Assessing Clear Sky OLR with CERES and AIRS

The RRTM calculations of clear sky OLR agree with CERES observations to ~1 W/m^2 with an uncertainty of ~1 W/m^2.

- 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 <u>ocean</u> bias is very constant (near -0.5 W/m^2) but the day/night bias varies greatly over some <u>land</u> surface types.

University of Wisconsin - Madison

Space Science and Engineering Center

<u>Leslie Moy</u>, Dave Tobin, Bob Knuteson, Lori Borg, Hank Revercomb (PI), Marty Mlynczak[1], and Joel Susskind[2]

[1]NASA Langley, [2]NASA GSFC

Summary Report

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

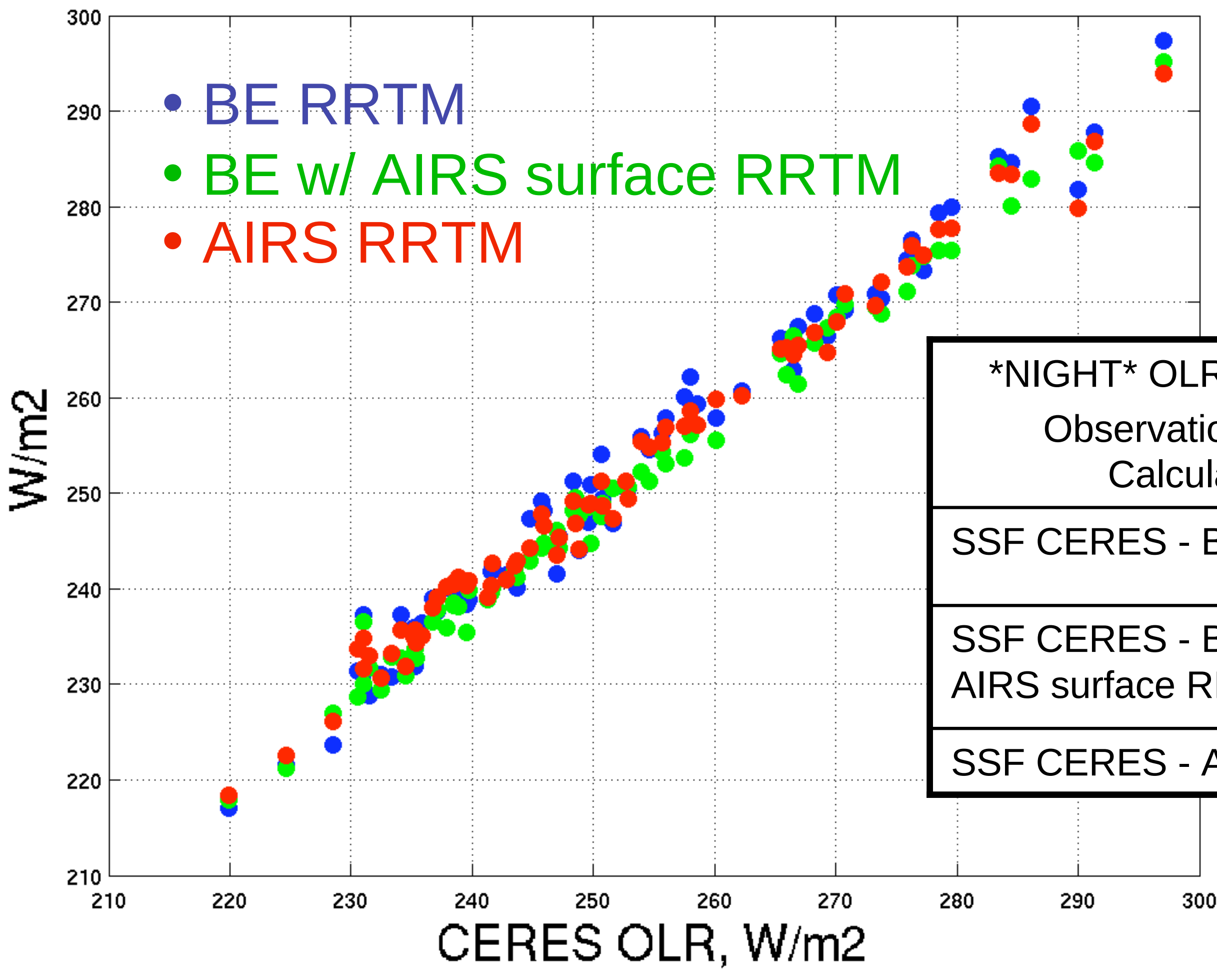
	****NIGHT**** OLR differences: Observations minus Calculations	Mean, W/m^2	Uncertainty in mean	Stdv , W/m^2	Pnts
SGP 2002 - 2005	SSF CERES - BE profile with Es=1, Ts(Beflux) RRTM	+0.5	~0.5	2.6	~74
SGP 2002 - 2005	SSF CERES - BE profile with AIRS surface RRTM	+0.8	~0.5	2.2	~74
SGP 2002 - 2005	SSF CERES - AIRS RRTM	+1.2*	~0.5	1.8	~74
	****NIGHT**** OLR differences: Observations minus Calculations				
Global 16Nov2002 Lat:[-60:60]	SSF CERES - AIRS RRTM	+0.9*	< 0.5	2.6	~17k
Global 18Feb2003 Lat:[-60:60]	SSF CERES - AIRS RRTM	+0.6*	< 0.5	2.6	~21k
Global 05May2003 Lat:[-60:60]	SSF CERES - AIRS RRTM	+0.6*	< 0.5	2.4	~22k
Global 09Aug2003 Lat:[-60:60]	SSF CERES - AIRS RRTM	+0.6*	< 0.5	3.1	~20k

* Adjusted for upper level water error based on AIRS spectral analysis. (~0.8 W/m^2).

Results at ARM's SGP

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

Night time Clear Sky OLR



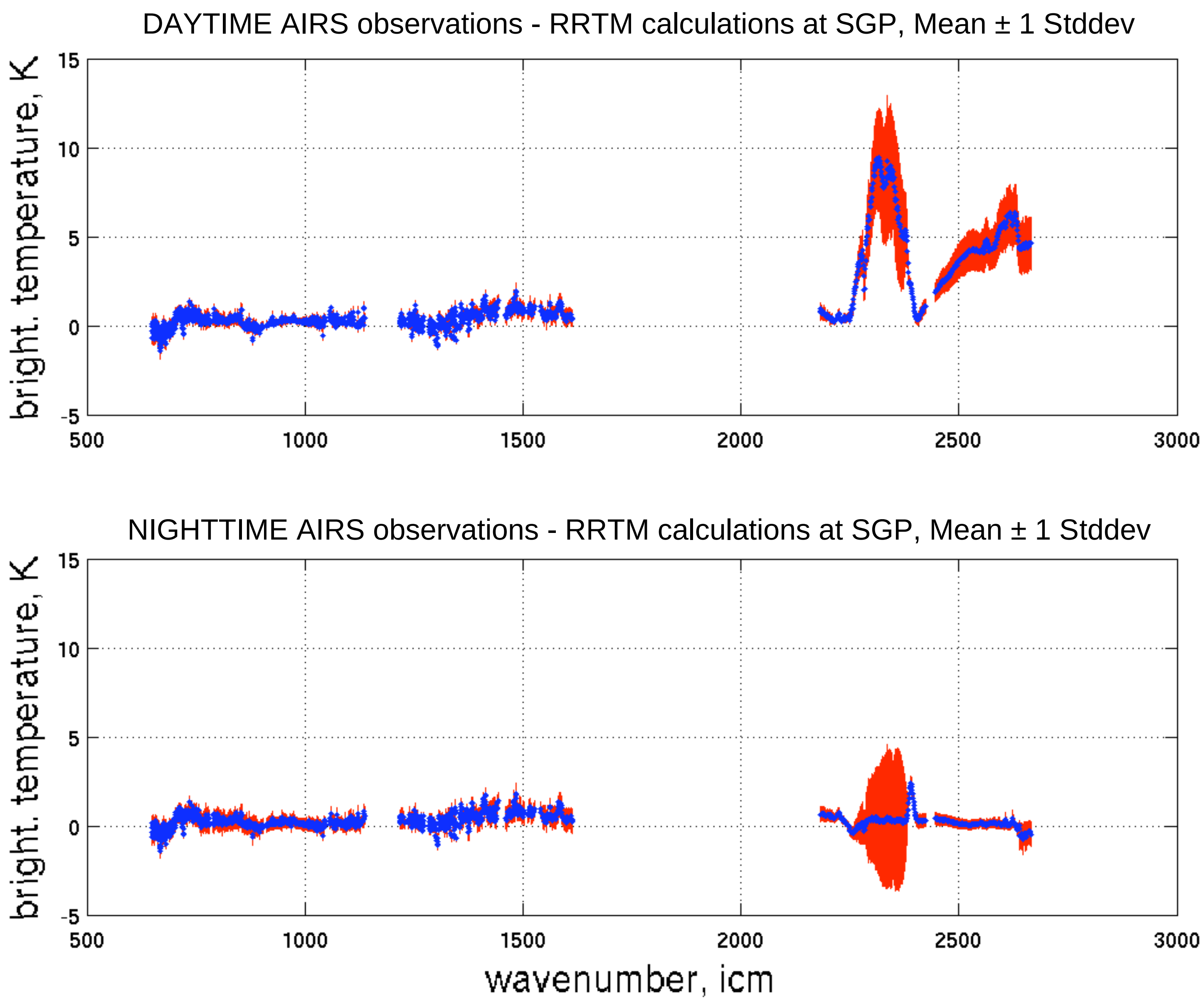
NIGHT OLR differences: Observations minus Calculations	Mean, W/m^2	Stdev , W/m^2
SSF CERES - BE RRTM	+0.5	2.6
SSF CERES - BE profile & AIRS surface RRTM	+0.8	2.2
SSF CERES - AIRS RRTM	+2.0*	1.8

