An Update on the Spectral Flux Estimation from the Collocated AIRS and CERES Measurements

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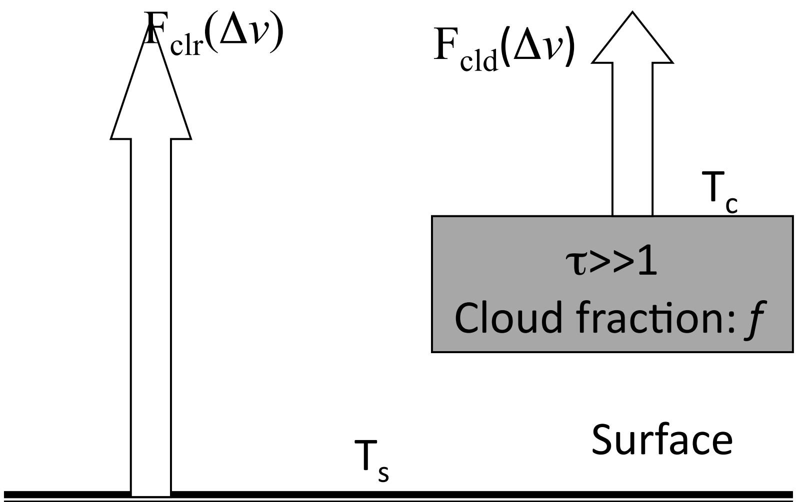
Outline

- Motivations: *why bother going for band by band?*
  - Broadband vs. band-by-band
  - Band-by-band CRF: fraction also matters
  - How to get it from observations: the algorithm
- Extending the algorithm to near global observations (80S – 80N)
  - Clear-sky
  - All-sky
- A case study: band-by-band CRE
  - "Infrared-effective" cloud top height
- Conclusion and discussion

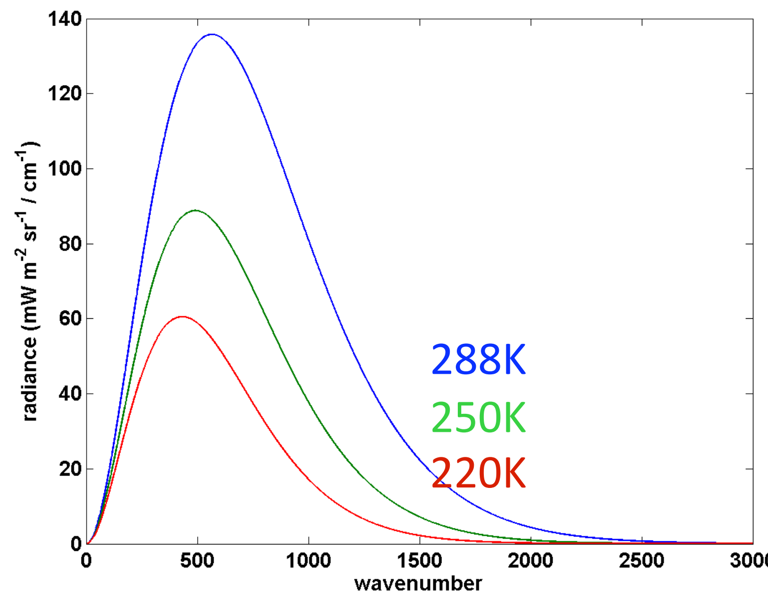
Why go band-by-band? $OLR = F_{H2O} + F_{CO2} + F_{wn} + \ldots$

- Practical reasons (for model evaluation):
  - Compensating biases for simulated broadband CRE and fluxes
    - Broadband TOA flux and CRE can be seemingly correct but for wrong reasons.
  - Band-by-band quantities are directly computed by each GCM
- Also
  - Band-by-band CREs provides extra insights

Why go band-by-band: Toy model A



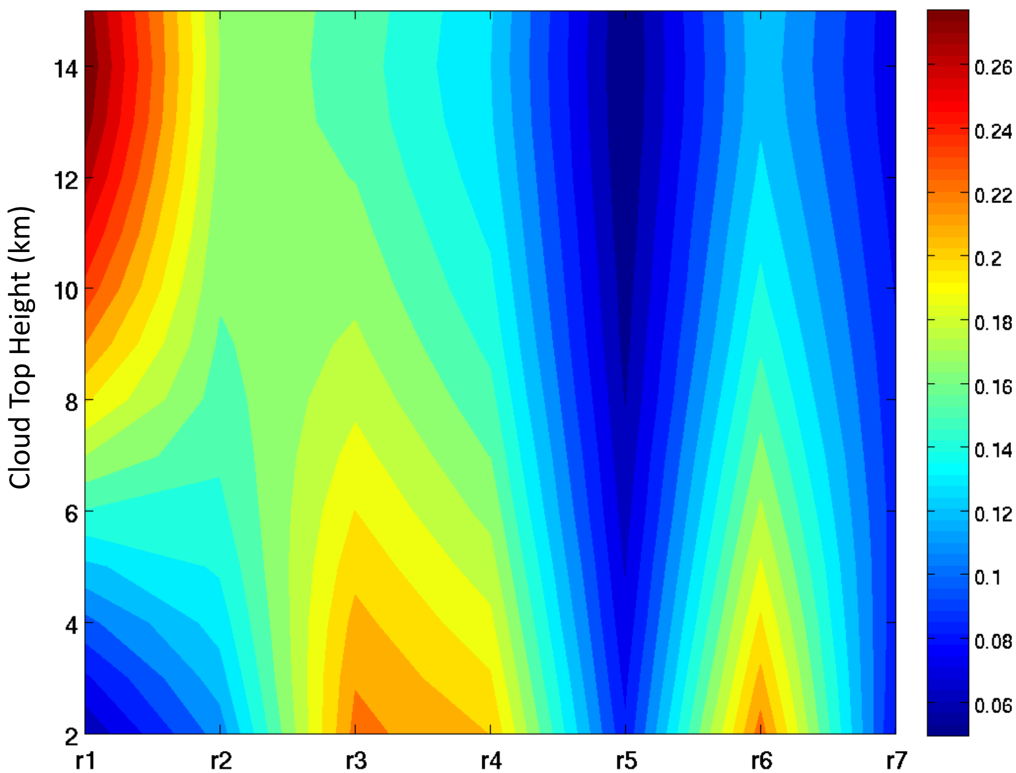
1. Blackbody cloud
2. Ignore atmospheric absorption



$$CRE_{LW} = \sigma T_s^{\ 4} - [f\sigma T_c^{\ 4} + (1-f)\sigma T_s^{\ 4}] = f\left[\sigma T_s^{\ 4} - \sigma T_c^{\ 4}\right]$$

CRE_{LW} *sensitive to both f and* T_c

Toy model B



Fractional contribution to the LW CRE (F_{CRE})

- Typical tropical sounding profiles of T, q, O_3, etc ("*McClatchey*" profiles)
- Realistic one-layer cloud (τ>>1) with top varying from 2km to 15km
- 7 bands as used in the GFDL model

Band1: 0-560 and 1400-2500 cm^{-1} (H_2O)

Band2: 560-800 cm^{-1} (CO_2, N_2O)

Band3: 800-900 cm^{-1} (WN)

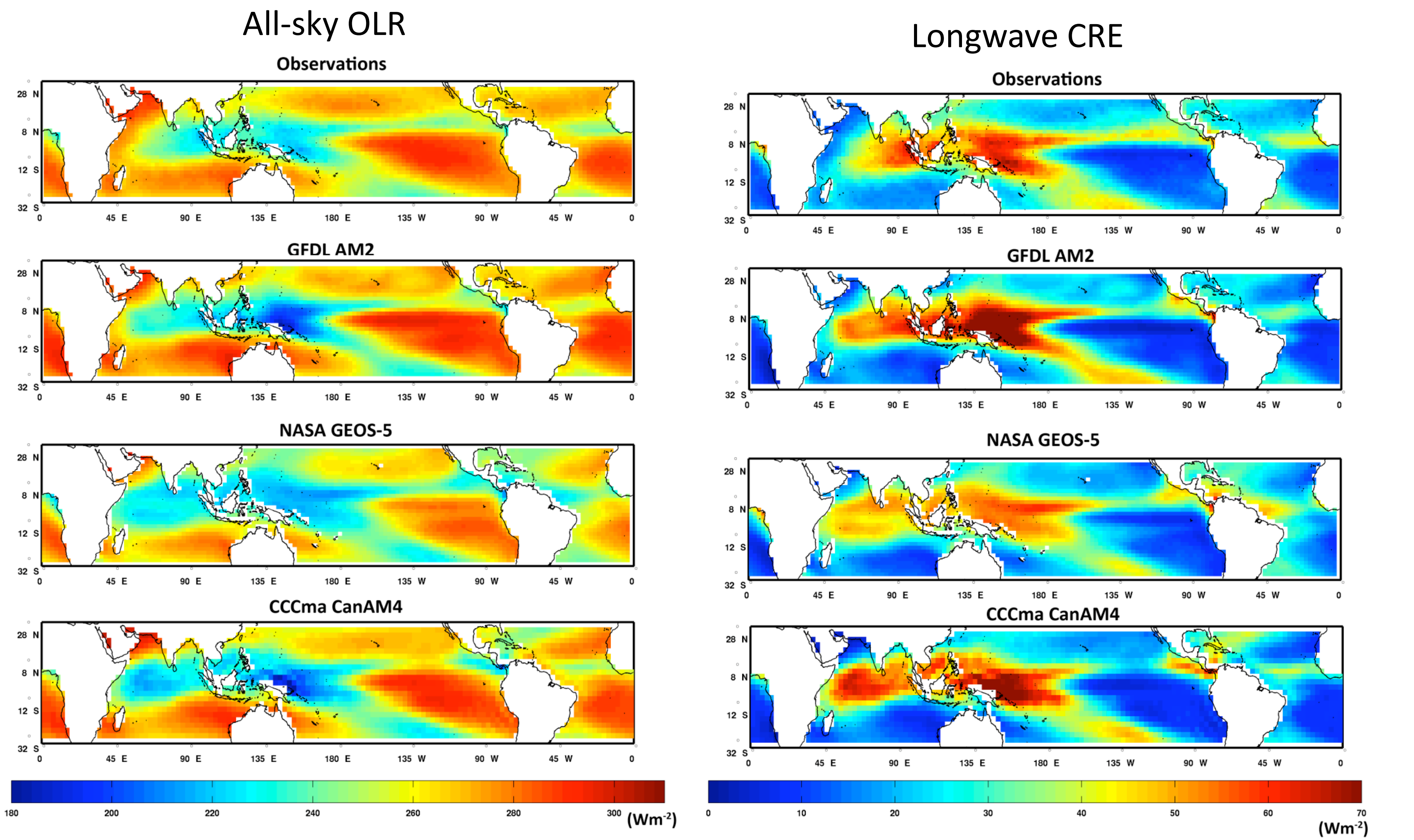
Band4: 900-990 cm^{-1} (WN)

Band5: 990-1070cm^{-1} (O_3)

Band6: 1070-1200cm^{-1} (WN)

