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

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CERES Instrument Working Group

CERES Spring Science Team Meeting
May 11, 2021

CERES Instrument Working Group

CERES Instrument Working Group

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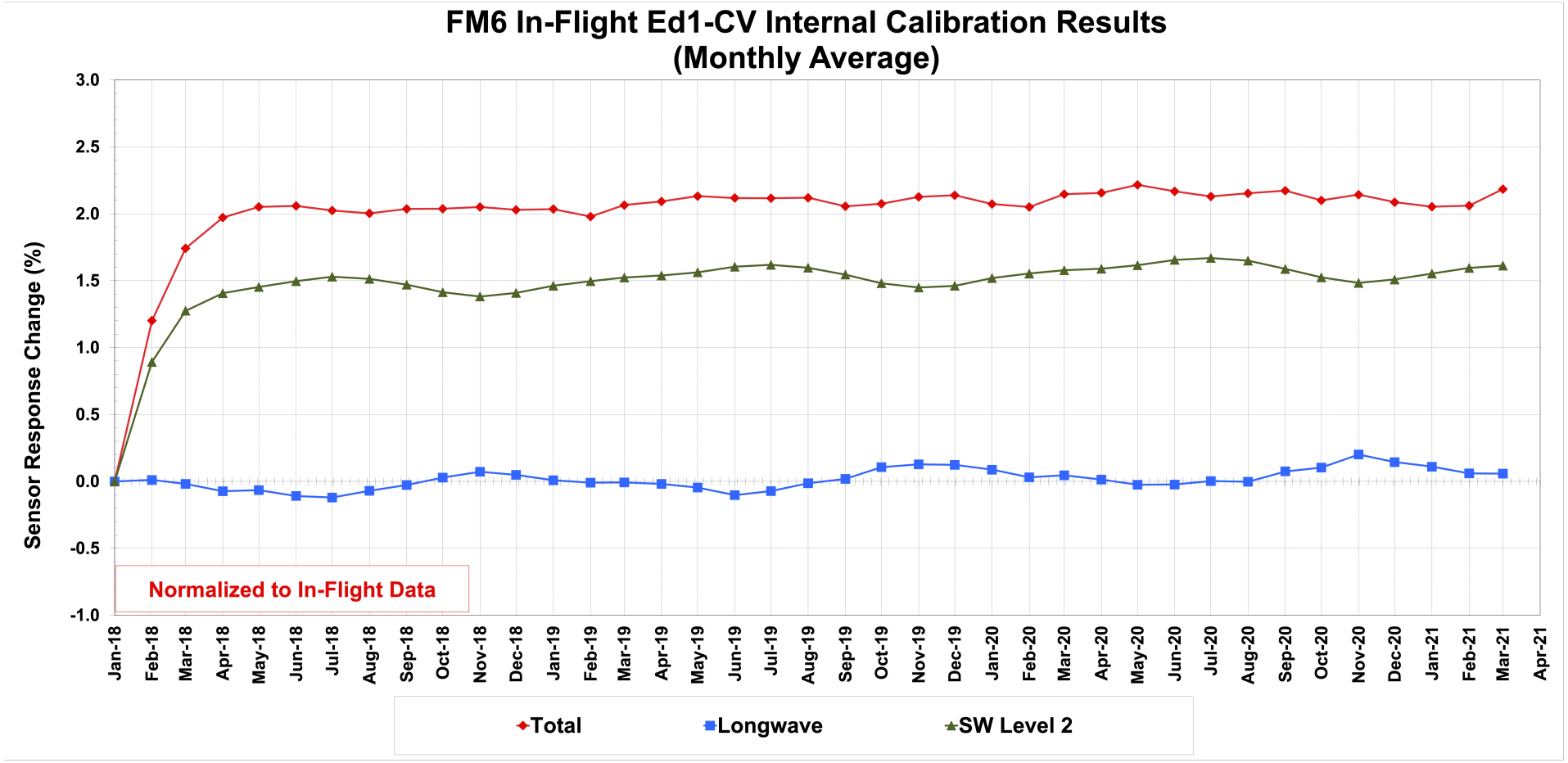
- **Flight Models (FM) 1-4, FM6 are operating in Crosstrack mode.**
- **FM5 is operating in Full Biaxial mode since Mar 23, 2020.**
- **Planning and testing ongoing in preparation for Aqua Deep Space Cal in Fall 2021.**
- **Planned/ongoing inter-comparison operations in 2021:**
  - Terra/FM1 – S-NPP/FM5: May 1 – Jul 31, 2021
  - Terra/FM1 – NOAA-20/FM6: May 1 – Jul 31, 2021
  - Terra/FM1 – Aqua/FM3: Jun 1 – 30, 2021
  - Terra/FM2 – GERB: Jun 1 – 30, 2021

Overpass region around 70^0 N

NOAA-20/FM6 Instrument Status

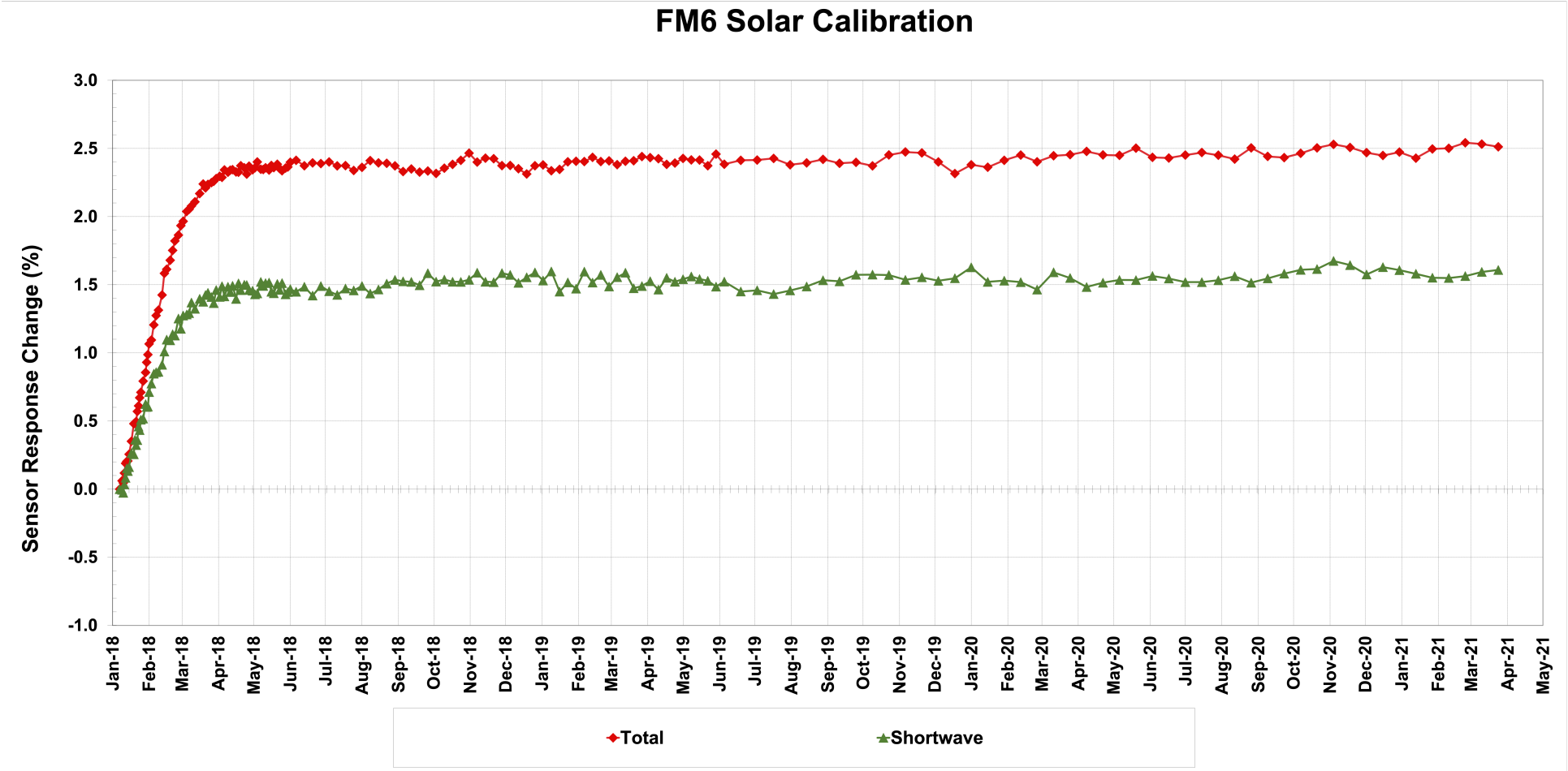
FM6 Internal Calibration

- **For SW and TOT channels, the responses to the on-board sources (SWICS lamp and Blackbodies) continue to be 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.**



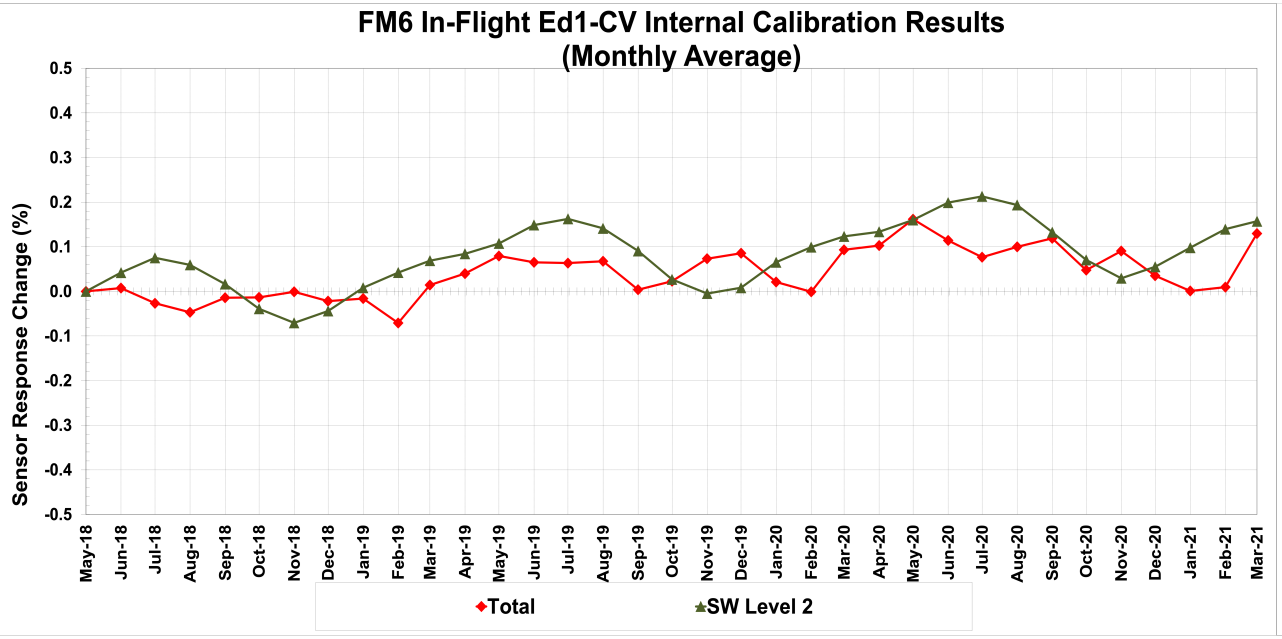
FM6 Solar Calibration

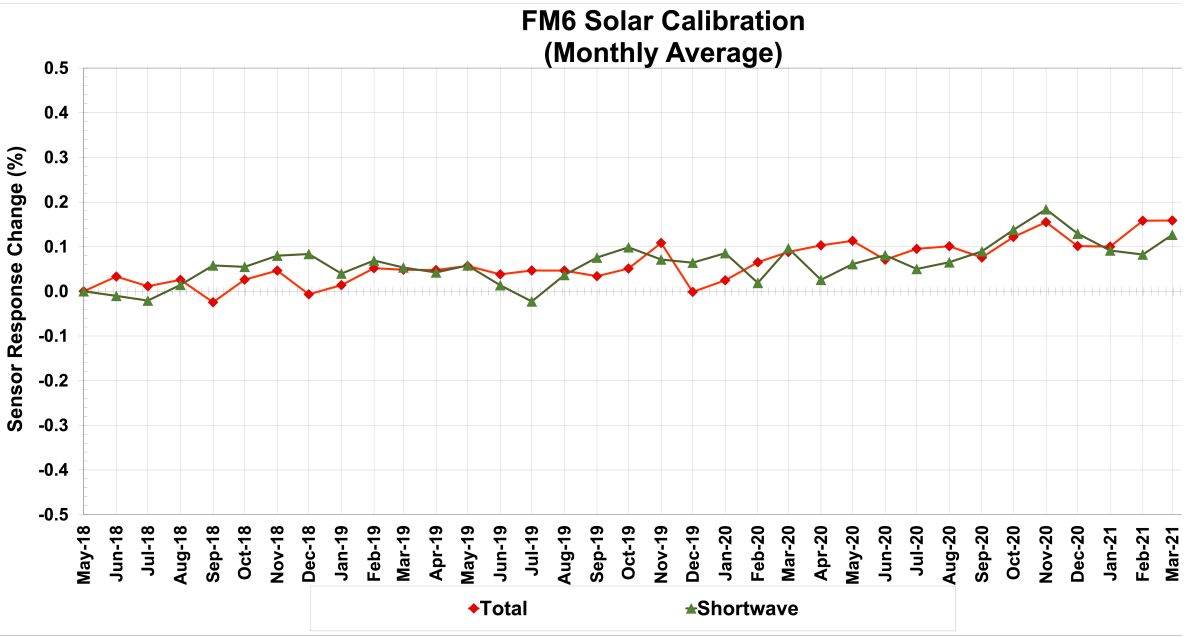
- **Response of the SW and TOT channels while viewing the MAM that is illuminated by the sun.**
- **After the initial rise of ~1.5% for SW, and ~2.3% for TOT, the response is very stable.**



FM6 Calibration- Internal and Solar Cal Since May 2018

FM6 Internal and solar calibration results show consistently very little change (~0.1%) since May 2018.





