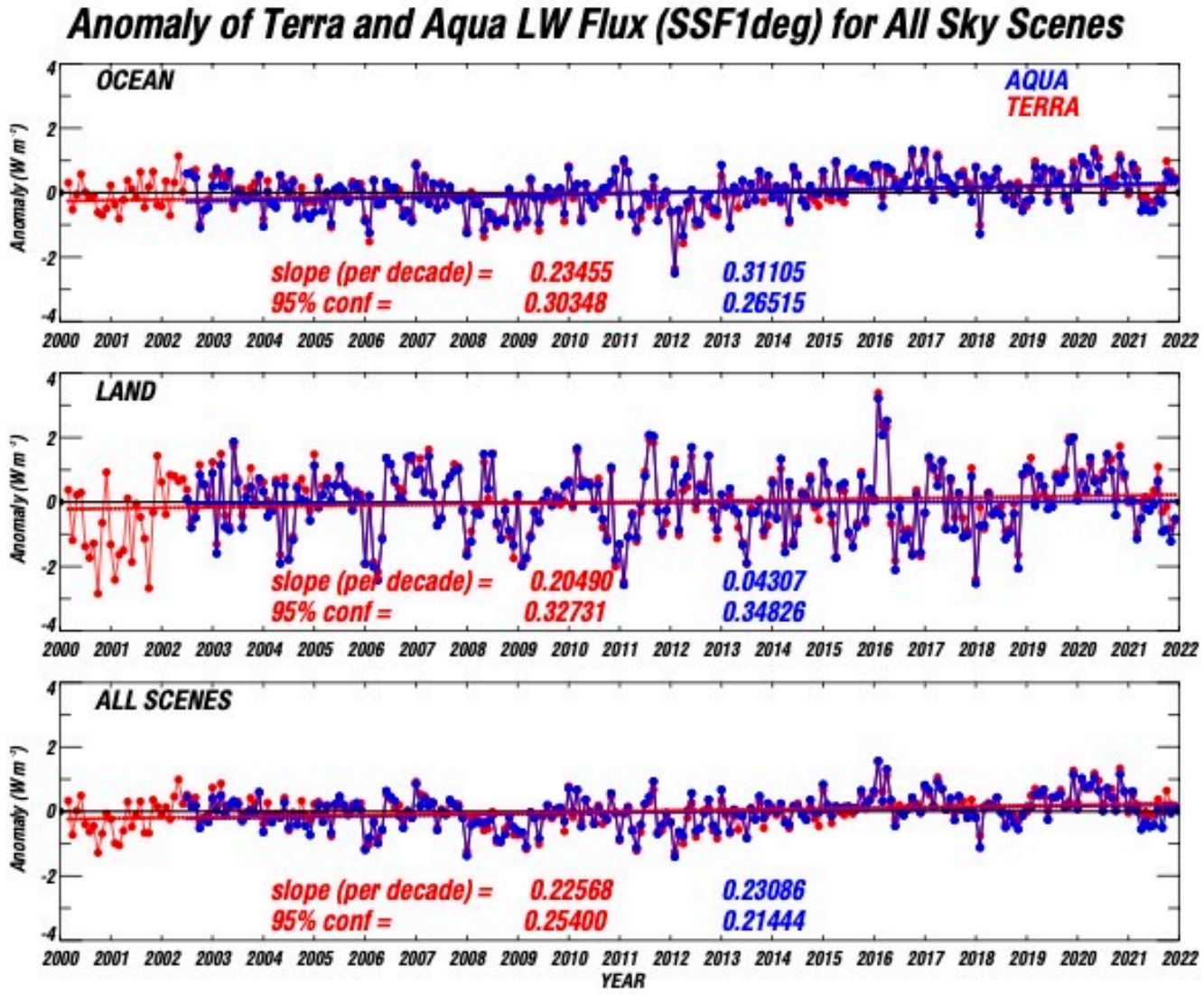
Validation: Terra and Aqua Ed-4 SW Flux Anomalies



SW flux anomalies show similar trends for Terra and Aqua

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Validation: Terra and Aqua Ed-4 LW Flux Anomalies



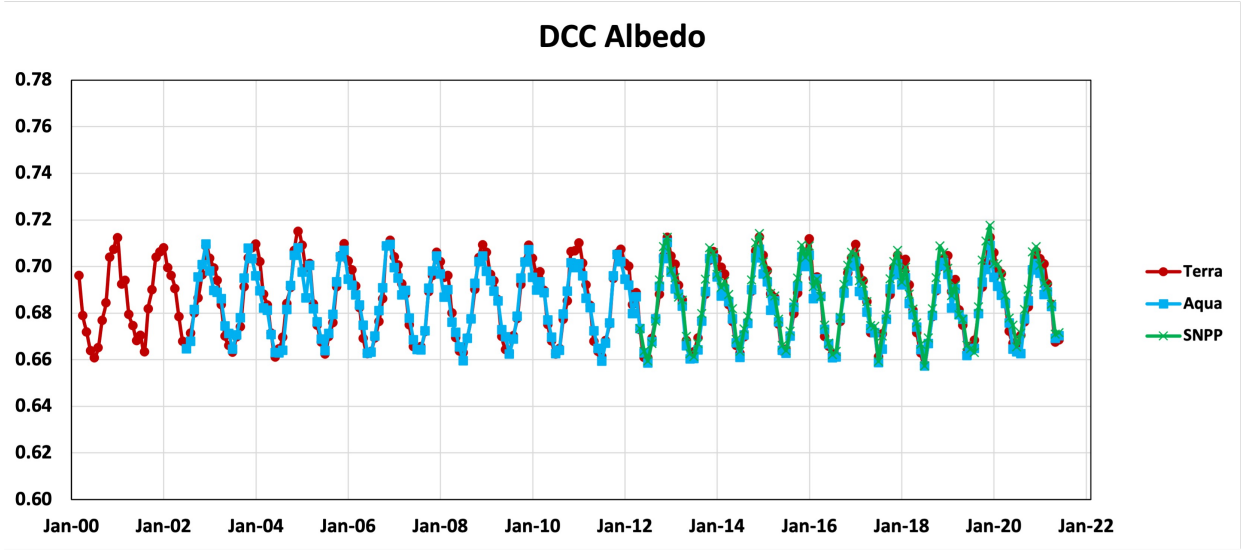
LW flux anomalies show similar trends for Terra and Aqua.