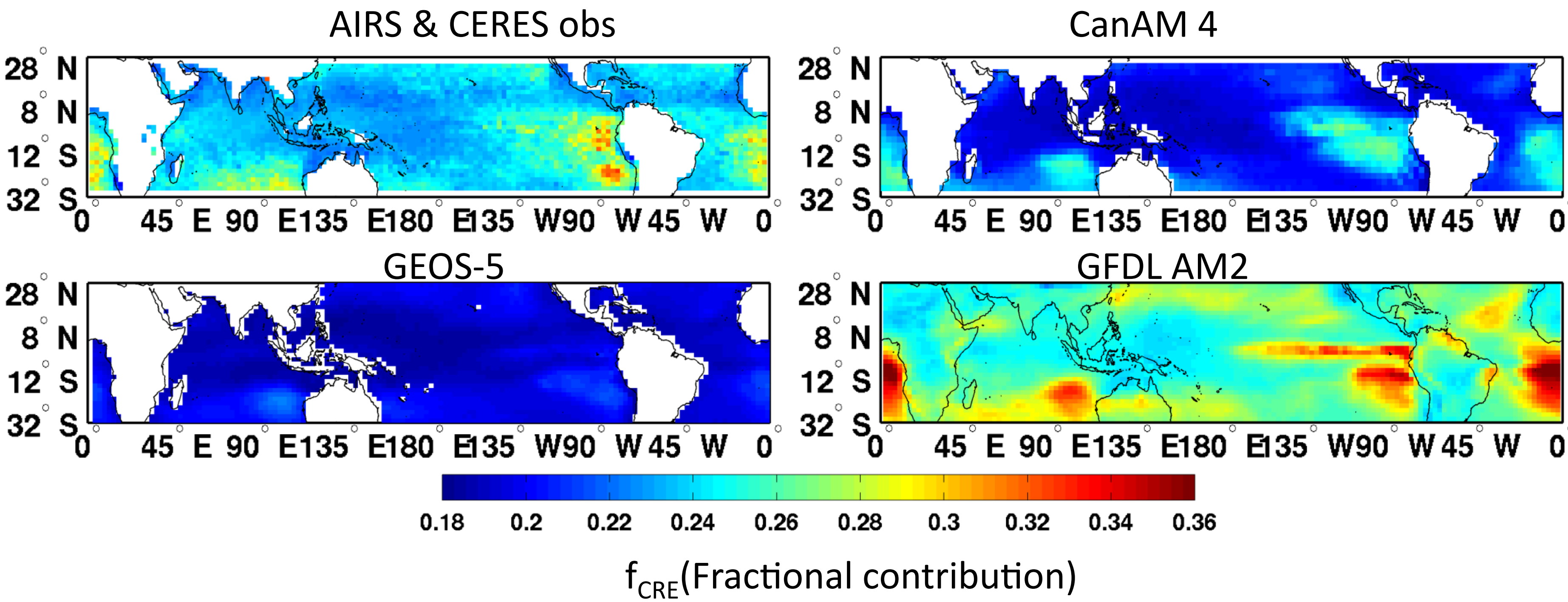
Band7: 1200-1400cm^{-1} (N2O, CH_4)

Multi-year averages



(Huang et al., 2012)

Band 5 (1070-1400 cm^{-1}): Long-term mean of fractional contribution to the LW CRE



GEOS -5: lower than obs. and a narrow range: 0.18-0.22

GFDL AM2: higher than obs.

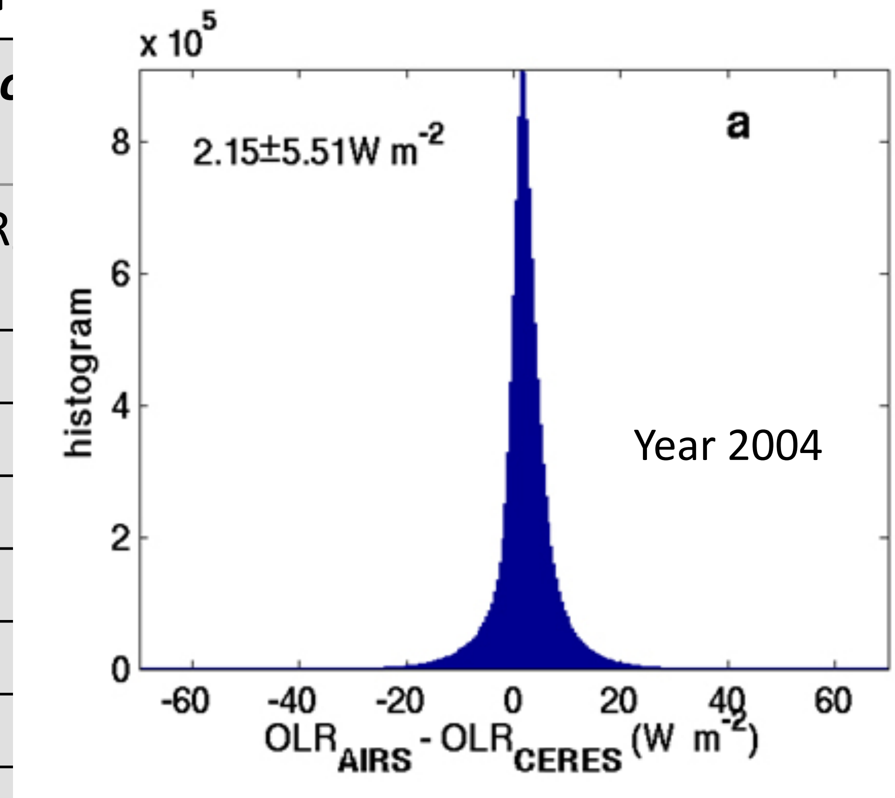
CanAM4: more similar to GEOS-5

Treatment of IR scattering matters here, but cannot explain the full discrepancies (only up to ~0.02-0.04 diff.)

(Huang et al., 2012)

How to observationally derive the

	Clear sky over the c	
	OLR_{AIRS_huang} - OLR (Wm^{-2})	
2003	0.84±1.56	
2004	0.67±1.52	
2005	1.42±1.68	
2006	1.55±1.74	
2007	1.73±1.86	
2008	0.94±2.09	
2009	0.96±2.15	1.83±6.06
2010	1.16±2.28	1.88±6.05



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  - spectrally, difference < ±5% (clear-sky) and < ± 3.6% (cloudy)
  - Broadband, good agreements with CERES OLR for all the years (~2.5Wm^{-2},i.e. ~2σ radiometric uncertainty) and for all cloud scene types (Huang et al., JGR, 2010)

Extending the algorithms: beyond the oceans

- How to taking the surface spectral emissivity into account?
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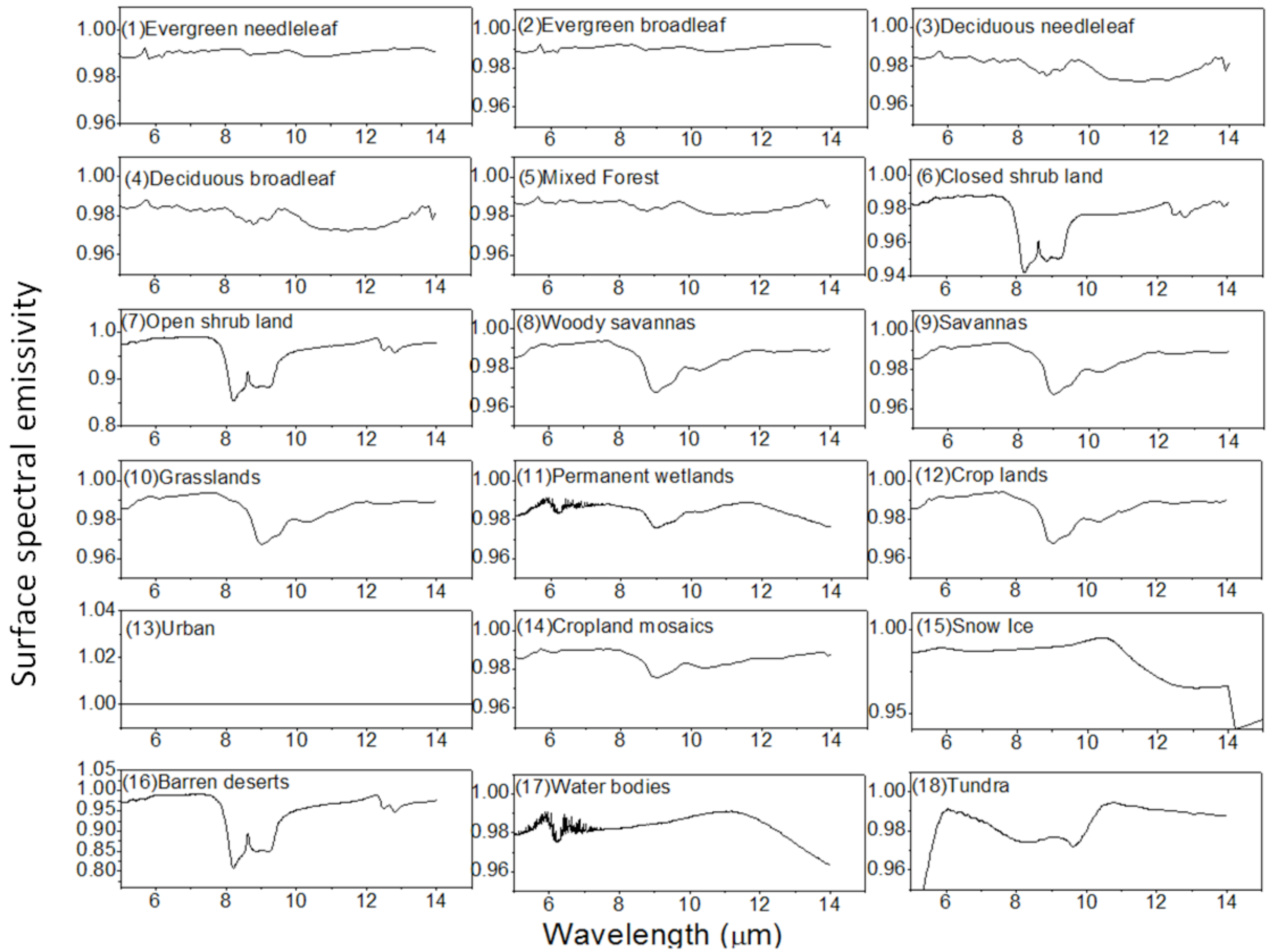
  - Appl



Correction for cloudy observations

For a given frequency v, everything being equal except the surface emissivity

$$F_1 = \frac{\pi R_1}{x_1}(ocean), F_2 = \frac{\pi R_2}{x_2}(other), \text{let } x_2 = x_1(1+\Delta x)$$

It can be shown that

$$\Delta x = (\varepsilon_{s1} - \varepsilon_{s2}) B(T_s) \left[\frac{2x_1}{R_2} \int_0^1 e^{-\frac{\tau}{\mu}} \mu d\mu - \frac{e^{-\frac{\tau}{\mu}}}{R_2} \right] = (\varepsilon_{s1} - \varepsilon_{s2}) B(T_s) \left[\frac{x_1}{R_2} \left(e^{-\tau} - \tau E_2(\tau) \right) - \frac{e^{-\frac{\tau}{\mu}}}{R_2} \right]$$

$\varepsilon_{s1}, \varepsilon_{s2}, x_1$, and R_2 is known to us.