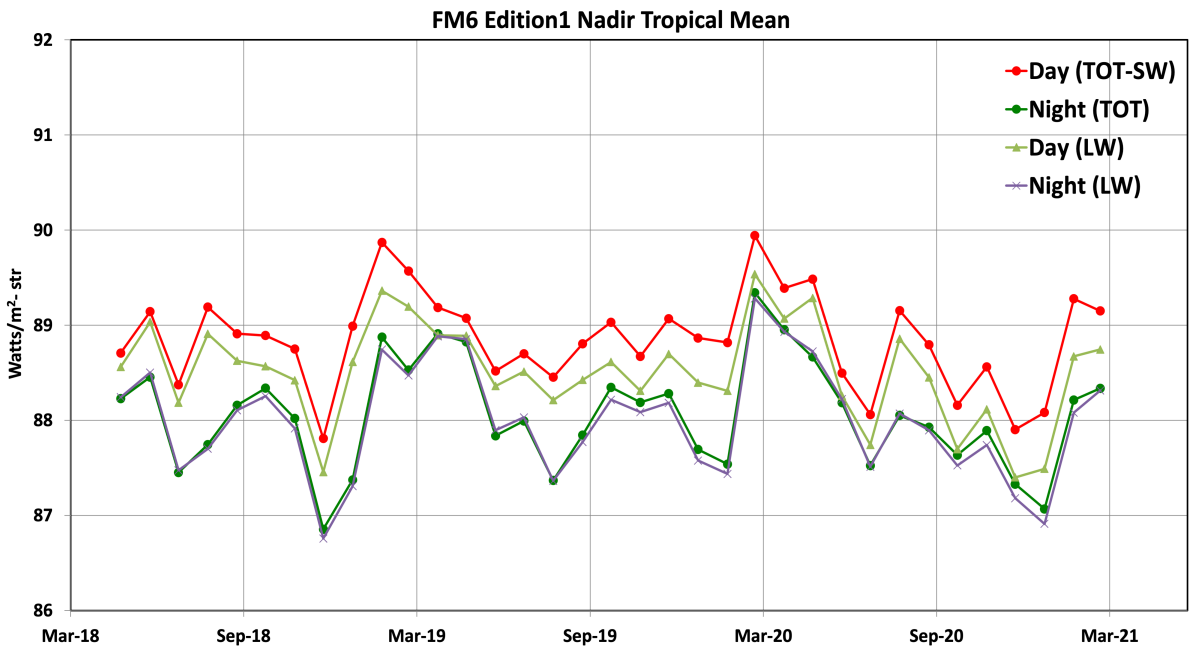
Validation – Tropical Mean

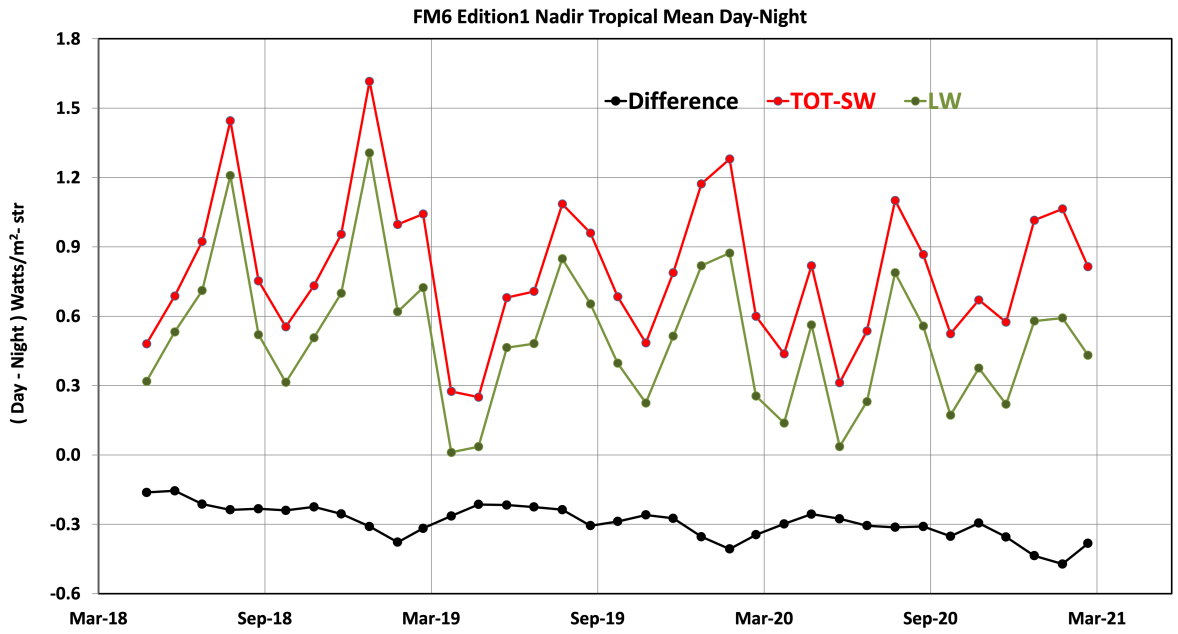
- Average of the ES-8 Nadir radiances over Tropical ocean (20^0N-20^0S) scenes under All-sky conditions.
- Two sets of TM Day-Night Differences (DN) are calculated:
  - TOT and SW sensors

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

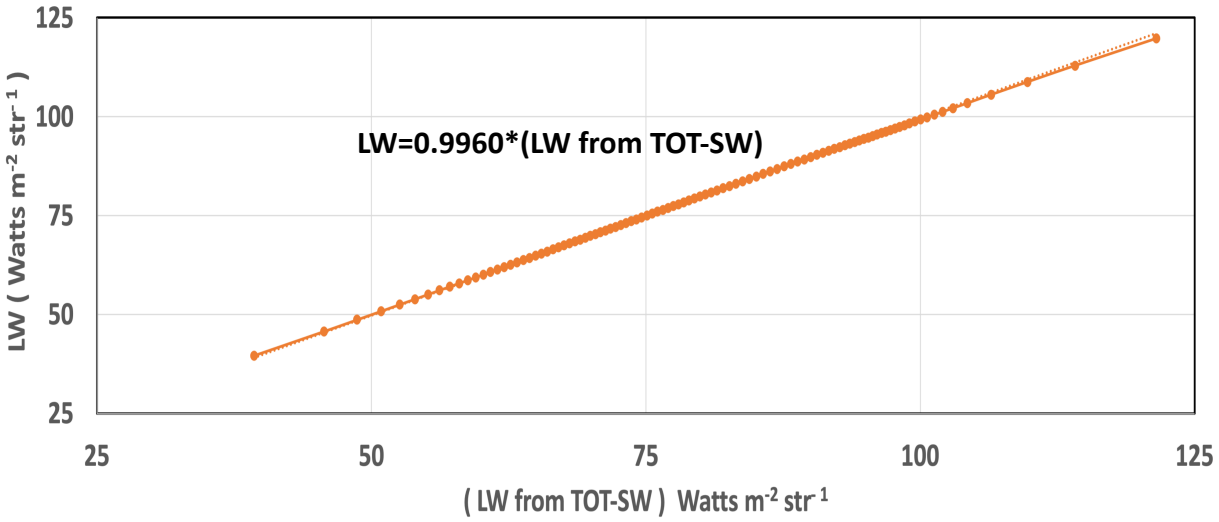




FM6 3-channel Consistency check- Global LW Day and Night

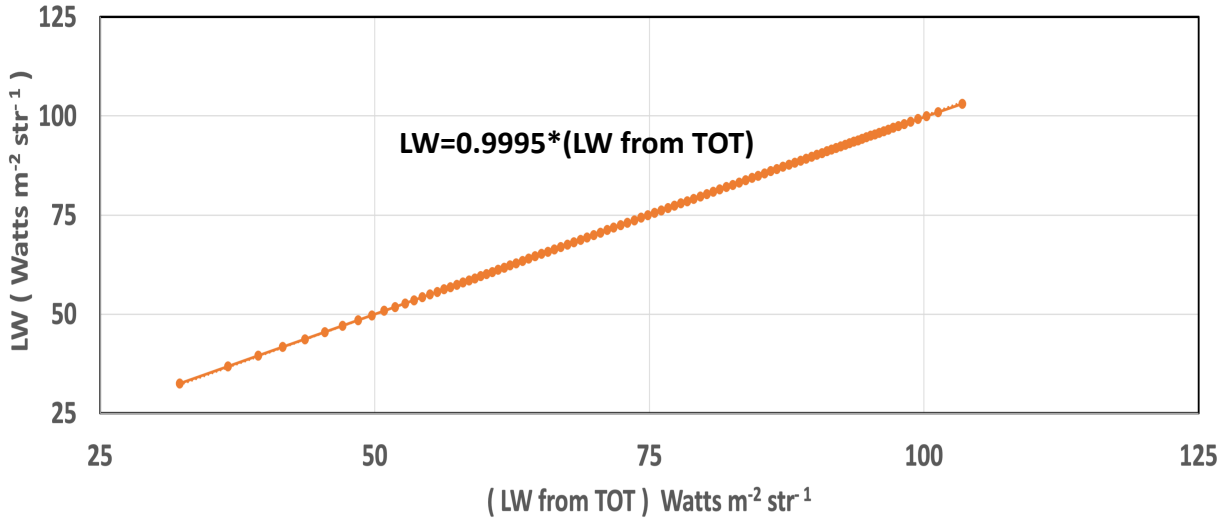
May 2018 - Mar 2021

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



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

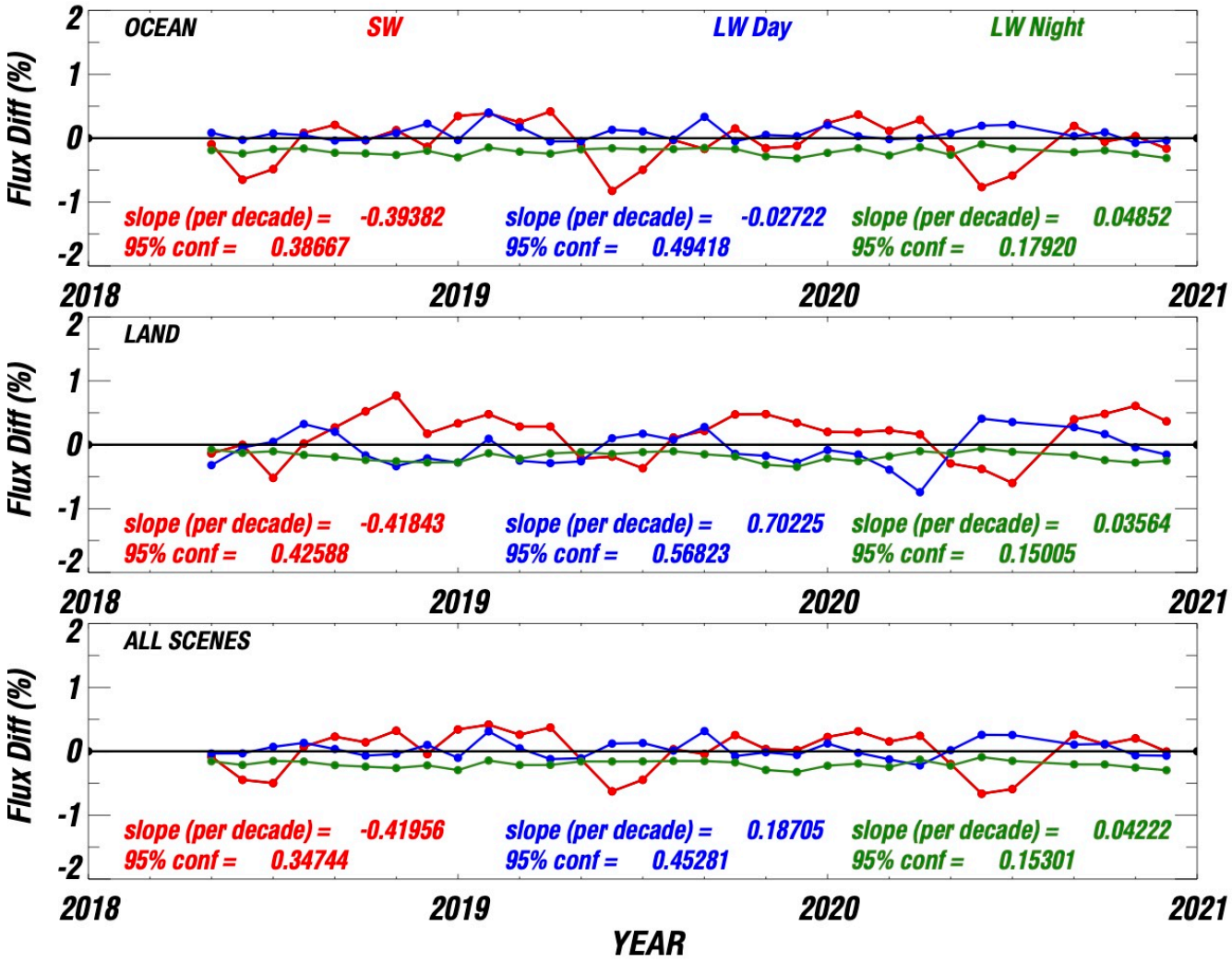
Nighttime Global Edition 1 ES-8 Nadir
LW from TOT vs. LW sensor



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

Validation: NOAA-20 (Ed1) – Aqua (Ed4) Global Flux difference

NOAA-20/FM6 shows consistency with the Aqua/FM3 instrument (Ed4) at BOM as well as long term.



Uses SSF data products, under all- sky conditions.

LW from TOT-SW

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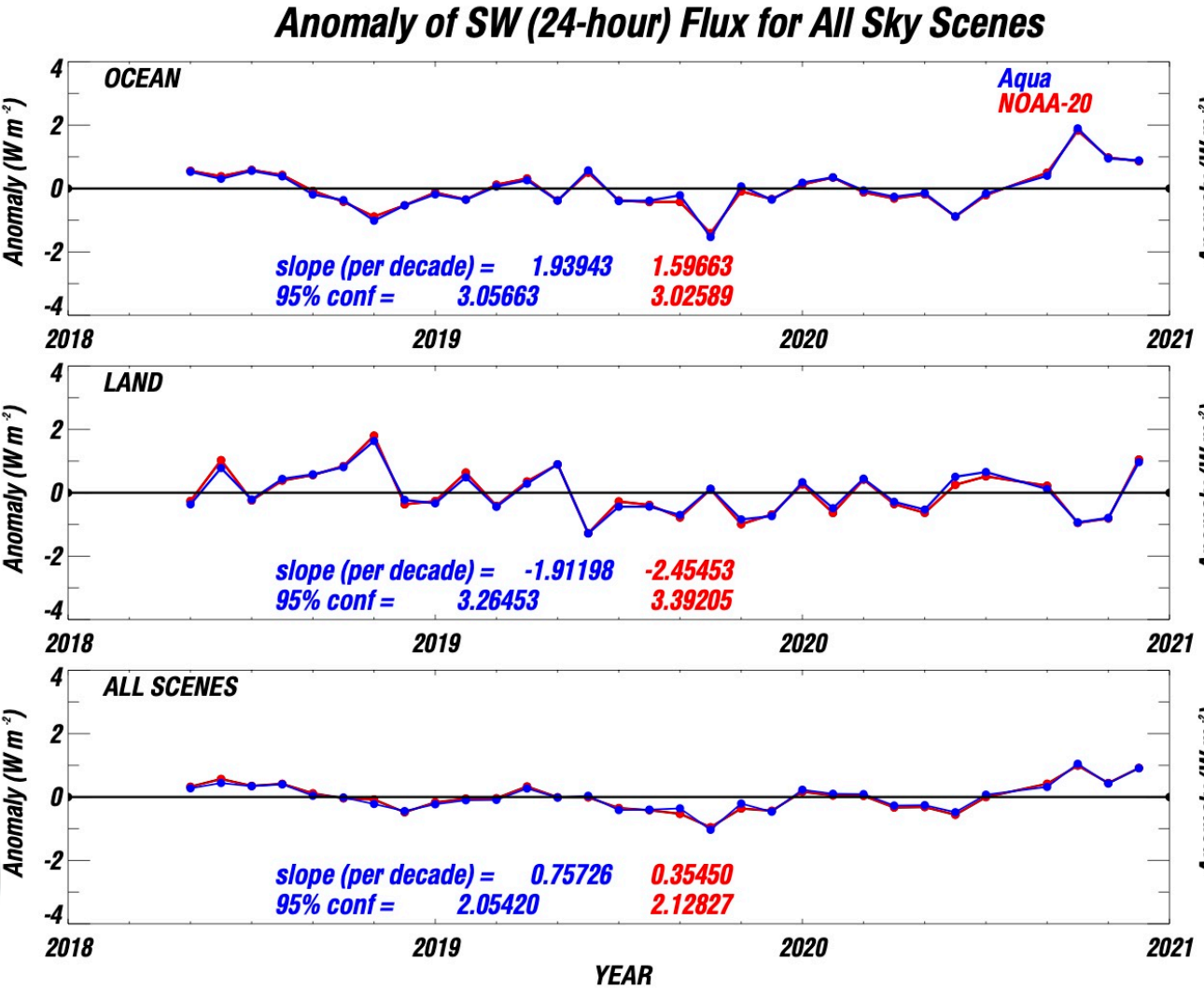
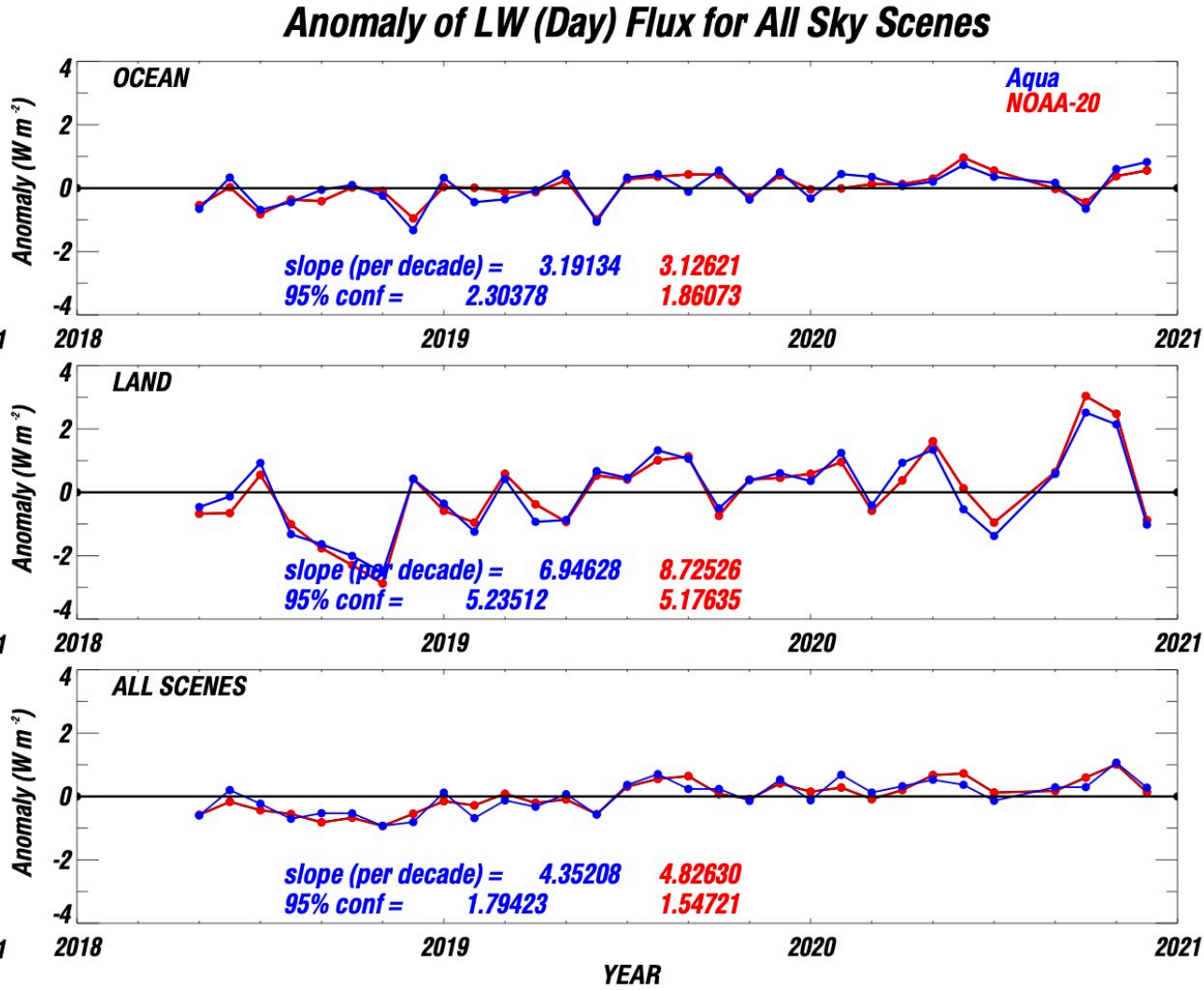
Validation: FM6 SW and LW day Flux Anomalies

