TOA and surface radiation budget derived from CALIPSO, CloudSat and MODIS derived cloud and aerosol properties

Seiji Kato[1], Fred G. Rose[2], Sunny Sun-Mack[2], Walter F. Miller[2],
Yan Chen[2], David Rutan[2], Norman G. Loeb[1], and Wenying Su[2]
[1]Climate Science Directorate, NASA Langley Research Center, Hampton, Virginia, USA.
[2] Science Systems and Applications Inc., Hampton, Virginia, USA.

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CALIPSO-CloudSat-CERES-MODIS (C3M) Merged Product

- Funded by the NASA Energy Water Cycle Study (NEWS) project.

Expected contribution of the product

To provide a global data set along the lidar/radar ground track with the most accurate and comprehensive aerosol properties, cloud properties, and vertical radiative flux profiles.

Area of studies that are greatly improved by our data set includes:

1. Assimilation and prediction by global aerosol models through better understanding of aerosol layer location.
2. Better understanding of multi-layered and polar cloud systems and their radiative impacts.
3. Better understanding of frequency of occurrence of thin cirrus and boundary layer clouds and their radiative impacts

Reference

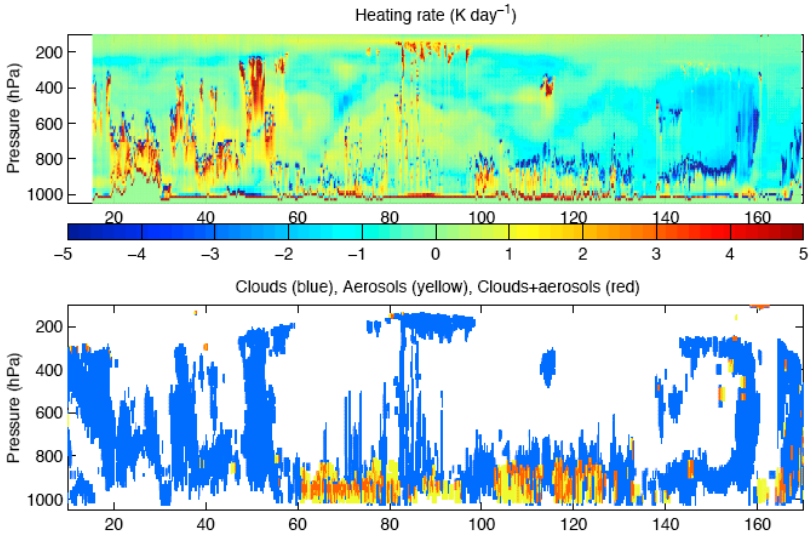
Kato, S., S. Sun-Mack, W. F. Miller, F. G. Rose, Y. Chen, P. Minnis, and B. A. Wielicki, 2010; Relationships among cloud occurrence frequency, overlap, and effective thickness derived from CALIPSO and CloudSat merged cloud vertical profiles, *J. Geophys. Res*. 115 D00H28, doi:10.1029/2009JD012277.

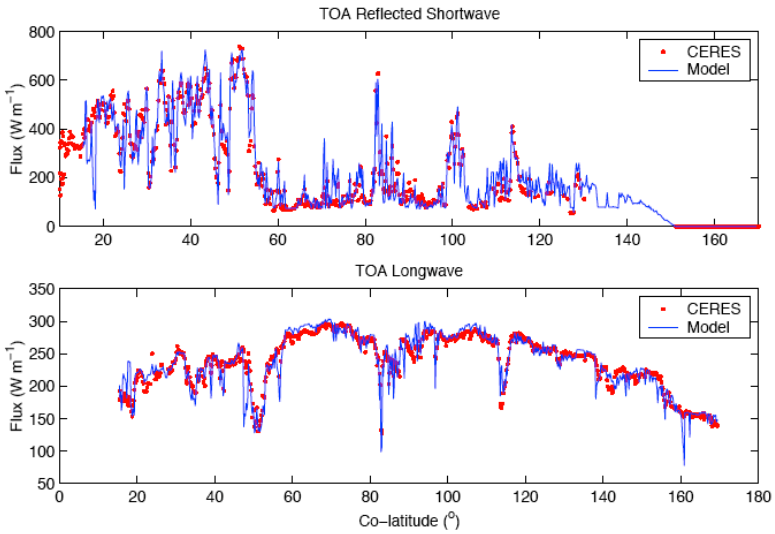
C3M (CCCM) product

- Contains:

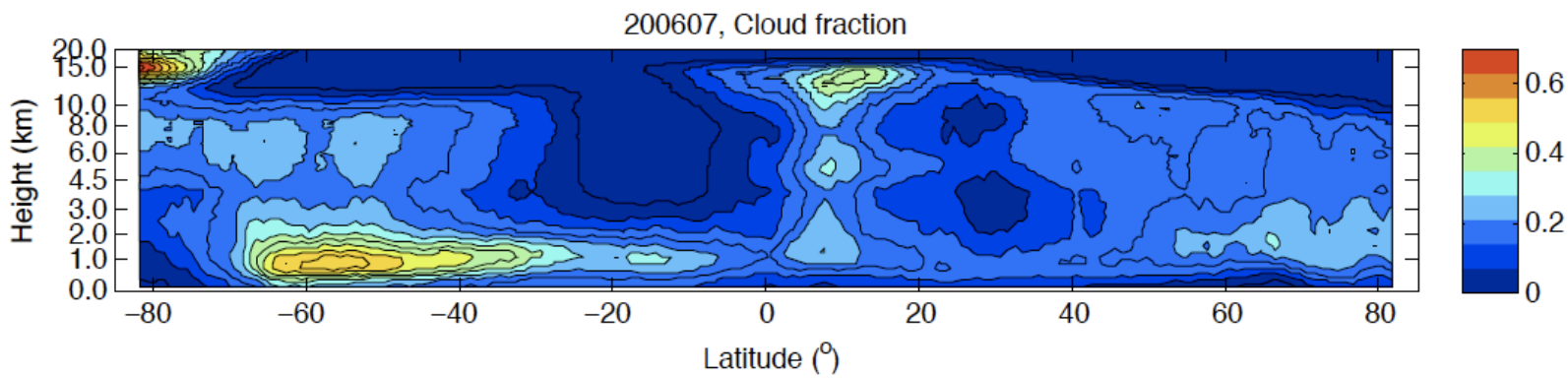
1. Merged CALIPSO, CloudSat derived clouds, CERES TOA radiative flux (SW, LW, and WN), MODIS (CERES_ST) derived cloud properties both along CALIPSO-CloudSat ground-track and over the whole CERES footprint,
2. MODIS derived cloud properties by an enhanced cloud algorithm,
3. CALIPSO and MODIS derived aerosol properties
4. Vertical radiative flux profiles computed with CALIPSO, CloudSat, and MODIS derived cloud properties.

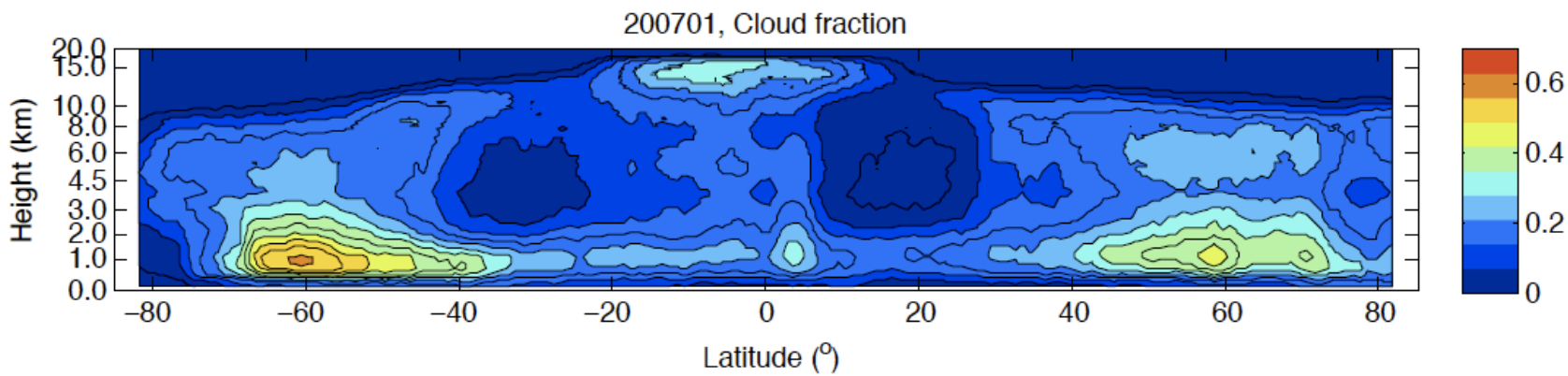
- 2.5 years of Data are available from http://eosweb.larc.nasa.gov/PRODOCS/ceres-news/table_ceres-news.html