* does not reflect upper level water vapor adjustment

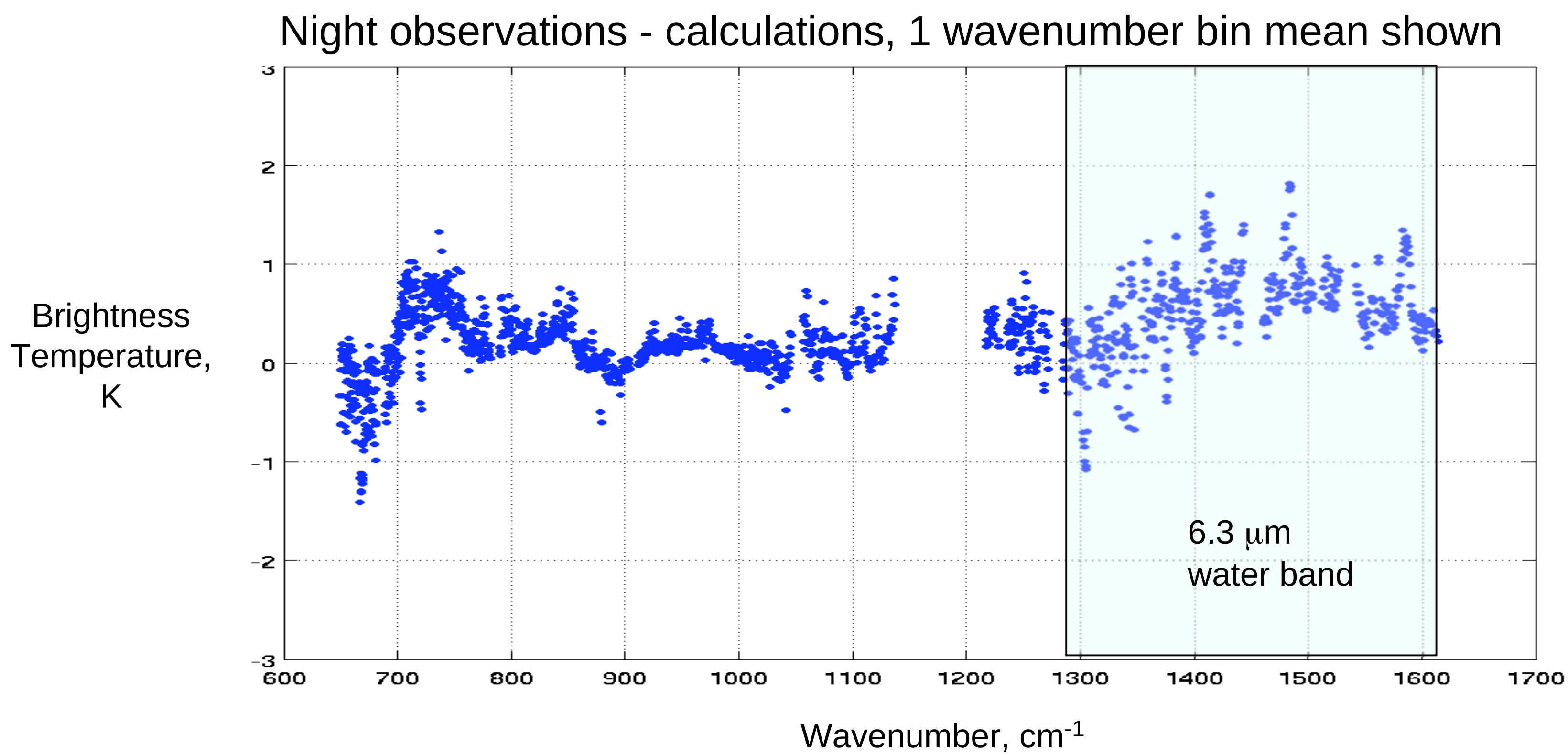
Day/Night Bias at SGP 2002-2005

OLR differences: Observations minus Calculations		Mean, W/m^2	Stdev, W/m^2	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.
- 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.

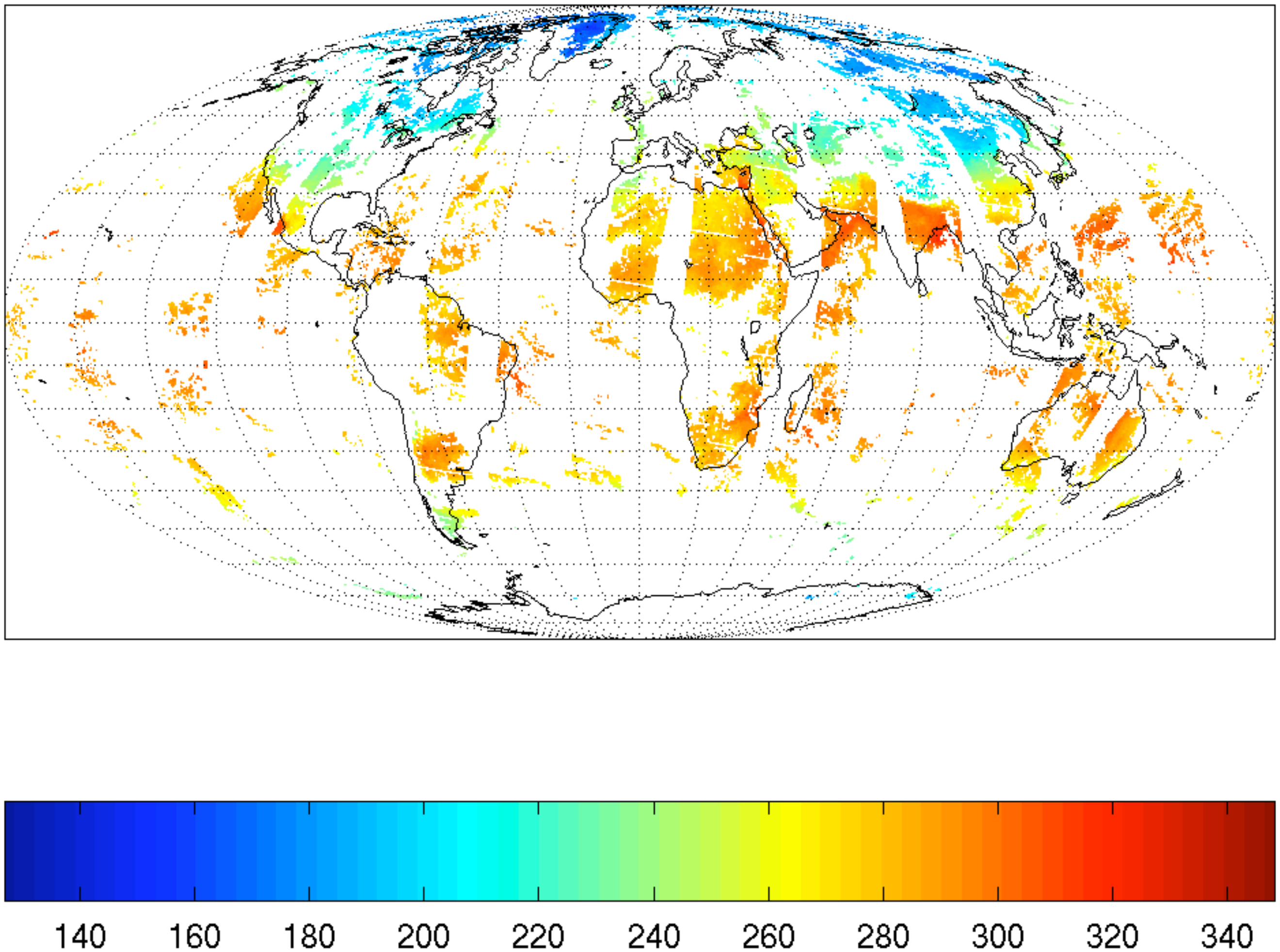

DAYTIME AIRS observations - RRTM calculations at SGP, Mean ± 1 Stddev
bright. temperature, K
15
10
5
0
-5
500
1000
1500
2000
2500
3000
NIGHTTIME AIRS observations - RRTM calculations at SGP, Mean ± 1 Stddev
bright. temperature, K
15
10
5
0
-5
500
1000
1500
2000
2500
3000
wavenumber, icm