Uses SSF data products

LW (Day) from TOT - SW





Aqua/NOAA-20 Intercomparisons

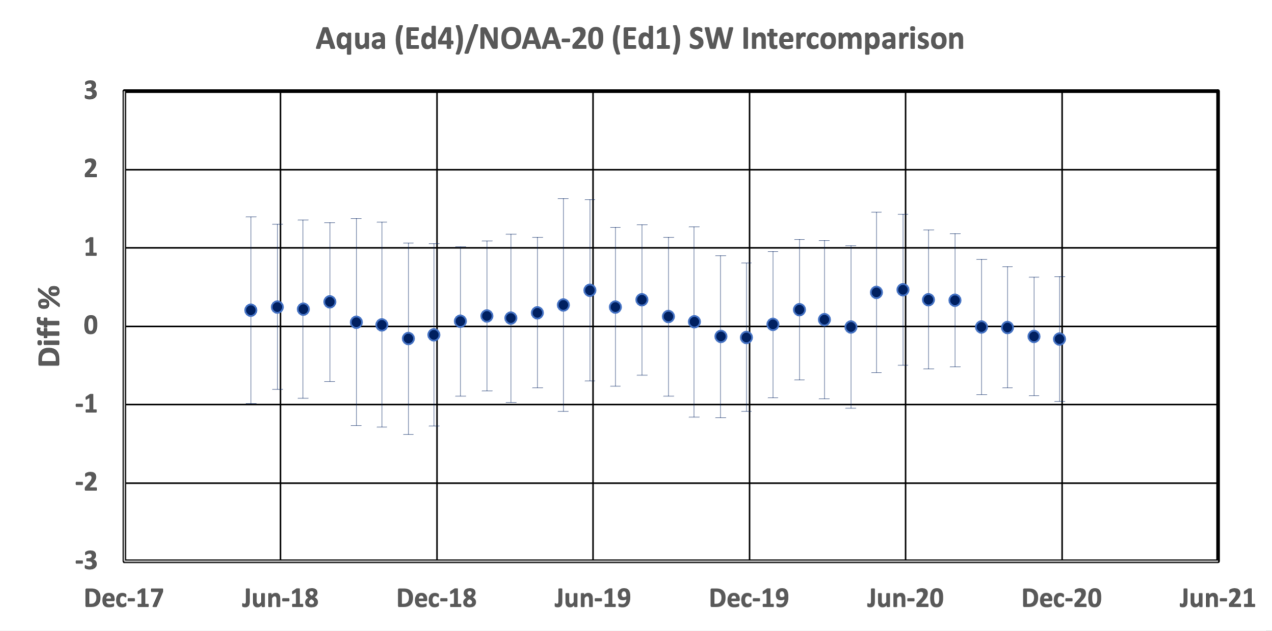
- The orbital geometries for Aqua and NOAA-20 are such that orbital overlaps occur every ~64 hours.
- Obtain spatially and temporally matched observations during every crossover.
- Use matching criteria to subset the data:
  - Lat. and Long. difference <= **0.05^0**
  - SZA, VZA difference < **2.0^0**
  - RAZ difference < **5^0**
- Obtain monthly all-sky SW reflectance and daytime LW radiance differences using the matched footprints.

FM3/FM6 All-sky Inter-comparisons: 2018-2020

Uses SSF data

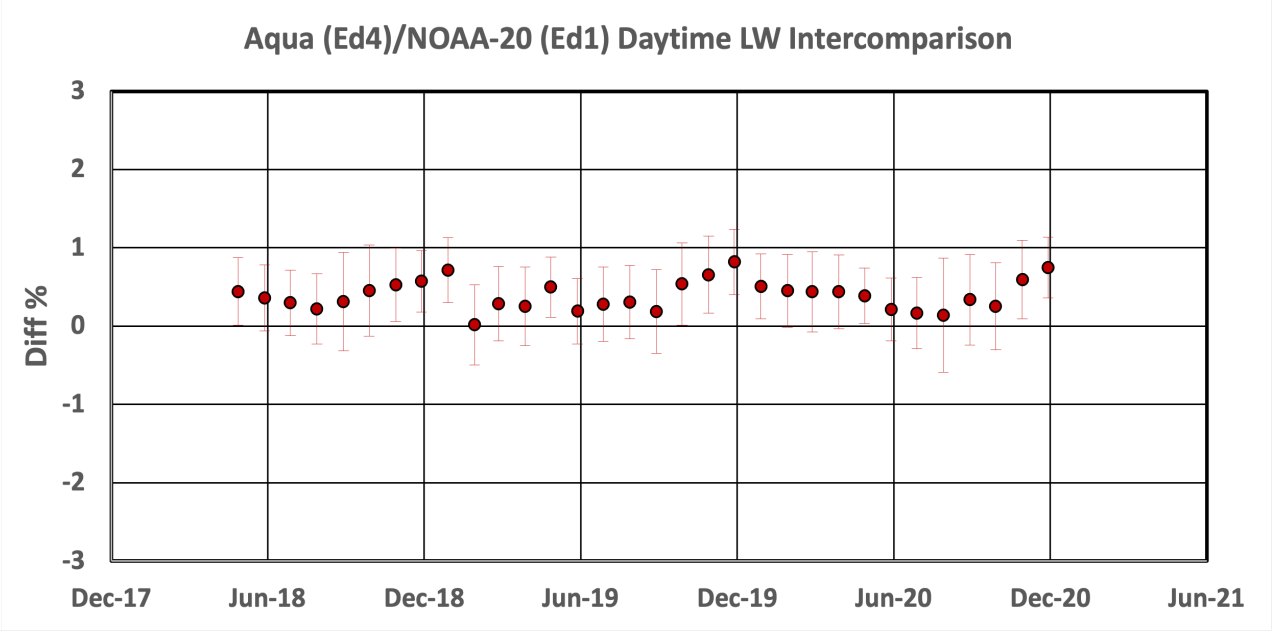
Difference of Reflectance:
FM3-FM6 %, 95% confidence interval

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



Difference of Radiance:
FM3-FM6 %, 95% confidence interval

Daytime LW for FM6 obtained from TOT -SW

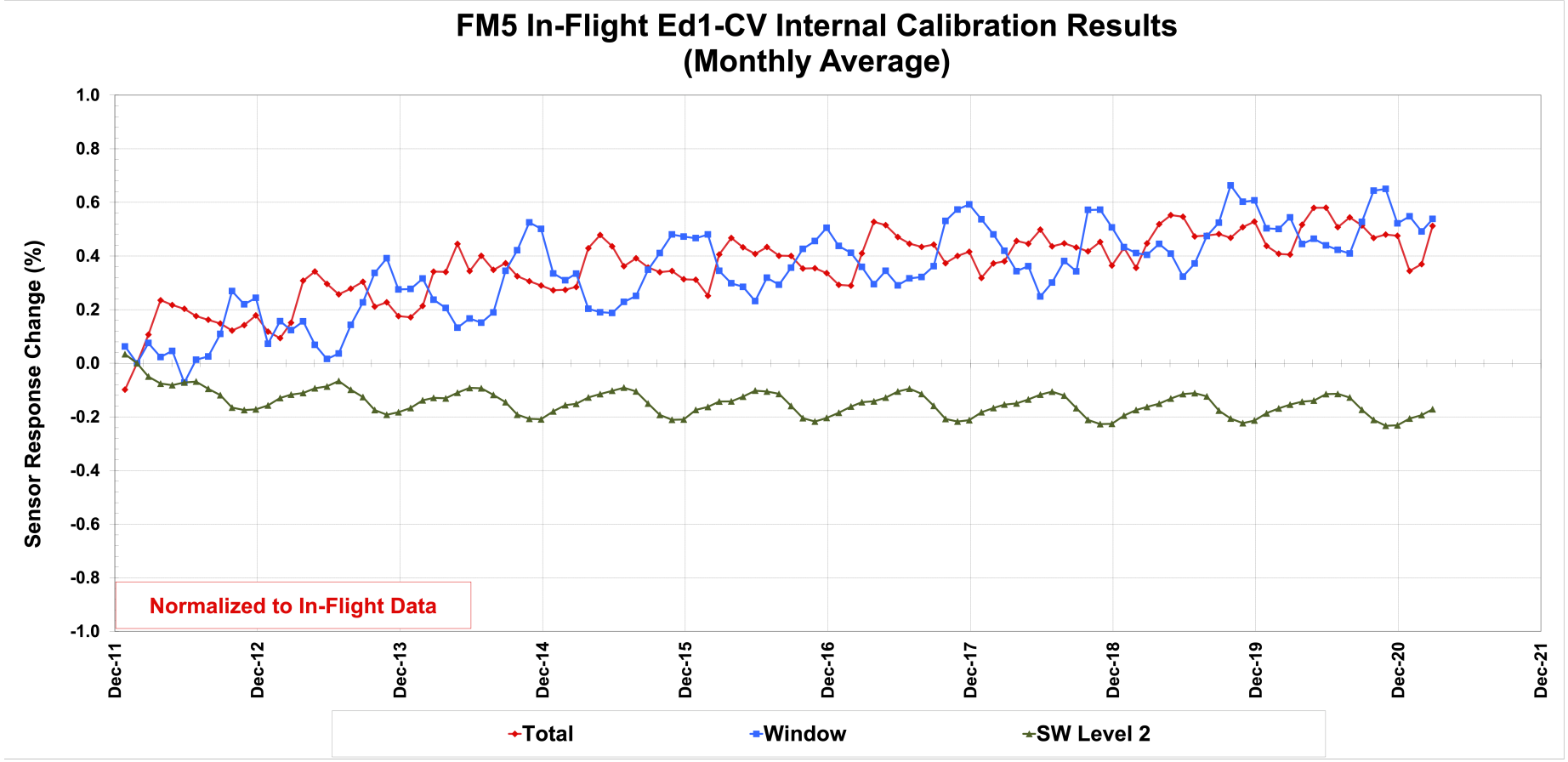


Radiometric scaling of FM6 to FM3 done in May 2018.

S-NPP/FM5 Instrument Status

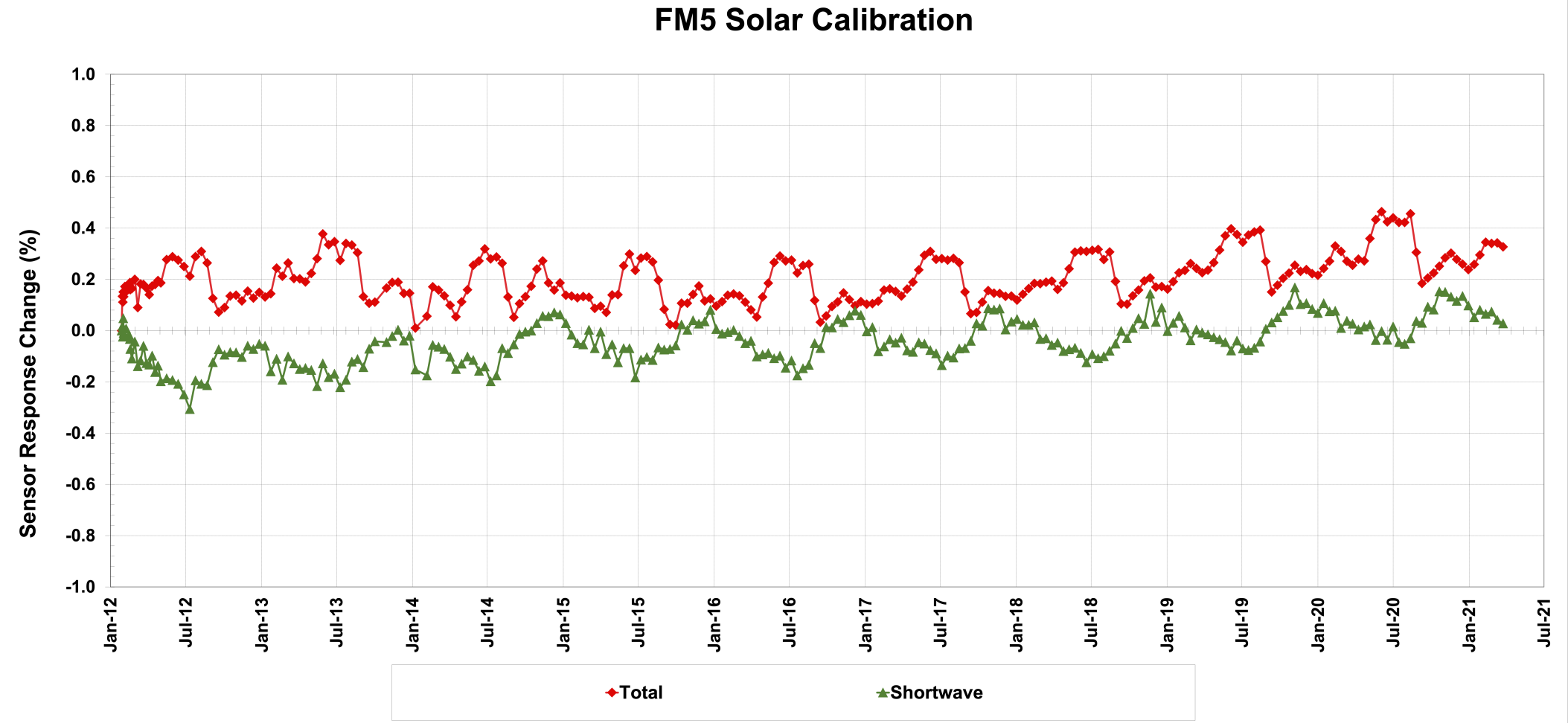
FM5 Internal Calibration

In response to the blackbodies, the FM5 TOT and WN sensors show a ~0.5% rise since start of mission.
SW channel's response to the SWICS has settled at ~-0.2% since start of mission.

