Assessing ARM Clear Sky BBHRP with CERES and AIRS

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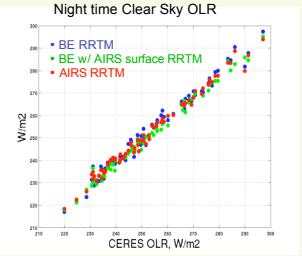
Clear Sky Analysis at SGP between September 2002 and February 2005 :

For the 2007 STM the BBHRP clear sky methodology was extended at the SGP site to cover multiple years. TOA flux calculations using RRTM were compared to GOES fluxes (which is based on a regression with CERES). This year we compare directly with CERES SSF FM-3 OLR within 10 km of the SGP site and 10 minutes of the Aqua overpass times, and a 99% clear sky requirement. We used interpolated sondes to Aqua overpass times (Best Estimate profiles, BE), and added RRTM calculations using NASA AIRS level 2 retrievals.

Night time Clear Sky OLR



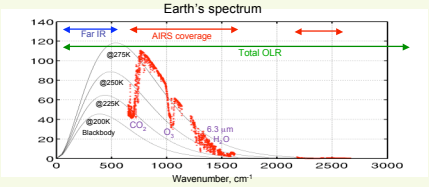
Day - Night Bias at SGP

OLR differences: Observations minus Calculations		Mean, W/m²	Stdev, W/m²	npts	Day-Nite Bias	Statistical uncertainty
SSF CERES - BE RRTM	Day	-0.2	4.6	53		
	Night	+0.5	2.6	74	-0.7	0.7
	D&N	+0.3	3.6	127		
SSF CERES - BE profile & AIRS surface RRTM	Day	-0.5	2.4	53		
	Night	+0.8	2.2	74	-1.3	0.4
	D&N	+0.3	2.3	127		
SSF CERES - AIRS RRTM	Day	+0.2	2.2	53		
	Night	+2.0	1.8	74	-1.8	0.4
	D&N	+1.3	2.4	127		

- Day/night differences are greater than the statistical uncertainties indicating a non-Gaussian source of bias.
- Our nighttime uncertainty estimates are elevated to ~1 W/m² to reflect this.
- We continue to study the source of the day/night bias; AIRS residuals are not significantly different between day and night, and CERES OLR is total minus solar.

AIRS Spectral flux analysis

Earth's spectrum



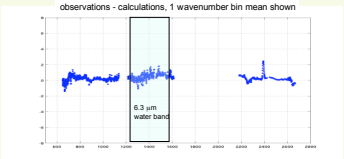
Partial fluxes (fluxes over a spectral range) are calculated from the radiances using:

$$F = \iint radiance \, dv \, d\psi$$

where v is wavelength, and ψ is solid angle.

Spectral Coverage	weight %	Flux W/m²	Percent Residual definition	%
Total OLR	100	263	100* (CERES - AIRS RRTM) / CERES	0.2
AIRS spectra	54	144	$100^* (F_{AIRS\ obs} - F_{AIRS\ calc}) / F_{AIRS\ obs}$	0.3
Far IR	45	116	inferred	[0.1-0.3]

AIRS spectral radiance analysis



* allows us to evaluate the profiles used as input to RRTM.
* the upper level water bands show a brightness temperature bias ~0.7K. 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.

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.)

Introduction

The overall objective of this research is to assess and improve the ARM Broad Band Heating Rate Profile (BBHRP) measurement-model comparison effort that will couple heating rates based on ARM data more directly into SCM and GCM models. Methods of determining OLR include measurements from broadband radiometers onboard satellites and calculations from radiative transfer models (RTM) requiring atmospheric profile and surface properties as inputs. We assess CERES against AER's RRTM calculations using ARM data and AIRS retrievals.

Summary of our technique

- SSF CERES is currently a better metric for BBHRP 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

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

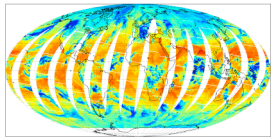
* True at SGP over 2.5 years, true globally (with some *understood* regional exceptions) for study day.
* True using ARM data as input to RRTM, true using AIRS sounding retrievals as input to RRTM.