$e^{-\tau} = f_1 e^{-(\tau_{1cld} + \tau_{clr})} + f_2 e^{-(\tau_{2cld} + \tau_{clr})} + (1 - f_1 - f_2) e^{-\tau_{clr}}$; $\tau_{\text{clr}}(\text{lat}, v)$ is obtained from a look-up table, τ_{cld} is from cloud emissivity in the CERES SSF data sets.

Asymptotic behaviors:

$\tau \to +\infty, \Delta x = 0;$

$\tau \to 0, x_1 = x_2 = 1; \Delta x = 0$

All collocated clear-sky observations in 2004 (80S-80N)

Surface Type	Daytime OLR_{AIRS_Huang}-OLR_{CERES} (Wm^{-2})	Nighttime OLR_{AIRS_Huang}-OLR_{CERES} (Wm^{-2})
Forest	0.58±1.43	-0.42±1.41
Savannas	-0.03±2.52	0.68±1.50
Grasslands	0.19±2.61	0.63±1.65
Dark Desert	-0.71±2.85	0.36±1.74
Bright Desert	1.67±2.62	1.42±2.28
Ocean	1.09±1.55	0.90±1.26

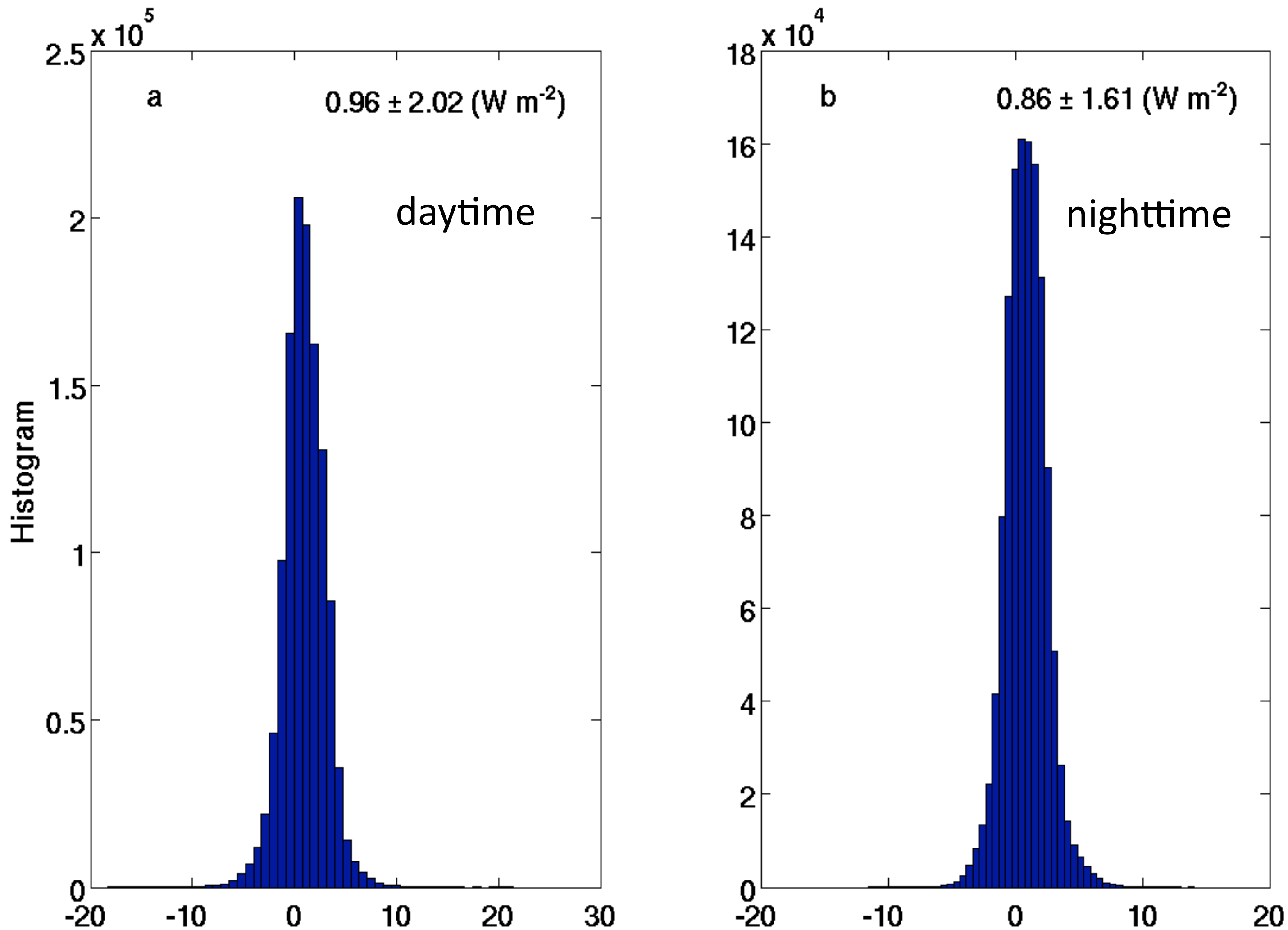
(Chen et al., 2012)

CERES 2σ radiometric calibration uncertainty: 1% (i.e. ~ 2.5W m^{-2})

OLR_{AIRS_huang}: OLR estimated from AIRS spectra

OLR_{CERES}: OLR from collocated CERES observation

all collocated clear-sky observations in 2004 (80S-80N)



OLR_{AIRS_Huang}-OLR_{CERES} (Wm^{-2})

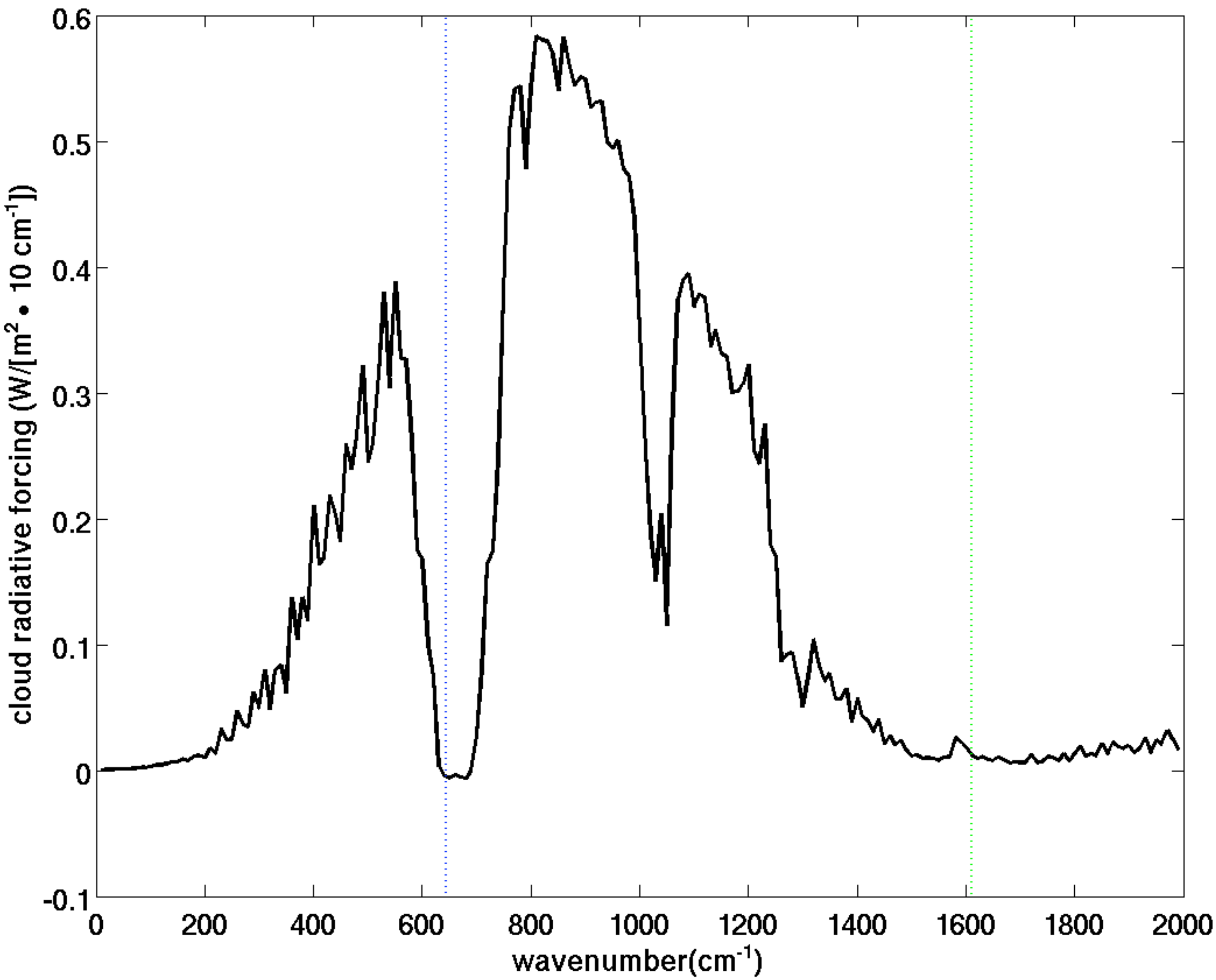
Collocated AIRS & CERES cloudy observations (over all lands)

$\Delta OLR = OLR_{AIRS\_Huang} - OLR_{CERES}$ ($W\ m^{-2}$), $\Delta OLR/OLR_{CERES}$

f ΔT_{sc}	<15k	15K-40K	>40K
0.001-0.5	2.34±2.86 (0.8%)	3.62±4.48 (1.3%)	2.84±5.94 (1%)
0.5-0.75	2.90±3.86 (1.1%)	4.24±7.25 (1.7%)	2.61±11.38 (1%)
0.75-0.999	2.81±3.56 (1.2%)	3.14±6.68 (1.4%)	0.47±11.45 (0.2%)
0.999-1.0	2.86±2.83 (1.3%)	4.04±4.33 (2%)	2.48±7.16 (1.5%)

Averages of all ΔOLR: 3.21Wm^{-2} (daytime) and 1.93 Wm^{-2} (nighttime)

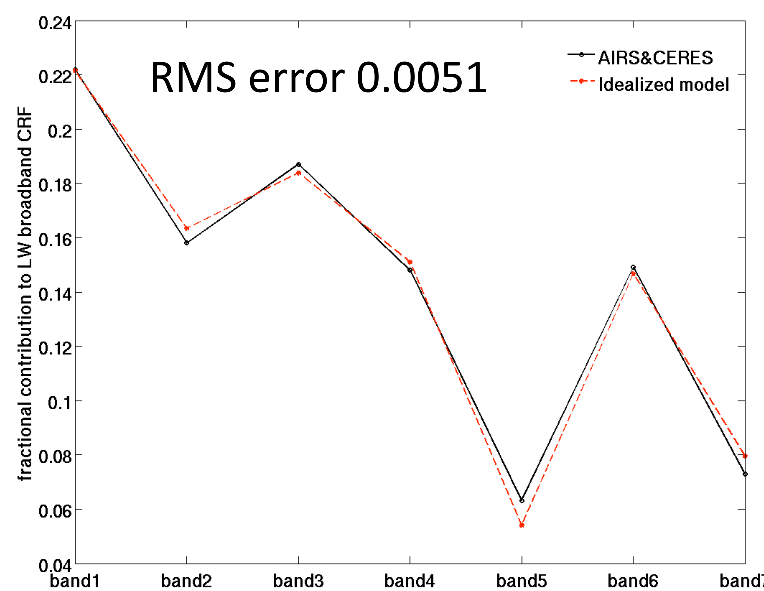
Averaged spectral LW cloud radiative effect (CRE) from AIRS & CERES collocated Observations (2004; 80S-80N)