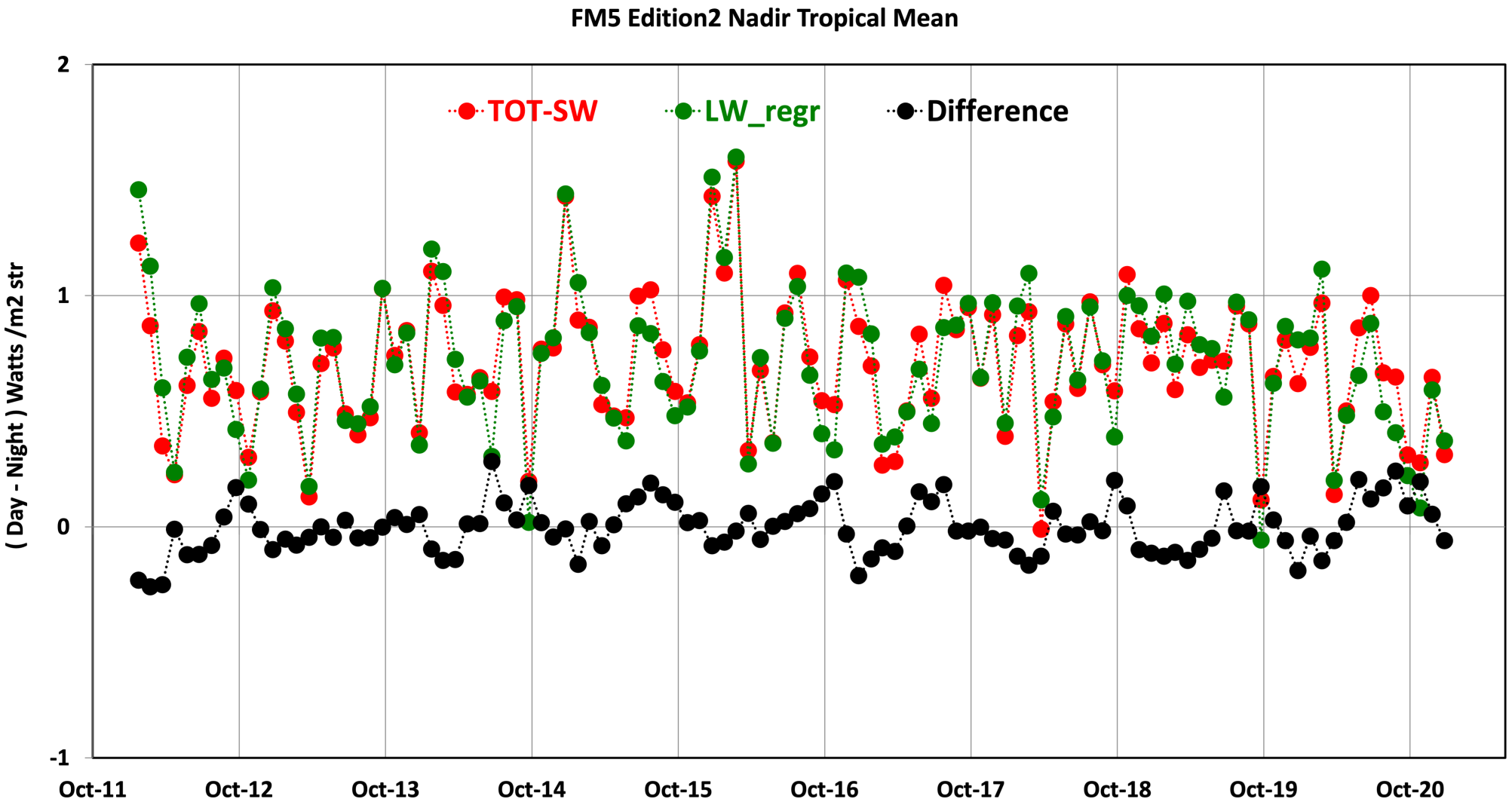


FM5 Solar Calibration

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



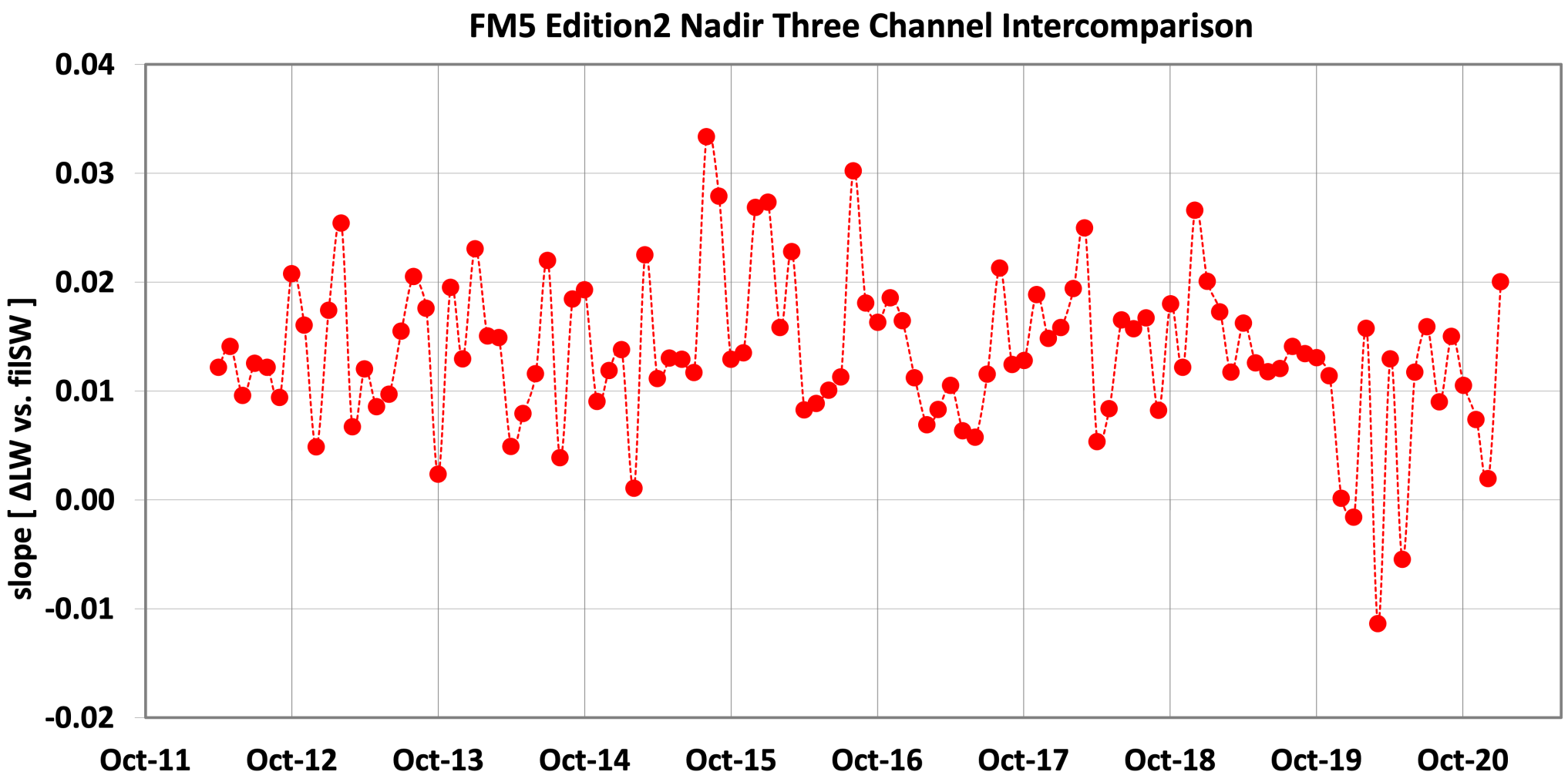
Validation- FM5 Tropical Mean



Validation: DCC 3-Channel Inter-comparison

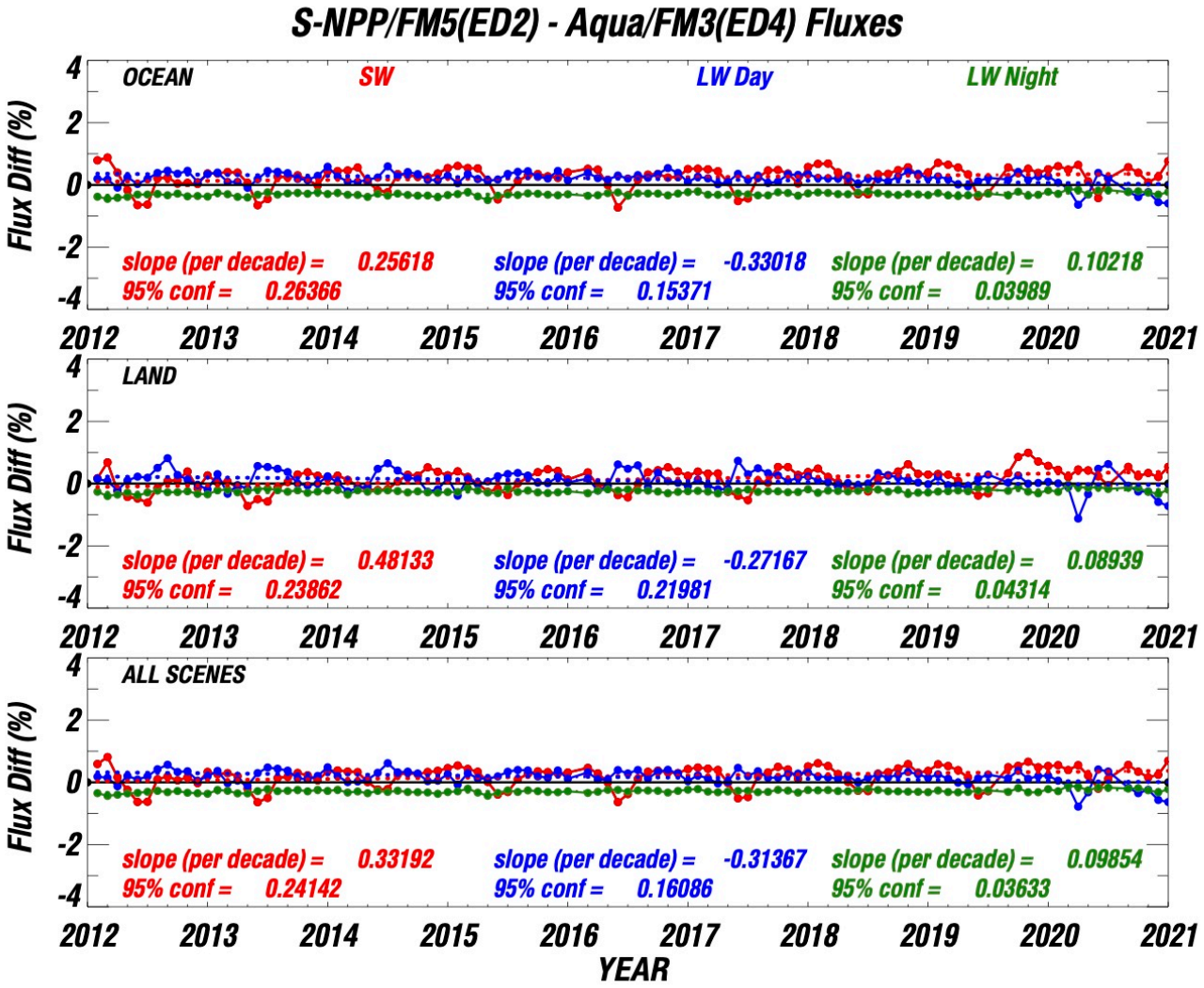
- Compare the radiances from the three sensors of the instrument when viewing Deep Convective Clouds (DCC).
- Two sets of longwave (LW) radiances obtained:
  - TOT and SW sensors
  - Trained WN sensor
- Monitor the trend between the difference of the two LW radiances in relation to the SW radiance.
-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

DCC 3-Channel Intercomparison



Validation: S-NPP (Ed2) – Aqua (Ed4) Global Flux difference

S-NPP/FM5 shows consistency with the Aqua/FM3 instrument (Ed4) at BOM as well as long term.



Uses SSF data products, under all sky conditions.