AIRS spectral radiance analysis



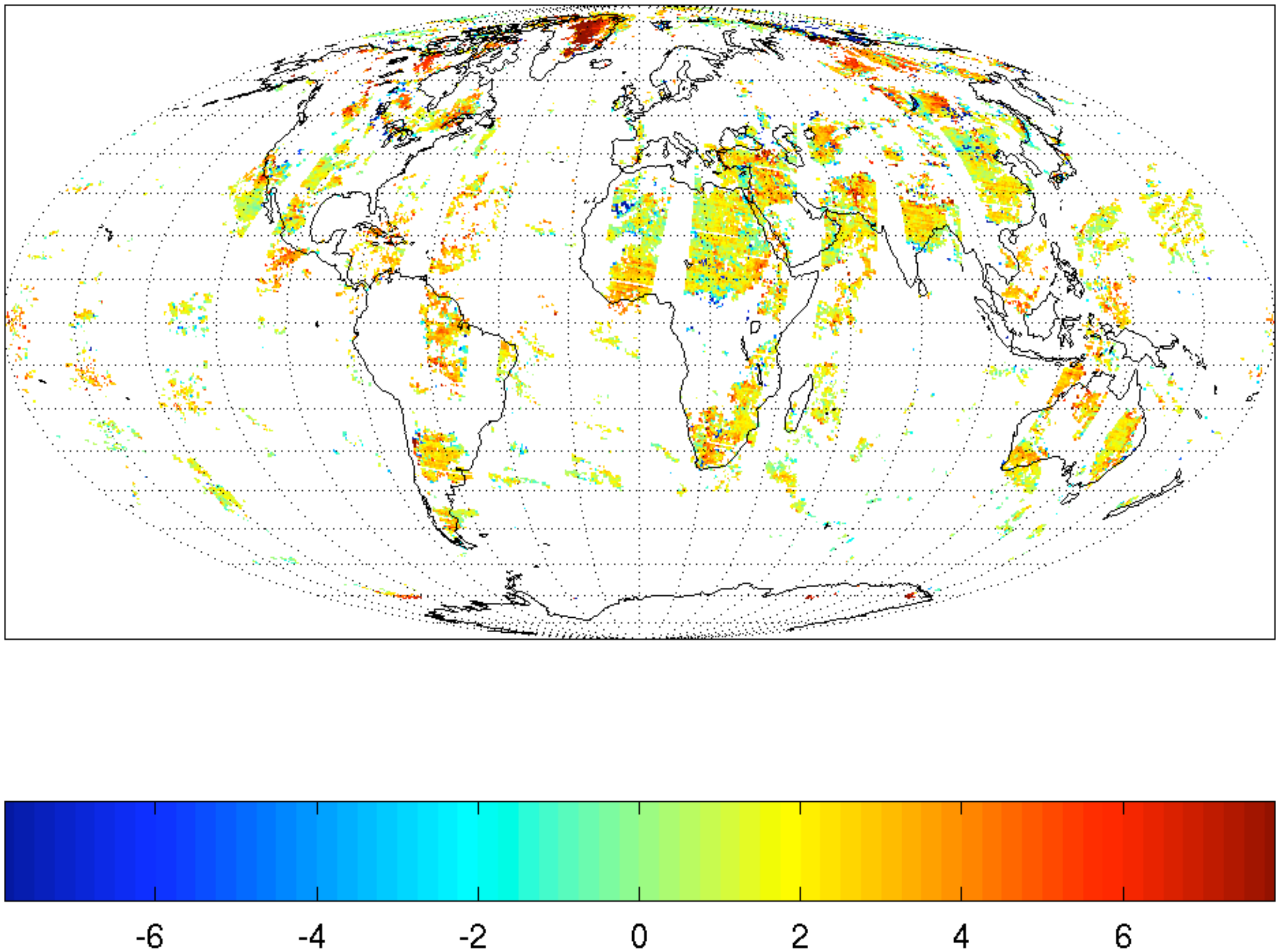
- allows us to evaluate the profiles used as input to RRTM.
- the upper level water bands show a brightness temperature bias ~0.7 K. Reducing the water vapor above 5km by 10% eliminates this bias.
- the far IR is very sensitive to upper level water vapor; the 10% reduction in the water vapor above 5km leads to a 0.2 W/m^2 in the 6.3 μm band and 0.5 W/m^2 in the far IR.

CERES clear sky OLR, W/m^2 nighttime 16 Nov 2002

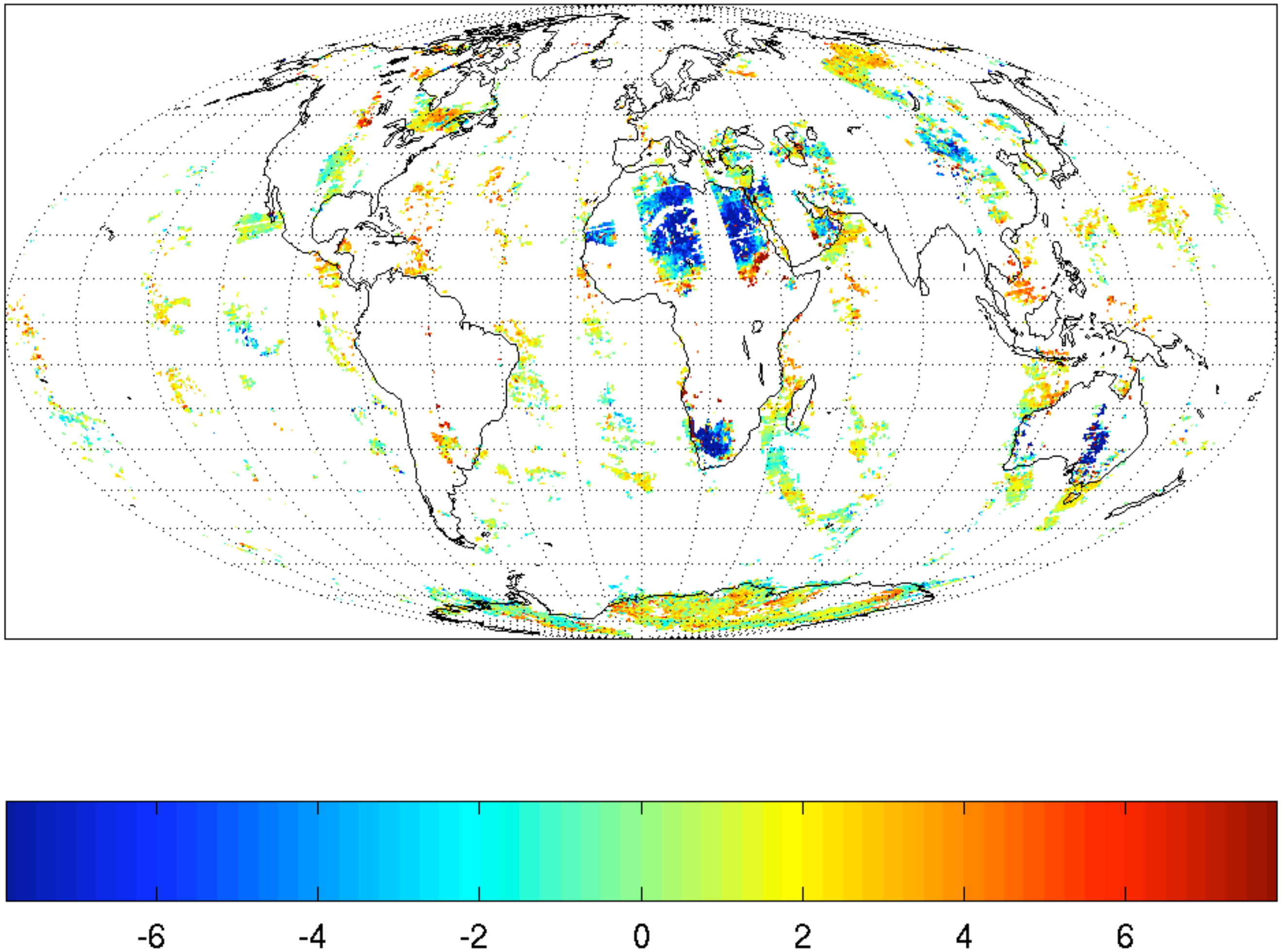


99% “Clear” from MODIS based CERES cloud mask

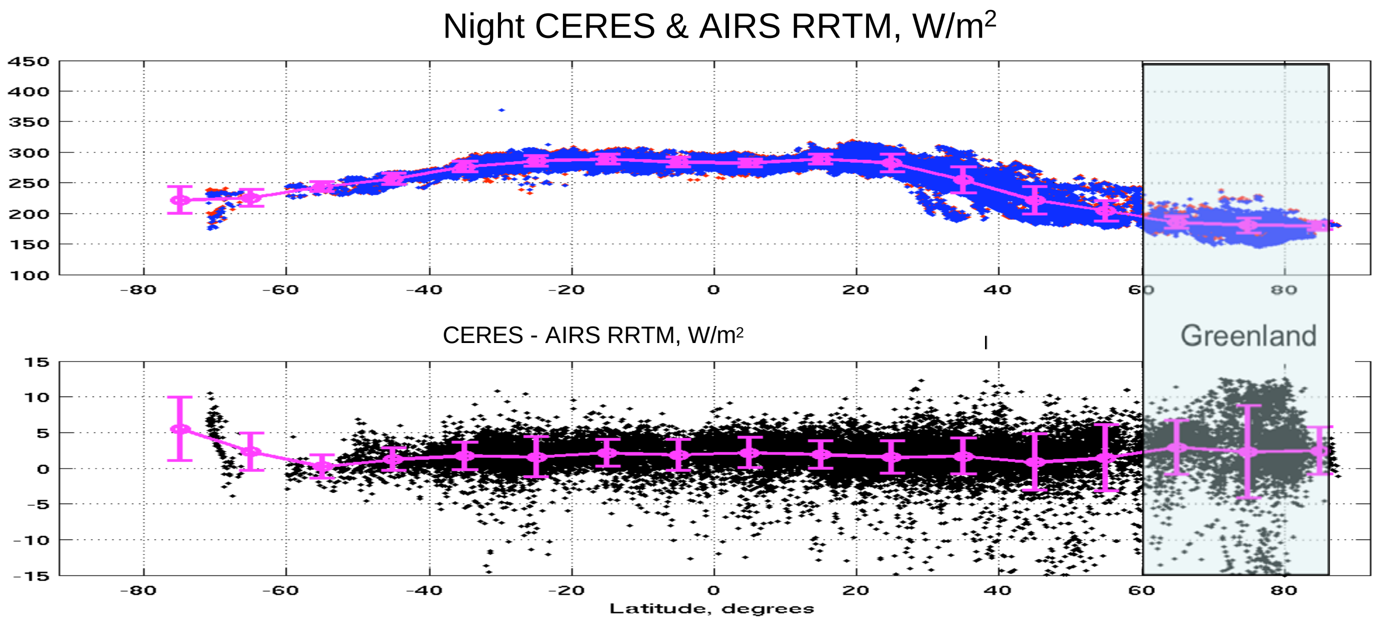
CERES - AIRS RRTM, W/m^2 clear sky OLR nighttime 16 Nov 2002

