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

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CERES Instrument Working Group

CERES Spring Science Team Meeting
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CERES Instrument Status Summary

• All CERES instruments continue to demonstrate stable performance.
  ▪ NOAA-20/FM6 instrument continues to operate in Crosstrack mode and instrument is performing nominally.
    • Noise events were observed in the SW channel between Nov 2023 and Feb 2024.
    • There was no impact on the on-board calibration or the L1-L3 data products.
  ▪ SNPP/FM5 is currently operating in Crosstrack scan mode and continues to perform nominally.
  ▪ Terra and Aqua CERES instruments are conducting Cross-track, biaxial, and GEOSCAN.
    • Validation studies show all instruments are performing consistently.

• Level 1 Data products
  ▪ NOAA-20/FM6 Edition 1 gains have been delivered through Mar 2024.
  ▪ S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Jan 2024.
  ▪ Terra and Aqua instruments’ Edition 4 gains and SRFs have been delivered through Feb 2024.
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: 0.2 - 100 microns)
  - Outgoing Longwave Radiances (WN channel (FM1-5): 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.

- On-board Calibration:
  - Blackbodies: TOT channel and WN/LW channel
  - SWICS Lamp - SW channel
  - Mirror Attenuator Mosaic (MAM): Solar Calibration - SW and TOT channel
# CERES Instrument Operations Summary

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**FM6 Stow Dwell**
- Stow dwell testing between Jan 11- Apr 2, 2024.
- Extended stow dwell on Jan 18-19, 1-orbit per day from Jan 17-Feb 21, reduced frequency from Feb 22- Apr 2 (about 2-orbits/week)

**GEOSCAN**
- 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.
CERES Instrument Operations Summary Cont’d

• Inter-comparison operations planned in summer 2024:
  - Terra/FM1 – S-NPP/FM5: May 1 – Jul 31, 2024
  - Terra/FM1 – NOAA-20/FM6: May 1 – Jul 31, 2024
  - Terra/FM1 – Aqua/FM3: Jun 1 – 30, 2024
  - Terra/FM2 – GERB: Jun 1 – 30, 2024
NOAA-20/FM6 Instrument Status
FM6 SW Noise Events
FM6 SW Noise events: Nov 2023- Feb 2024

• Starting late November 2023, SW channel began exhibiting periods of count shifts in SW channel telemetry.
  ▪ Other parameters (engineering, science, or housekeeping) unaffected.
  ▪ Total and LW channels did not exhibit these count shifts.

• This was identified by observing a sudden increase in the number of space view sample averages flagged as ‘bad’ (exceeded a standard deviation threshold).

• Instrument was put into stow-dwell mode to observe characteristics of the noise events
  ▪ Count shifts remained consistent at ~4 count.
  ▪ Duration of events varied from 1 to 100+ samples (.01 to 1+ seconds).
  ▪ Occurrence was independent of orbital location, beta angle, solar activity.
  ▪ Developed and executed a long dwell Internal calibration sequence which verified that the shifts did not scale with magnitude of signal.

• No similarity to failure of FM4 SW channel in 2005.
• Since mid Feb 2024, noise events reduced frequency to about once per month.
• Several investigations carried out showed no impact of count shifts on the data products.
FM6 SW Noise events: Impact to Data products

• Compare NOAA20 clear ocean near-nadir (VZA<20) footprint radiance observations with NB2BB computed radiances (Analysis by: Wenying Su)
  ▪ Used NOAA20 Ed1b NB2BB coefficients developed for EBAF processing to derive clear ocean footprint NB2BB radiances.
  ▪ Compare the CERES observed radiance against the NB2BB radiance for tropical regions (30° S to 30° N) and extratropical (30°-60° N/S) region.
  ▪ Data used: Dec 2022 and Dec 2023.
Tropical Region Comparison

No impact observed due to noise events

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Extra-tropical region comparison

No impact observed due to noise events

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FM6 SW Noise events : Actions/Next steps

• Tiger team currently working to evaluate and determine root-cause.
  ▪ Developed a 'fish bone' table of potential causes.
  ▪ Building circuit models, inspecting instrument build history, studying telemetry and instrument state, and tracking fault occurrences to generate supporting or refuting evidence for those potential causes.
  ▪ Isolated the circuitry where the problem originates from, and continuing to conduct engineering simulations to try and replicate what was observed.

• CERES IWG closely monitoring the instrument telemetry and performance.
  ▪ Occurrences of these SW noise events has reduced to about 1 per month on average over the last few months.
FM6 Calibration/Validation
FM6 Internal Calibration

- For SW and TOT channels, the responses to the on-board sources continue to be quite stable (<0.2%) after the initial rise of ~1.5% (SW) and ~2% (TOT) since start of mission.
- LW Channel shows ~0.2% change.
- Count shifts did not impact the internal calibration data or the process of generating the SW channel gains.