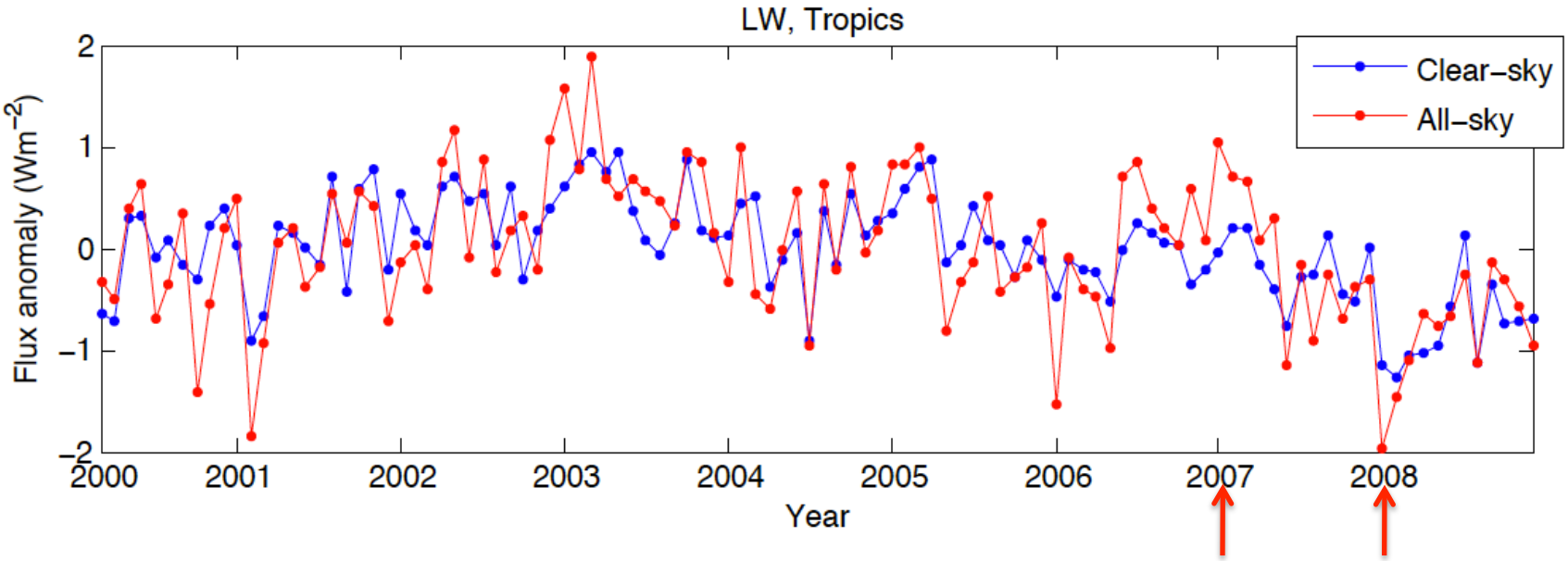
Cloud profile from CALIPSO and CloudSat



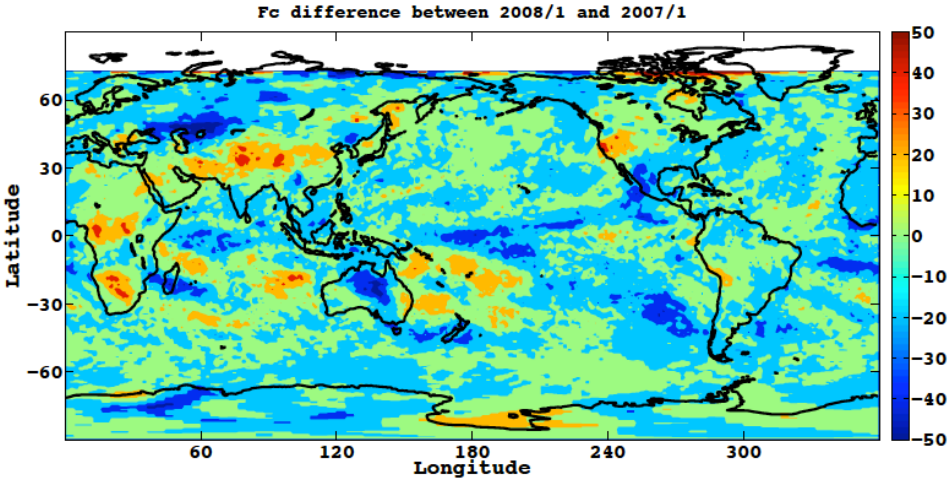


Cloud fraction in a 200 m by 1 degree volume