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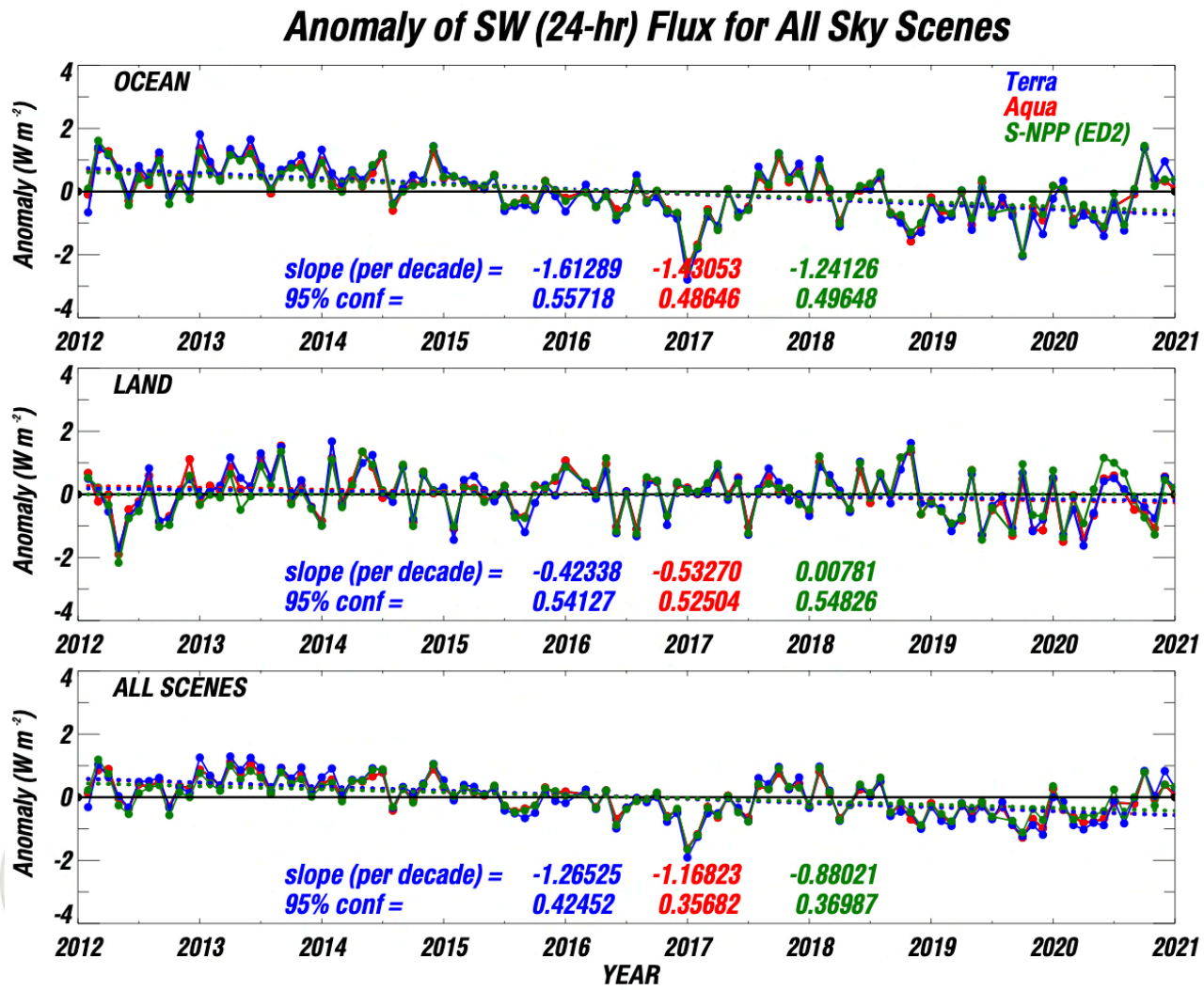
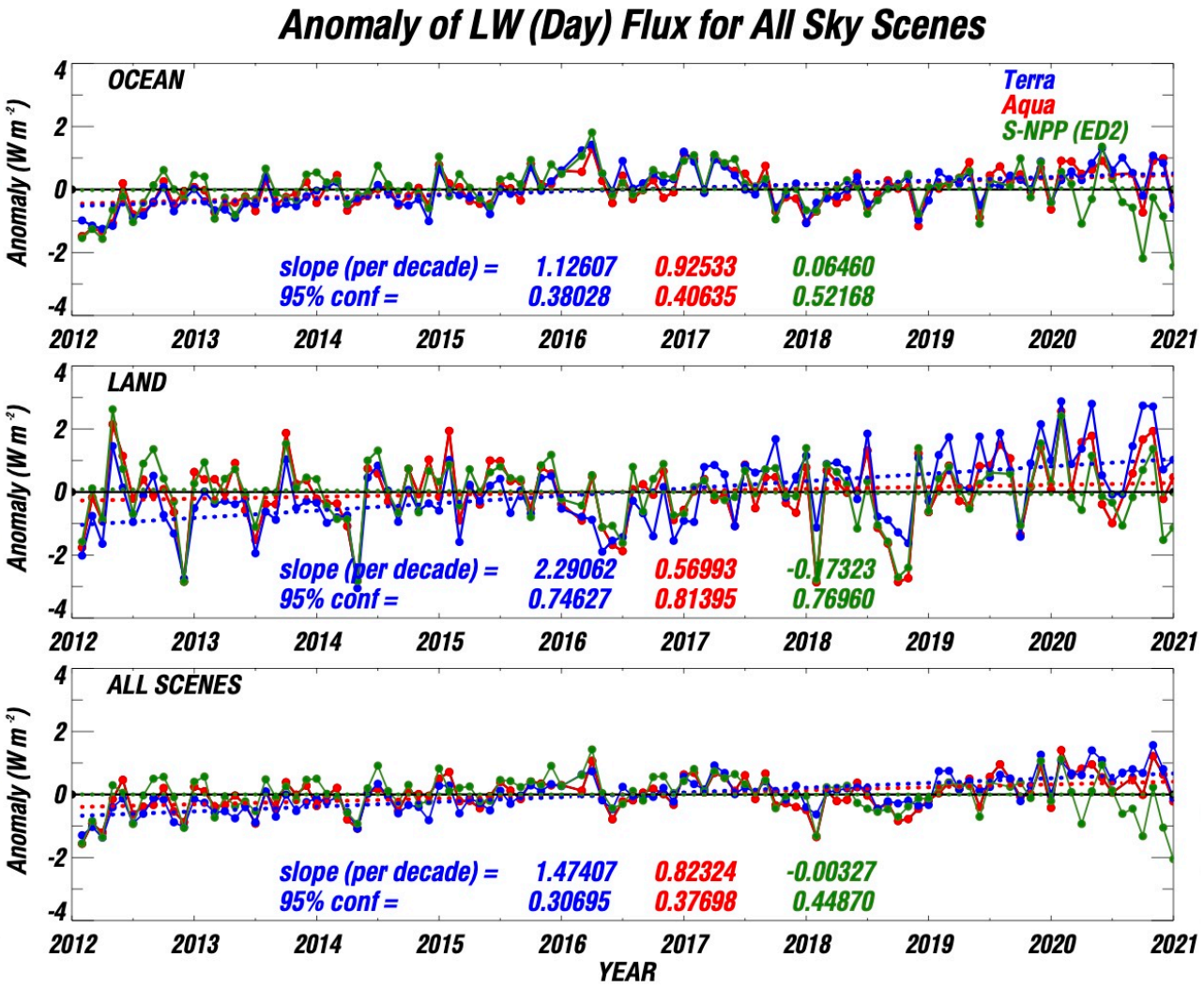
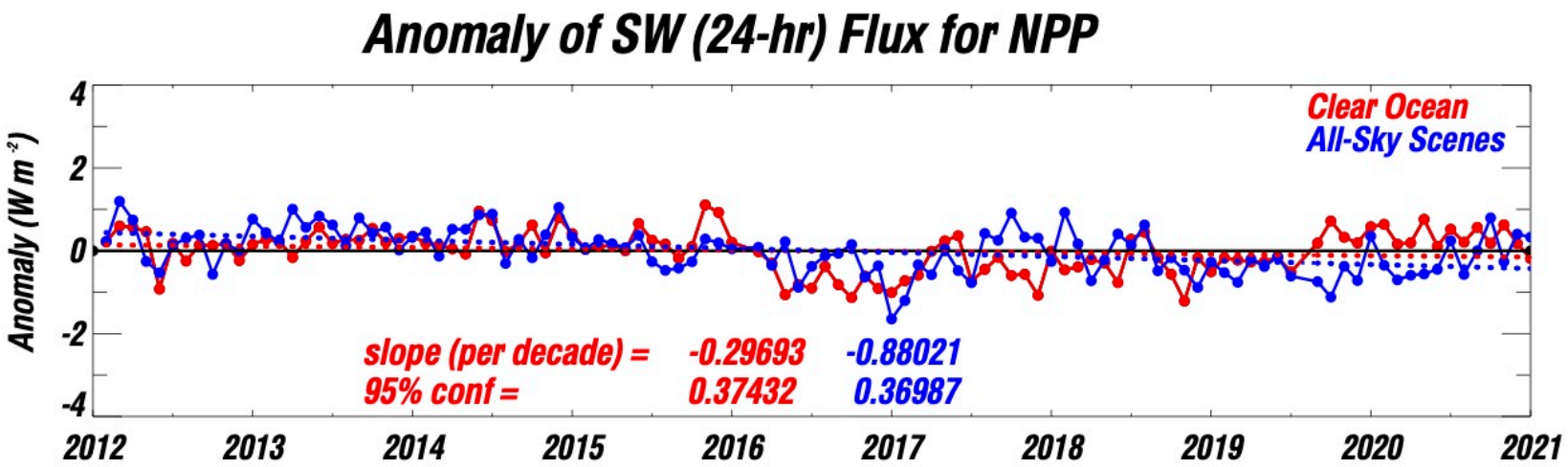
Validation: FM5 SW and LW day Flux Anomalies

Uses SSF data products





Validation: FM5 SW anomaly for Clear Ocean



FM5 SW anomaly trend for clear ocean scenes does not show any change in behavior after FM5 instrument transitioned to biaxial mode.

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:
  - Lat. and Long. difference <= **0.05^0**
  - SZA, VZA difference < **2.0^0**
  - RAZ difference < **5^0**
- Obtain monthly all-sky SW reflectance and daytime LW radiance differences using the matched footprints.
- *Since FM5 is now operating in biaxial mode, the number of matched footprints drastically reduces.*

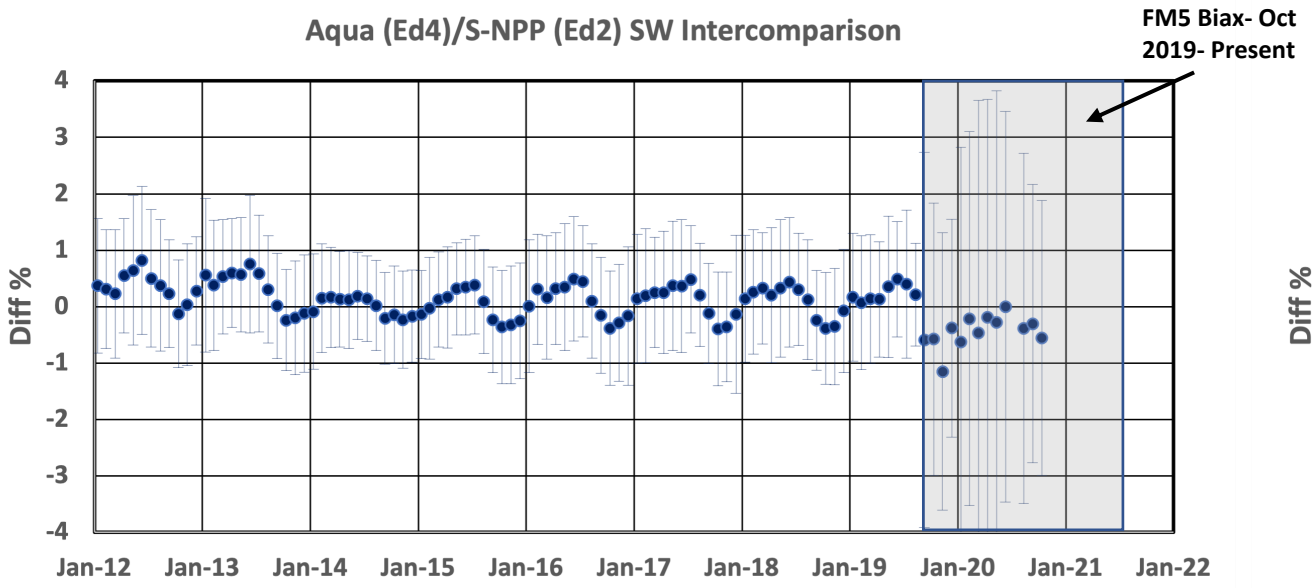
FM3/FM5 All-sky Inter-comparisons: 2012-2020

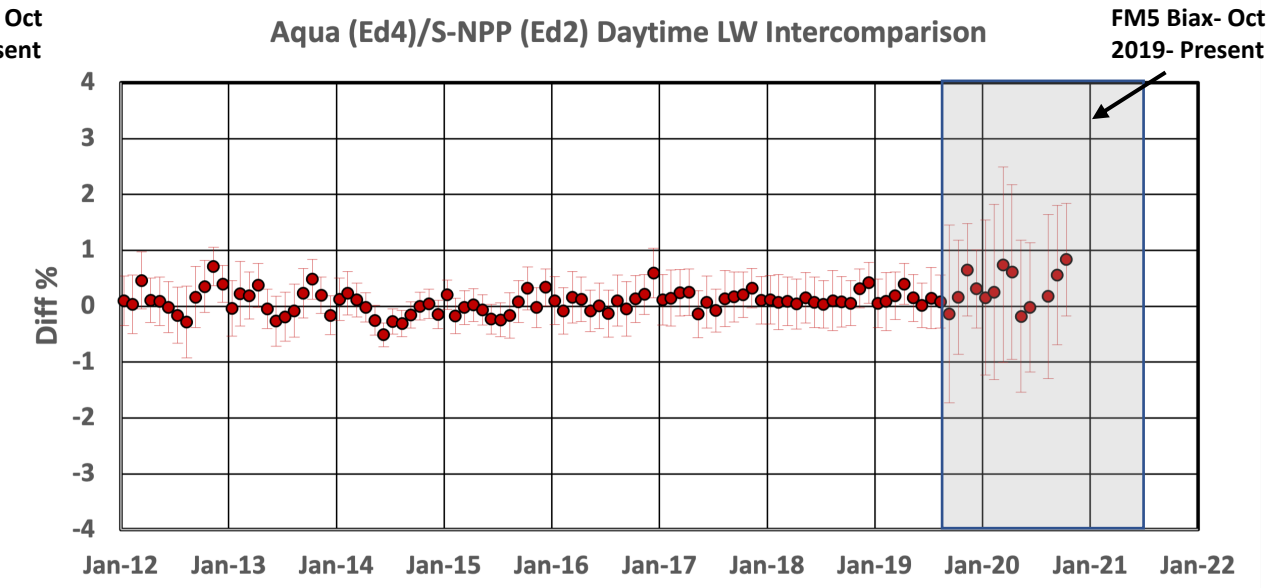
Difference of Reflectance:
FM3-FM5 %, 95% confidence interval

Uses SSF data

Difference of Radiance:
FM3-FM5 %, 95% confidence interval

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





2014 data used for the radiometric scaling FM5 to FM3.

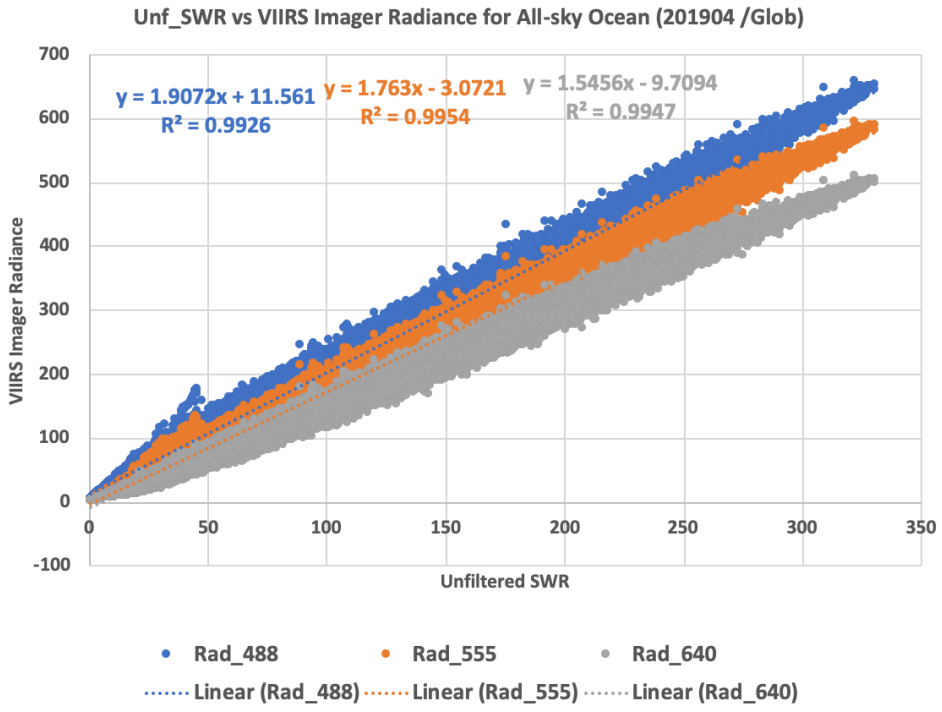
Larger differences observed after FM5 switched to biaxial mode are driven by the drastic reduction in number of spatially and temporally matched observations.

S-NPP CERES SW and VIIRS Comparisons

- Monitor any changes to relationship between CERES FM5 SW radiances and VIIRS radiances after FM5 transitioned to biaxial mode.
  - Use the 488nm, 555nm, and 640nm VIIRS channels.
  - Regressions performed monthly, using nadir all-sky ocean footprints.
  - Months from first year are considered 'baseline'.