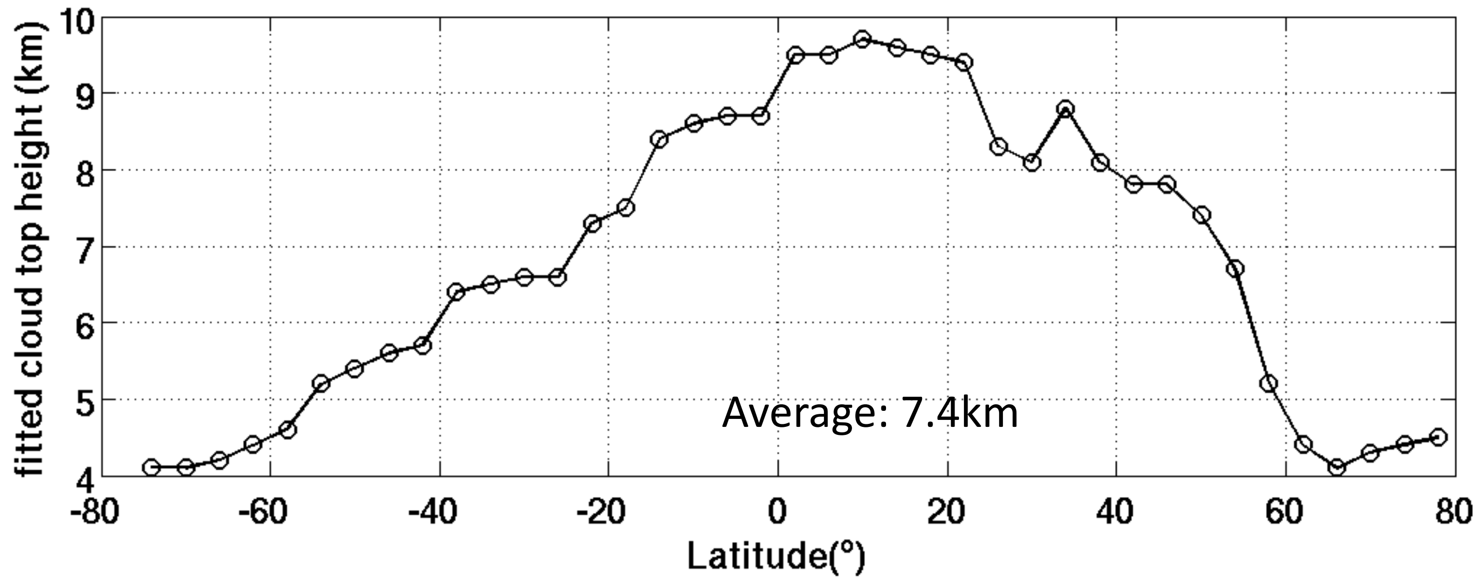
Comparison with AM2: 80S-80N averaged band-by-band CRE

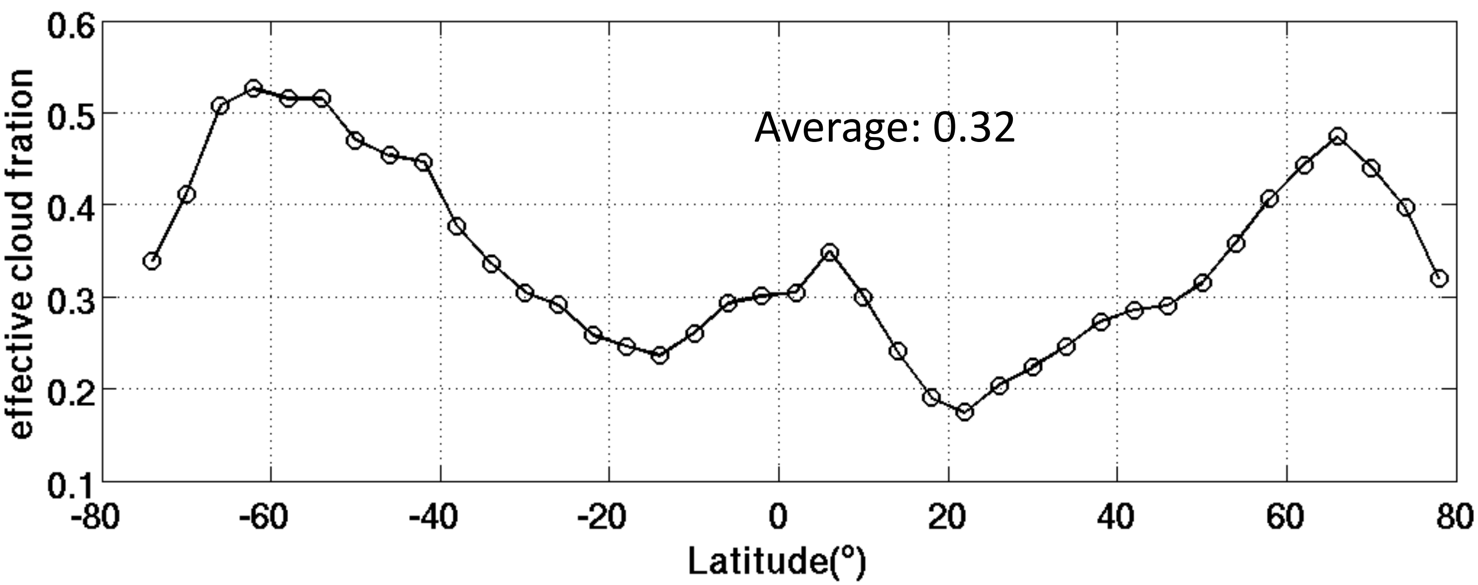
	Collocated AIRS with CERES (2004)	AM2 simulation (2004)
	Wm^{-2}	Wm^{-2}
LW broadband	30.2 (100%)	26.2(100%)
$0\text{-}560cm^{-1}$ & $>1400cm^{-1}$	6.7 (22.2%)	5.0 (19.1%)
$560\text{-}800cm^{-1}$	4.8 (15.8%)	3.6 (13.7%)
$800\text{-}900cm^{-1}$	5.6 (18.7%)	5.1 (19.5%)
$900\text{-}990cm^{-1}$	4.5 (14.8%)	4.4 (16.8%)
$990\text{-}1070cm^{-1}$	1.9 (6.32%)	1.4 (5.3%)
$1070\text{-}1200cm^{-1}$	4.5 (14.9%)	4.8 (18.3%)
$1200\text{-}1400cm^{-1}$	2.2 (7.3%)	1.9 (7.3%)
"Infrared-effective" cloud top height	10.0km	9.1km
"Infrared-effective" cloud fraction	25.24%	25.7%
Background Profile	1976 US standard	AM2 climatology

Compare to arithmetic average from SCIAMACHY retrieval 7.3±0.9km for CTH; 65%±7% for cloud fraction (Kokhanovsky et al., 2011).



Fitting the CTH: zonal-mean background profiles from ERA-interim 2004



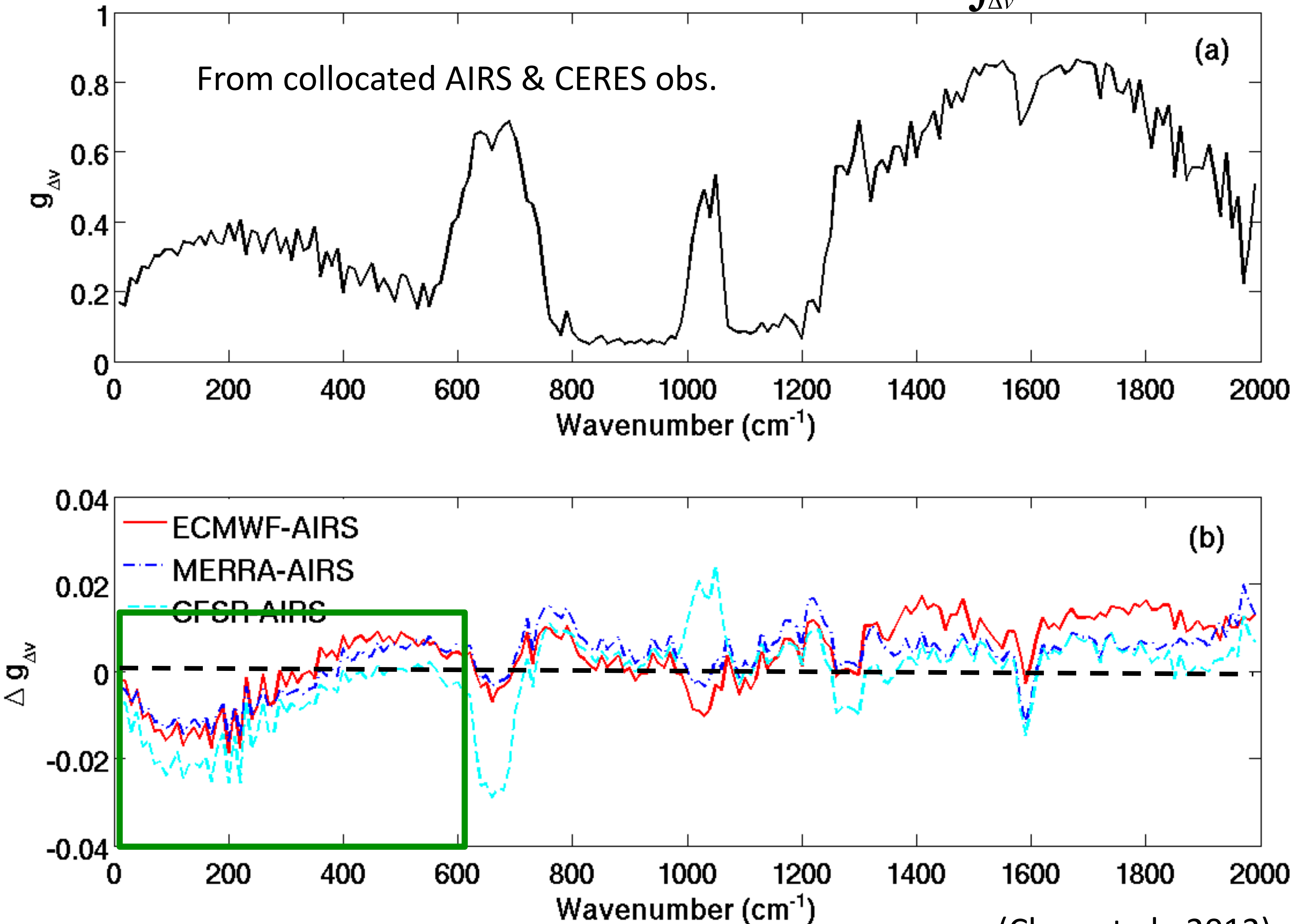


Conclusions & Discussions

- Band-by-band comparison directly evaluate the flux and CRE of each band, constituting a much more rigorous validation of GCM/reanalysis radiant flux and CRE.
- We extended both clear-sky and cloudy-sky algorithms to land surfaces and the comparisons with collocated CERES OLR show similar agreements as those over the tropical oceans.
- Snow surface in high latitude and high altitude areas
  - Little water vapor, surface is “visible” from space even in far-IR
  - No good spectral emissivity data for snow in the far-IR (ASTER database stops at 700cm^{-1})
  - This could be an issue for polar radiation budgets
    - Much more energy leaving from far-IR than from other spectral regions

Global clear-sky spectral greenhouse parameter (efficiency)

$$g_{\Delta v} = \frac{\int_{\Delta v} \varepsilon_{sv} B_v(T_s)dv - F_{\Delta v}(TOA)}{\int_{\Delta v} \varepsilon_{sv} B_v(T_s)dv}$$



(Chen et al., 2012)

Thank You !