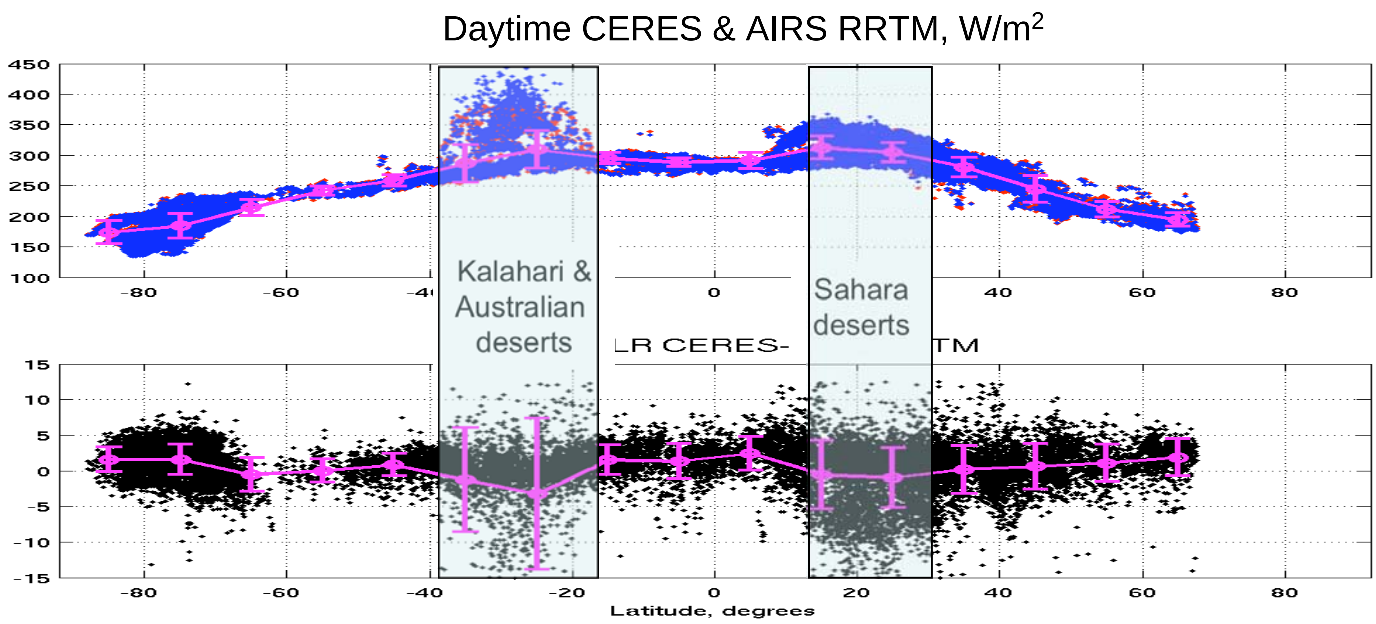


CERES - AIRS RRTM, W/m^2
clear sky OLR daytime 16 Nov 2002



Latitude dependence for 16 Nov 2002





Method for determining uncertainty in the mean

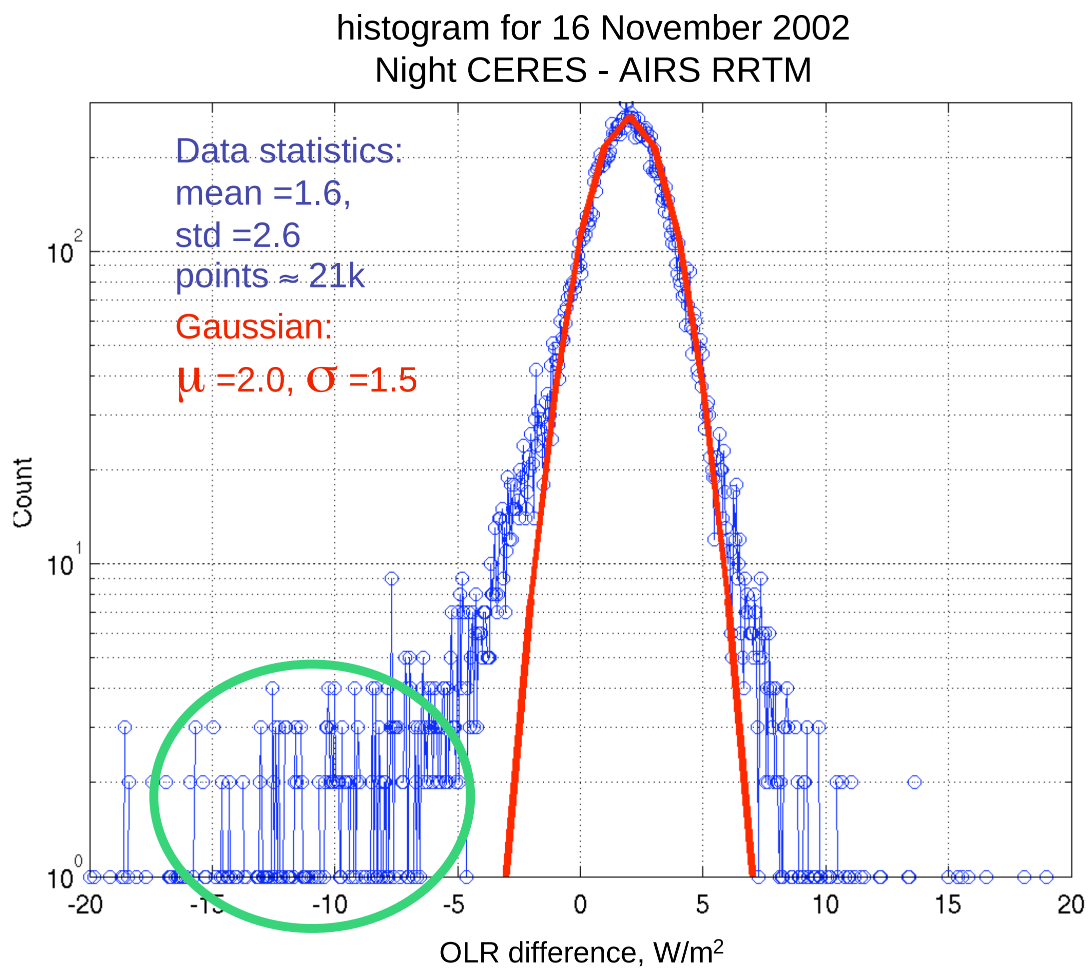
Data restricted to NIGHT time and latitudes between 60S and 60N to exclude known problem regions.

- 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/m^2) 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.

