Clouds and the Earth’s Radiant Energy System

FM-6 Radiometric Performance : Initial Results

Instrument Working Group
Kory Priestley, presenting

Earth Radiation Budget Science Team Meeting
NASA Langley Research Center
May 15, 2018
Newest Team Member
Newest Team Member

Really Grandpa???
Executive Summary

- NOAA-20 launched on 11/18/17
- CERES operational power applied 11/29/17
- CERES opened covers on 1/5/18 and began Earth observations
- CERES has *successfully* completed all commissioning activities
- All aspects of performance are as expected and acceptable
- LaRC processing system fully operational - No SDR products for CERES
- We are thankful for the close and collaborative coordination with the JPSS team
CERES on NOAA-20 First Light Images

- Contamination covers completed opening at 12:57AM ET January 5th.
- Global maps of the instantaneous Reflected Solar and Emitted Thermal TOA Fluxes.
- The data time period spans 24 hours from about 1:50PM ET Friday January 5th.
- Timing was perfect to capture the tail-end of the ‘Bomb Cyclone’ Snow event which moved through the Mid-Atlantic Region January 3rd.
Earth Radiation Budget Science Processing

Leveraging NASA’s 2+ decade investment in the Earth Radiation Budget Science Team

‘Autonomous’ processing stream necessary for characterizing instrument performance
## CERES Flight Radiometric Validation Activities

<table>
<thead>
<tr>
<th>Product</th>
<th>Spatial Scale</th>
<th>Temporal Scale</th>
<th>Metric</th>
<th>Spectral Band</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On-Board</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal BB</td>
<td>Filtered Radiance</td>
<td>N/A</td>
<td>N/A</td>
<td>Absolute Stability</td>
</tr>
<tr>
<td>Internal Lamp</td>
<td>Filtered Radiance</td>
<td>N/A</td>
<td>N/A</td>
<td>Absolute Stability</td>
</tr>
<tr>
<td>Solar</td>
<td>Filtered Radiance</td>
<td>N/A</td>
<td>N/A</td>
<td>Relative Stability</td>
</tr>
<tr>
<td>Theoretical Line-by-Line</td>
<td>Filtered Radiance</td>
<td>&gt; 20 Km</td>
<td>Instantaneous</td>
<td>Inter-Channel Theoretical Agreement</td>
</tr>
<tr>
<td>Unfiltering Algorithm</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Theoretical Validation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inter-satellite (Direct Comparison)</td>
<td>Unfiltered Radiance</td>
<td>1-deg Grid</td>
<td>1 per crossing</td>
<td>Inter-Instrument Agreement, Stability</td>
</tr>
<tr>
<td>Globally Matched Pixels (Direct Comparison)</td>
<td>Unfiltered Radiance</td>
<td>Pixel to Pixel</td>
<td>Daily</td>
<td>Inter-Instrument Agreement</td>
</tr>
<tr>
<td>Tropical Mean (Geographical Average)</td>
<td>Unfiltered Radiance</td>
<td>20N – 20S</td>
<td>Monthly</td>
<td>Inter-Channel Agreement, Stability</td>
</tr>
<tr>
<td>DCC Albedo</td>
<td>Unfiltered Radiance</td>
<td>&gt;40 Km</td>
<td>Monthly</td>
<td>Inter-Instrument agreement, Stability</td>
</tr>
<tr>
<td>DCC 3-channel</td>
<td>Unfiltered Radiance</td>
<td>&gt;100 Km</td>
<td>Monthly</td>
<td>Inter-Channel consistency, stability</td>
</tr>
<tr>
<td>Time Space Averaging</td>
<td>Fluxes</td>
<td>Global</td>
<td>Monthly</td>
<td>Inter-Instrument Agreement</td>
</tr>
<tr>
<td>Lunar Radiance Measurements</td>
<td>Filtered Radiance</td>
<td>Sub Pixel</td>
<td>Quarterly</td>
<td>Inter-Instrument Agreement</td>
</tr>
</tbody>
</table>
• Noise Equivalent Radiance is statistically indistinguishable from that measured during the pre-launch radiometric Calibration in 2014.
Scan Angle Dependent Bias Values

TOT Channel

SW Channel

LW Channel
3.4.1 CERES On-Orbit Calibration
   • CERES shall perform on-orbit calibration for all channels.

3.4.3 CERES Solar Calibration
   • CERES shall be capable of performing bi-weekly radiometric calibrations using the Sun as a calibration source.