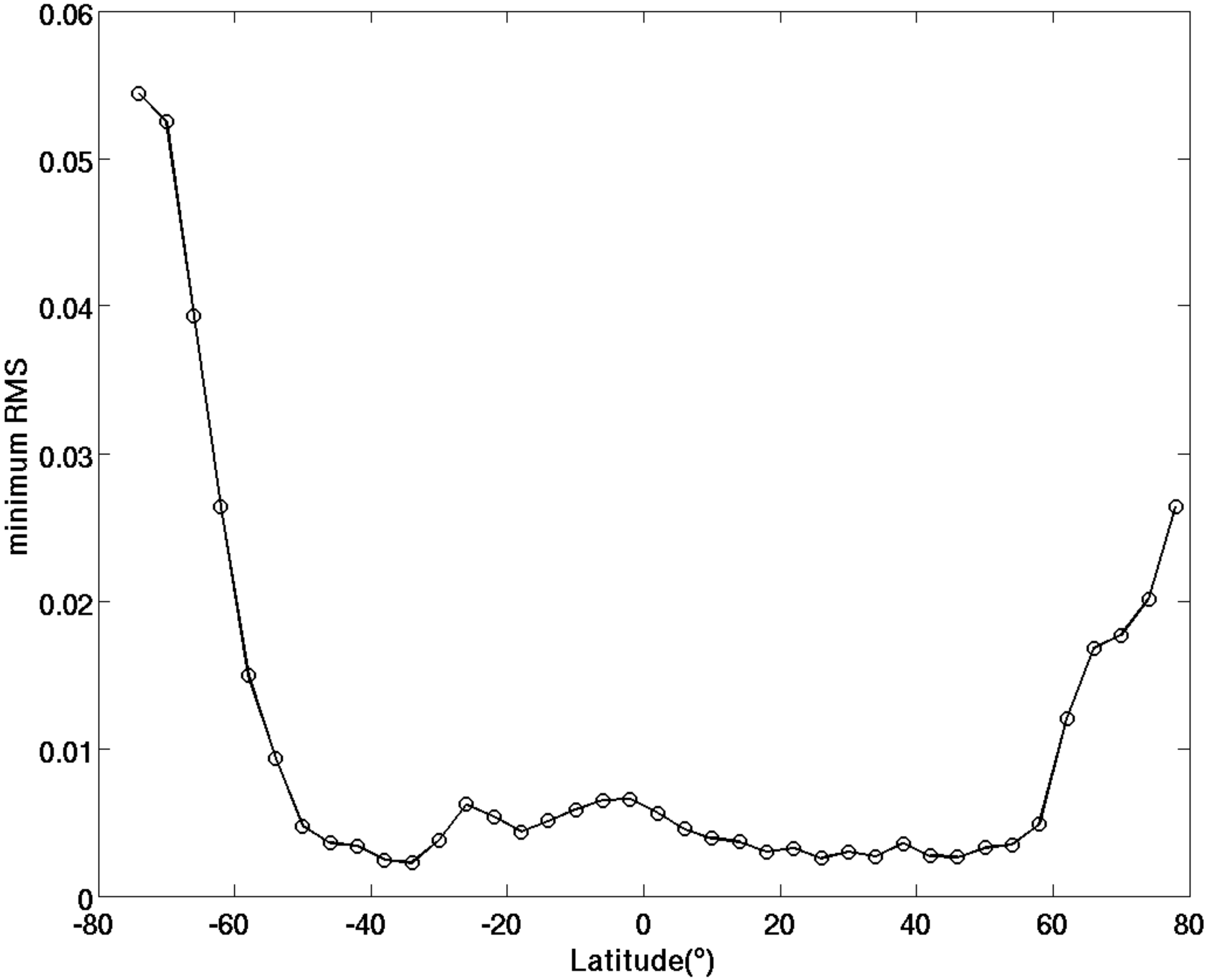
References:

- Huang et al., 2008: Spectrally resolved fluxes derived from collocated AIRS and CERES measurements and their application in model evaluation, Part I: clear sky over the tropical oceans, *JGR-Atmospheres*, 113, D09110, doi: 10.1029/2007JD009219.
- Huang et al., 2010: Spectrally resolved fluxes derived from collocated AIRS and CERES measurements and their application in model evaluation, Part II: cloudy sky and band-by-band cloud radiative forcing over the tropical oceans over the tropical oceans, *JGR-Atmospheres,* 115, D21101, doi: 10.1029/2010JD013932.
- Huang et al., 2012: Longwave band-by-band cloud radiative effect and its application in GCM evaluation, *Journal of Climate*, in press (available at Early Online Release).
- Chen et al., 2012: Comparisons of clear-sky outgoing far-IR flux inferred from satellite observations and computed from three most recent reanalysis products, *Journal of Climate*, in press (available at Early Online Release).

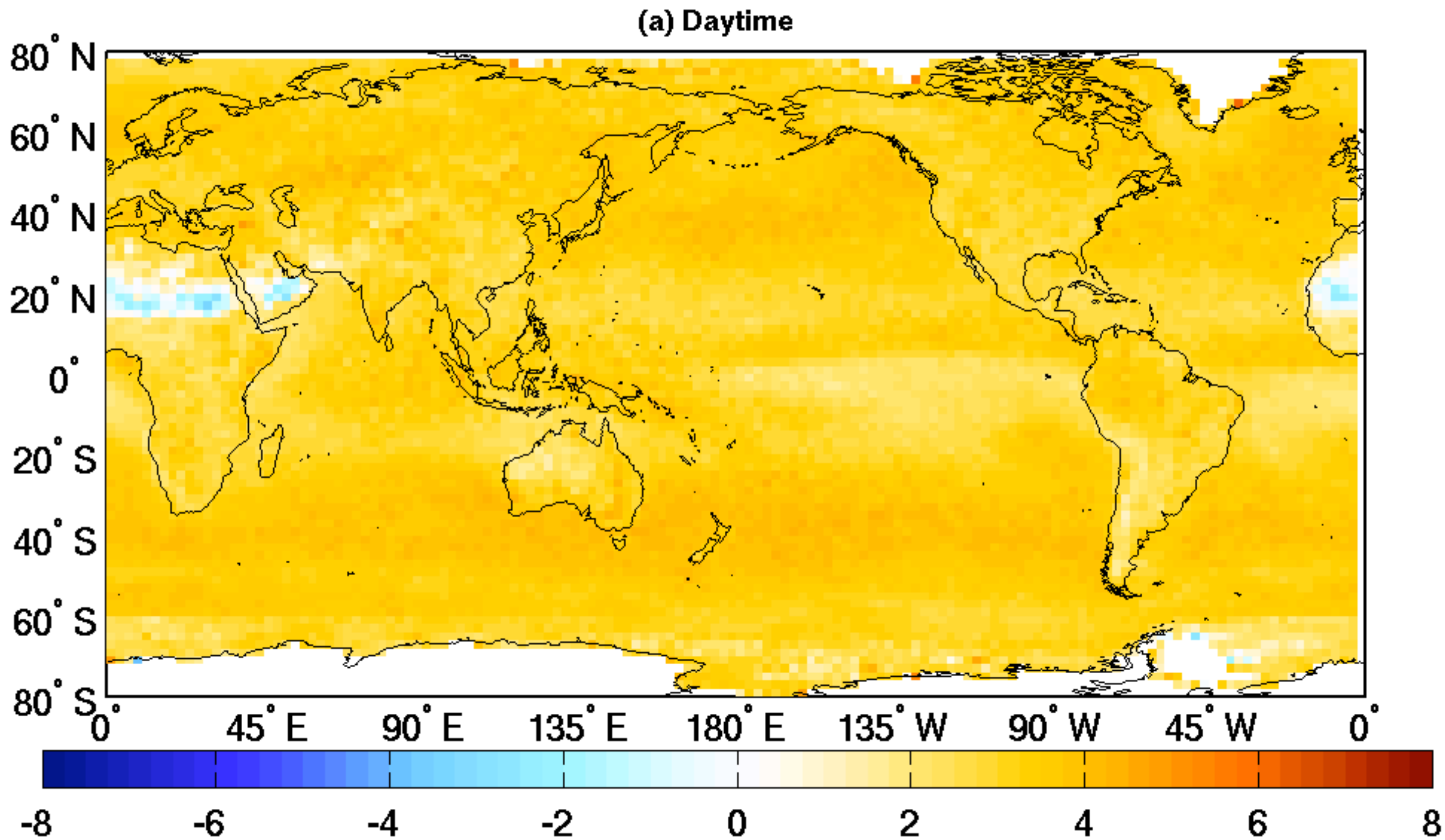
Collocated AIRS & CERES observations (desert only) $\Delta OLR = OLR_{AIRS\_Huang} - OLR_{CERES}$ (W m^{-2}), $\Delta OLR/OLR_{CERES}$

f\\ΔT_{sc}	**<15k**	**15K-40K**	**>40K**
0.001-0.5	2.44±3.79 (0.9%)	3.25±5.12 (1.2%)	1.49±7.61 (0.5%)
0.5-0.75	2.79±4.16 (1.1%)	3.34±7.80 (1.3%)	1.39±12.75 (0.5%)
0.75-0.999	2.67±3.67 (1.1%)	1.45±6.47 (0.6%)	-1.17±10.97 (-0.5%)
0.999-1.0	2.61±2.80 (1.2%)	3.15±4.00 (1.6%)	1.28±6.64 (0.7%)