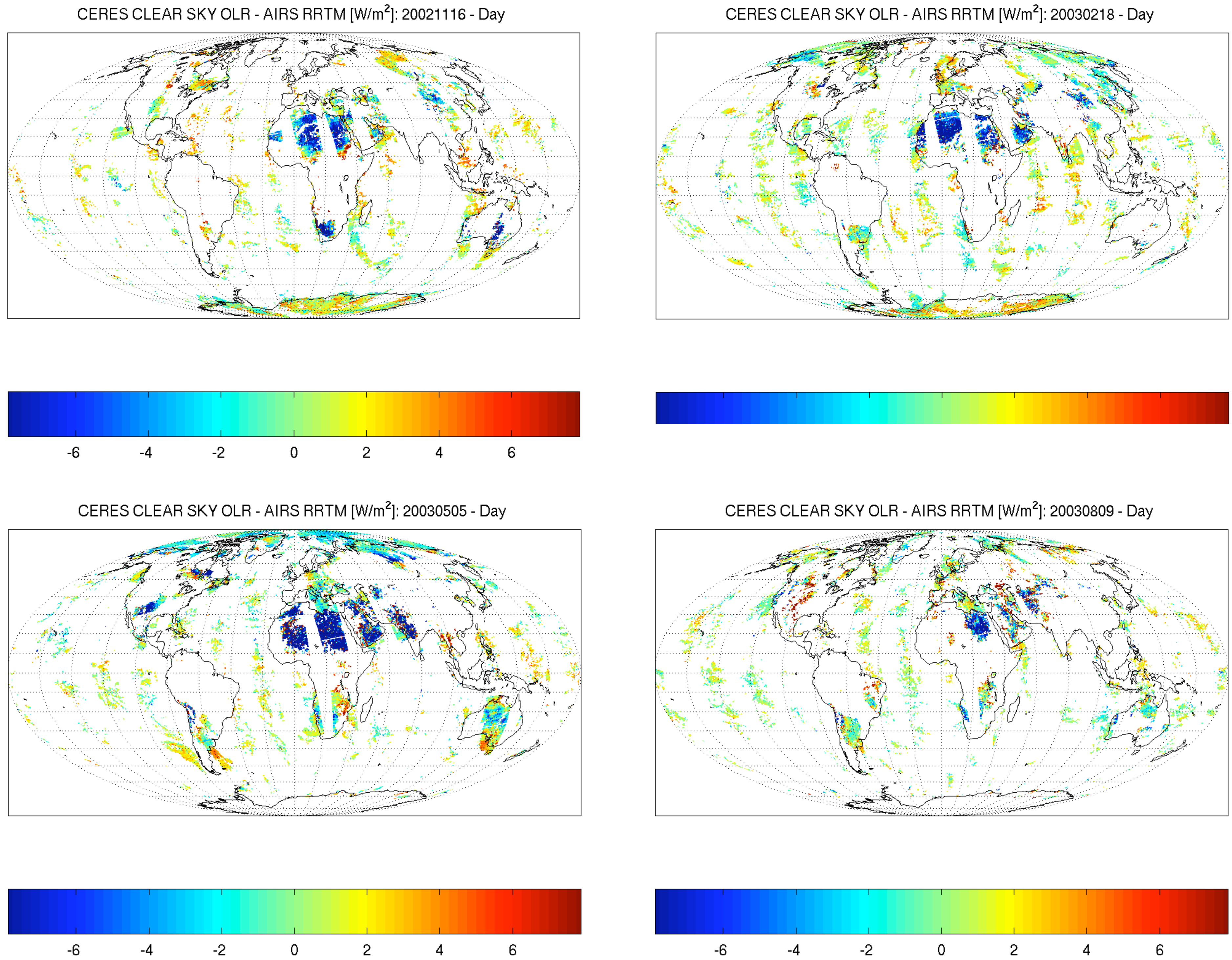
- Deviation between the mean of the original histogram and the Gaussian is:

$$|\bar{x} - \mu| \approx 0.4 \text{ W/m}^2$$

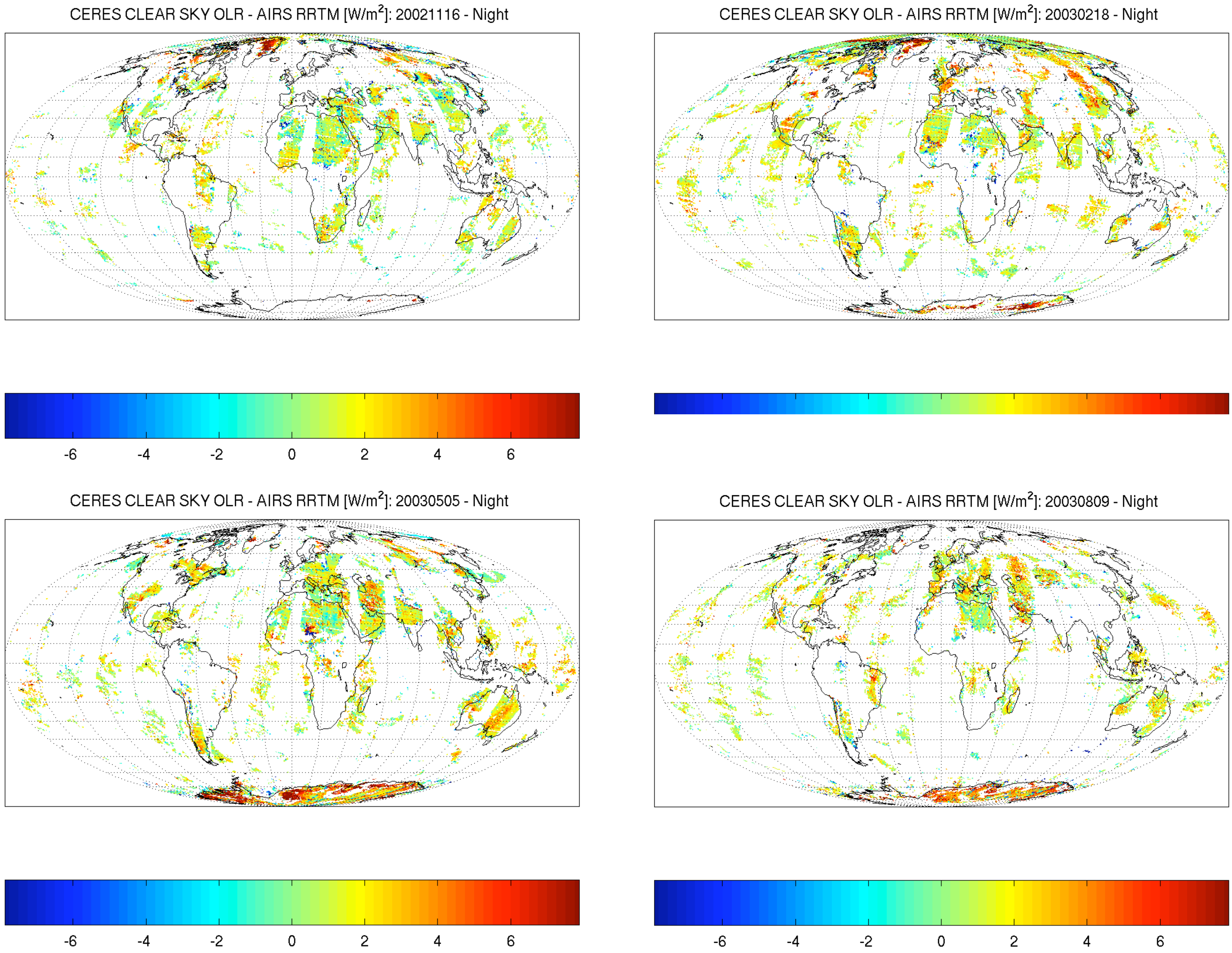


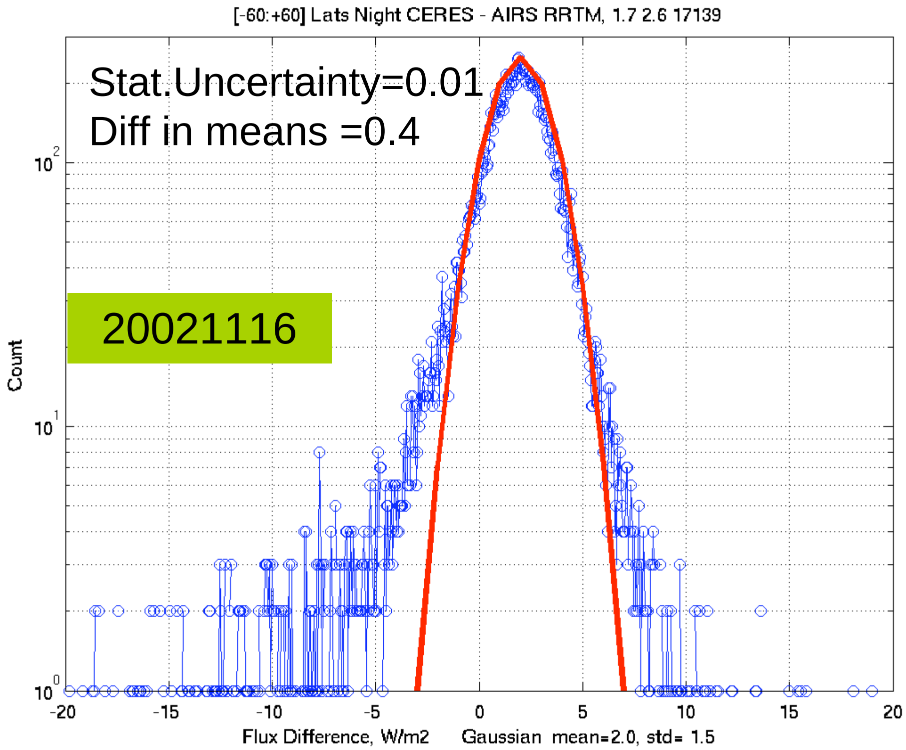
We assign the complete difference between the mean of the full distribution with uncorrected tail and the mean of the Gaussian component to uncertainty in the mean (<0.5 W/m^2).