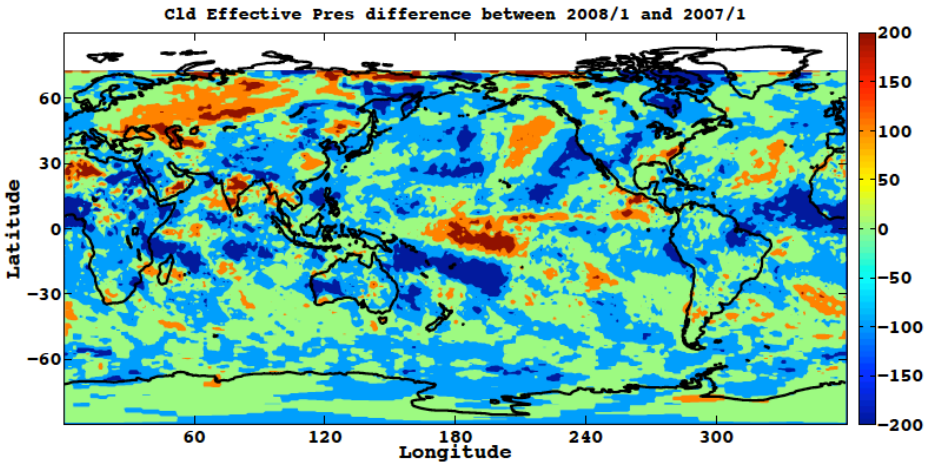
LW TOA anomalies over tropics



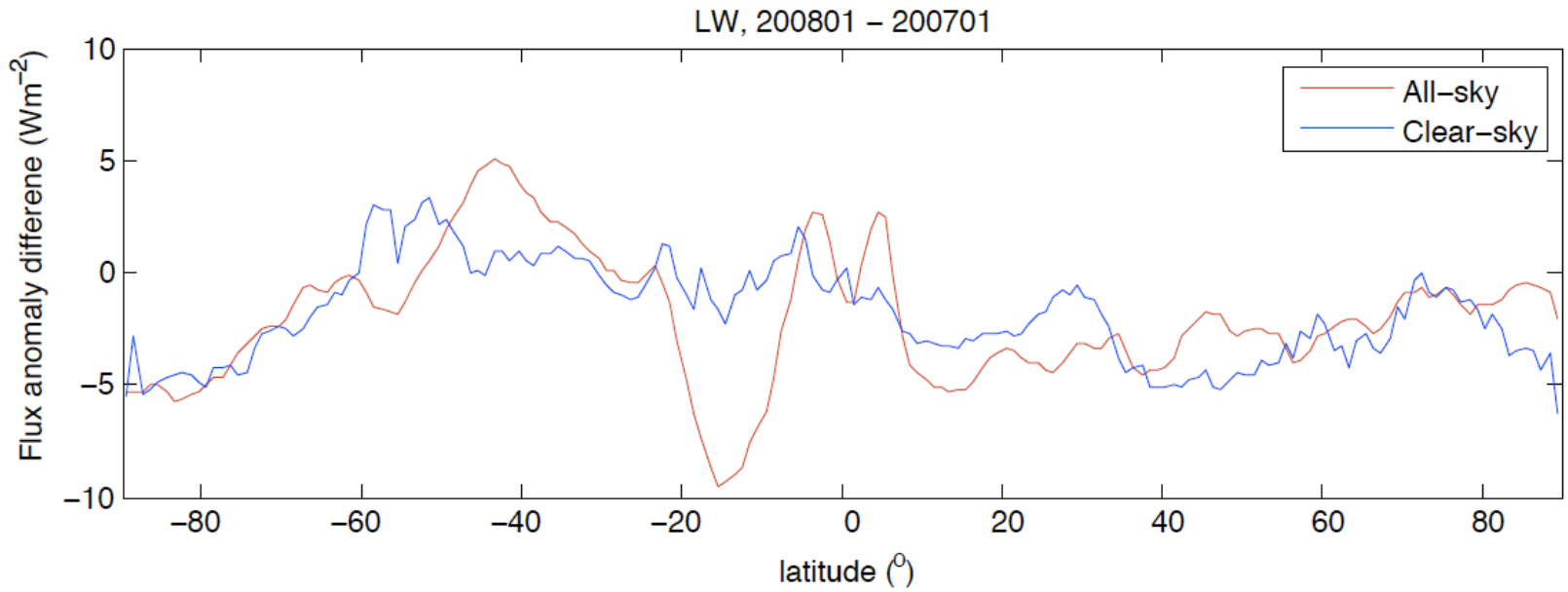
Cloud fraction difference 200801 - 200701