From fitting data of 2004

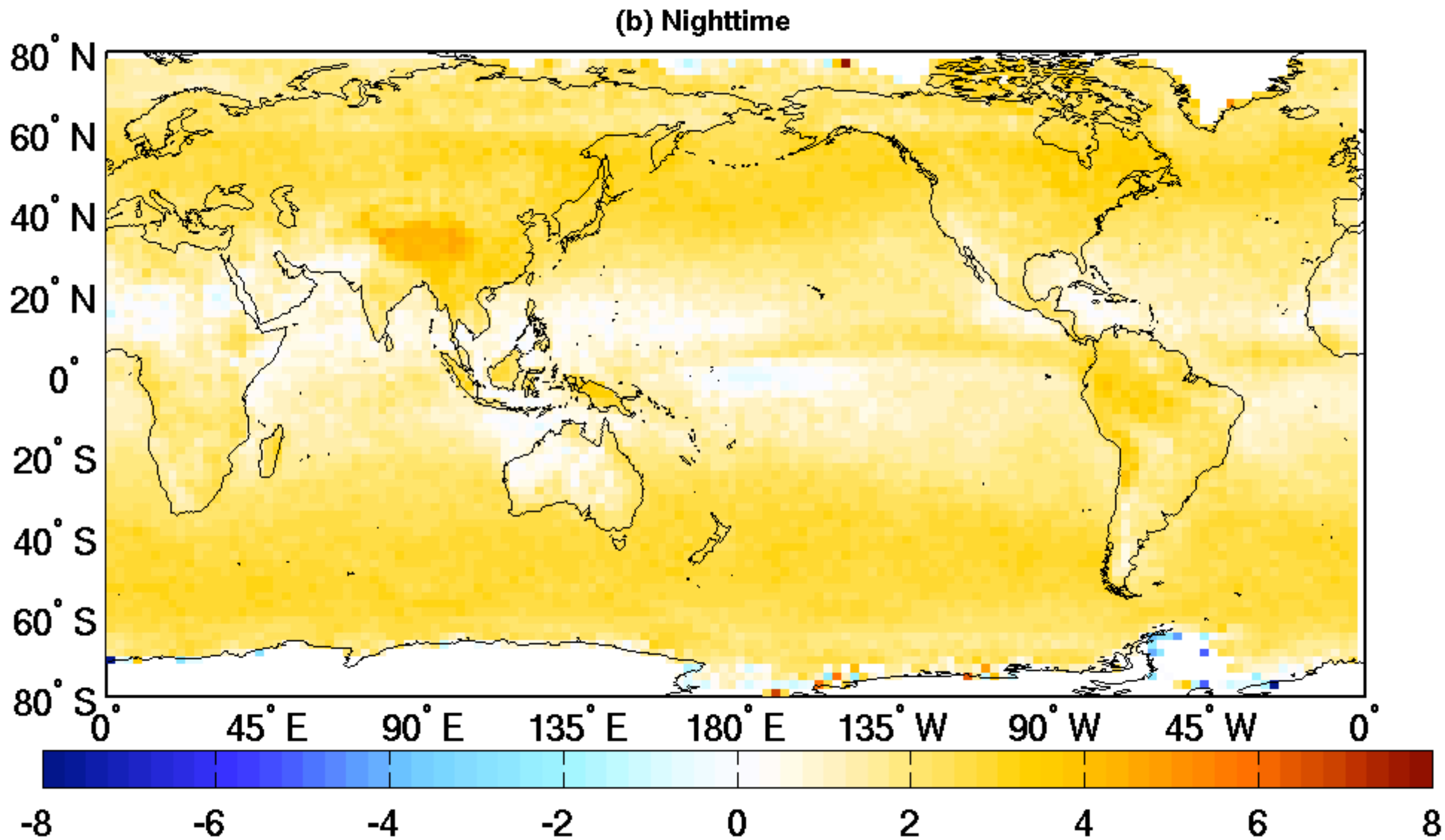


OLR_{AIRS}-OLR_{CERES}



Near global mean: 3.20±4.79 w/m^{-2}, the same as old result

OLR$_{AIRS}$-OLR$_{CERES}$



Near global mean:1.92±4.02 W/m^{-2} , the same as old result

2004 land , daytime, window region

$f\backslash \Delta T_{sc}$	<15k	15K-40K	>40K
0.001-0.5	0.90±1.64 (1%)	1.92±2.74 (2%)	2.26±3.91 (2%)
0.5-0.75	0.95±2.52 (1.2%)	1.51±4.18 (2%)	0.82±7.44 (1%)
0.75-0.999	0.55±1.93 (0.8%)	0.59±3.65 (0.9%)	-1.22±6.16 (-2%)
0.999-1.0	0.19±1.52 (0.3%)	0.35±2.09 (0.7%)	-0.36±3.31 (-1%)

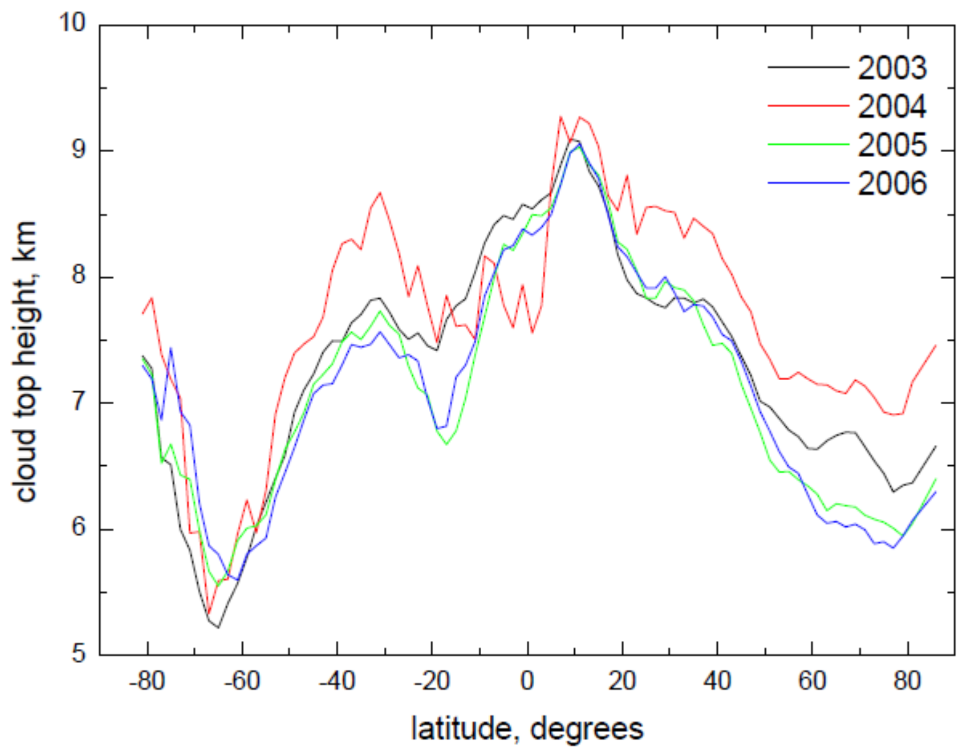
2004 desert , daytime, window region

f\ΔT$_{sc}$	<15k	15K-40K	>40K
0.001-0.5	1.51±2.06 (1.6%)	1.87±2.84 (1.9%)	2.26±4.07 (2.1%)
0.5-0.75	1.09±2.75 (1.5%)	1.43±4.46 (1.8%)	0.64±8.74 (0.8%)
0.75-0.999	0.58±1.88 (0.9%)	0.31±3.59 (0.5%)	-1.56±6.40 (-2.6%)
0.999-1.0	0.18±1.05 (0.3%)	0.02±1.69 (0.05%)	-0.49±3.09 (-1.3%)

Global Distribution of Cloud Top Height as Retrieved from SCIAMACHY Onboard ENVISAT Spaceborne Observations

Alexander Kokhanovsky *, Marco Vountas and John P. Burrows

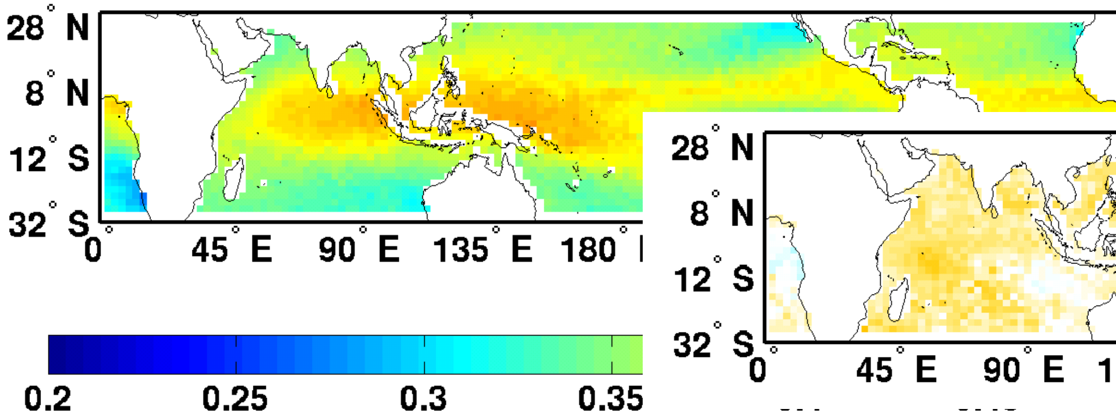
Figure 3. The latitudinal behavior of cloud top height (CTH) for 2003–2006.



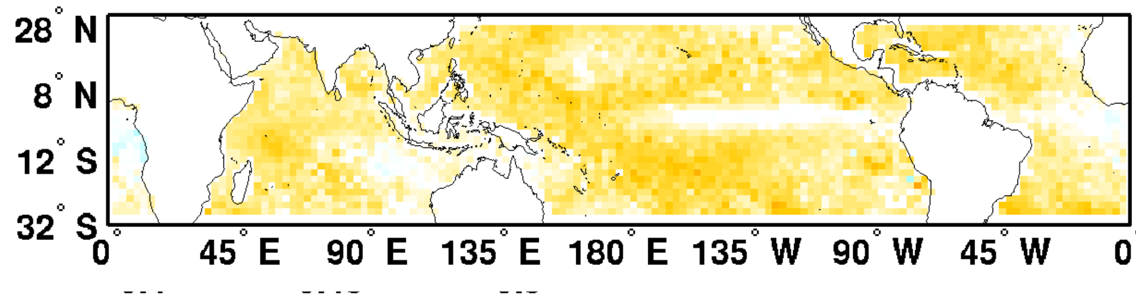
The probability of a given cloud top height for 4 years of measurements is shown in Figure 4 for 2003–2006. Here, the latitude is plotted along the OX axis and CTH along the OY axis. It follows that there is some variability of the pattern from one year to another but generally we see that the clouds are higher at ICTZ, as reported in the figures above as well. The derived (from Level 2 data) global average CTH is 7.3 ± 0.9. The corresponding results for cloud fraction and cloud optical thickness derived using SACURA as applied to SCIAMACHY [3] are 0.65 ± 0.07 and 22.5 ± 9.5, respectively. As was mentioned hereinabove, the obtained results are applicable to the case of optically thick clouds only. This explains the difference with the ISCCP results.