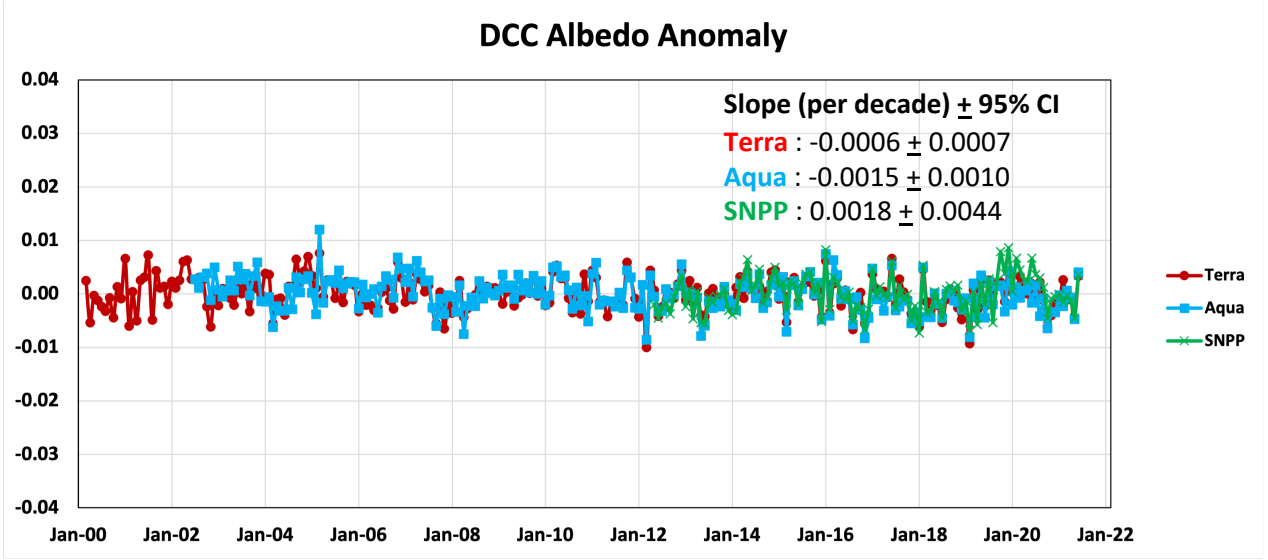
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Validation: DCC Albedo

- Observe the long-term trends of DCC albedo.
  - Uses Level-2 products (SSF), calculate monthly means of DCC footprints.
  - Trend the DCC albedos for instruments on Terra, Aqua, S-NPP.
- For Terra and Aqua, consider data from instruments operating in cross-track mode.
- Criteria for selecting DCC:
  - Consider all footprints with VZA, SZA < 40 deg.
  - Latitude bands: 30^0 N-S, Over Ocean.
  - Cloud Fraction= 100%.
  - Use MODIS/VIIRS 11um channel to identify footprints with brightness temperature <210K.
  - WN channel filtered radiance < 1 $Wm^{-2}sr^{-1}um^{-1}$.

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, with no significant long-term trends.

Slope (per decade) ± 95% CI
Aqua-Terra: -0.0007 ± 0.0012
SNPP-Terra: 0.0025 ± 0.0028
SNPP-Aqua: 0.0034 ± 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

CERES Instrument Working Group

SUMMARY

- **All CERES instruments continue to perform nominally.**
  - **NOAA-20/FM6 instrument on-board calibrations continue to show the sensors' stable performance after the initial response rise.**
  - **SNPP/FM5 is currently operating in full biaxial mode, collecting ADM data.**
    - ***No evidence of deviation of instrument performance since transitioning to biaxial mode.***
  - **Validations show that all instruments are performing consistently.**
    - ***Validation using long-term DCC albedos : FM1-FM5 show consistent and stable performance.***
- **Data products**
  - **NOAA-20/FM6 Edition 1 gains have been finalized and delivered through Aug 2022.**
  - **S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Aug 2022.**
  - **Terra and Aqua instruments' Edition 4 gains and SRFs have been delivered through Jul 2022.**
- **Members of the IWG continue to engage with the Libera team through bi-weekly Cal/Val Working group meetings.**

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.