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

Mohan Shankar
CERES Instrument Working Group
CERES Fall Science Team Meeting,
Lawrence Berkeley National Lab,
Berkeley, CA
October 29, 2019
## Instrument Working Group

**Chair:** Kory Priestley

<table>
<thead>
<tr>
<th>Instrument Operations</th>
<th>Data Management</th>
<th>Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>- B. Mike Tafazoli</td>
<td>- Denise Cooper</td>
<td>- Susan Thomas—</td>
</tr>
<tr>
<td>- Janet Daniels</td>
<td>- Dale Walikainen</td>
<td>Phillip Hess</td>
</tr>
<tr>
<td>- Christopher Brown</td>
<td>- A. Thomas Grepiotis</td>
<td>Hyung Lee</td>
</tr>
<tr>
<td>- John Butler</td>
<td>- Mark Timcooe</td>
<td>Nathaniel Smith</td>
</tr>
<tr>
<td>- Alexander Thickstun</td>
<td>- Dianne Snyder</td>
<td>Nichie Smith</td>
</tr>
<tr>
<td>- Adam Horn</td>
<td></td>
<td>Z. Peter Szewczyk</td>
</tr>
<tr>
<td>- Carol Kelly</td>
<td></td>
<td>Robert Wilson</td>
</tr>
<tr>
<td>- William Edmonds</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CERES Instrument Operations

• Flight Models (FM) 1-4, FM6 are in nominal mode of operation- Crosstrack.
• FM5 is operating in Biaxial mode since Oct 1, 2019.
• Support of the MOSAiC Expedition:
  • CERES FM2 targeting the location of the Polarstern.
  • Trial runs being planned during the next few months.
• Inter-comparison Operations during summer 2019
  • Terra/FM1 – S-NPP/FM5: May 1 – Jul 31, 2019
  • Terra/FM1 – NOAA-20/FM6: May 1 – Jul 31, 2019
  • Terra/FM1 – Aqua/FM3: Jun 1 – 30, 2019
  • Terra/FM2 – GERB: Jun 1 – 30, 2019

Overpass region around 70° N

60° N – 0° (Equator)
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).
- LW Channel (calibrated using blackbody) continues to show very little variation.
FM6 SWICS Silicon Photodiode

FM6 Si PD, the SWICS lamp monitor, continues to show significantly improved performance over the PDs from other CERES instruments.
FM6 Solar Calibration

- Solar Calibration results for SW and TOT channels show similar performance to the response to on-board calibration sources.
- After the initial rise of ~1.5% for SW, and ~2.5% for TOT, the response is very stable.
In comparison with FM5 solar calibration trends, the results from FM6 show the MAMs are stable.
Validation – Tropical Mean

- Average of the Nadir radiances over Tropical ocean (20°N-20°S) scenes under All-sky conditions.

- TM Day-Night Difference (DN) is calculated:
  - TOT and SW sensors
    \[ \text{DN} = \text{TM}_D(\text{TOT-SW}) - \text{TM}_N(\text{TOT}) \]
  - LW sensor
    \[ \text{DN} = \text{TM}_D(\text{LW}) - \text{TM}_N(\text{LW}) \]

- Difference in the two DN values point to an anomaly in the shortwave regions of the sensors.
Validation - FM6 Tropical mean
FM6 3-channel Consistency check - LW Day and Night

**Day**
TOT- SW vs. LW sensor

**Night**
LW from TOT vs. LW sensor

- LW = 0.98(TOT - SW)
- LW = 0.97(LW from TOT)
FM6 Edition-1 path forward

• Update the sensor gains.
  • Start from May 2018.

• Perform radiometric scaling to Aqua/FM3 at BOM
  • We’ve used SSFs earlier and we will need to evaluate the ability to use ES-8s in case SSFs are not available.

• Look for long term trends in validation studies to point to spectral changes (none observed so far):
  • Tropical Mean
  • 3-channel Consistency checks: TOT-LW vs. SW and LW + SW vs. TOT for various scenes.
S-NPP/FM5 Instrument Status
FM5 Biaxial mode test run

• FM5 was operated in biaxial mode between Aug 18 – Sept 1, 2019 as a test run.