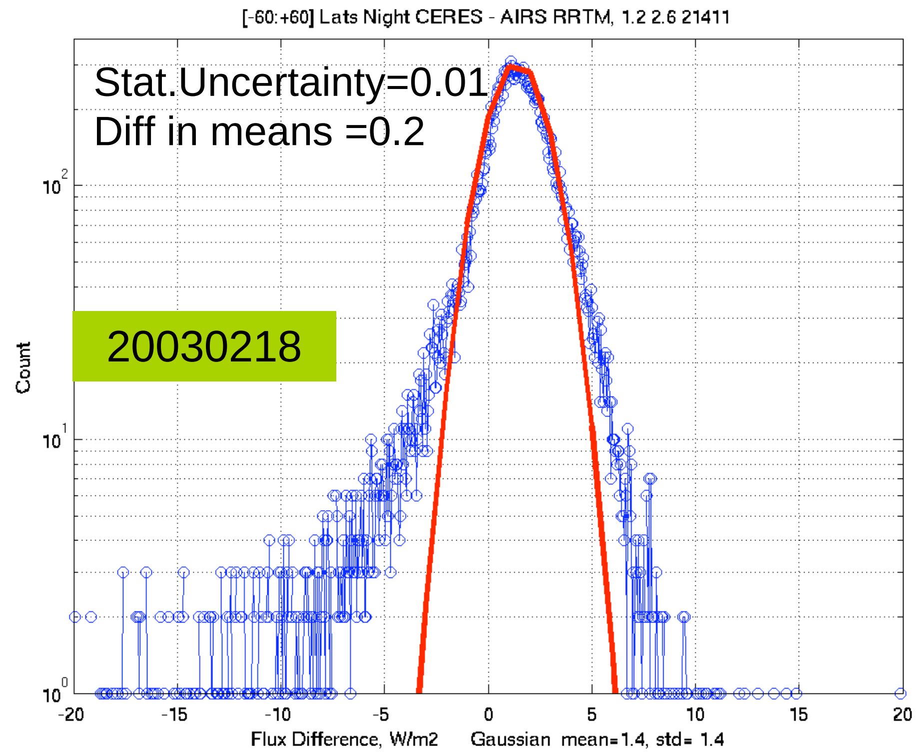
Ceres-AIRS RRTM Maps ~ DAY

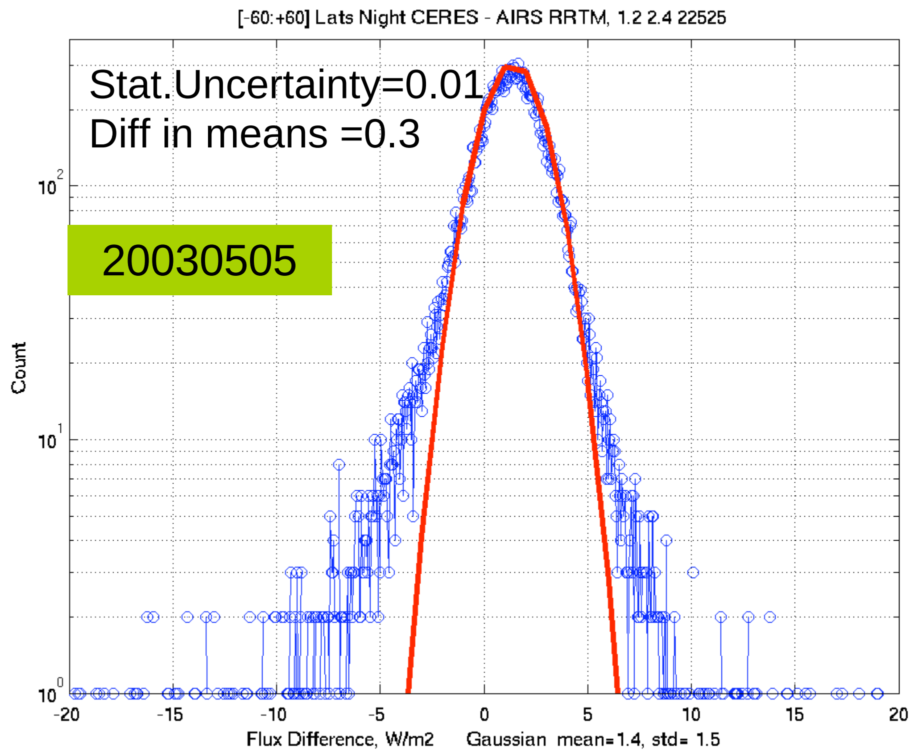


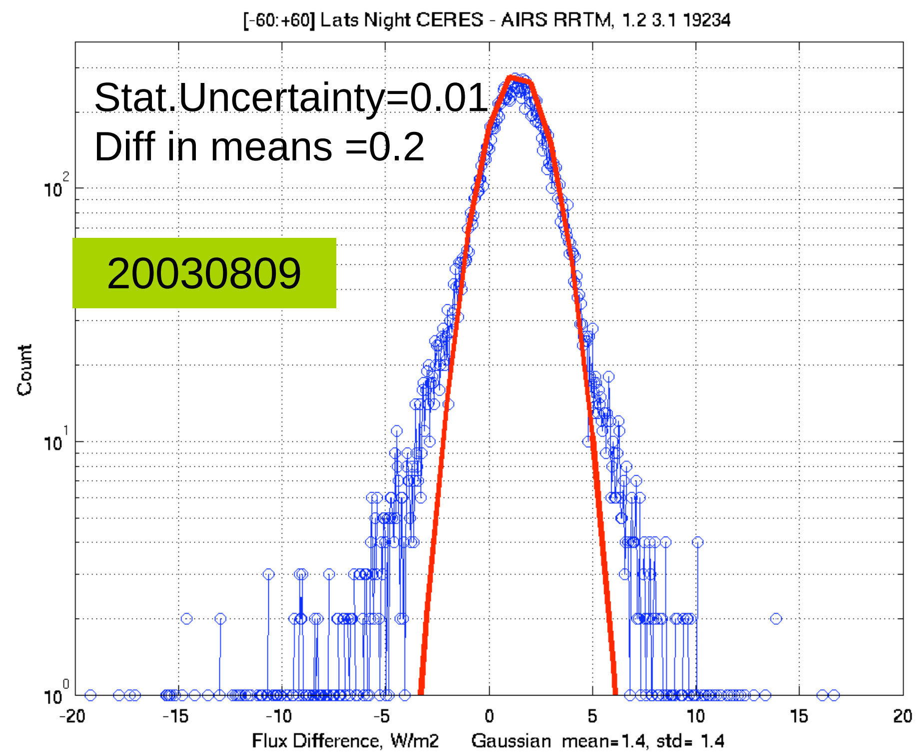
Ceres-AIRS RRTM Map ~ Night

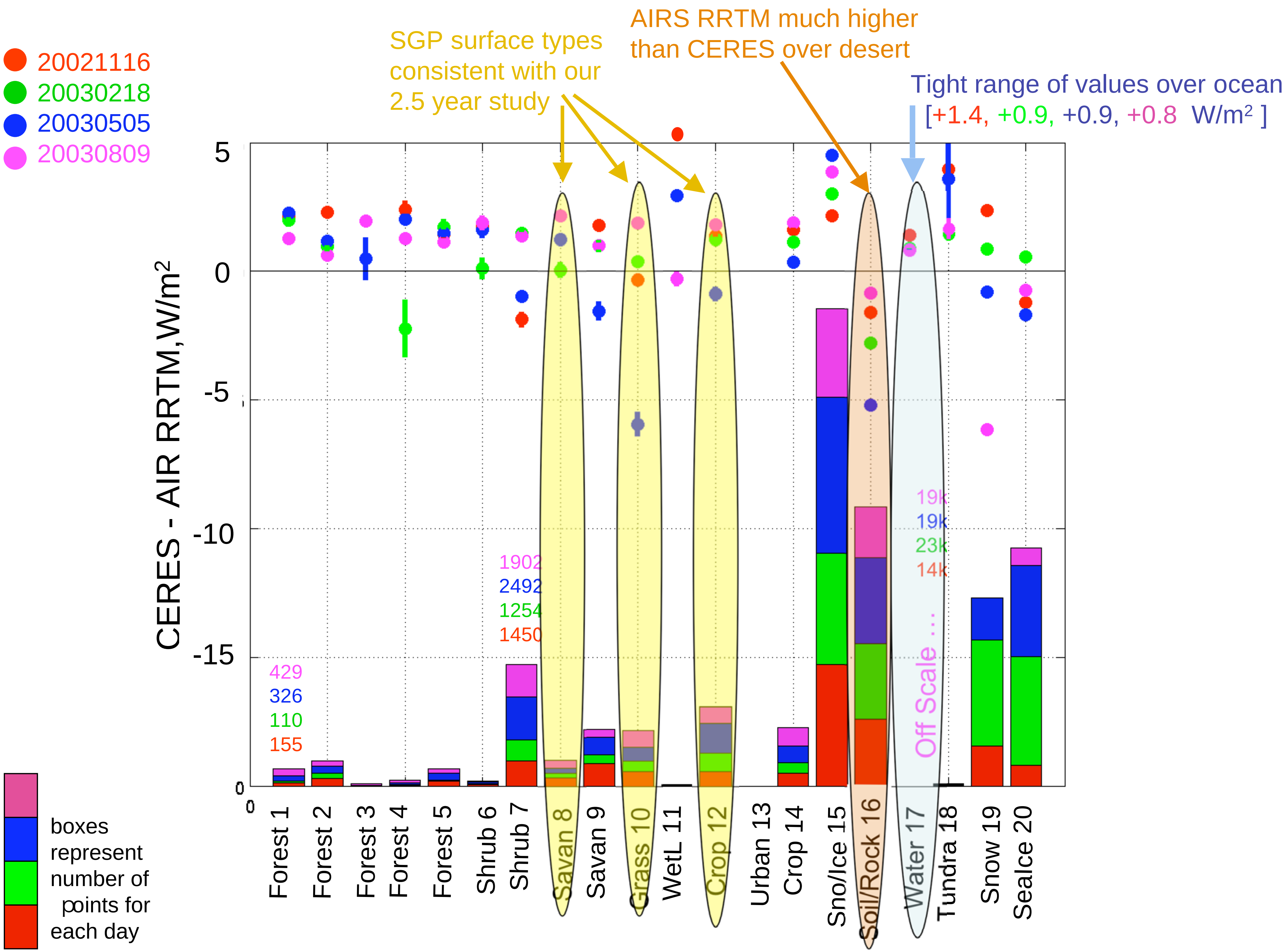



[-60:+60] Lats Night CERES - AIRS RRTM, 1.7 2.6 17139
Stat.Uncertainty=0.01
Diff in means =0.4
20021116
Count
Flux Difference, W/m2 Gaussian mean=2.0, std= 1.5