Collocated AIRS & CERES obs. LW broadband

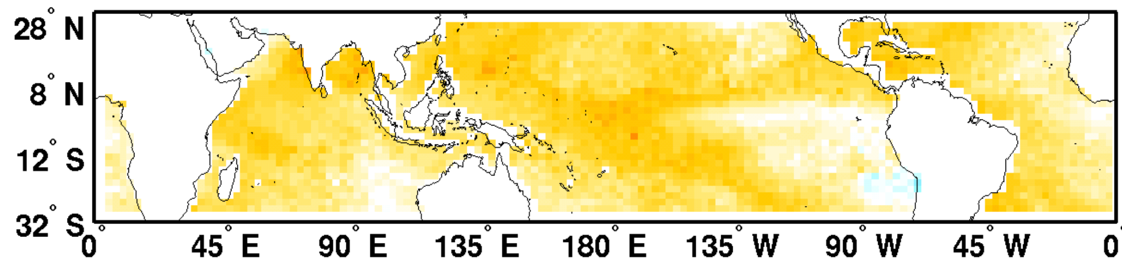
2004 Annual Mean



GFDL AM2 - Obs

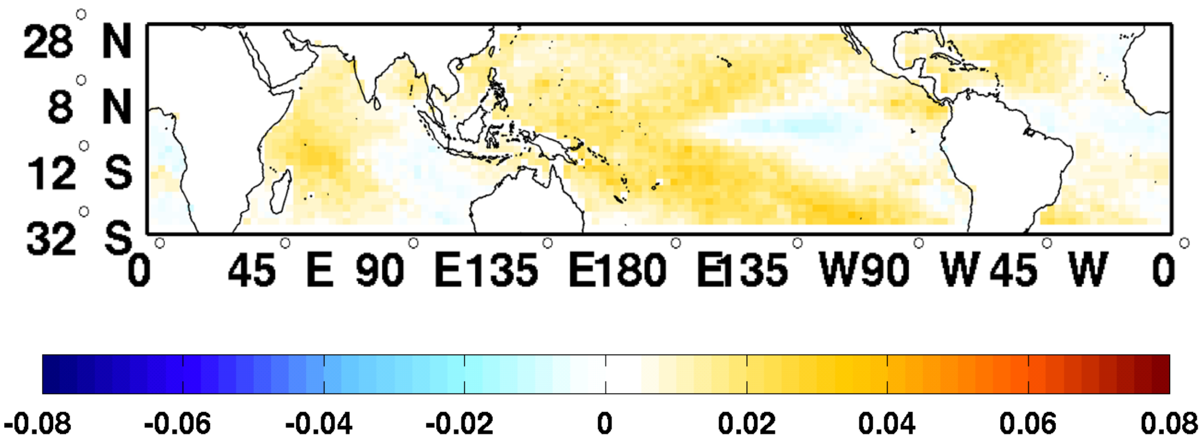


GEOS5 - Obs

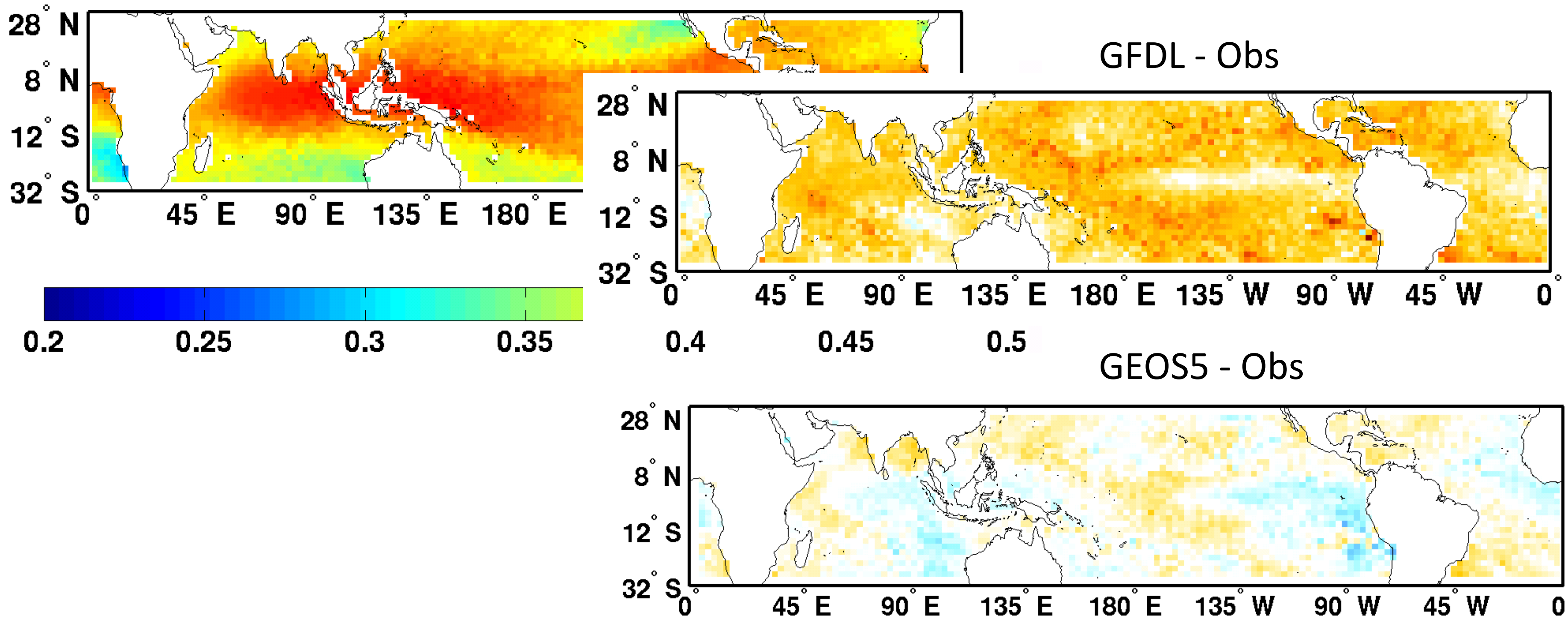


Obs	289.5 W m^{-2}
GFDL AM2	283.3 W m^{-2}
GEOS5	281.0 W m^{-2}
CGCM3.1	286.6 W m^{-2}

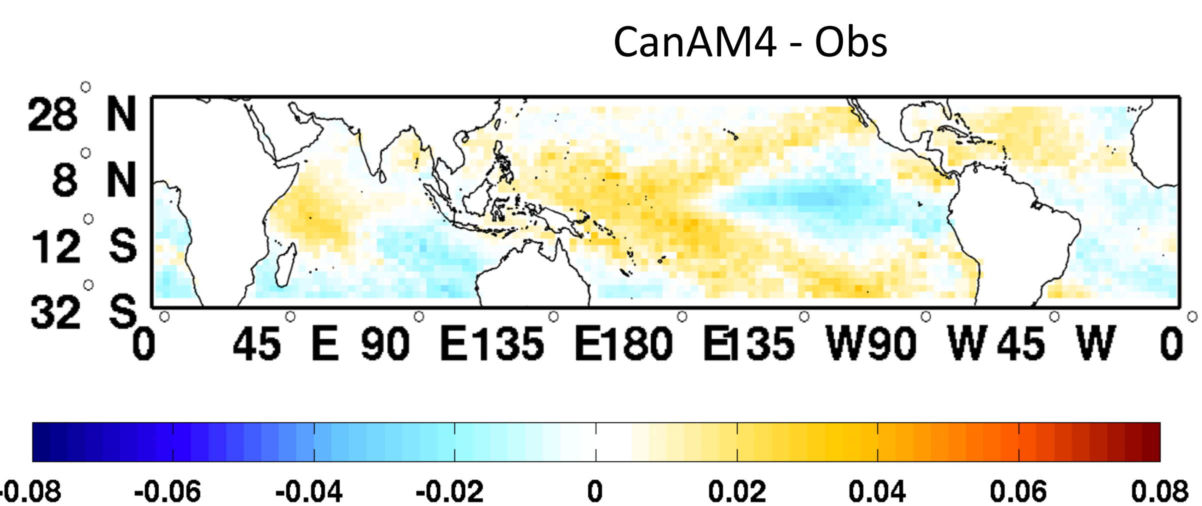
CanAM4 - Obs



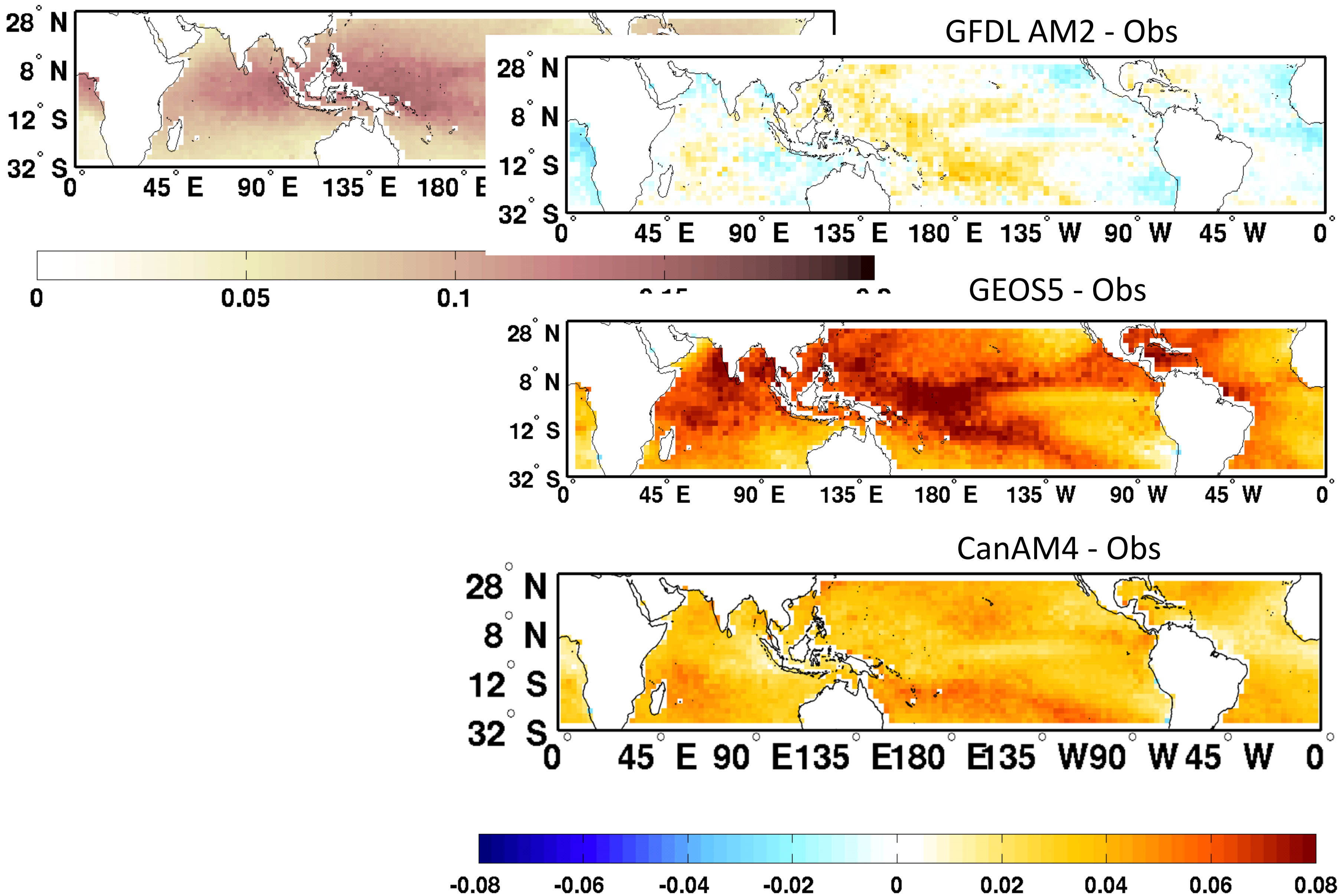
Collocated AIRS & CERES obs. H_2O bands (0-540cm^{-1}, >1400 cm^{-1})