• Total channel resets occurred due to obstruction by the HRD antenna that appears in the telescope FOV during space view in azimuth angle range 101-112 degrees.
  • Space look corruption occurs for all three channels, but the TOT channel signal was large enough to cause resets.

• The azimuth angle range has now been revised to start at 115 degrees.
FM5- Biaxial operation

FM5 is operating in Biaxial mode since 10/1/2019.

Low solar Beta angle, Az range 115 - 259 deg

High solar Beta angle, Az range 115 - 270 deg

El Range: Short scan

10/1/19- 10/13/19

10/13/19 onward
FM5 Internal Calibration

FM5 TOT and WN sensors show a ~0.5% rise, while the SW channel settled after initial ~0.2% drop in response.
FM5 Solar Calibration

- FM5 Solar calibration results show the MAMs are very stable. TOT response is steady, while the SW response shows a slight upward trend.
- Currently the team is performing analysis to compare internal calibration and solar calibration.

![](chart.png)
FM5 Edition 2

• The Beginning of Mission (BOM) SRF for FM5 was adjusted to radiometrically scale the SW for FM5 to FM3 in 2014 for global all-sky, all scenes based on inter-comparison data.
  • Re-evaluated the pre-launch instrument test data and used a Lagrange multiplier based optimization approach to obtain optimal solution.
  • TOT channel did not require any BOM adjustments.

• Observed a small upward long-term trend in the LW day validation studies.

• Used the regression between the LW (Day-Night) and WN (Day-Night) for Ocean and Land scenes to adjust the SW/TOT SRF using the functional form:

\[ D(\lambda) = [1 - e^{-\alpha \lambda}] + \beta \]
Validation: S-NPP – Aqua (Ed 4) Flux difference

FM5 Edition 2 shows more consistency with the Aqua/FM3 instrument (Ed4) at BOM as well as long term.
Validation: FM5 SW and LW day Anomalies

Anomaly of S-NPP SW Flux (24h) for All Sky Scenes

Ocean:
- Slope (per decade) = -1.59983
- 95% conf = 0.65567

Land:
- Slope (per decade) = 0.20033
- 95% conf = 0.81667

All Scenes:
- Slope (per decade) = -1.05749
- 95% conf = 0.48240

Anomaly of S-NPP LW (Day) Flux for All Sky Scenes

Ocean:
- Slope (per decade) = 2.25161
- 95% conf = 0.48873
- 0.66579

Land:
- Slope (per decade) = 1.43560
- 95% conf = 1.24249
- 1.24654

All Scenes:
- Slope (per decade) = 2.01111
- 95% conf = 0.48555
- 0.33433

CERES Instrument Working Group
Validation - FM5 Tropical Mean

![Graph showing Nadir Tropical Mean FM5 Edition2](image)
Validation: DCC 3-Channel Intercomparison

- 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

- The trend between the difference of the two LW radiances and the SW radiance is monitored over time.

- Highlights inconsistencies in the relationship in the response functions of the SW sensor and the shortwave part of the TOT sensor.
DCC 3-Channel Intercomparison

FM5 Nadir Three Channel

slope [ΔIW vs. fISW]

-0.01 0.00 0.01 0.02 0.03 0.04


Edition1 Edition2
CERES Instrument Working Group

Orbital Overlaps every ~64 hours

Spatially and temporally matched observations

Matching criteria:
- Lat. and Long. difference ≤ 0.05°
- SZA, VZA difference < 2.0°
- RAZ difference < 5°

Aqua-NPP Intercomparisons

CERES FM3 on Aqua
Altitude: 704 km
Inclination: 98.2°
Equatorial Crossing: 1:36 PM

CERES FM5 on S-NPP
Altitude: 824 km
Inclination: 98.7°
Equatorial Crossing: 1:27 PM

Orbital Overlaps every ~64 hours
FM5/FM3 Inter-comparisons SW: 2012-2018

Difference of Reflectance:
FM5-FM3 %

\[
\text{Reflectance} = \frac{SW_{\text{rad}} \times \pi}{F \times \cos(SZA)}
\]