**FM6 In-Flight Ed1-CV Internal Calibration Results**
(Monthly Average)
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 ~2.5% for TOT, the response is quite stable.
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**

FM6 Solar & Internal Calibration
(Monthly Average)

Solar SW - Reflected Solar from MAM
Int SW - Lamp: ~3000K brightness temp.

**TOT Channel**

FM6 Solar & Internal Calibration
(Monthly Average)

Solar TOT – Reflected Solar from MAM
Int Total - Blackbody: ~300 K

Edition 1-CV products
Validation – FM6 Tropical Mean (TM)

• Average of the Nadir radiances over Tropical ocean (20°N-20°S) scenes under All-sky conditions.
  ▪ Uses latest version of ES-8 data products (Edition 1) - All calibration updates have been applied.

• Two sets of TM Day-Night Differences (DN) are calculated:
  ▪ TOT and SW sensors
    \[ DN = TM_D(TOT-SW) - TM_N(TOT) \]
  ▪ LW sensor (FM6 has a broadband LW channel)
    \[ DN = TM_D(LW) - TM_N(LW) \]

• Trends of the difference in the two DN values highlight any inconsistencies in the Reflected Solar wavelengths of the TOT and SW sensors.
Validation - FM6 ES-8 Tropical mean Day-Night

Edition 1 products
FM6 3-channel Consistency check - Global Day-Night Differences

May 2018 - Feb 2024
Edition 1 ES-8, Global, All-sky, Nadir Radiance

FM6 Edition 1 Global Mean LW radiance

Day-Night Difference

Edition 1 data products
Aqua/NOAA-20 Intercomparisons

- The nominal orbital geometries for Aqua and NOAA-20 are such that orbital overlaps occur every ~64 hours.
  - *Aqua’s orbit has drifted from its nominal MLT starting Jan 2022.*
- Obtain spatially and temporally matched observations during every crossover.
- No special operations are conducted to match viewing geometries; Instruments continue operating in their nominal modes:
  - *FM6 in Crosstrack scan mode, FM3 in Biaxial scan mode since Mar 2023.*
- Use matching criteria to subset the data:
  - SZA, VZA difference < 2.0°
  - RAZ difference < 5°
  - Distance between centroid of footprints < 7 km
- Obtain monthly all-sky SW reflectance and LW radiance differences using the matched footprints.
- *Since FM3 started operating in biaxial scan mode, the number of matched footprints drastically reduced.*
Radiometric scaling of FM6 to FM3 done in May 2018.

Larger uncertainties after FM3 switched to biaxial mode are driven by the drastic reduction in number of spatially and temporally matched observations.

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

Daytime LW for FM6 obtained from TOT-SW

FM3 Biax- Mar 2023- Present

Aqua (Ed4)/NOAA20 (Ed1) Daytime LW Intercomparison

Aqua MLT drift start Jan 2022

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

Nighttime LW for FM6 obtained from TOT

FM3 Biax- Mar 2023- Present

Aqua (Ed4)/NOAA20 (Ed1) Nighttime LW Intercomparison

Aqua MLT drift start Jan 2022

Radiometric scaling of FM6 to FM3 done in May 2018.

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

Larger uncertainties after FM3 switched to biaxial mode are driven by the drastic reduction in number of spatially and temporally matched observations.

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NOAA-20 SW and LW Flux Anomaly (Level 3)

Terra started drifting to earlier MLT in Apr 2021

Terra and NOAA20 flux anomalies are consistent

NOAA-20: CER_SSF1deg-Month_NOAA20-VIIRSEdition1
Terra: CER_SSF1deg-Month_Terra-MODISEdition4A
S-NPP/FM5 Instrument Status
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—<0.4% change since Start of mission.

![FM5 Solar Calibration Monthly Average](image)

- BIAX started Oct 2019
- SNPP spacecraft anomaly Aug 2022
- XTK started Oct 2023

**Edition 1-CV products**

**NORMALIZED TO FIRST MONTH**

- 2% Full Scale
Validation – Tropical Mean (FM 1-5)

• Average of the ES-8 Nadir radiances over Tropical ocean (20°N-20°S) scenes under All-sky conditions.
  ▪ Uses latest version of data products - All calibration updates have been applied (Gains and SRFs).

• Two sets of TM Day-Night Differences (DN) are calculated:
  ▪ TOT and SW sensors
    \[ \text{DN}_{\text{TOT}} = \text{TM}_D(\text{TOT}) - \text{TM}_N(\text{TOT}) \]
  ▪ \( \text{LW}_r \) (FM 1-5 use a ‘trained’ WN- Narrow to BB regression)
    \[ \text{DN}_{\text{LW}} = \text{TM}_D(\text{LW}) - \text{TM}_N(\text{LW}) \]

• 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 Edition2 Nadir TM Day-Night Difference

- **TOT-SW**
- **LW_regr**
- **Difference of the two Day-Night differences**

Edition 2 products

- BIAX started - Oct 2019
- XTK started - Oct 2023

**Graph Details**

- X-axis: Jan-12 to Jan-24
- Y-axis: (Day - Night) Watts/m² str

The graph illustrates the day-night difference in the FM5 Edition2 Nadir TM dataset over several years, with key milestones indicated:
- **BIAX** started in Oct 2019
- **XTK** started in Oct 2023

**Legend**

- Red: TOT-SW
- Green with arrow: LW_regr
- Black: Difference of the two Day-Night differences
Aqua/S-NPP Intercomparisons

• The nominal orbital geometries for Aqua and S-NPP are such that orbital overlaps occur every ~64 hours.
  ▪ Aqua’s orbit has drifted from its nominal MLT starting Jan 2022.

