Comparisons of Top-of-atmosphere Radiation Budget from Multiple Data Sets: GEWEX Radiative Flux Assessment Results

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Earth Radiation Budget Workshop
École Normale Supérieure (ENS), Paris, France
13-16 September 2010
GEWEX RFA TOA Radiation Overview

- GEWEX Radiative Flux Assessment (RFA) is a community based activity (first of its kind for TOA and surface radiative flux) commissioned by GEWEX Radiation Panel.

- Assess our current understanding and capability to derive TOA radiative fluxes from analysis of satellite observations.

- Identify uncertainties and outstanding issues in flux estimation (including satellite calibration, input data sources, spatial and temporal gap filling, and other assumptions).

- The final report will be an useful reference for developing future climate data requirements for radiative fluxes as well as for understanding current data limitation and uncertainty for future IPCC report.
## GEWEX RFA TOA Radiation Datasets

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Satellite Source</th>
<th>Spatial Coverage</th>
<th>Temporal Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CERES**</td>
<td>Terra, Aqua</td>
<td>Global</td>
<td>03-2000 to 10-2005</td>
</tr>
<tr>
<td>ISCCP-FD</td>
<td>Geo + Polar</td>
<td>Global</td>
<td>07-1983 to 12-2004</td>
</tr>
<tr>
<td>GEWEX SRB</td>
<td>Geo + Polar</td>
<td>Global</td>
<td>07-1983 to 06-2005</td>
</tr>
<tr>
<td>FORTH</td>
<td>Geo + Polar</td>
<td>Global</td>
<td>01-1984 to 12-2004</td>
</tr>
<tr>
<td>UMD SRB/SW**</td>
<td>Geo + Polar</td>
<td>Global</td>
<td>07-1983 to 12-2004</td>
</tr>
<tr>
<td>UMD HIRS/OLR**</td>
<td>NOAA Polar</td>
<td>Global</td>
<td>01-1979 to 09-2003</td>
</tr>
<tr>
<td>ERBE Scanner</td>
<td>ERBS, N9, N10</td>
<td>Global</td>
<td>02-1985 to 05-1989</td>
</tr>
<tr>
<td>ERBE NonScanner</td>
<td>ERBS</td>
<td>60N to 60S</td>
<td>1985 to 1999</td>
</tr>
<tr>
<td>ScaRaB Scanner***</td>
<td>Meteor, Resurs</td>
<td>Global</td>
<td>1994-95, 1998-99</td>
</tr>
</tbody>
</table>

* CERES: SRBAVG-GEO, SRBAVG-nonGEO, ERBE-like, and EBAF; ** UMD SRB/SW, UMD HIRS/OLR: single component data; *** ScaRaB: only few months available from each mission
Outlines

• Examine the consistencies and the differences of TOA Radiation data sets in GEWEX RFA Archive for the CERES/Terra period (March 2000 to February 2004)
  
  ➢ Focus on baseline climatology (absolute values) and deseasonalized anomaly (variability) comparisons
  
  ➢ CERES (four sets), ISCCP-FD, and LaRC GEWEX SRB
  
  ➢ Longwave, Shortwave, Net (all-sky and clear-sky)
  
  ➢ Regional, zonal, tropical (20N to 20S), global (90N to 90S)
  
  ➢ Truth: CERES SRBAVG-GEO (regional) and Ensemble mean (zonal, tropical, and global)

• Tropical mean Longwave time series comparison (1979 to 2005)
Baseline Climatology Comparisons
Major regional shortwave patterns are similar for all six datasets.

Differences in mid-latitude storm track areas (both hemisphere), stratus regions off the west coast of major continents, regions over ITCZ and the western Pacific.
Regional Differences: Longwave Radiation

- Regional longwave differences are small for CERES-based products; but larger for ISCCP-based product
- Geostationary artifacts are noticeable for both GEWEX SRB and ISCCP FD product
Regional Differences: Shortwave Radiation

- Much larger differences than longwave; geostationary artifacts in most shortwave products
- Horizontal lines over the polar regions are artifacts for missing shortwave data
Regional Differences: Net Radiation

- Complicated patterns due to combined longwave and shortwave effects; shortwave differences dominate the net differences
- Improving shortwave should lead to better agreement in Net
Zonal Mean: Longwave Radiation

All-sky

Clear-sky

Legend:  = CERES EBAF,  = CERES ERBE-like,  = CERES GEO,  = CERES nonGEO,  = LaRC GEWEX SRB,  = ISCCP-FD

- All-sky: very good agreements over N.H. high latitudes
- Clear-sky: larger differences than all-sky through all latitude zones
Zonal Mean: Shortwave Radiation

All-sky

Clear-sky

Legend: ○ = CERES EBAF, ● = CERES ERBE-like, ▲ = CERES GEO, ▼ = CERES nonGEO, + = LaRC GEWEX SRB, X = ISCCP-FD

• All-sky: Clear separation between CERES-based and ISCCP-based products

• Clear-sky: Large differences for CERES ERBE-like data in high latitudes (ERBE clear-sky scene ID issue)
### Annual Global Mean TOA Radiation Budget