F=1361 W/m²

2014 data used for the radiometric scaling FM5 to FM3.
FM5/FM3 Inter-comparisons LW day: 2012-2018

FM5: Ed1
FM3: Ed4

Difference of Radiance: FM5-FM3 %

FM5: Ed2
FM3: Ed4

S-NPP/Aqua LW Day Intercompare
Terra & Aqua Instruments’ Status
CERES FM1-FM4
Terra- FM1 & FM2 Internal Calibration

- For FM1, TOT channel shows ~0.6% rise, SW channel shows ~0.1% drop, and WN channel shows ~0.5% rise after initial drop.
- For FM2, TOT channel shows ~1% rise, SW channel shows ~0.5% 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 ~0.5% rise, and WN channel shows ~0.8% drop.
- For FM4, TOT channel shows ~1% rise, while WN channel shows ~0.25% rise.
Terra- FM1 & FM2 Solar Calibration

Revisiting the analysis for solar calibration for all instruments.
Since the transition over to raster scan for solar calibration, SW channel data shows a drop of response of ~1% and TOT channel shows a drop of ~1.5% for both FM1 and FM2 instruments. Focusing on the raster scan data and comparing with the internal calibration results.
Aqua Solar Calibration, Raster Scan only

FM3 SW shows ~1% drop in response since start of raster scan. TOT channel from both FM3 and FM4 show a similar 2% drop in response.
Validation: Terra and Aqua Ed-4 SW Flux Anomalies

SW flux anomalies show similar trends for all three instruments.
Validation: Terra and Aqua Ed-4 DLW Flux Anomalies

LW flux anomalies show similar trends for all three instruments.
Validation- Terra and Aqua Tropical Mean
Validation- DCC 3-Channel Intercomparison

Terra and Aqua Nadir Three Channel

slope [ΔLW vs. mSW]


FM1
FM2
FM3
FM4
SUMMARY

• CERES FM6 instrument continues to show stable performance after the initial sensor response rise.
  • ICM and solar calibration show good agreement.
  • Validations so far show no indication of spectral changes.

• CERES FM5 Edition 2 has been validated and is ready for delivery. All validation studies show that Edition 2 corrects for the trends observed in Daytime LW in the Edition 1 validation studies.

• Terra and Aqua instruments’ gains and SRFs for Edition 4 processing were delivered through June 2019. Validation results show consistent trends between all three instruments (FM1-FM3).
Backup
S-NPP HRD Antenna and FOV blockage
Simultaneous Earth observation with Aqua/FM3

May – December 2018

ΔTime < 1 min; ΔRAZ < 10°; ΔVZA < 10°

<table>
<thead>
<tr>
<th>(FM6-FM3)/FM6</th>
<th>FM6 Radiance [W m⁻² sr⁻¹]</th>
<th>Relative Error [%]</th>
<th>α-confidence [95%]</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortwave</td>
<td>79 / 88</td>
<td>3.34 / 3.67</td>
<td>.6 / .5</td>
<td>22/30</td>
</tr>
<tr>
<td>LW daytime</td>
<td>76 / 76</td>
<td>1.95 / 1.18</td>
<td>.2 / .1</td>
<td>23/31</td>
</tr>
<tr>
<td>LW nighttime</td>
<td>66 / 68</td>
<td>1.97 / 1.90</td>
<td>.2 / .1</td>
<td>22/42</td>
</tr>
</tbody>
</table>

- Edition 1-CV for FM6 and Edition 4 for FM3 are used
- Shown differences are computed as “average of differences” to avoid error cancellation
Comparison of FM6/FM5/FM3 with FM1

Minor Plane Scan (Greenland)
ΔRAZ < 10°; ΔVZA < 10°
Edition 4 for FM3; Edition 1 for FM5; Edition 1-CV for FM6
Terra and Aqua Ed-4 Night Flux Anomalies
TERRA/AQUA/S-NPP Instrument Anomalies

Anomaly of Terra/Aqua/NPP_ED2 SW Flux (24h) for All Sky Scenes

Anomaly of Terra/Aqua/SNPP_ED2 LW Flux (Day / Global / All Sky)