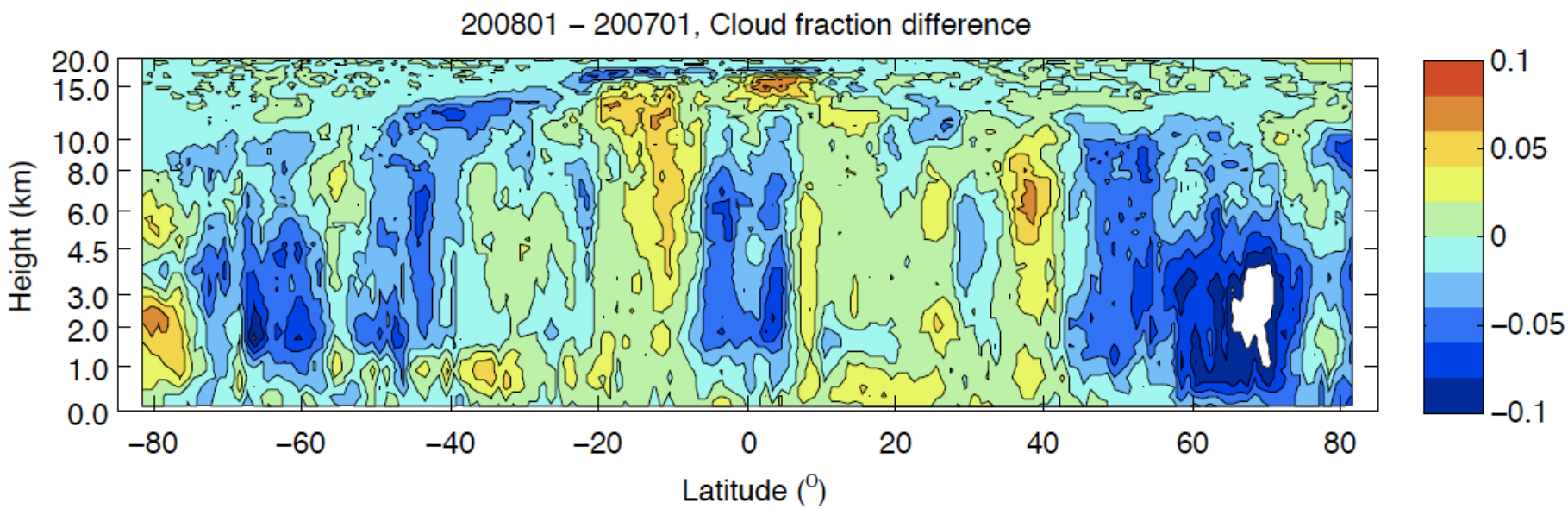


Cloud effective pressure 200801 - 200701

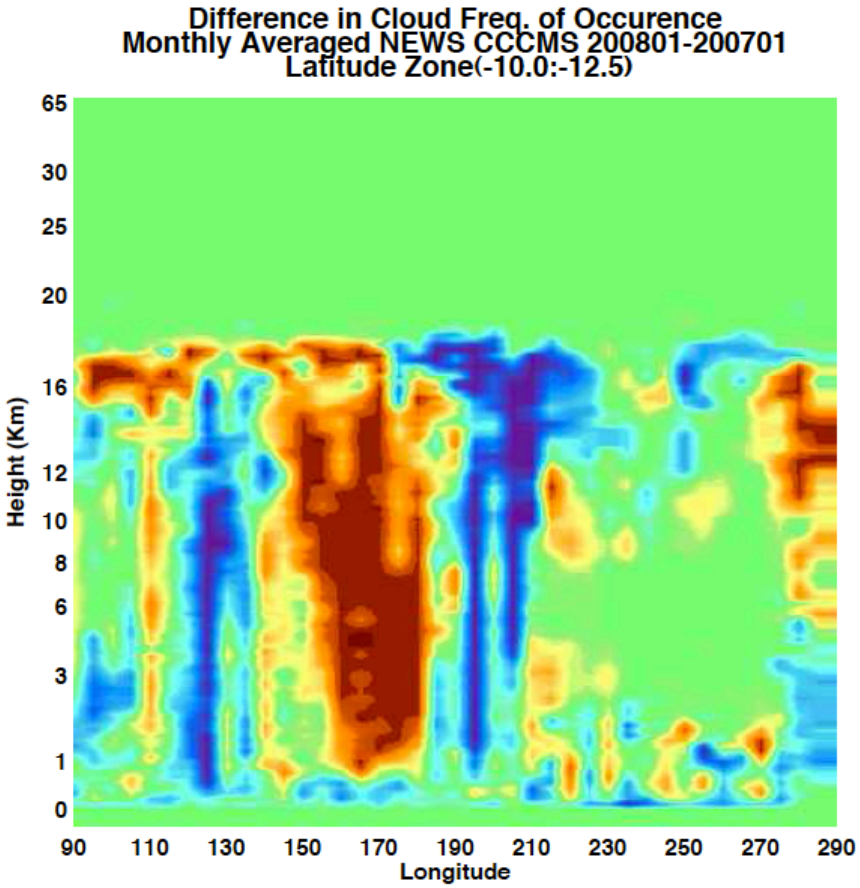


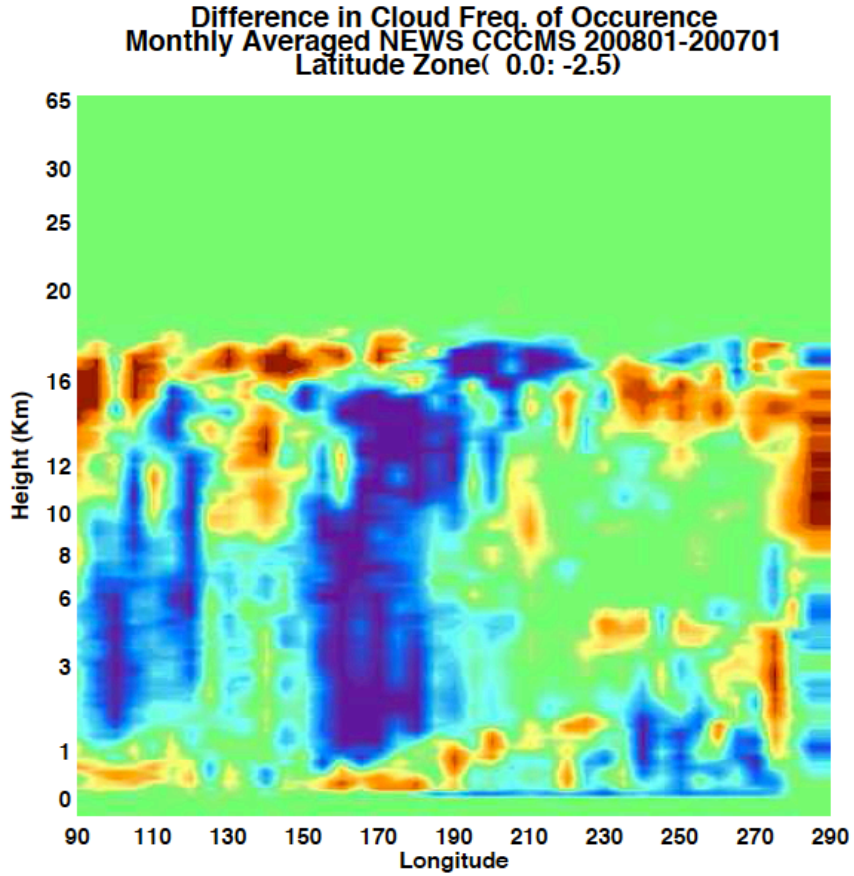
TOA LW anomaly difference and cloud fraction difference