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Ensemble Mean</th>
<th>Abs. SD (1-sigma)</th>
<th>Rel. SD (1-sigma)</th>
<th>Range (Min, Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Incoming</td>
<td>341.3</td>
<td>0.7</td>
<td>0.2%</td>
<td>340.0, 341.8</td>
</tr>
<tr>
<td>Longwave</td>
<td>238.3</td>
<td>1.8</td>
<td>0.8%</td>
<td>235.6, 240.5</td>
</tr>
<tr>
<td>Shortwave</td>
<td>99.9</td>
<td>3.2</td>
<td>3.2%</td>
<td>96.6, 105.2</td>
</tr>
<tr>
<td>Net</td>
<td>3.2</td>
<td>3.2</td>
<td>100.0%</td>
<td>-0.4, 7.0</td>
</tr>
<tr>
<td>Clear Longwave</td>
<td>266.1</td>
<td>2.7</td>
<td>1.0%</td>
<td>262.0, 268.0</td>
</tr>
<tr>
<td>Clear Shortwave</td>
<td>52.0</td>
<td>1.9</td>
<td>3.6%</td>
<td>49.2, 54.5</td>
</tr>
<tr>
<td>Clear Net</td>
<td>23.1</td>
<td>3.3</td>
<td>14.3%</td>
<td>18.1, 26.2</td>
</tr>
</tbody>
</table>

- Agreement: LW within 1%, SW within 3.6% of the ensemble mean
- Disagreement: Largest relative SD for Net due to small Net value; smallest for solar incoming
Deseasonalized Anomaly Comparisons
All-sky Longwave and Shortwave Anomaly

Globe: 90N to 90S

Tropics: 20N to 20S

- CERES-based data have smaller variability than ISCCP-based data
- SW variability > LW variability; Tropical variability > Global variability

Legend:  = CERES EBAF,  = CERES ERBE-like,  = CERES GEO,  = CERES nonGEO,  = LaRC GEWEX SRB,  = ISCCP-FD
Clear-sky Longwave and Shortwave Anomaly

Globe: 90N to 90S

Legend: = CERES EBAF, = CERES ERBE-like, = CERES GEO, = CERES nonGEO, + = LaRC GEWEX SRB, X = ISCCP-FD

- Clear-sky results are similar to all-sky results
- Jump in clear-sky longwave ISCCP time-series due to changes in TOVS sounder

Tropics: 20N to 20S
All-sky and Clear-sky Net Anomaly

Globe: 90N to 90S

Tropics: 20N to 20S

Legend:
- = CERES EBAF, = CERES ERBE-like, = CERES GEO, = CERES nonGEO, = LaRC GEWEX SRB, = ISCCP-FD

- ISCCP-based global net time series show large negative trend
- CERES-based global net time series are very stable with time
### Global Mean Variability: TOA Radiation Budget

<table>
<thead>
<tr>
<th>Parameters (Wm^{-2})*</th>
<th>EBAF</th>
<th>ERBE-like</th>
<th>SRBAVG G-GEO</th>
<th>SRBAVG -NonGeo</th>
<th>GEWEX SRB</th>
<th>ISCCP-FD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longwave</td>
<td>0.4</td>
<td>0.5</td>
<td>0.4</td>
<td>0.4</td>
<td>0.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Shortwave</td>
<td>0.5</td>
<td>0.7</td>
<td>0.5</td>
<td>0.5</td>
<td>1.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Net</td>
<td>0.5</td>
<td>0.6</td>
<td>0.5</td>
<td>0.5</td>
<td>1.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Clear Longwave</td>
<td>0.4</td>
<td>0.3</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>1.9</td>
</tr>
<tr>
<td>Clear Shortwave</td>
<td>0.3</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Clear Net</td>
<td>0.4</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
<td>1.1</td>
<td>1.8</td>
</tr>
</tbody>
</table>

* 1-sigma value based on 4 years of data

- Globally, ISCCP-based products have 1.2 to 4 times more variability than CERES-based datasets
Tropical Mean Time Series Comparisons
The two ISSCP-based products (GEWEX SRB and ISSCP FD) provide the upper and the lower range of these datasets.

Instrument calibration difference between ERBE and CERES.
ERBE and CERES differences (~4 Wm$^{-2}$) can be removed using overlapping data period.

Adjusted broadband longwave time series agrees well with narrowband UMD HIRS.
Summary

• Regional differences are complicated; due to differences in processing algorithm, data sampling, instrument calibration, and missing data; LW comparisons are better than SW’s or Net’s.

• Zonal mean differences, relative to ensemble mean, show distinct separation between CERES-based and ISCCP-based data products for shortwave radiation; large differences in ERBE-like clear-sky shortwave flux in the polar regions (ERBE clear-sky Scene ID issue).

• Globally, agreement with ensemble mean is within 1% (1-sigma) for LW, 3.6% for SW; all-sky Net agrees to within 3.2 Wm$^{-2}$ (1-sigma) of the ensemble mean; similar results for tropical mean.

• Improving shortwave fluxes can bring these data sets closer together.

• CERES-based products have smaller variability than ISCCP-based datasets (1.2 to 4 times smaller for global mean).

• Large tropical mean longwave calibration difference (~4 Wm$^{-2}$) between CERES and ERBE instruments can be removed using overlapping data period.