• Obtain spatially and temporally matched observations during every crossover.

• No special operations conducted;

• Use matching criteria to subset the data:
  ▪ SZA, VZA difference < 2.0°
  ▪ RAZ difference < 5°
  ▪ Distance between footprints < 7 km

• Obtain monthly all-sky SW reflectance and LW radiance differences using the matched footprints.

• When instruments operated in biaxial mode, the number of matched footprints drastically reduced.
Larger uncertainties when instruments are operated in biaxial mode due to the drastic reduction in number of spatially and temporally matched observations.

CERES Instrument Working Group
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.

Larger uncertainties when instruments are operated in biaxial mode due to the drastic reduction in number of spatially and temporally matched observations.

CERES Instrument Working Group
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 ~0.4% since start of mission.
• For FM2, TOT channel shows ~1.25% rise, SW channel shows ~0.7% drop since start of mission. WN channel shows ~0% change until the transition to BIAX in Nov. 2021.

Edition 1-CV products

Total, WN- Blackbody: ~300 K
SW- Lamp: ~3000K brightness temp.
Aqua- FM3 and FM4 Internal Calibration

- For FM3, TOT channel shows ~0.9% rise, SW channel shows ~0.3% rise, and WN channel shows ~0.6% drop since start of mission.
- For FM4, TOT channel shows ~1.2% rise, while WN channel shows ~0.25% rise since start of mission.
Terra & Aqua Solar Calibration

Since the start of BIAX, the TOT and SW channels on FM2 shows a drop in response of ~0.5%, FM3 drops by ~0.4%. TOT channel on FM4 showed a drop of ~1.2% while in BIAX.
Validation - Terra and Aqua Tropical Mean

- **FM1 Tropical Mean**
  - Terra MLT drift start Apr 2021

- **FM2 Tropical Mean**
  - Terra MLT drift start Apr 2021

- **FM3 Tropical Mean**
  - Aqua MLT drift start Jan 2022

Uses Edition 4 ES-8 data products
Validation: Terra and Aqua Ed-4 SW Flux Anomalies

Level 3 Edition 4 products

Terra started drifting to earlier MLT in Apr 2021. Aqua started drifting to later MLT in Jan 2022.

Note: Aqua record stops in Feb 2023; FM3 was transitioned to BIAxis mode in Mar 2023.

Terra: CER_SSF1deg-Month_Terra-MODIS_Edition4A
Aqua: CER_SSF1deg-Month_Aqua-MODIS_Edition4A
Validation: Terra and Aqua Ed-4 LW Flux Anomalies

Level 3
Edition 4 products

Terra: CER_SSF1deg-Month_Terra-MODIS_Edition4A
Aqua: CER_SSF1deg-Month_Aqua-MODIS_Edition4A

Terra started drifting to earlier MLT in Apr 2021. Aqua started drifting to later MLT in Jan 2022.

Note: Aqua record stops in Feb 2023; FM3 was transitioned to BIAX mode in Mar 2023.
SUMMARY

• CERES instruments on Terra and Aqua performing operations to support scientific studies as their orbits drift.

• All CERES instruments continue to perform nominally.
  ▪ NOAA-20/FM6 instrument is operating in crosstrack scan mode;
    • SW Channel noise events during Nov 2023 through Feb 2024 caused no impact to the higher-level data products and their occurrences are now less frequent.
    • IWG continues to closely monitor telemetry for future occurrences.
  ▪ SNPP/FM5 operating in crosstrack scan mode and continues to perform nominally.
  ▪ Terra and Aqua instruments’ performance are monitored through validation studies as well as inter-comparisons with other CERES instruments, all studies show instruments are performing consistently.

• Level 1 Data products
  ▪ NOAA-20/FM6 Edition 1 gains have been delivered through Mar 2024.
  ▪ S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Jan 2024.
  ▪ Terra and Aqua instruments’ Edition 4 gains and SRFs have been delivered through Feb 2024.

IWG continues to support Libera Cal-Val and Ops meetings.
Backup
Instrument Product-line definitions

• **NOAA-20**
  - *Edition 1*: Incorporates the most up-to-date calibration corrections, radiometric scaling to Aqua.

• **S-NPP**:
  - *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 4*: Incorporates the most up-to-date calibration corrections, radiometric scaling and time varying SRF adjustments to SW and TOT channels.