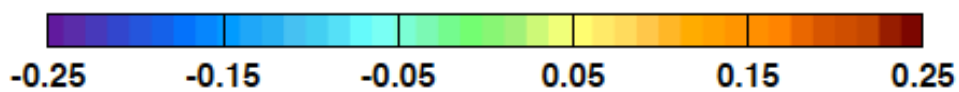




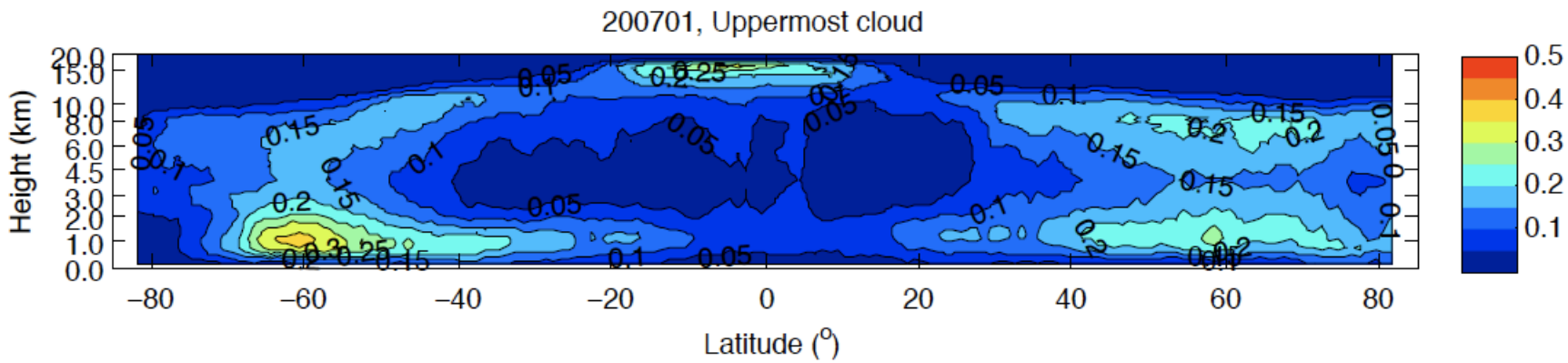
Longitudinal cloud occurrence difference 200801 - 200701