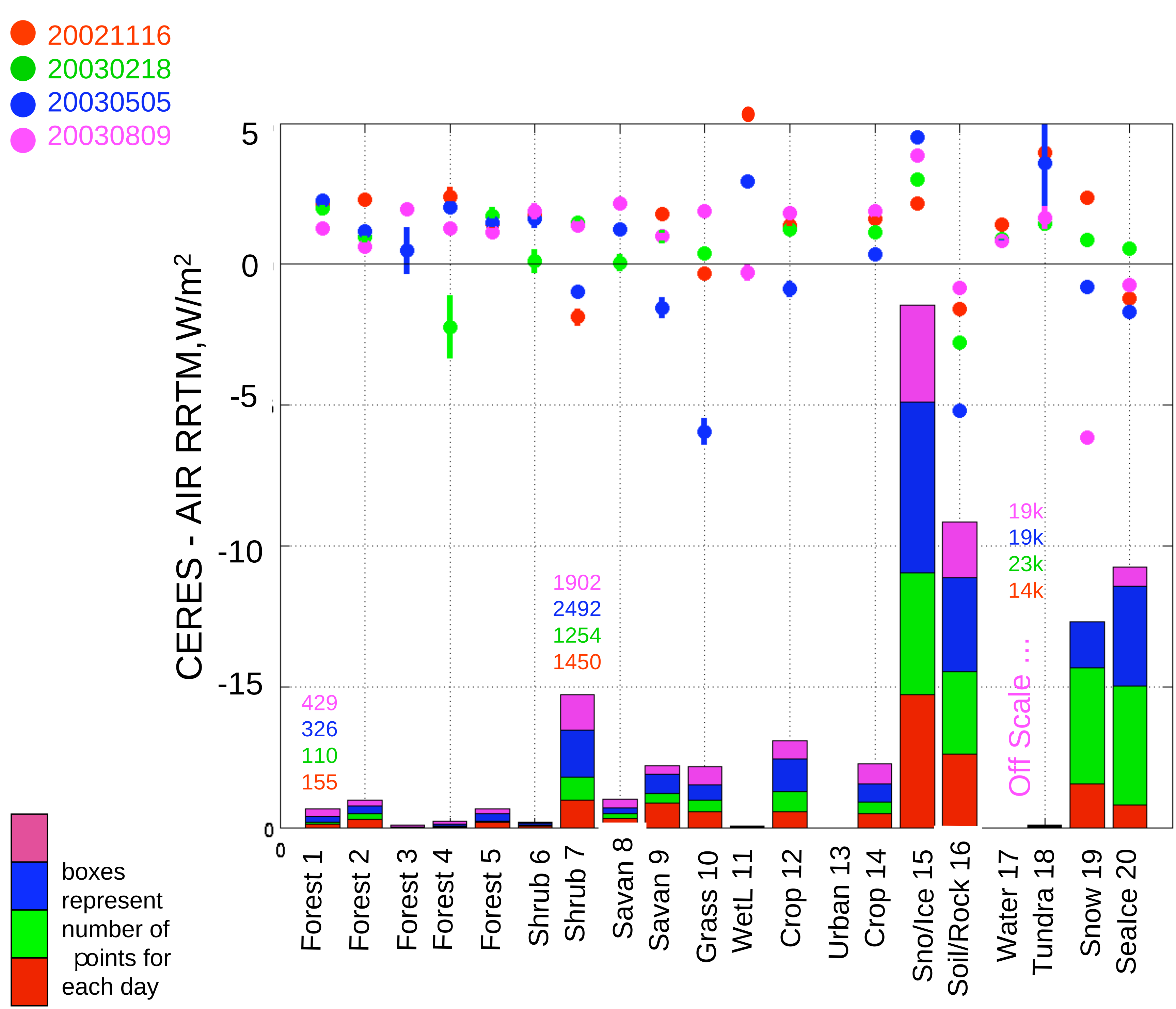

[-60:+60] Lats Night CERES - AIRS RRTM, 1.2 2.6 21411
Stat.Uncertainty=0.01
Diff in means =0.2
20030218
Count
Flux Difference, W/m2 Gaussian mean=1.4, std= 1.4


[-60:+60] Lats Night CERES - AIRS RRTM, 1.2 2.4 22525
Stat.Uncertainty=0.01
Diff in means =0.3
20030505
Count
Flux Difference, W/m2 Gaussian mean=1.4, std= 1.5

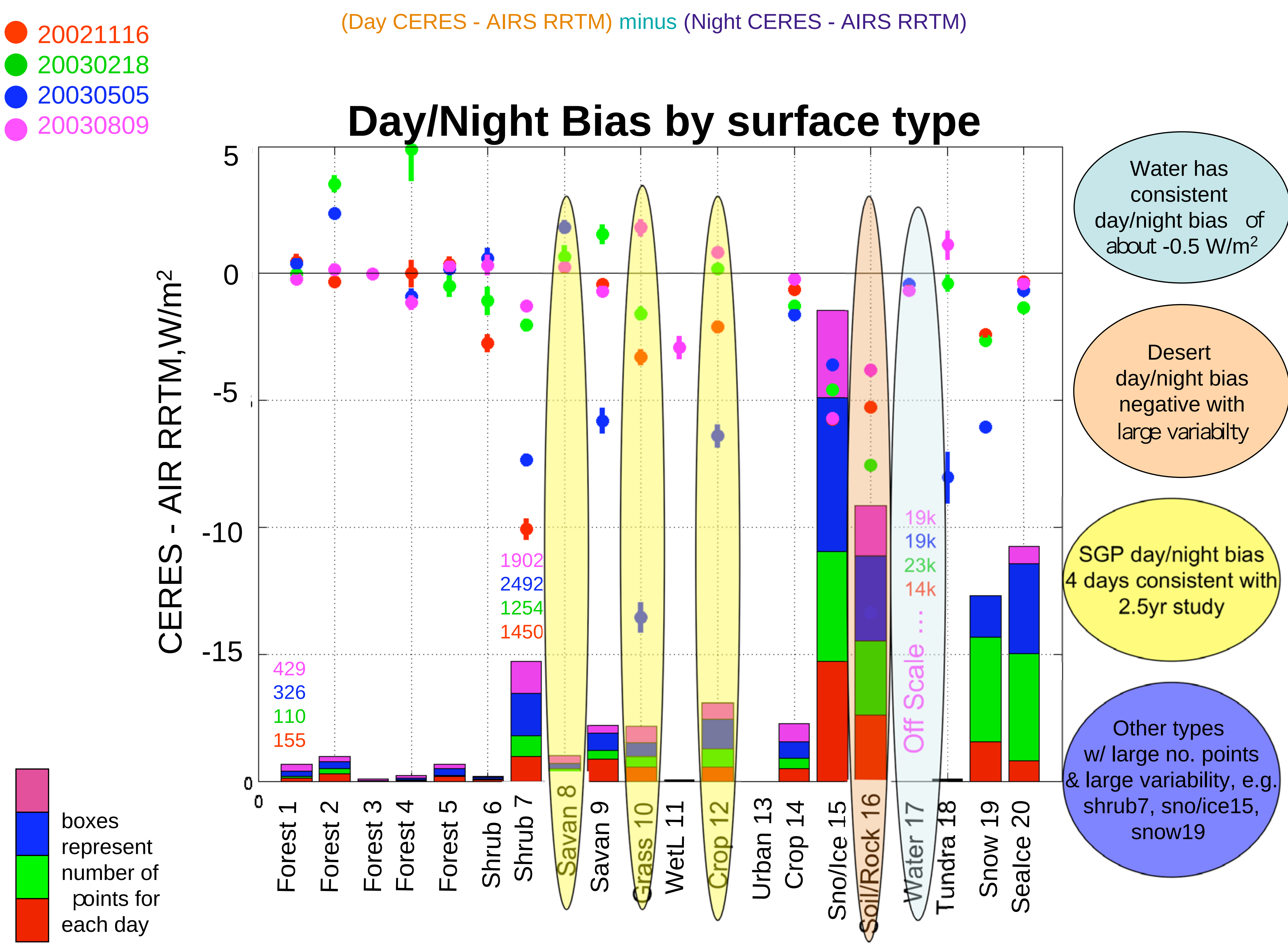

[-60:+60] Lats Night CERES - AIRS RRTM, 1.2 3.1 19234
Stat.Uncertainty=0.01
Diff in means =0.2
20030809
Count
Flux Difference, W/m2 Gaussian mean=1.4, std= 1.4