3.4.4 CERES Lunar Calibration
   • CERES shall be capable of performing periodic radiometric calibrations using the Moon as a calibration source.
ICM contains 2 subassemblies

Shortwave Internal Calibration Source (SWICS):
- Lamp and focusing optics
- Reference Detector
- Folding Mirror

Internal BlackBody (IBB):
- Concentric grooved blackbodies
- Heaters and PRTs

During Calibration we view the SWICS lamp with two independent detectors
CERES SW sensor and Reference Photodiode
FM1-FM5 Instruments Shortwave Channel Gain Stability
First 365 days post cover opening

Covers closed duration varies with mission
Limited Cal data (FM1-FM4) prior to cover opening
All Instruments Shortwave Channel Gain Stability
First 365 days post cover opening

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All Instrument SW SWICS Level 3 SiPD Reference Detector
First 365 days post cover opening

Part Change for FM-6 to address known susceptibility to degradation
### All Instruments Total Channel Gain stability

**First 365 days post cover opening**

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Days Since Launch</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM1_TLGN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM2_TLGN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM3_TLGN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM4_TLGN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM5_TLGN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM6_TLGN</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Channel Cals have higher noise than SW**

![Graph showing % Change vs Days Since Launch for different instruments](image_url)
Internal Cal Results – Covers Open

Note: All Axes 2.5% full scale
Solar and Internal Cal Comparison

Note: Both datasets Normalized to 1/9/18

Note: All Axes 3.0% full scale
New Broadband LW channel enables many new Validation capabilities

Note: At-Launch Production strategy
Earth Viewing Data
FM-6 Nighttime OLR Intra-Channel Comparison - Nadir (LW-LWc) Daily ES-8

Note: At-Launch Production strategy
Earth Viewing Data
LWc implies Longwave Channel
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FM-6 Daytime OLR Intra-Channel Comparison - Nadir (LW-LWc) Daily ES-8

Daytime Outgoing Longwave Radiation (OLR) Nadir Comparison (Total - Shortwave) minus (Longwave)

Daytime Outgoing Longwave Radiation (OLR) Nadir Comparison (Total - Shortwave) minus (Longwave)

Daytime OLR Nadir Radiance (Total - Shortwave)

Note: At-Launch Production strategy
Earth Viewing Data
LWc implies Longwave Channel
S-NPP to NOAA-20 TOA Flux Comparison

- CERES FM5 to FM6 Intercomparisons underway (Insufficient data collected to date)
- Diagnostic Tools developed
- Qualitative Analyses (ES-8 product) look very promising

Note: At-Launch Production strategy (FM6) Edition1-CV Production Strategy (FM5) Earth Viewing Data
CERES FM5 to FM6 2.5-deg monthly average comparisons (ERBE-Like S4 product, January 2018)

Note: At-Launch (FM6) Edition1-CV (FM5) Earth Viewing Data
Geolocation and Pointing Accuracy – Coastline Detection

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Detections</th>
<th>Mean Xt Error (km) 95% Confidence Interval</th>
<th>Mean At Error (km) 95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM6</td>
<td>112</td>
<td>-0.60 +/- 0.53 km</td>
<td>-1.22 +/- 0.89 km</td>
</tr>
</tbody>
</table>

January 6th – January 30th Baseline1-QC BDS and ES8 files

Success Criteria
Objective: Utilize the full moon as a quasi-point source to complete a near steady-state raster scan across the CERES FOV.

Goals

• Validate pre-launch alignment measurements
• Measure inter-channel relative pointing accuracy
• Map out spatial non-uniformities in the CERES Optics/Detectors
  • This type of mapping is not performed under vacuum prior to launch.
• Measure Lunar Radiances for future instrument intercomparisons.

~ By combining knowledge of the motion of the moon relative to the spacecraft and the programmability of the CERES Instruments we obtain........~
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Post-Launch Lunar Calibrations
IFOV Uniformity Mapping & Coregistration

TOT Channel
SW Channel
LW Channel
Post-Launch Lunar Calibrations
IFOV Uniformity Mapping & Coregistration

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TOT Channel
SW Channel
LW Channel
Lunar Cal Results – Covers Opened

Pointing Knowledge/Co-Registration

- Knowledge Requirement
- Pointing Requirement

Scan Angle

Cross-Scan Angle

Total
Shortwave
Longwave

IFOV
Lunar Cals Spanning Beta Angle Variation

Total - Orbit 7
Effective Beta Angle = 26.5°

Total - Orbit 8
Effective Beta Angle = 22.6°

Total - Orbit 6
Effective Beta Angle = 18.8°

Total - Orbit 9
Effective Beta Angle = 14.9°

Total - Orbit 10
Effective Beta Angle = 11.0°

Solar Azimuth
Solar Elevation

Solar Azimuth
Solar Elevation

Solar Azimuth
Solar Elevation

Solar Azimuth
Solar Elevation

Solar Azimuth
Solar Elevation
Yaw Maneuver Results—Shortwave Channel

Lunar Cals Spanning Beta Angle Variation

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• LaRC processing system fully operational - No SDR products for CERES
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*The Science Team is happy to inherit the CERES Instrument*
Aqua/NPP/NOAA-20 Flight Cal Locations

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- Lunar Observations
- Solar Calibrations
- Internal Calibration Sequence
• Preliminary success will be analyzed after 60 days over all 5 criteria.
  • Absolute success will be measured longer term trending to maintain requirements throughout instrument life.
  • Acquire valid Lunar calibration measurements on each side of the full moon and one near full moon.
  • Perform crosstrack scanning for more than 60 days. (Currently ~35)
• Verify pointing accuracy to 746 (3σ) arcseconds and knowledge to 378 (3σ) arcseconds (Lunar)
• Verify footprint is geolocated within 10% of the footprint size with 95% confidence (Coastline)