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 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 and Aqua instruments are conducting Cross-track, biaxial, and GEOSAT scans.
    • Validations show that all instruments are performing consistently.

• Level 1 Data products
  ▪ NOAA-20/FM6 Edition 1 gains have been delivered through March 2023.
  ▪ S-NPP/FM5 Edition 2 gains and SRFs have been delivered through January 2023.
  ▪ Terra and Aqua instruments’ Edition 4 gains and SRFs have been delivered through February 2023.
# CERES Instrument Operations Summary

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**GEOSAT:**
- 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.
• Inter-comparison operations planned in summer 2023:
  - Terra/FM1 – S-NPP/FM5: May 1 – Jul 31, 2023
  - Terra/FM1 – NOAA-20/FM6: May 1 – Jul 31, 2023
  - Terra/FM1 – Aqua/FM3: Jun 1 – 30, 2023
  - Terra/FM2 – GERB: Jun 1 – 30, 2023
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 (<0.2%) 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 quite stable.
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.

Edition 1-CV products
Validation – FM6 Tropical Mean

• 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
    $\text{DN} = \text{TM}_D(\text{TOT-SW}) - \text{TM}_N(\text{TOT})$
  ▪ LW sensor (*FM6 has a broadband LW channel*)
    $\text{DN} = \text{TM}_D(\text{LW}) - \text{TM}_N(\text{LW})$

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

FM6 Nadir TM Day-Night Difference

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

May 2018 - Jan 2023
Edition 1 ES-8, Global, All-sky, Nadir Radiance

FM6 Edition 1 Global Mean LW radiance

Day-Night Difference

Edition 1 data products

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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.

• 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°
  ▪ RAZ difference < 5°
  ▪ Distance between centroid of footprints < 7 km

• Obtain monthly all-sky SW reflectance and LW radiance differences using the matched footprints.
Difference of Reflectance:
FM3-FM6 %, 95% CI

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

Radiometric scaling of FM6 to FM3 done in May 2018.

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

Edition 1 Data products
FM3/FM6 LW All-sky Inter-comparisons: May 2018-Dec 2022

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

Edition 1 Data products
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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NOAA-20 SW and LW Flux Anomaly (Level 3)

Terra, Aqua and NOAA20 flux anomalies are consistent

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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.
- SW response shows a slight upward trend in latter part of mission.

![Graph showing solar calibration results over time with normalized first month and markers for Biaxial started in Oct 2019 and SNPP spacecraft anomaly]
Validation – Tropical Mean (FMs 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.

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

• 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 Edition2 Nadir TM Day-Night Difference

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

Edition 2 products

(Day - Night) Watts/m²/str

Jan-12 Jan-13 Jan-14 Jan-15 Jan-16 Jan-17 Jan-18 Jan-19 Jan-20 Jan-21 Jan-22 Jan-23 Jan-24

CERES Instrument Working Group
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°
  ▪ RAZ difference < 5°
  ▪ 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.
Difference of Reflectance:
FM3-FM5 %, 95% CI

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

2014 data used for the radiometric scaling FM5 to FM3.

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

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Reflectance = \( \frac{S_{\text{rad}} \times \pi}{F \times \cos(SZA)} \)

F=1361 W/m²

FM5 Biax: Oct 2019- Present

Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM5-VIIRS_Edition2A
Difference of Daytime Radiance:
FM3-FM5 %, 95% CI

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

Data:
CER_SSF_Aqua - FM3 - MODIS_Edition4A
CER_SSF_NOAA20 - FM5 - VIIRS_Edition2A
FM3/FM5 LW All-sky Inter-comparisons: Feb 2012- Dec 2022

2014 data used for the radiometric scaling FM5 to FM3.

Larger uncertainties after FM5 switched to biaxial mode are driven by 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.

Total, WN- Blackbody: ~300 K
SW- Lamp: ~3000K brightness temp.
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 ~1.2% rise, while WN channel shows ~0.25% rise since start of mission. FM4 transitioned to BIAAX in Jul 2021, back to XTK in Mar 2023.
Since the transition to biaxial scanning, the TOT and SW channel on FM2 shows a drop in response of ~0.5%, while the TOT channel on FM4 shows a drop of ~0.8%.
Validation - Terra and Aqua Tropical Mean

FM1 Tropical Mean

FM2 Tropical Mean

FM3 Tropical Mean

Uses Edition 4 data products
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.

Edition 4 products

**Anomaly of Terra and Aqua LW Flux (SSF1deg) for All Sky Scenes**

**Ocean**
- Terra: CER_SSF1deg-Month_Terra-MODIS_Edition4A
- Aqua: CER_SSF1deg-Month_Aqua-MODIS_Edition4A
SUMMARY

• CERES instruments on Terra and Aqua have started operations to support scientific studies as the orbit drifts.

• 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.
    • No evidence of deviation of instrument performance since transitioning to biaxial mode.
  ▪ Terra and Aqua instruments’ performance are monitored through validation studies as well as inter-comparisons with other CERES instruments.

• Level 1 Data products
  ▪ NOAA-20/FM6 Edition 1 gains have been delivered through Mar 2023.
  ▪ S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Jan 2023.
  ▪ Terra and Aqua instruments’ Edition 4 gains and SRFs have been delivered through Feb 2023.

• 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**
  - *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.
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**

\[ \text{LW} = 0.9960 \times (\text{LW from TOT-SW}) \]

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

\[ \text{LW} = 0.9995 \times (\text{LW from TOT}) \]

Daytime
\[ \text{LW}_{\text{TOT-SW}} - \text{LW}_{\text{LWC}} = 0.4\% \]

Nighttime
\[ \text{LW}_{\text{TOT}} - \text{LW}_{\text{LWC}} = 0.05\% \]
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.
Validation - DCC 3-Channel Intercomparison