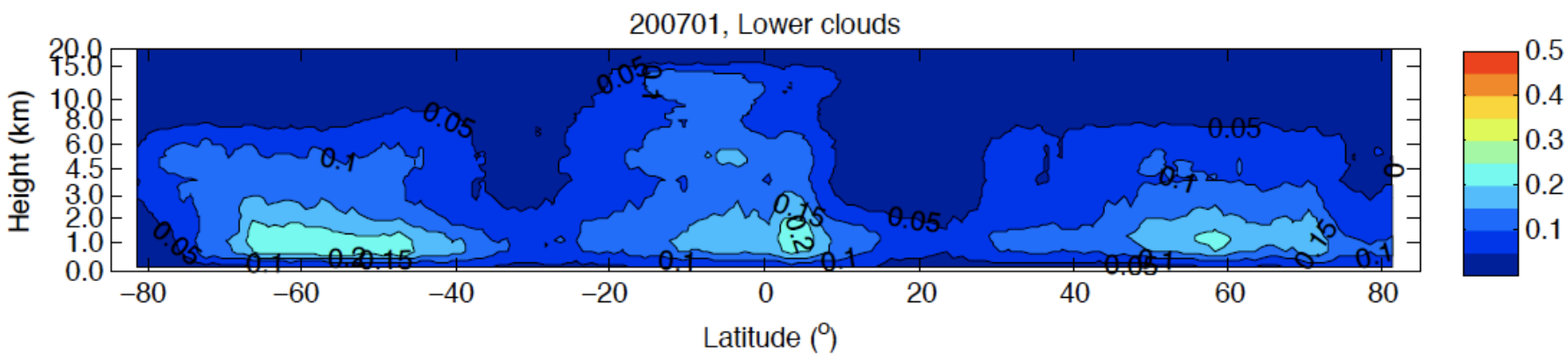






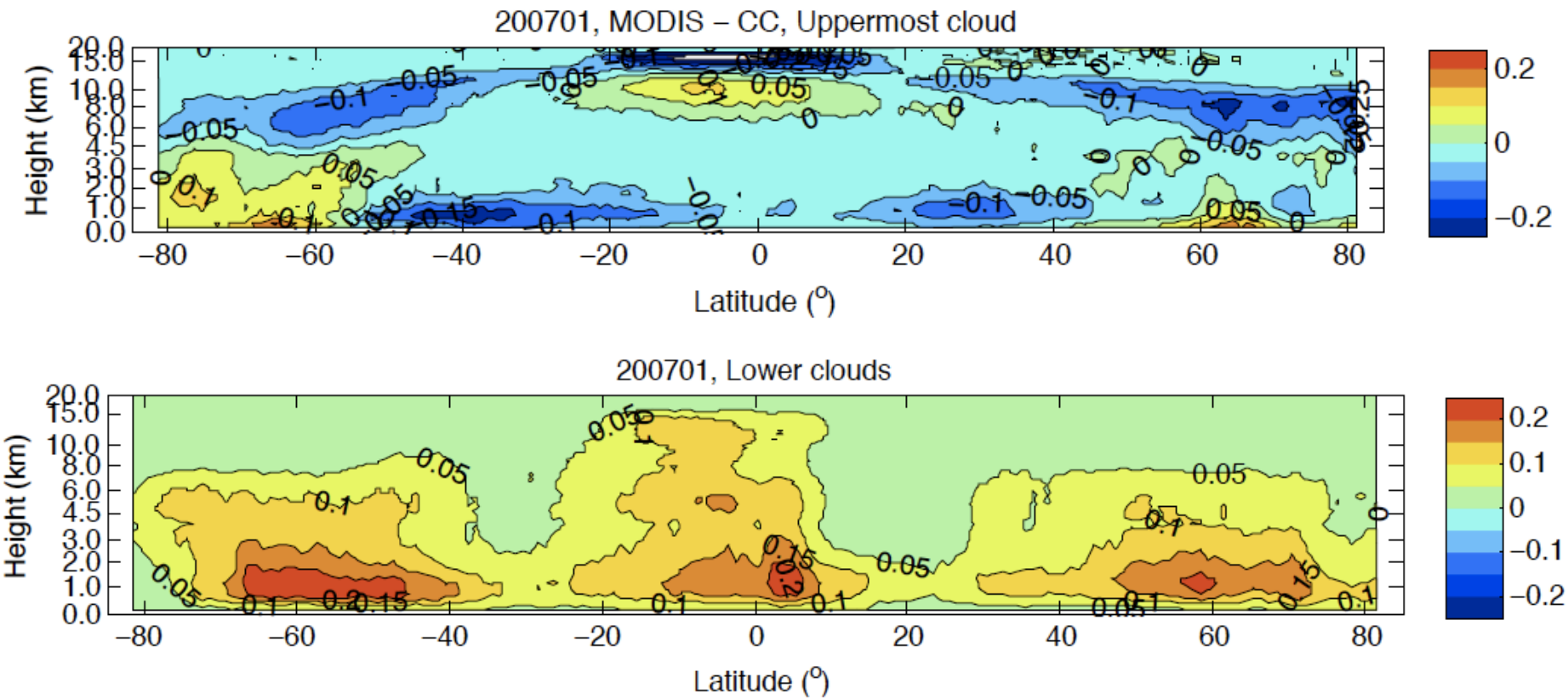
Uppermost cloud layer and lower level clouds





Separate vertical cloud profile into the uppermost cloud layer and lower clouds

Cloud profile difference



Physical thickness of uppermost clouds is estimated by an empirical relationship (Ed2).
Missing low-level clouds is due to cloud overlap.
Need to include overlapping clouds in surface longwave irradiance estimates.

Global annual mean surface irradiance

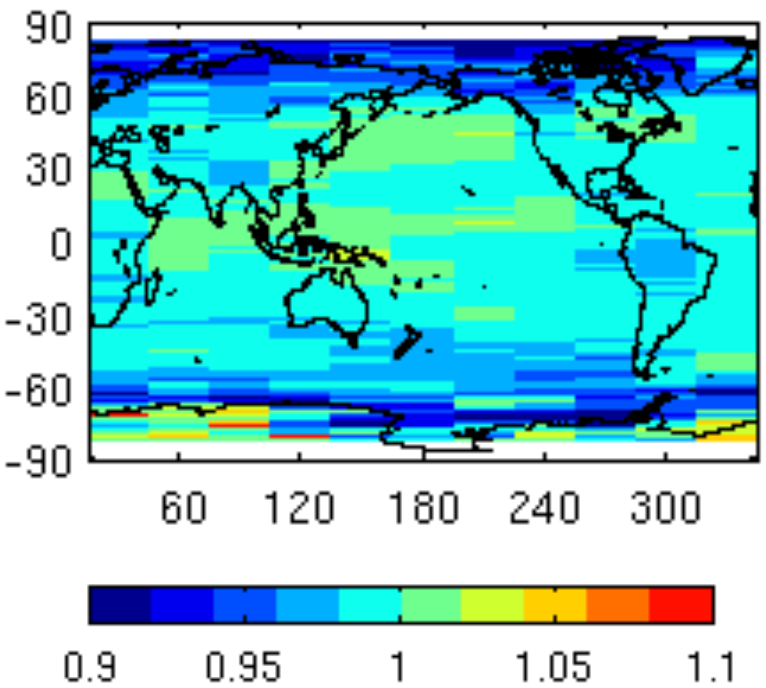
	Trenberth et al. (2009)	CERES Ed2 estimate (Doelling et al. 2009)	ISCCP Zhang et al. (2004)	GEWEX SRB (Stackhouse et al, 2010)
Surface Longwave Down (Wm^{-2})	333	342.2	344.7	343.9
Surface Longwave Up (Wm^{-2})	396	397.9	395.6	396.5
Surface Shortwave NET (Wm^{-2})	161	165.9	165.2	166.6