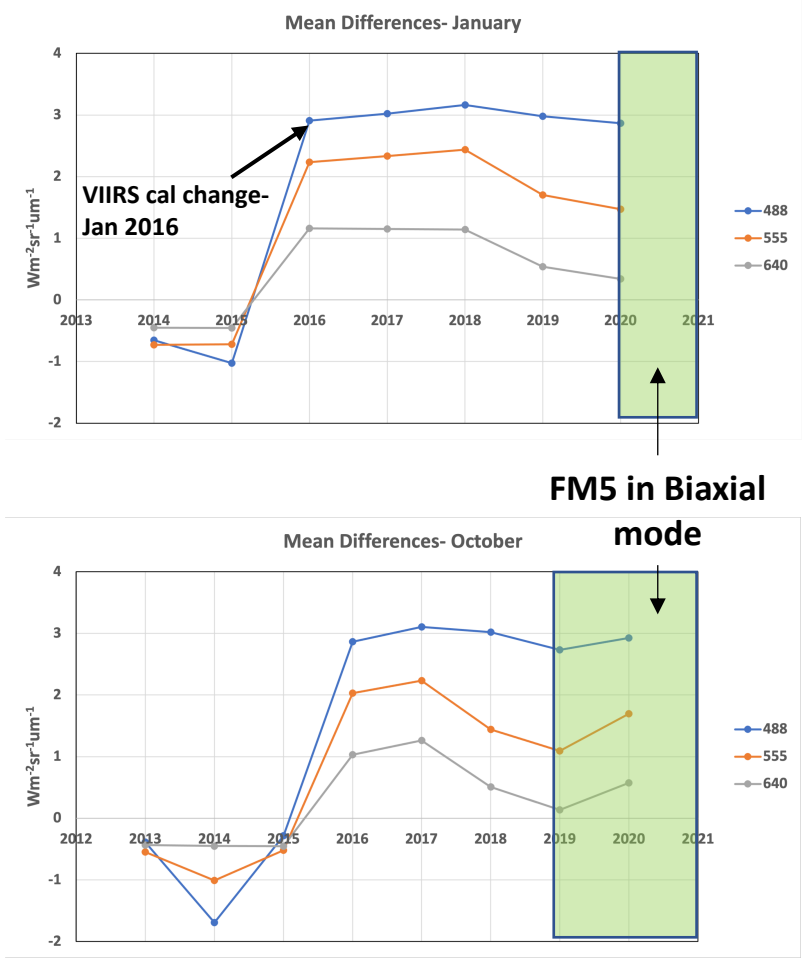
- After first year in mission, observe change in regression coefficients for every month across subsequent years:
  - Derive VIIRS radiance estimate using the regression coefficients of corresponding month of baseline year, for every CERES footprint (V1).
  - Derive VIIRS radiance estimate using the regression coefficients for the current month, for every CERES footprint (V2).
  - Calculate mean difference of (V1 – V2) across all CERES footprints.

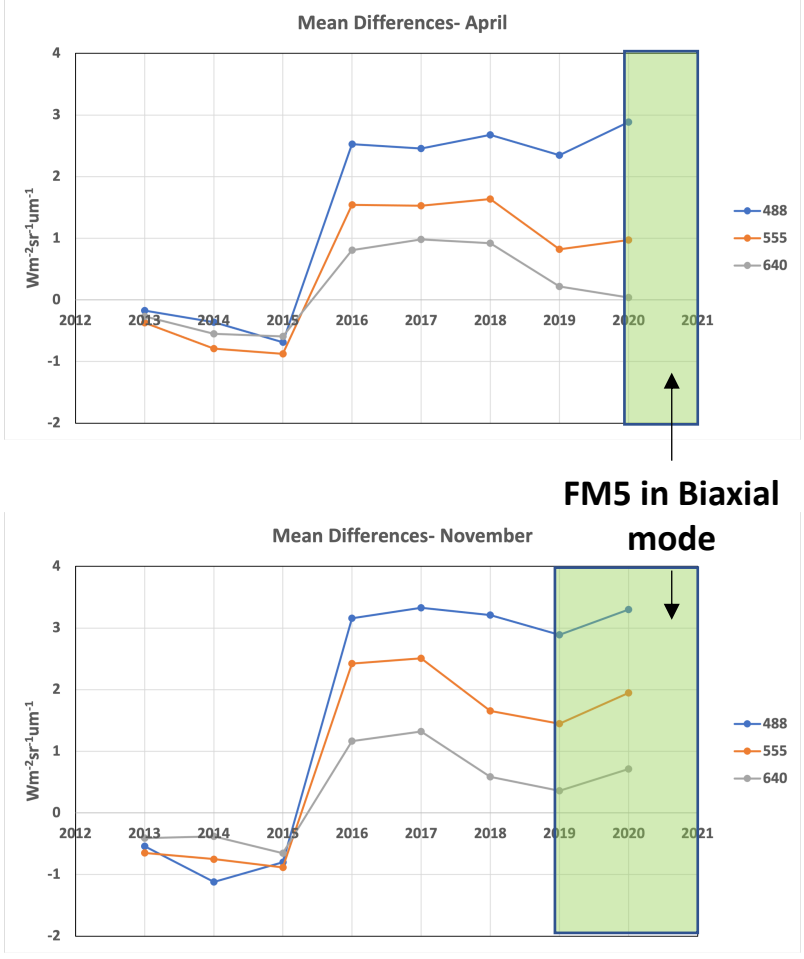
- Any changes in CERES SW channel performance after transitioning to biaxial mode would change the slope of the regression, resulting in larger mean differences.
  - Assumes that VIIRS channels are stable.

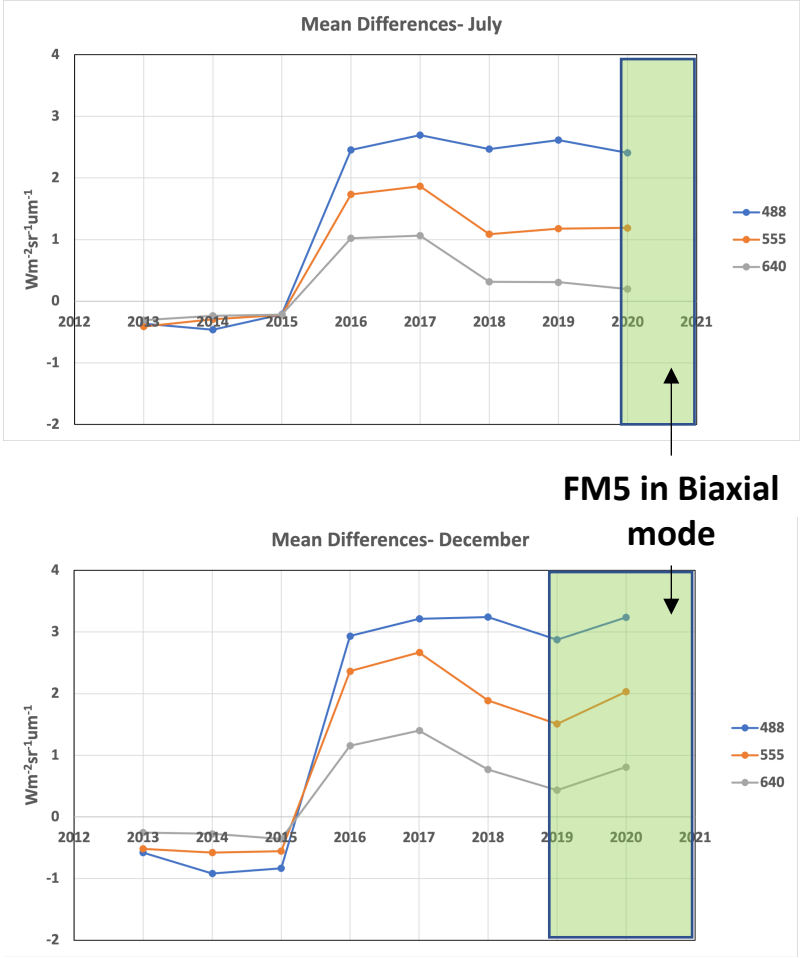


S-NPP CERES and VIIRS Comparisons

Difference in VIIRS Radiance Estimates







No observed change in the relationship between CERES FM5 SW channel and VIIRS on S-NPP after FM5 placed in biaxial mode of operation (October 2019).

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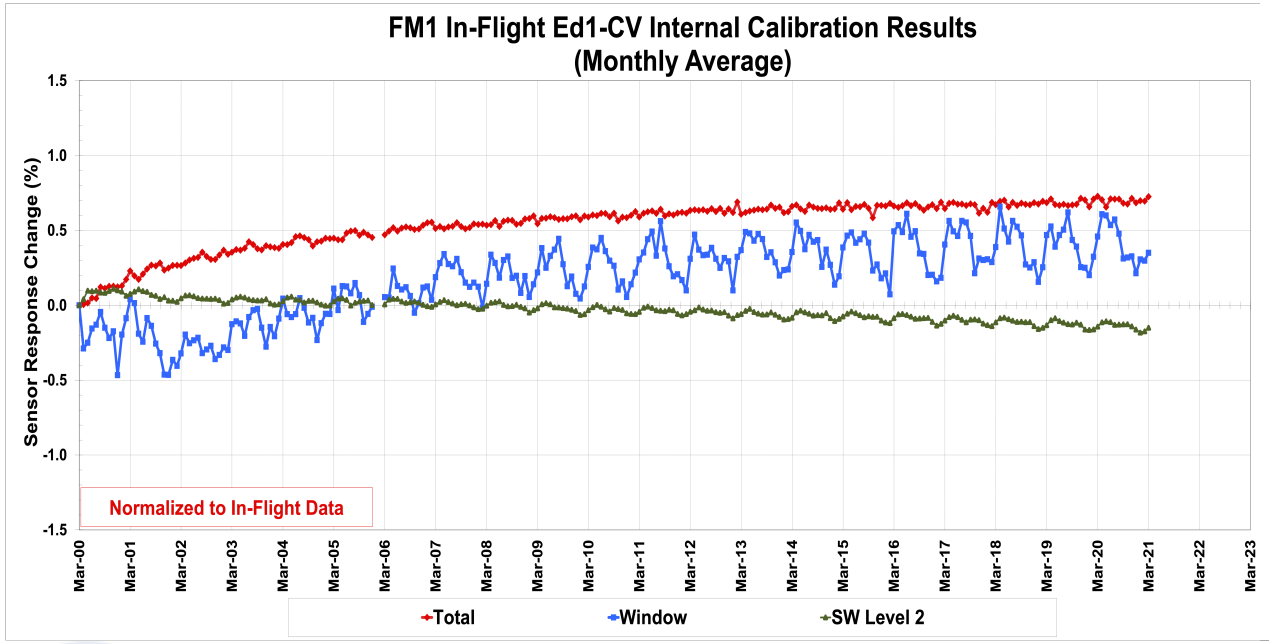
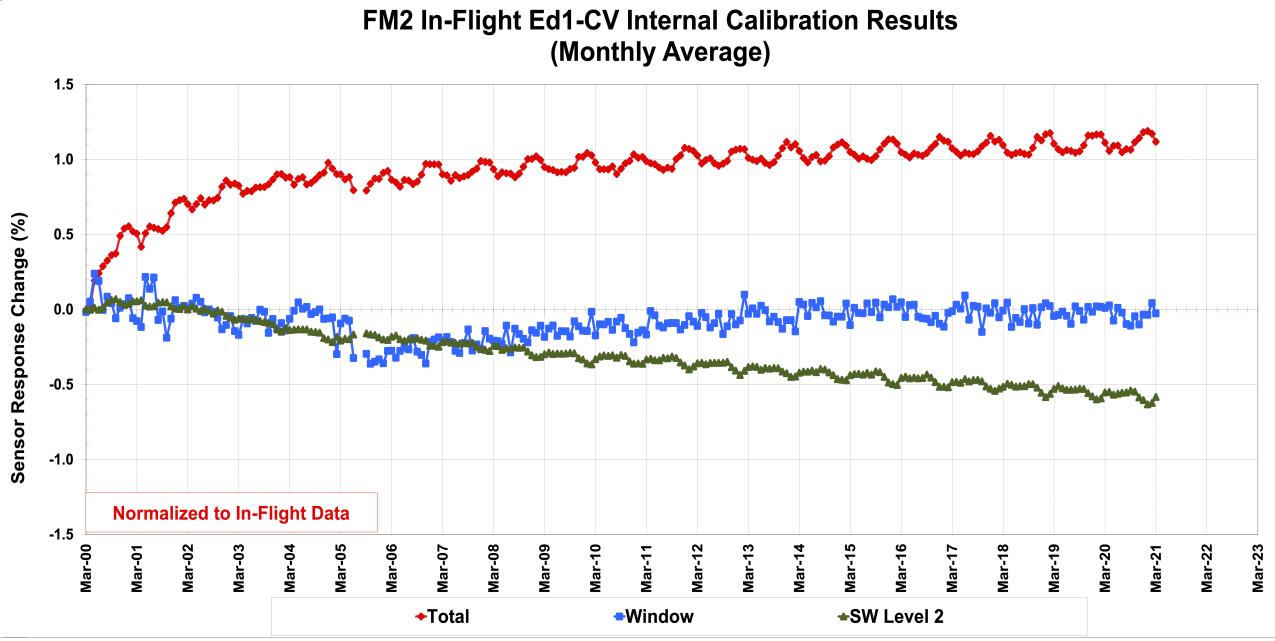
Terra & Aqua Instruments' Status
CERES FM1-FM4

Terra- FM1 & FM2 Internal Calibration

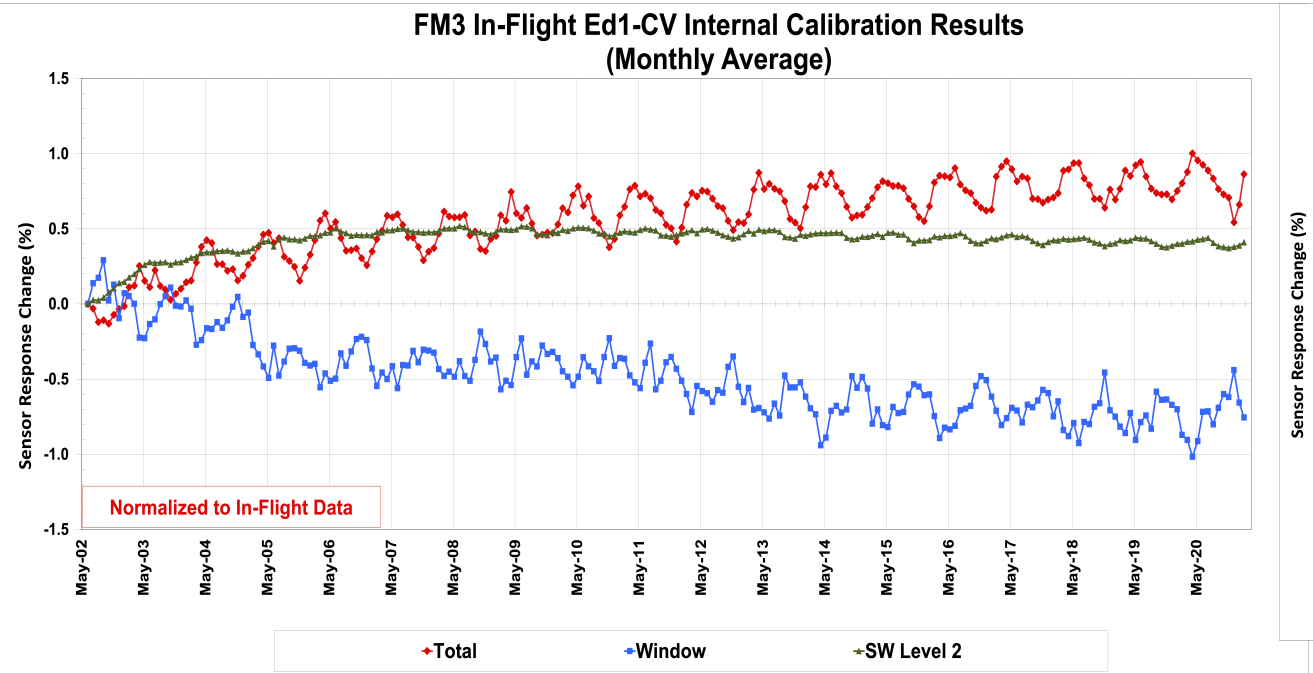
- **For FM1, TOT channel shows ~0.7% rise, SW channel shows ~0.1% drop, and WN channel shows a rise of ~0.4% since start of mission.**
- **For FM2, TOT channel shows ~1.2% rise, SW channel shows ~0.6% drop, while WN channel shows ~0% change since start of mission.**

