Assessing Clear Sky OLR with CERES and AIRS

The RRTM calculations of clear sky OLR agree with CERES observations to ~1 W/m² with an uncertainty of ~1 W/m².

• True at SGP over 2.5 years, true globally (with some understood regional exceptions) for four study days.
• True using ARM data as input to RRTM, true using AIRS sounding retrievals as input to RRTM.
• True over most CERES surface types with large exception over the desert and ice/snow. The day/night ocean bias is very constant (near -0.5 W/m²) but the day/night bias varies greatly over some land surface types.

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**Goal:** To assess and improve clear sky OLR.

**Approach:** Use CERES fluxes & AIRS radiances and retrievals.

- **SSF CERES** is currently a better metric for OLR assessment than GOES.
- **AIRS spectral radiance analysis** allows us to evaluate the atmospheric and surface estimates.
- **AIRS spectral flux analysis** allows us to interpret uncertainties in the flux products, and infer uncertainties in the far IR.
- Using **AIRS retrievals** allows for *global* RRTM calculations of OLR and heating rate *profiles*. 
### Summary of Results

<table>
<thead>
<tr>
<th>Date</th>
<th>Region</th>
<th>Methodology</th>
<th>Mean, W/m²</th>
<th>Uncertainty in mean</th>
<th>Stdv, W/m²</th>
<th>Pnts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NIGHT</strong> OLR differences:</td>
<td></td>
<td>Observations minus Calculations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGP 2002 - 2005</td>
<td>SSF CERES - BE profile with Es=1, Ts(Beflux) RRTM</td>
<td>+0.5</td>
<td>~0.5</td>
<td>2.6</td>
<td>~74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SSF CERES - BE profile with AIRS surface RRTM</td>
<td>+0.8</td>
<td>~0.5</td>
<td>2.2</td>
<td>~74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SSF CERES - AIRS RRTM</td>
<td>+1.2*</td>
<td>~0.5</td>
<td>1.8</td>
<td>~74</td>
<td></td>
</tr>
<tr>
<td>Global 16Nov2002 Lat:[-60:60]</td>
<td>SSF CERES - AIRS RRTM</td>
<td>+0.9*</td>
<td>&lt; 0.5</td>
<td>2.6</td>
<td>~17k</td>
<td></td>
</tr>
<tr>
<td>Global 18Feb2003 Lat:[-60:60]</td>
<td>SSF CERES - AIRS RRTM</td>
<td>+0.6*</td>
<td>&lt; 0.5</td>
<td>2.6</td>
<td>~21k</td>
<td></td>
</tr>
<tr>
<td>Global 05May2003 Lat:[-60:60]</td>
<td>SSF CERES - AIRS RRTM</td>
<td>+0.6*</td>
<td>&lt; 0.5</td>
<td>2.4</td>
<td>~22k</td>
<td></td>
</tr>
<tr>
<td>Global 09Aug2003 Lat:[-60:60]</td>
<td>SSF CERES - AIRS RRTM</td>
<td>+0.6*</td>
<td>&lt; 0.5</td>
<td>3.1</td>
<td>~20k</td>
<td></td>
</tr>
</tbody>
</table>

* Adjusted for upper level water error based on AIRS spectral analysis. (~0.8 W/m²).
Results at ARM’s SGP

~74 night cases between Sept. 2002 & Feb. 2005

Night time Clear Sky OLR

- BE RRTM
- BE w/ AIRS surface RRTM
- AIRS RRTM

*NIGHT* OLR differences:
Observations minus Calculations

<table>
<thead>
<tr>
<th></th>
<th>Mean, W/m²</th>
<th>Stdev, W/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSF CERES - BE RRTM</td>
<td>+0.5</td>
<td>2.6</td>
</tr>
<tr>
<td>SSF CERES - BE profile &amp; AIRS surface RRTM</td>
<td>+0.8</td>
<td>2.2</td>
</tr>
<tr>
<td>SSF CERES - AIRS RRTM</td>
<td>+2.0*</td>
<td>1.8</td>
</tr>
</tbody>
</table>

* does not reflect upper level water vapor adjustment
### Day/Night Bias at SGP 2002-2005

#### OLR differences: Observations minus Calculations

<table>
<thead>
<tr>
<th></th>
<th>Mean, W/m²</th>
<th>Stdev, W/m²</th>
<th>npts</th>
<th>Day-Nite Bias</th>
<th>Statistical uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SSF CERES - BE RRTM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day</td>
<td>-0.2</td>
<td>4.6</td>
<td>53</td>
<td>-0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Night</td>
<td>+0.5</td>
<td>2.6</td>
<td>74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D&amp;N</td>
<td>+0.3</td>
<td>3.6</td>
<td>127</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SSF CERES - BE profile &amp; AIRS surface RRTM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day</td>
<td>-0.5</td>
<td>2.4</td>
<td>53</td>
<td>-1.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Night</td>
<td>+0.8</td>
<td>2.2</td>
<td>74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D&amp;N</td>
<td>+0.3</td>
<td>2.3</td>
<td>127</td>
<td></td>
<td></td>
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<td><strong>SSF CERES - AIRS RRTM</strong></td>
<td></td>
<td></td>
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<tr>
<td>Day</td>
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<td>2.2</td>
<td>53</td>
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<tr>
<td>Night</td>
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</tbody>
</table>