	NIGHT OLR differences: Observations minus Calculations	Mean, W/m²	Uncertainty in mean	Stdv, W/m²	Pnts
SGP 2002 - 2005	SSF CERES - BE RRTM	+0.5	~1	2.6	~74
SGP 2002 - 2005	SSF CERES - BE profile with AIRS surface RRTM	+0.8	~1	2.2	~74
SGP 2002 - 2005	SSF CERES - AIRS RRTM	+1.2*	~1	1.8	~74
	NIGHT OLR differences: Observations minus Calculations				
Global 16Nov2002 Lat:[-60:60]	SSF CERES - AIRS RRTM	+0.9*	< ± 0.5	2.6	~21k

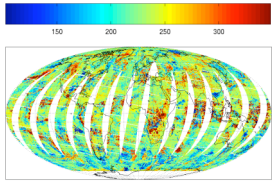
* Adjusted for upper level water error based on spectral analysis at SGP (~0.8 W/m²).

All Sky Global Analysis of 16 November 2002

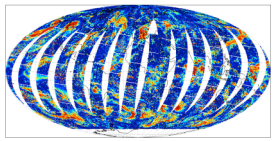
NASA AIRS L2 cloud retrieval product reports the cloud fraction and optical depths for up to two clouds. We calculated OLR with RRTM assuming grey clouds.



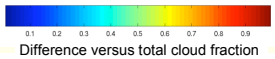
AIRS RRTM All Sky OLR - Night



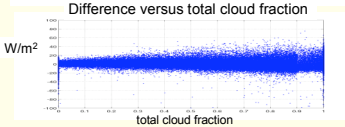
Night All Sky OLR CERES - AIRS RRTM



Total Cloud Fraction

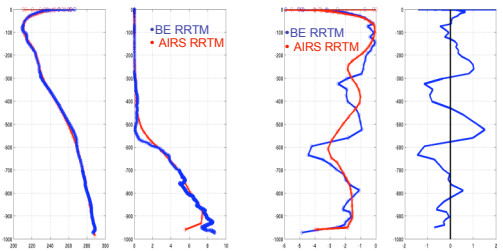


Difference versus total cloud fraction



Example of a Profile at SGP: Sept 20, 2002

AIRS retrievals' vertical resolution has a smoothing effect compared to sonde data.



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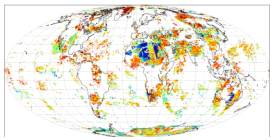
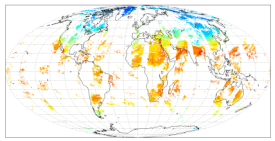
Clear Sky Global Analysis of 16 November 2002

Clear sky OLR RRTM calculations using NASA AIRS L2 retrievals (version 5) were compared to SSF CERES.

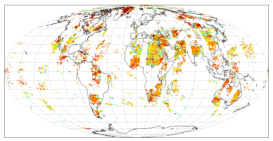
Day CERES - AIRS RRTM, W/m²



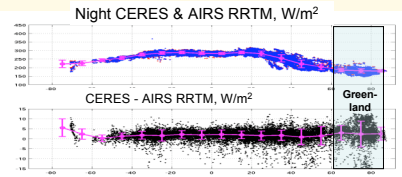
NIGHT CERES clear sky OLR, W/m²



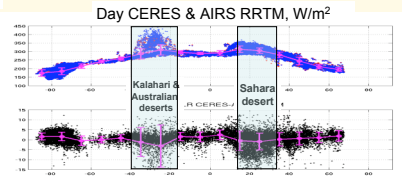
Night CERES - AIRS RRTM, W/m²



Night CERES & AIRS RRTM, W/m²

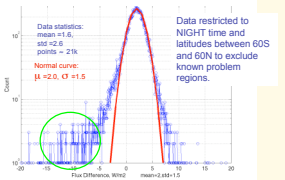


Day CERES & AIRS RRTM, W/m²



Determining uncertainty in the mean

Histogram for 16Nov2002
Night CERES - AIRS RRTM



- 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: $|x - \mu| \approx 0.4$ W/m²

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).