0.02 in fraction ~ 2.7 Wm^{-2}



Collocated AIRS & CERES obs., window region (800-980cm^{-1})



Far-IR flux comparisons with ECMWF ERA-interim, NASA MERRA, and NOAA CFSR

Fact: We never has spectrally resolved measurement for the far-IR (0-600 cm^{-1}) from space except IRIS in 1970s for 10 months of 400-600cm^{-1}, even it contributes to >30%-50% of OLR

Globally averaged annual-mean flux in 2004 (80S-80N)

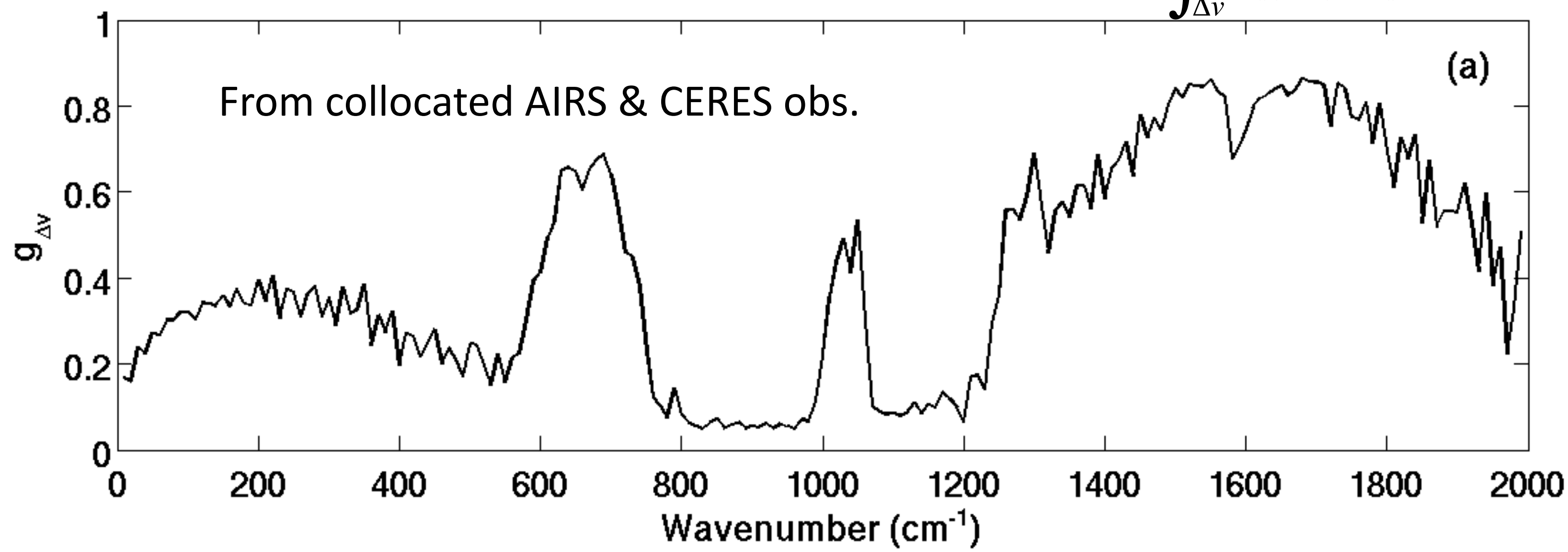
Band	F_{AIRS} (W m^{-2})	F_{ECMWF}-F_{AIRS} (W m^{-2})	F_{MERRA}-F_{AIRS} (W m^{-2})	F_{CFSR}-F_{AIRS} (W m^{-2})
0-200 cm^{-1}	8.95	0.17±0.03 (1.8%)	0.17±0.04 (1.8%)	0.20±0.03 (2.2%)
200-400 cm^{-1}	37.86	0.14±0.04 (0.4%)	0.37±0.04 (1.0%)	0.23±0.07 (0.6%)
400-600 cm^{-1}	67.61	-0.58±0.06 (-0.9%)	-0.29±0.06 (-0.4%)	-0.49±0.05 (-0.7%)
1400-1800 cm^{-1}	5.05	-0.27±0.02 (-5.4%)	-0.09±0.02 (-1.8%)	-0.20±0.03 (-4.0%)
OLR	273.74	-2.03±0.26(-0.74%)	3.36±0.69(1.23%)	0.58±[illegible].11(0.21%)

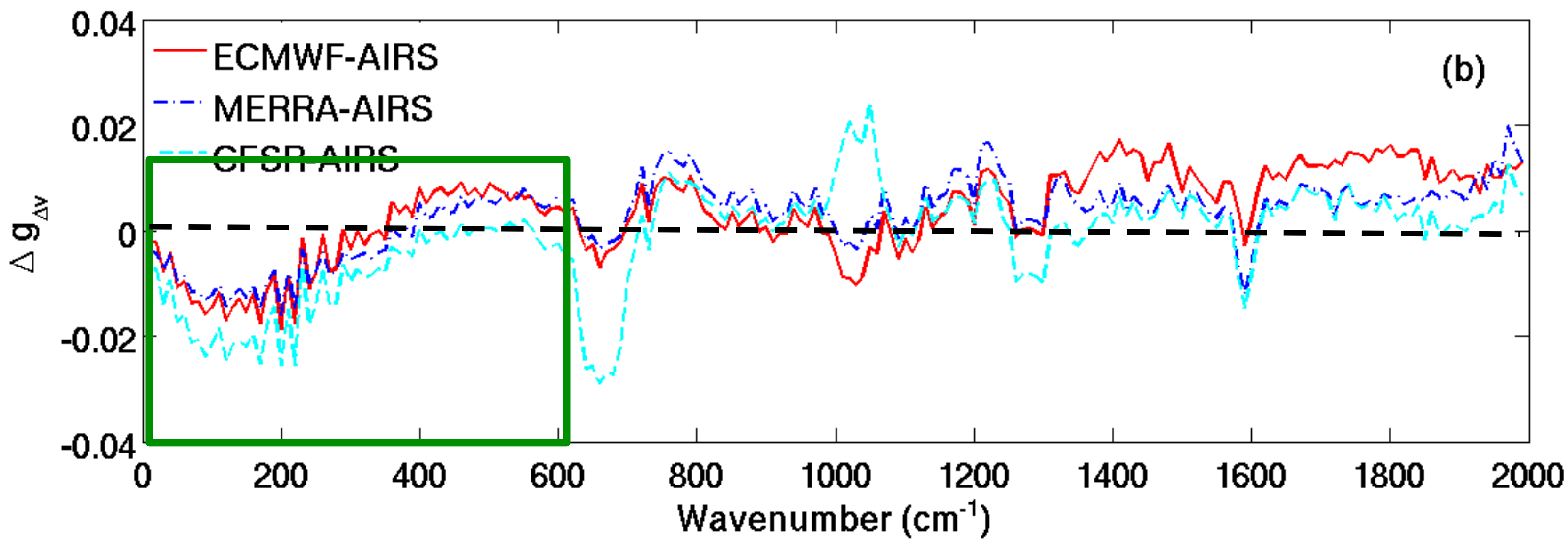
Little month-to-month change

Compensation differences from different bands

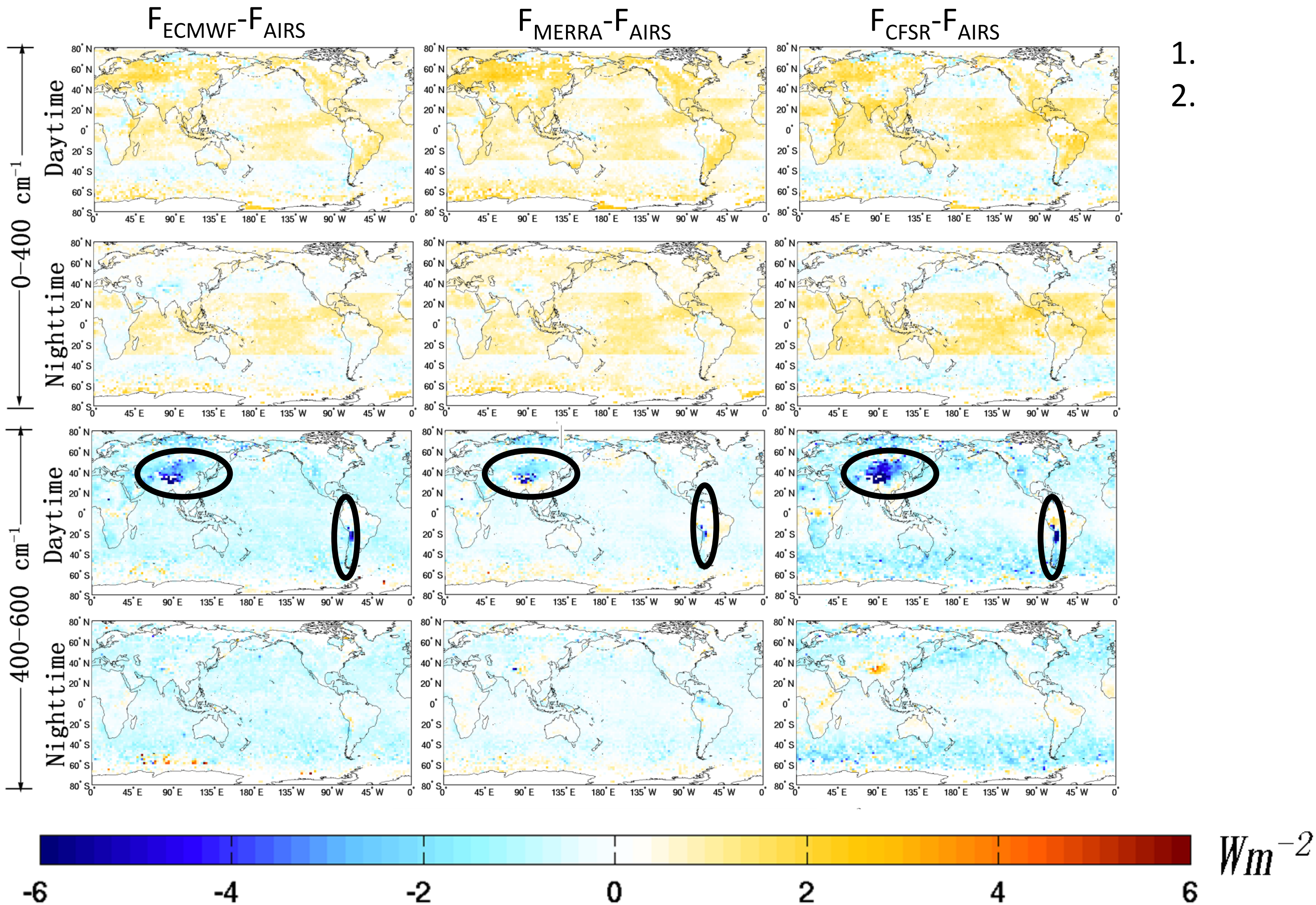
Global spectral greenhouse parameter (efficiency)

$$g_{\Delta v} = \frac{\int_{\Delta v} \varepsilon_{sv} B_v(T_s)dv - F_{\Delta v}(TOA)}{\int_{\Delta v} \varepsilon_{sv} B_v(T_s)dv}$$





Spatial and Diurnal Differences



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