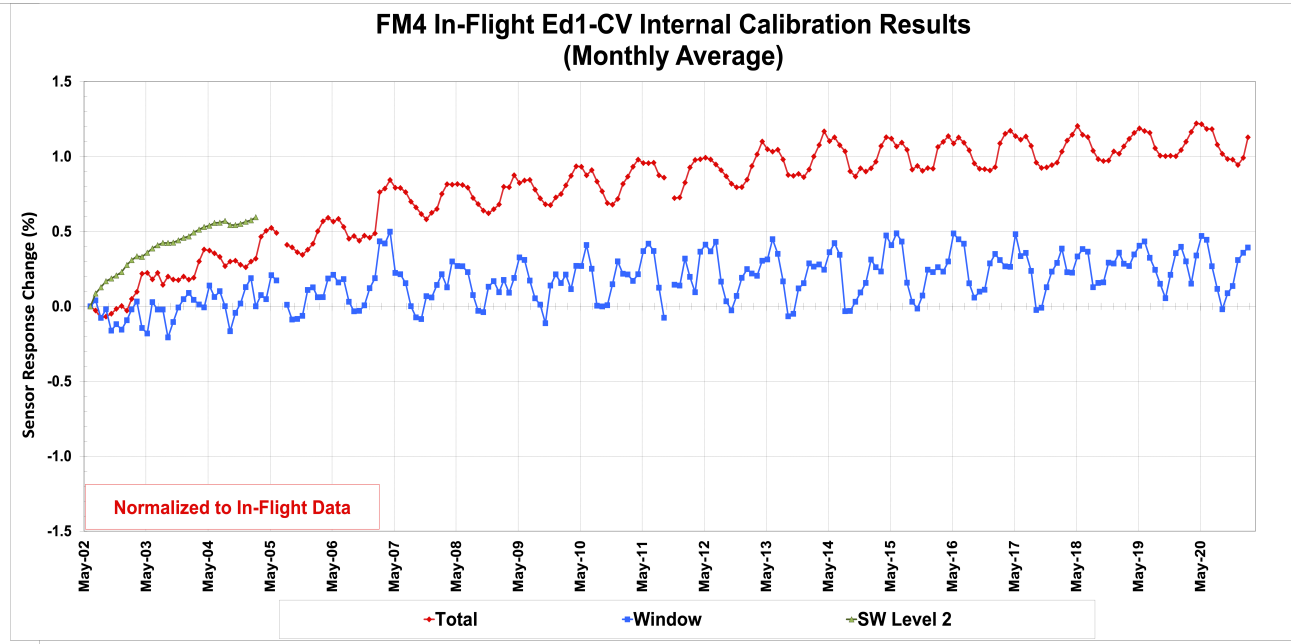




Aqua- FM3 and FM4 Internal Calibration

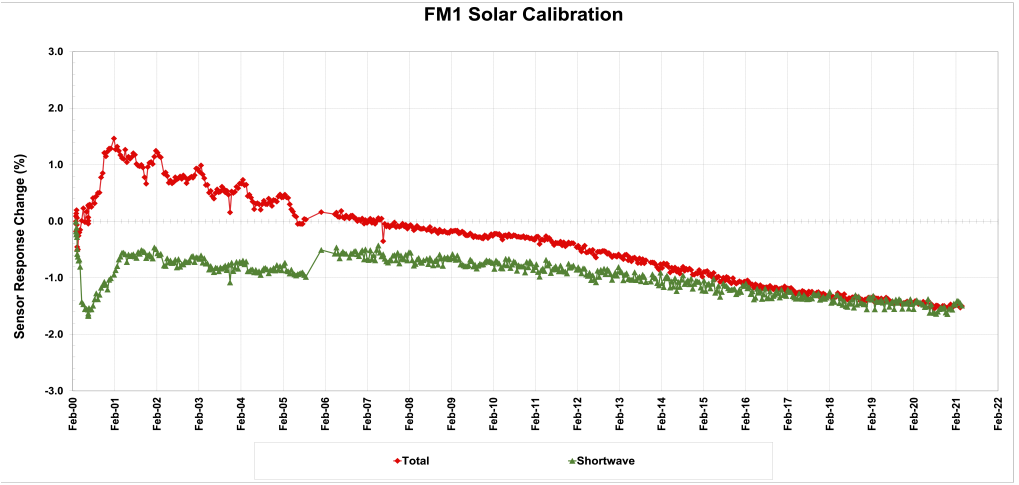
- **For FM3, TOT channel shows ~0.8% rise, SW channel shows ~0.4% rise, and WN channel shows ~0.8% drop since start of mission.**
- **For FM4, TOT channel shows ~1% rise, while WN channel shows ~0.25% rise since start of mission.**

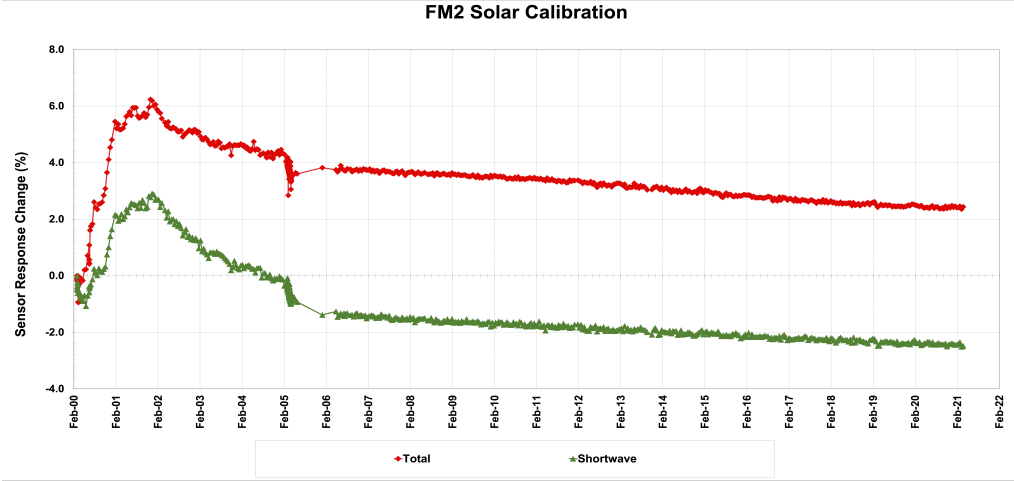


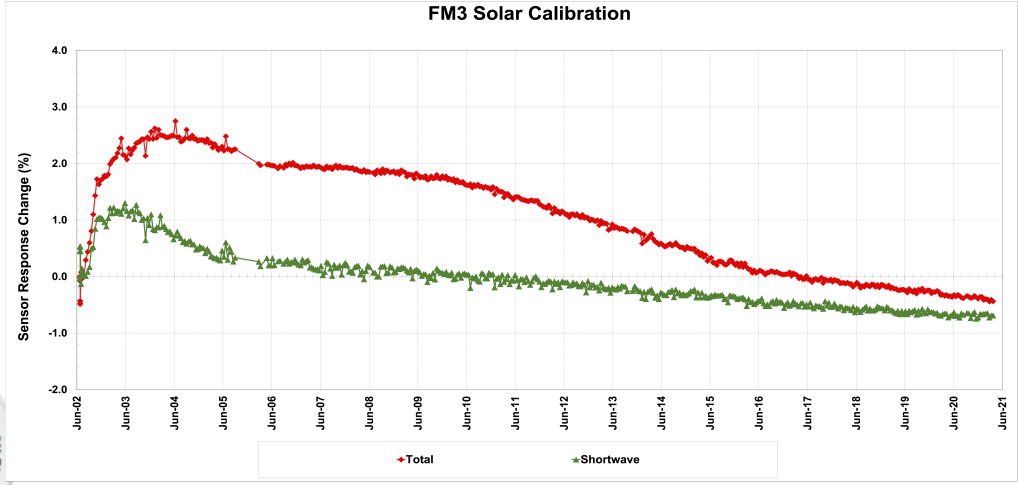


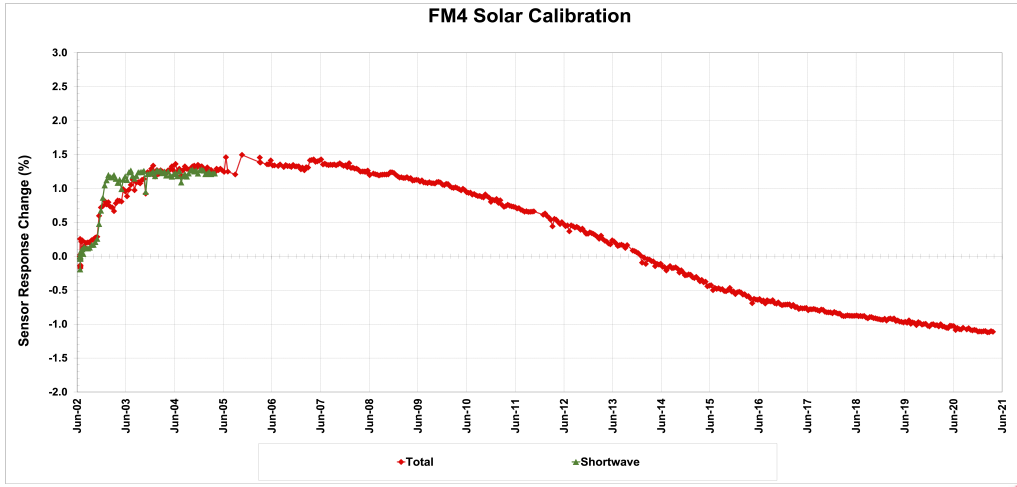
Terra & Aqua Solar Calibration

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.

