Comparison of the Earth’s short-wave radiation measured by ERB instruments (CERES/GERB)

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Presentation Outline

• Special mode of a CERES instrument
• Comparing FM1 and FM4 for the ERB dataset
• Matching GERB instrument geometry
• Comparison of CERES/GERB unfiltered SW radiances for the ERB dataset
Clouds and the Earth’s Radiant Energy System Instrument

- Narrow field-of-view (15x30km at nadir) scanning radiometer:
  - Shortwave channel (0.3-5µm),
  - Total channel (0.3-100µm),
  - Window channel (8-12µm)
- PFM on board TRMM (1998, failed 06/2000)
- FM1 & FM2 on board Terra (in service from 03/2000)
- FM3 & FM4 on board Aqua (in service from 06/2002)
CERES

Calibration stability monitored with:

• On-board calibration sources (blackbodies, lamps, solar)
• Multi-channel and multi-instrument consistency
• Geophysical validation

Gain drifts can be detected at the 0.1% level, and corrected!

A part of validated data set for the radiation budget since 1984
Terra & Aqua orbits

- Sun-synchronous, inclination angle 98.2° and 81.8°
- Equatorial crossing time: 10:30AM and 1:30PM
- about 15 minutes apart at nodes
CERES normal operation modes

- Cross-track (XT) Scan
- Rotational Azimuth Plane Scan (RAPS)
Special mode

Programmable Azimuth Plane Scan (PAPS) mode:

• Scanning plane orientation follows a prescribed schedule
  ✓ Step-wise changes of the azimuth angle
  ✓ Time and angle changes depend on satellite position in an orbit
• Increases sampling by an order of magnitude

PAPS applications:

• Special observations
  ✓ Earth targets
  ✓ Matching viewing geometry of other instruments
  ✓ Sampling within required scan plane orientation
Comparing remote sensing instruments

Comparison of instrument measurements should be performed under the most ideal conditions
FM1/FM4 comparison

To validate FM4 (Aqua) radiances for ERB dataset

Campaign around the summer solstice of ’02 and ‘03

Greenland appears to be the most homogenous:

• FM1 (Terra) and FM4 (Aqua) 15 minutes apart
• Scans orthogonal to the solar plane
• VZA matched within 10°, RAZ within 1°
• About 90 sec of data per orbit
FM1 scan over Greenland

Unfiltered shortwave radiances at 13:40 on 07/10/2003

Watts per square meter per steradian
FM4 scan over Greenland

Unfiltered shortwave radiances at 13:54 on 07/10/2003

Watts per square meter per steradian
FM1 scanning pattern

Unfiltered shortwave radiances on 07/10/2003

Watts per square meter per steradian
FM4 scanning pattern

Unfiltered shortwave shortwave on 07/10/2003
Data processing constraints

Direct comparison of radiances:
  • difference of averages

No time issue:
  • Terra – Aqua 15 minutes apart

Spatial noise dominates:
  • averaging over 1° x 1° grid-boxes
  • at least 20 footprints or 75% of area covered

Matching geometry:
  • 10° tolerance for the VZA for all three channels
  • 1° tolerance for the relative azimuth for shortwave
Statistics

Direct comparison of radiances:

• Each orbital crossing is an independent sample
• Difference computed over a grid-box and orbital crossing
• Uncertainty estimated using a 95% confidence level

\[ \alpha - \text{test: } \epsilon = \frac{t_{\alpha/2} \sigma}{\sqrt{N}} \]
Shortwave radiances

\[ y = 0.9x + 1.45 \]

\[ y = 0.94x + 2.3 \]