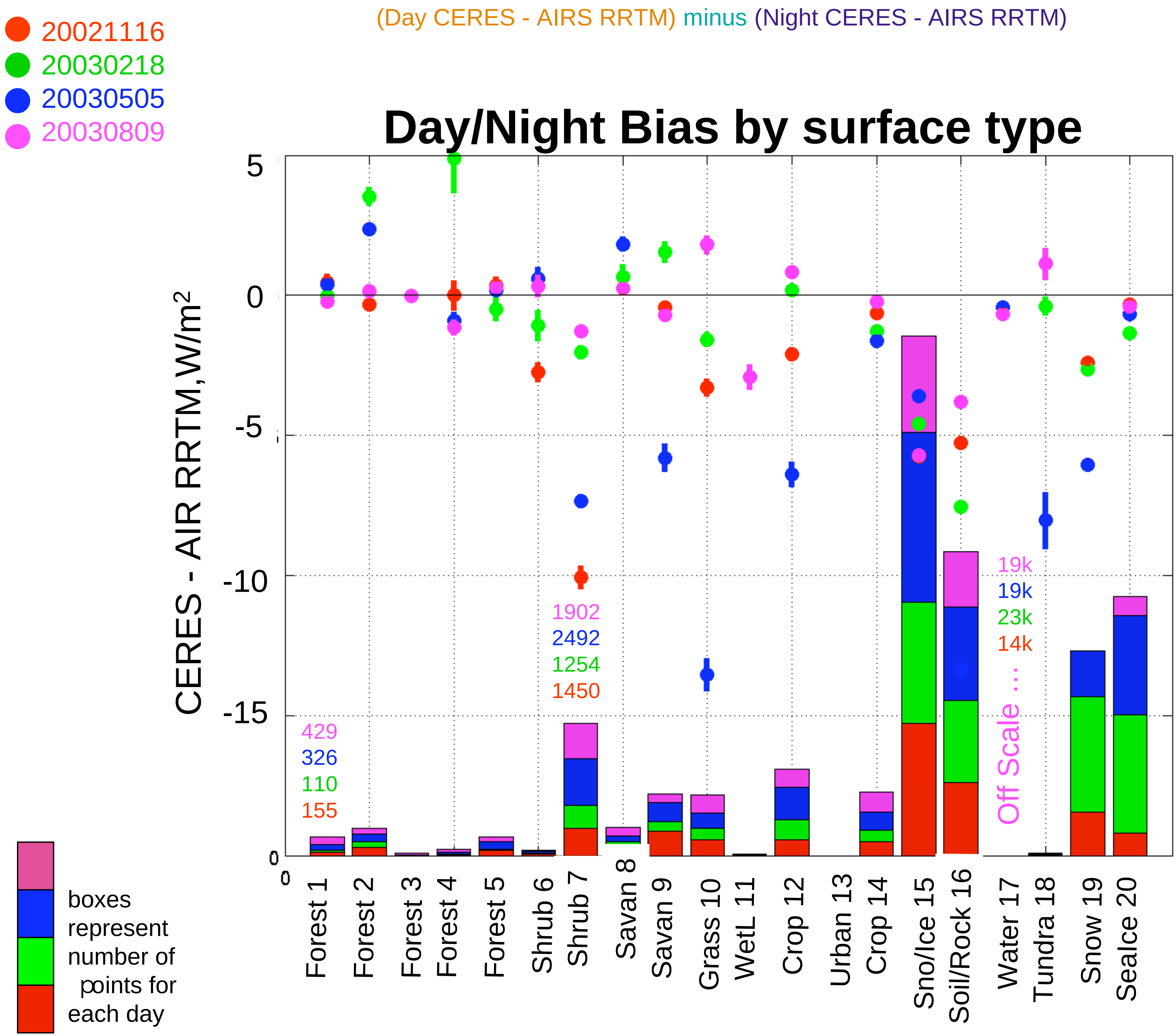
20021116
20030218
20030505
20030809
SGP surface types consistent with our 2.5 year study
AIRS RRTM much higher than CERES over desert
Tight range of values over ocean
[+1.4, +0.9, +0.9, +0.8 W/m²]
CERES - AIR RRTM,W/m²
5
0
-5
-10
-15
429
326
110
155
1902
2492
1254
1450
19k
19k
23k
14k
Off Scale ...
Forest 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
SeaIce 20
boxes represent number of points for each day



20021116
20030218
20030505
20030809
CERES - AIR RRTM,W/m2
5
0
-5
-10
-15
0
429
326
110
155
1902
2492
1254
1450
19k
19k
23k
14k
Off Scale ...
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
SeaIce 20
boxes represent number of points for each day



(Day CERES - AIRS RRTM) minus (Night CERES - AIRS RRTM)
20021116
20030218
20030505
20030809
Day/Night Bias by surface type
CERES - AIR RRTM,W/m²
5
0
-5
-10
-15
1902
2492
1254
1450
429
326
110
155
19k
19k
23k
14k
Off Scale ...
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
SeaIce 20
Water has consistent day/night bias of about -0.5 W/m²
Desert day/night bias negative with large variabilty
SGP day/night bias 4 days consistent with 2.5yr study
Other types w/ large no. points & large variability, e.g. shrub7, sno/ice15, snow19
boxes represent number of points for each day



20021116
20030218
20030505
20030809
(Day CERES - AIRS RRTM) minus (Night CERES - AIRS RRTM)
Day/Night Bias by surface type
CERES - AIR RRTM,W/m2
5
0
-5
-10
-15
0
429
326
110
155
1902
2492
1254
1450
19k
19k
23k
14k
Off Scale ...
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
SeaIce 20
boxes
represent
number of
points for
each day

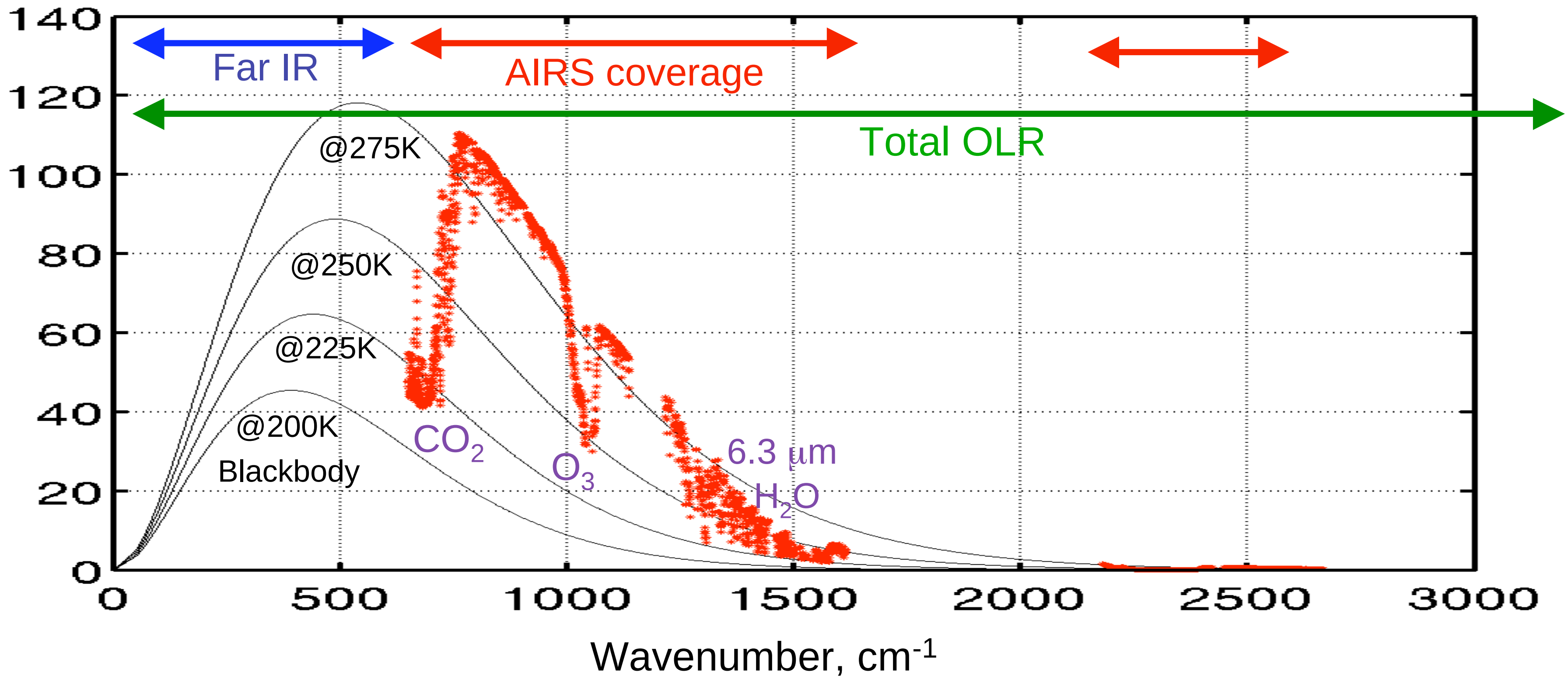
AIRS Spectral flux analysis

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:

$$F = \iint radiance \; d\nu \; d\psi$$

where ν is wavelength, and ψ 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.

Spectral Coverage	weight %	Flux W/m^2	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		[0.1-0.3]

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/m^2.)

Assessing ARM Clear Sky OLR with CERES and AIRS

The RRTM calculations of clear sky OLR agree with CERES observations to ~1 W/m^2 with an uncertainty of ~1 W/m^2.

- 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. The day/night <u>ocean</u> bias is very constant (near -0.5 W/m^2) but the day/night bias varies greatly over some <u>land</u> surface types.

Future work will include cloudy conditions…