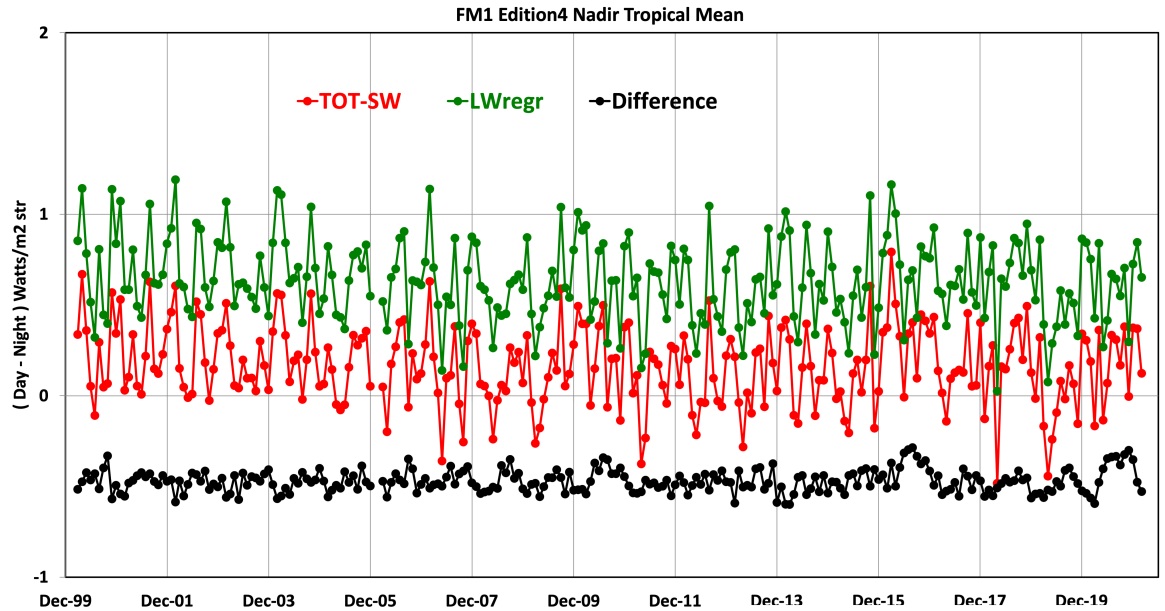


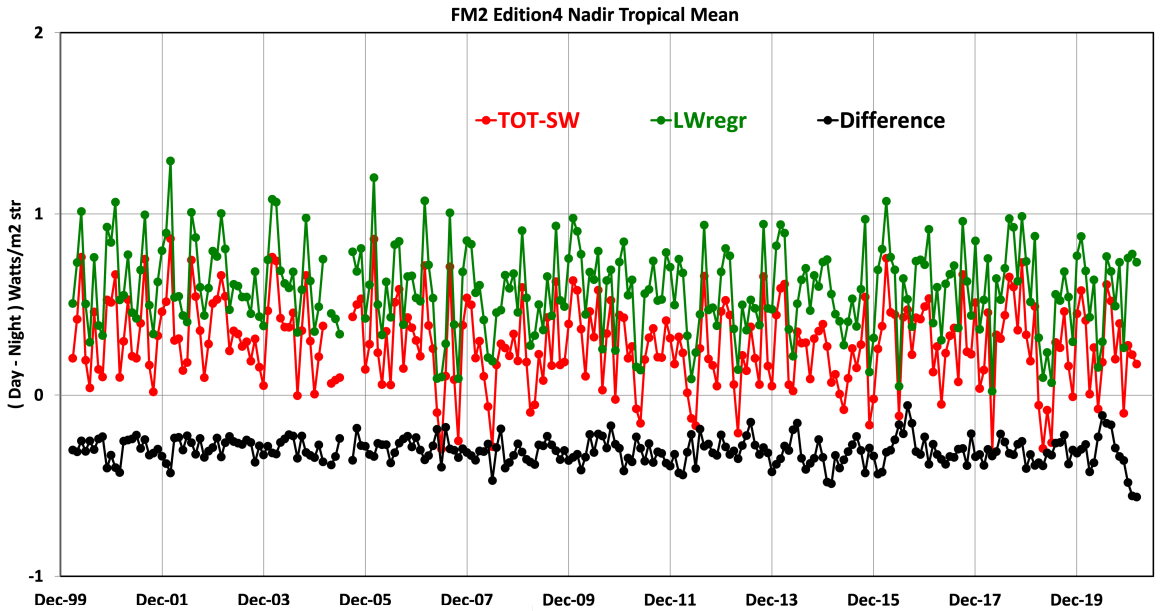


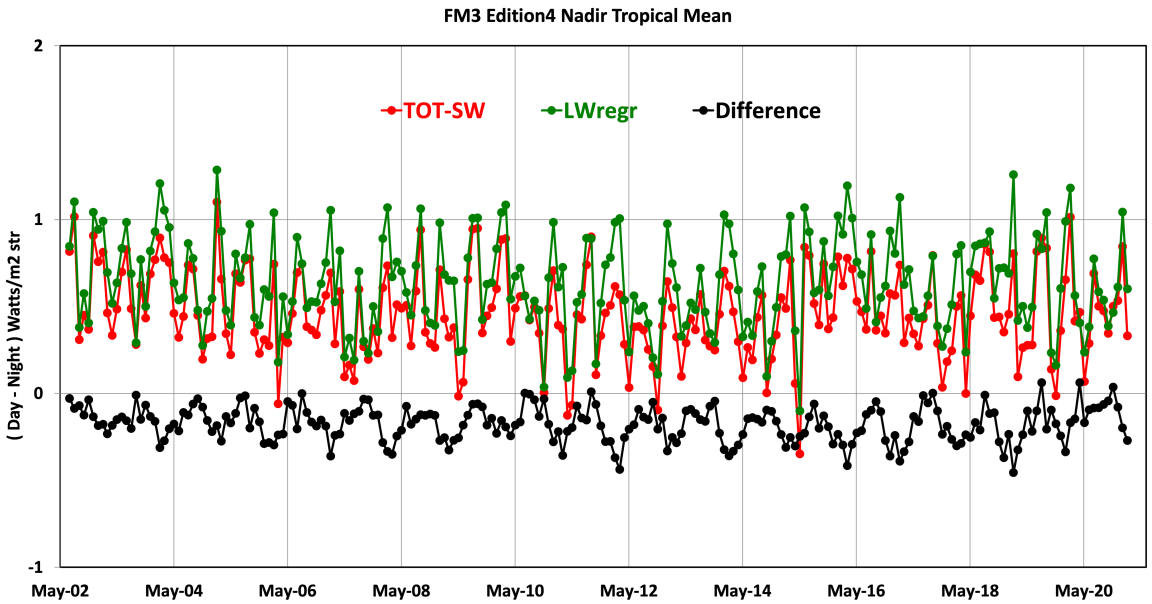




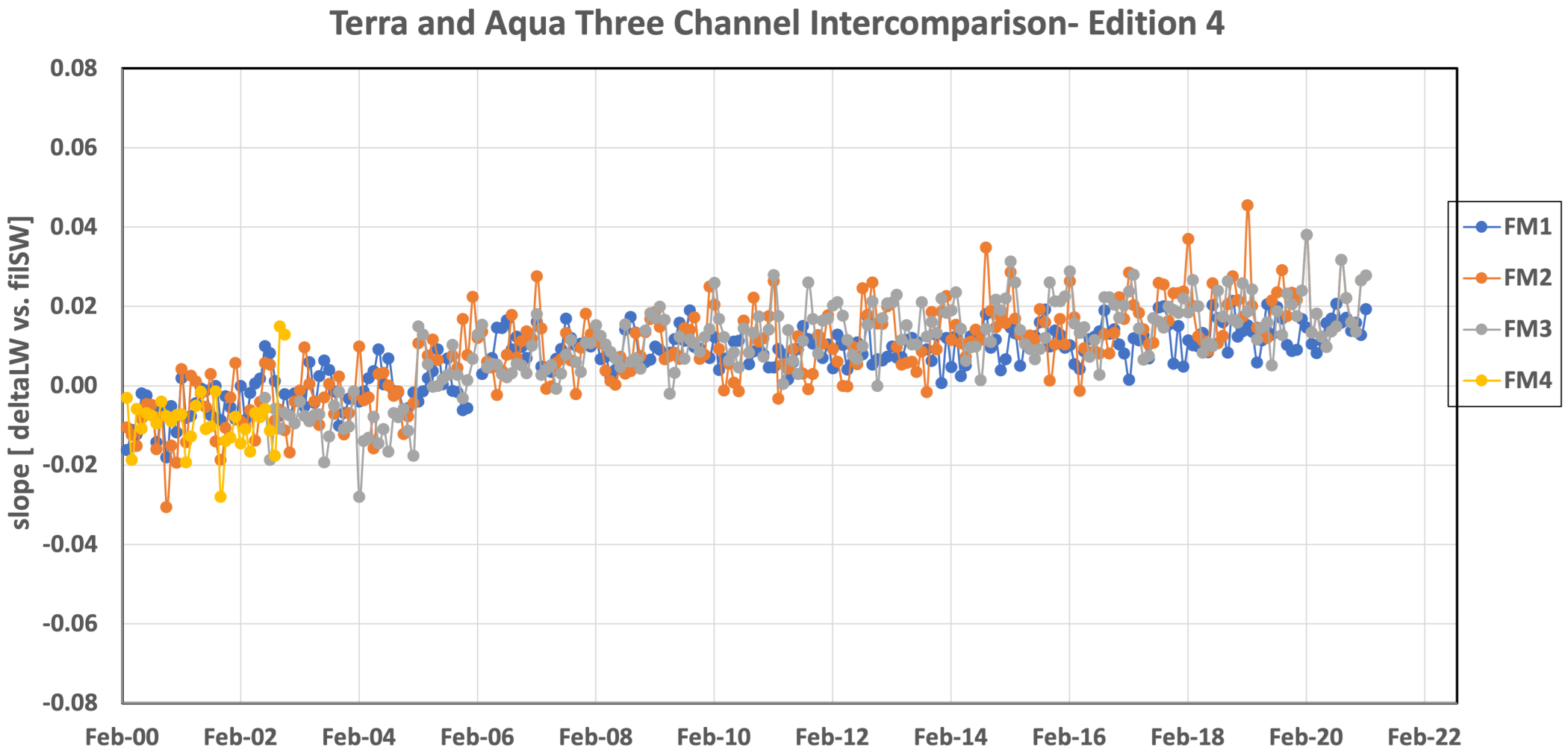
Validation- Terra and Aqua Tropical Mean



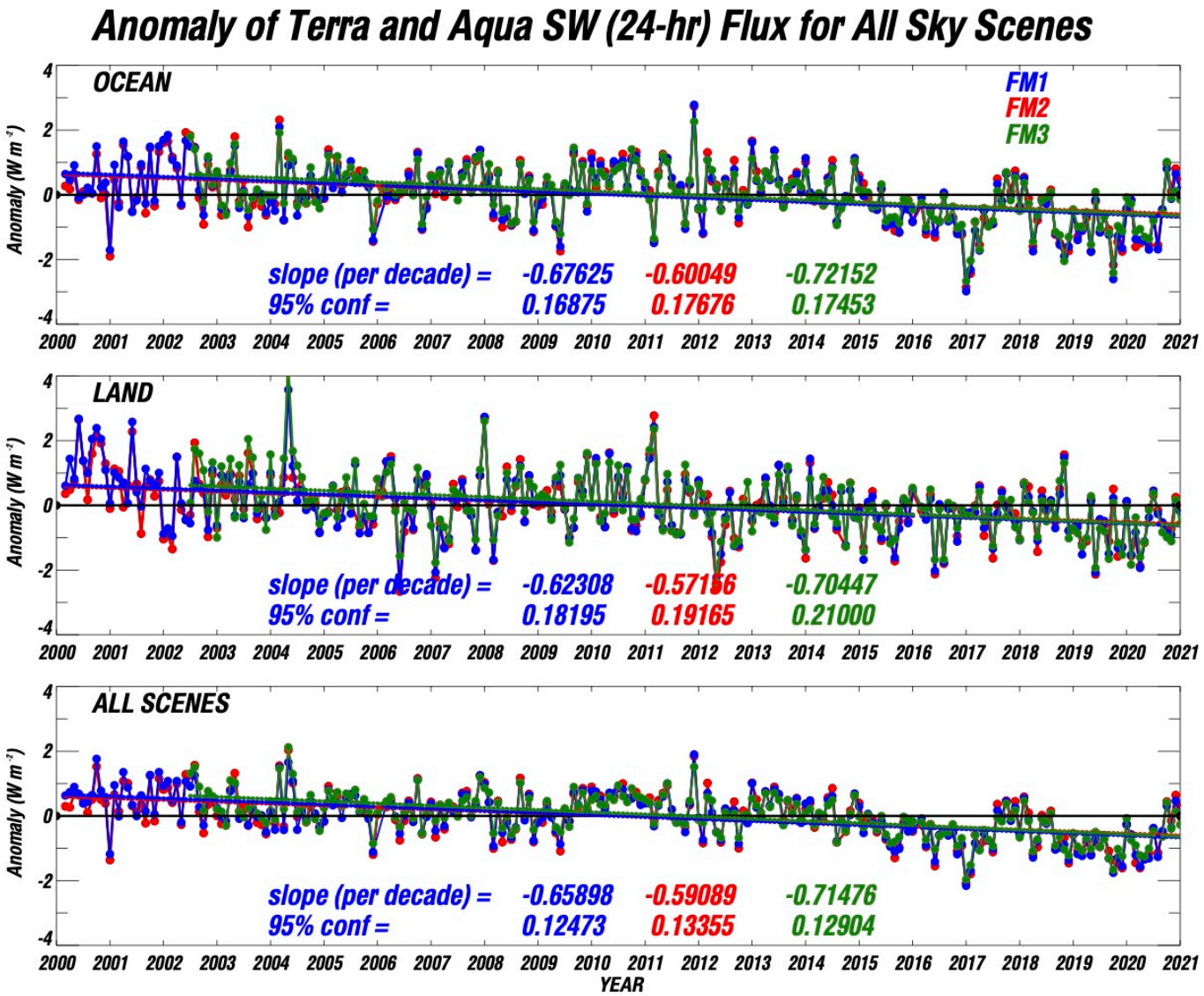




Validation- DCC 3-Channel Intercomparison



Validation: Terra and Aqua Ed-4 SW Flux Anomalies



SW flux anomalies show similar trends for all three instruments

Uses SSF data products

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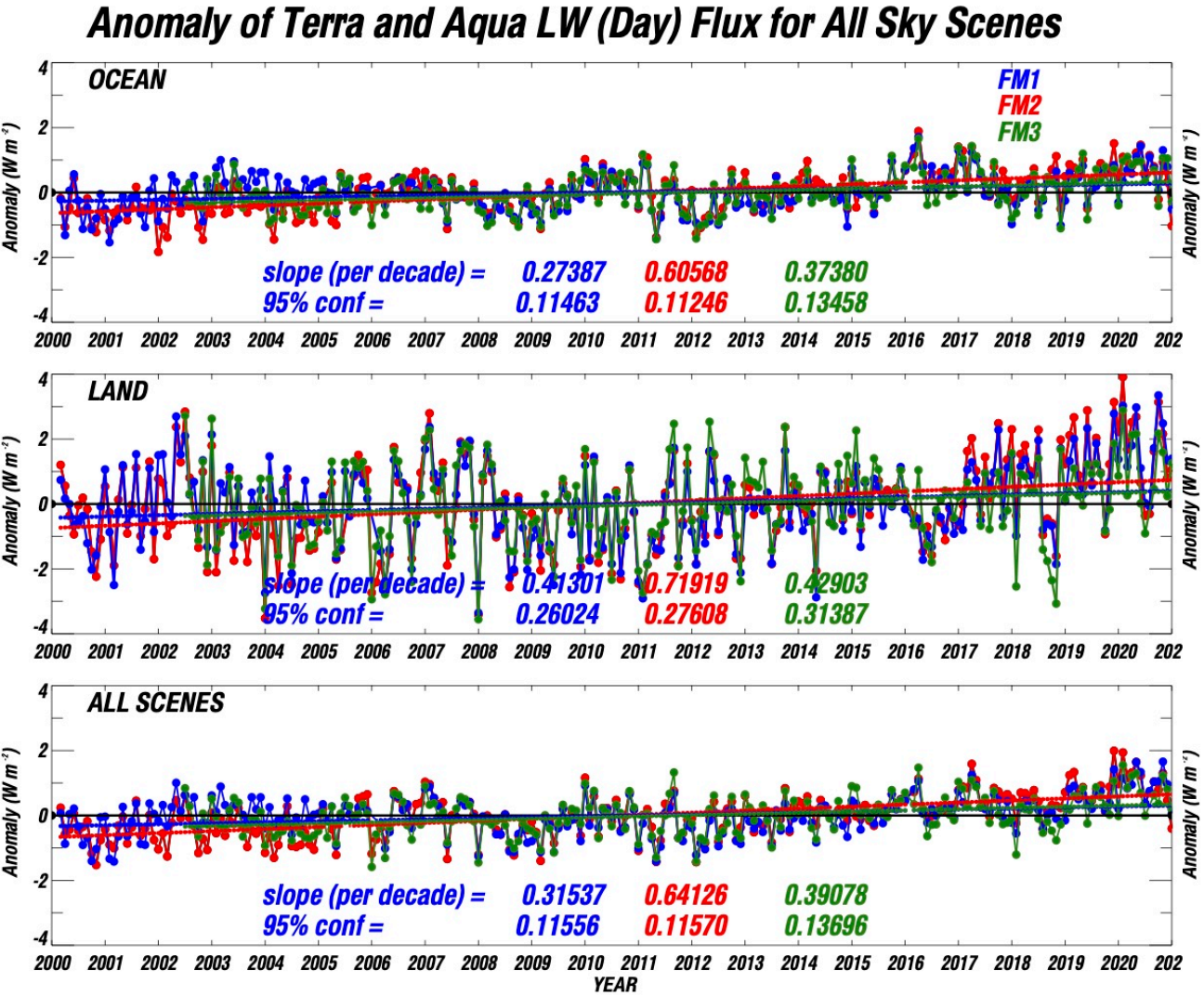
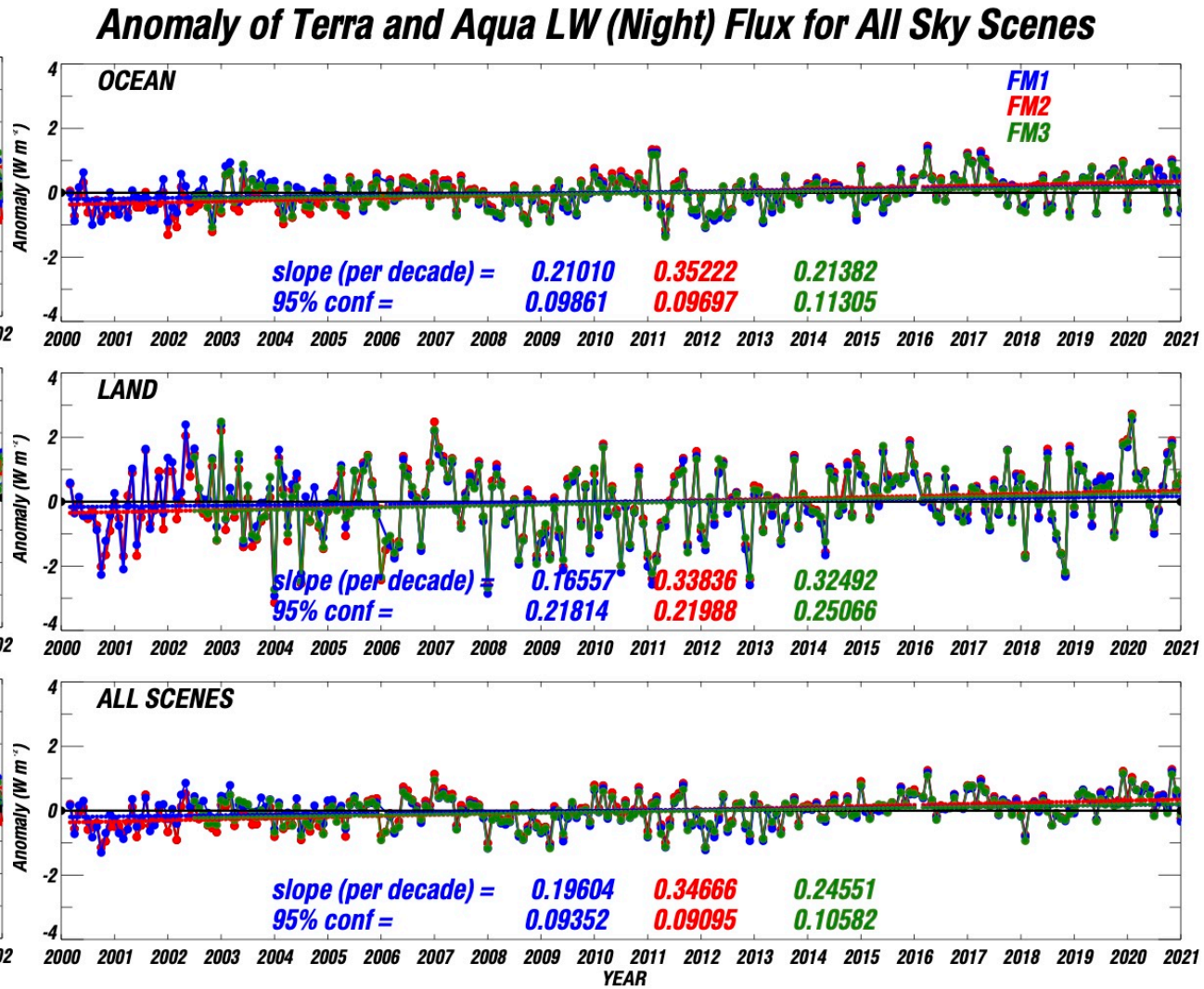
Validation: Terra and Aqua Ed-4 LW Flux Anomalies

LW flux anomalies show similar trends for all three instruments

Uses SSF data products





SUMMARY

- **All CERES instruments continue to perform nominally.**
  - **FM6 instrument continues to show stable performance after the initial sensor response rise.**
  - **FM5 is currently operating in full biaxial mode, collecting ADM data.**
    - ***Validations and other studies show no evidence of change to SW channel performance since transitioning to biaxial mode.***
  - **FM1-FM4 continue to perform normally.**
  - **Validations show that all instruments are performing consistently.**
- **Data products**
  - **NOAA-20/FM6 Edition 1 gains have been finalized and delivered through Mar 2021.**
  - **S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Mar 2021.**
  - **Terra and Aqua instruments' Edition 4 gains and SRFs have been delivered through Feb 2021.**

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.