\[ y = 0.99x + 1.1 \]
SW radiances over Greenland

\[ y = 1.00x - 0.96 \]
## Results for Greenland

<table>
<thead>
<tr>
<th>Period</th>
<th>Mean FM4 [Wm(^{-2})sr(^{-1})]</th>
<th>Δ mean [Wm(^{-2})sr(^{-1})]</th>
<th>Δ mean [%]</th>
<th>Δσ [%]</th>
<th>(N_{\text{orbX}})</th>
<th>α–test [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>July, 2002</td>
<td>157.3</td>
<td>0.33</td>
<td>0.2</td>
<td>1.20</td>
<td>30</td>
<td>0.4</td>
</tr>
<tr>
<td>August, 2002</td>
<td>145.1</td>
<td>0.21</td>
<td>0.1</td>
<td>0.90</td>
<td>13</td>
<td>0.4</td>
</tr>
<tr>
<td>June, 2003</td>
<td>156.9</td>
<td>−0.87</td>
<td>−0.6</td>
<td>0.60</td>
<td>25</td>
<td>0.2</td>
</tr>
</tbody>
</table>
FM1/FM4 summary

- Comparison procedure for FM1 and FM4 was shown to be well planned and executed.
- Data analysis fully demonstrated the 1% consistency in radiance measurements (small spread).
- Experiment is repeated during the summer solstice every year in an effort to monitor the CERES performance.
- CERES instruments have delivered a high quality Earth radiation budget (ERB) data set since 1998.
GERB measurements

• Geo-stationary Earth Radiation Budget instrument
  ✓ On board MSG located at 3.4W (10.5 W)
  ✓ Array of 256 detectors covering the visible portion of the Earth
  ✓ Short and long-wave radiation image every 15min.
CERES/GERB comparison

To validate GERB radiances for ERB dataset

- Campaign around the winter solstice of 2003
  - PAPS matches GERB viewing geometry
  - FM2 on Terra in this special mode for about 15 days
  - 4 daytime orbits per day for about 85 min scanning
  - Unfiltered shortwave radiances are produced by RMIB for this study
  - GERB pointing accuracy is improved using SEVIRI data
  - GERB geolocation error is about a half of its footprint without bias
CERES/GERB daily scanning
CERES/GERB daily scanning
CERES/GERB daily scanning
CERES/GERB daily scanning
CERES/GERB comparison

- **Clear ocean**
  \[ y = 0.836x + 5.04 \]

- **Clear desert**
  \[ y = 0.997x - 0.55 \]

- **Overcast**
  \[ y = 1.044x - 2.88 \]

- **All-sky**
  \[ y = 1.038x - 0.09 \]
## Preliminary results for SW

<table>
<thead>
<tr>
<th>Scene ID</th>
<th>Mean FM2 [Wm$^{-2}$sr$^{-1}$]</th>
<th>$\Delta$ mean [Wm$^{-2}$sr$^{-1}$]</th>
<th>$\Delta$ mean %</th>
<th>$\Delta\sigma$</th>
<th>$N_{\text{orbX}}$</th>
<th>$\alpha$–test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear ocean</td>
<td>30.8</td>
<td>0.2</td>
<td>0.7</td>
<td>3.2</td>
<td>140</td>
<td>0.37</td>
</tr>
<tr>
<td>Clear desert</td>
<td>75.3</td>
<td>0.7</td>
<td>1.0</td>
<td>2.2</td>
<td>42</td>
<td>0.65</td>
</tr>
<tr>
<td>Overcast</td>
<td>145.5</td>
<td>-8.9</td>
<td>-6.2</td>
<td>7.4</td>
<td>166</td>
<td>1.14</td>
</tr>
<tr>
<td>All-sky</td>
<td>81.0</td>
<td>-2.8</td>
<td>-4.0</td>
<td>11.3</td>
<td>621</td>
<td>0.92</td>
</tr>
</tbody>
</table>
CERES/GERB summary

• Preliminary results presented
• Large amount of data using the PAPS mode
• 1% consistency in the middle of spectrum
• More bias for bright scenes
• GERB’s improved pointing accuracy is a key to promising results
• Further improved geolocation needed!
Concluding remarks

- CERES participated in variety of campaigns
- PAPS mode for special observations
- Planning tools reside on a website
- Rapid response due to automation
- Free service to the science community

http://asd-www.larc.nasa.gov/PAPS/cgi-bin/rygar.cgi