- Day/night differences are greater than the statistical uncertainties indicating a non-Gaussian source of bias.
- We continue to study the source of the day/night bias; AIRS radiance residuals are not significantly different between day and night, and global results show the bias is a function of CERES surface type.
DAYTIME AIRS observations - RRTM calculations at SGP, Mean ± 1 Stddev

NIGHTTIME AIRS observations - RRTM calculations at SGP, Mean ± 1 Stddev
• allows us to evaluate the profiles used as input to RRTM.
• the upper level water bands show a brightness temperature bias ~0.7 K. Reducing the water vapor above 5km by 10% eliminates this bias.
• the far IR is very sensitive to upper level water vapor; the 10% reduction in the water vapor above 5km leads to a 0.2 W/m² in the 6.3 μm band and 0.5 W/m² in the far IR.
CERES clear sky OLR, W/m$^2$
nighttime 16 Nov 2002

99% “Clear” from MODIS based CERES cloud mask
CERES - AIRS RRTM, W/m²
clear sky OLR nighttime 16 Nov 2002
CERES - AIRS RRTM, W/m²
clear sky OLR daytime 16 Nov 2002
Latitude dependence for 16 Nov 2002

Night CERES & AIRS RRTM, W/m²

Daytime CERES & AIRS RRTM, W/m²
Method for determining uncertainty in the mean

Data restricted to NIGHT time and latitudes between 60S and 60N to exclude known problem regions.

• We attribute the Gaussian component to spatial mismatch between CERES and AIRS footprints. For the Gaussian shown, the statistical uncertainty is very small (0.01 W/m²) and not representative of the true uncertainty of the mean.

• The negative tail of the histogram is consistent with undetected clouds and distorts the mean.

• Deviation between the mean of the original histogram and the Gaussian is:\n  \[ | \bar{X} - \mu | \approx 0.4 \text{ W/m}^2 \]

We assign the complete difference between the mean of the full distribution with uncorrected tail and the mean of the Gaussian component to uncertainty in the mean (<0.5 W/m²).
Stat. Uncertainty = 0.01
Diff in means = 0.4

Stat. Uncertainty = 0.01
Diff in means = 0.2

Stat. Uncertainty = 0.01
Diff in means = 0.3

Stat. Uncertainty = 0.01
Diff in means = 0.2
Global obs-calc by surface type

Forest 1
Forest 2
Forest 3
Forest 4
Forest 5
Shrub 6
Shrub 7
Savan 8
Savan 9
Grass 10
WetL 11
Crop 12
Urban 13
Crop 14
Sno/Ice 15
Soil/Rock 16
Water 17
Tundra 18
Snow 19
Sealce 20

CERES - AIR RRTM, W/m²

SGP surface types consistent with our 2.5 year study
AIRS RRTM much higher than CERES over desert
Tight range of values over ocean

[+1.4, +0.9, +0.9, +0.8 W/m² ]

boxes represent number of points for each day
Global obs-calc by surface type

- Forest
- Shrub
- Savan
- Grass
- WetL
- Crop
- Urban
- Crop
- Snow/Ice
- Soil/Rock
- Water
- Tundra
- Snow
- Seale

Boxes represent number of points for each day.
**Day/Night Bias by surface type**

- **Water** has a consistent day/night bias of about **-0.5 W/m²**
- **Desert** day/night bias is negative with large variability
- **SGP** day/night bias is 4 days consistent with a 2.5yr study
- Other types with large number of points and large variability, e.g., shrub7, sno/ice15, snow19

Boxes represent the number of points for each day.
Day/Night Bias by surface type

Boxes represent the number of points for each day.
AIRS Spectral flux analysis

AER’s LBLRTM and RRTM calculated radiances and fluxes for the same set of atmospheric and surface conditions were produced at SGP over a 2.5 year study period. Partial fluxes (fluxes over a spectral range) are calculated from the radiances using:

\[ F = \iiint \text{radiance} \, d\nu \, d\psi \]

where \( \nu \) is wavelength, and \( \psi \) is solid angle. The residuals are expressed as a fractional error to eliminate errors in the integral over the solid angles.

Earth’s spectrum
AIRS spectral flux analysis allows us to:

1) improve the flux derived from AIRS retrievals using RRTM, and
2) infer the error in the far IR.

<table>
<thead>
<tr>
<th>Spectral Coverage</th>
<th>weight %</th>
<th>Flux W/m²</th>
<th>Percent Residual Definition</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total OLR</td>
<td>100</td>
<td>263</td>
<td>$100 \times \frac{(\text{CERES - AIRS RRTM})}{\text{CERES}}$</td>
<td>0.2</td>
</tr>
<tr>
<td>AIRS spectra</td>
<td>54</td>
<td>144</td>
<td>$100\times\frac{(F_{\text{AIRS obs}} - F_{\text{AIRS calc}})}{F_{\text{AIRS obs}}}$</td>
<td>0.3</td>
</tr>
<tr>
<td>Far IR</td>
<td>45</td>
<td>116</td>
<td></td>
<td>[0.1-0.3]</td>
</tr>
</tbody>
</table>

Assuming CERES errors are similar throughout the entire spectrum, and that there are no cancellation of errors between CERES and RRTM, we can infer the error in the far IR. (Our analyses show that CERES and AIRS agree in the window channels to approximately 0.1 W/m².)
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Future work will include cloudy conditions…