With CALIPSO and CloudSat = 352.8 W m^{-2}

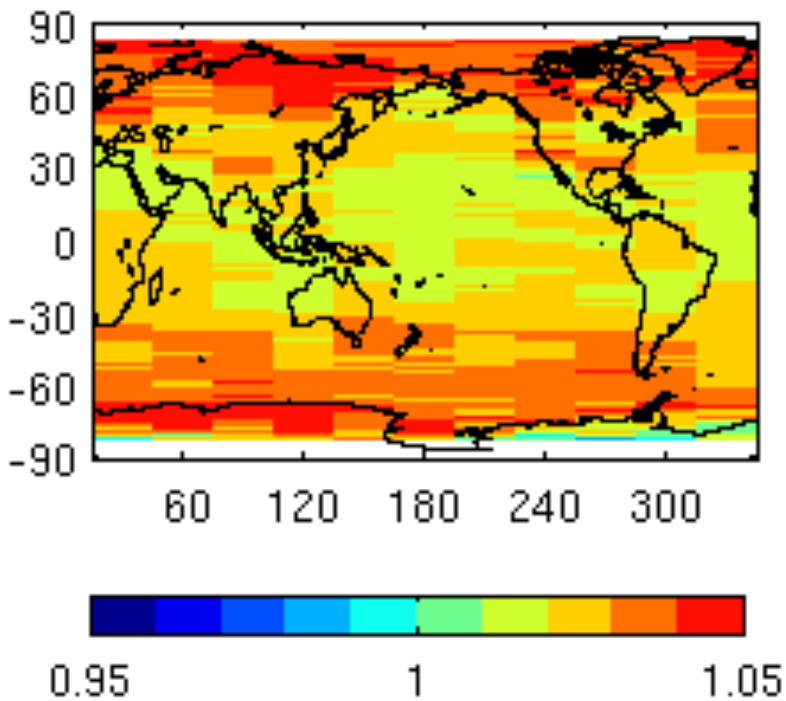
Surface Irradiance ratio

(**With** CALIPSO and CloudSat)/(**Without** CALIPSO and CloudSat)

Shortwave



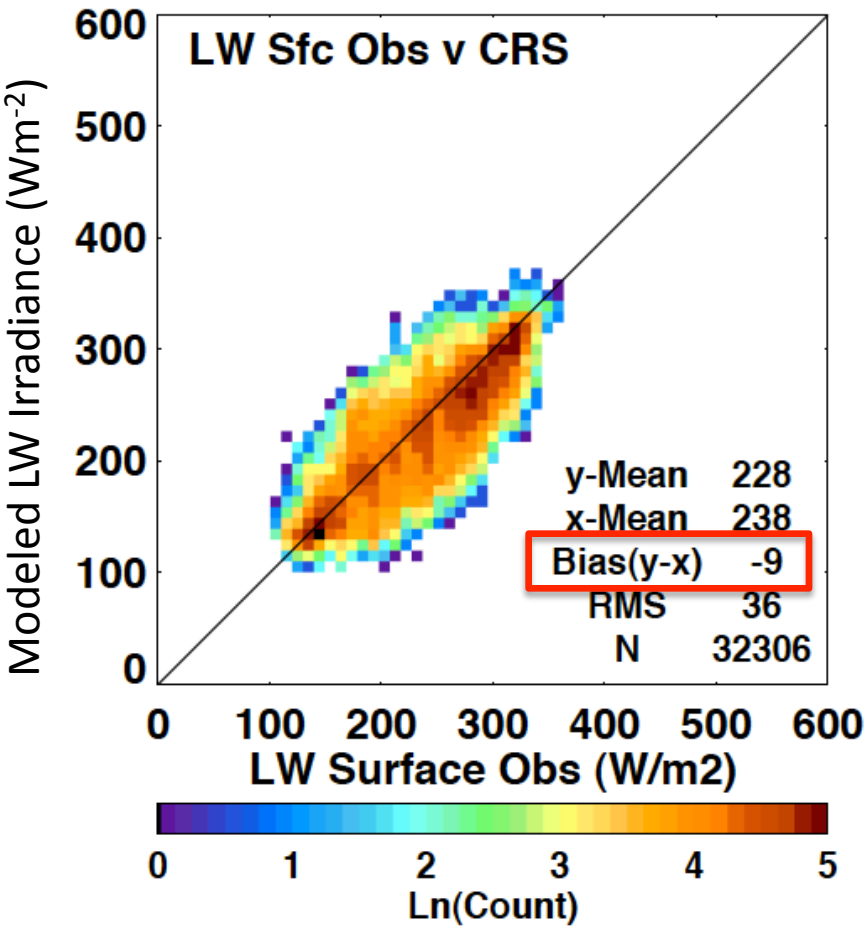
Longwave



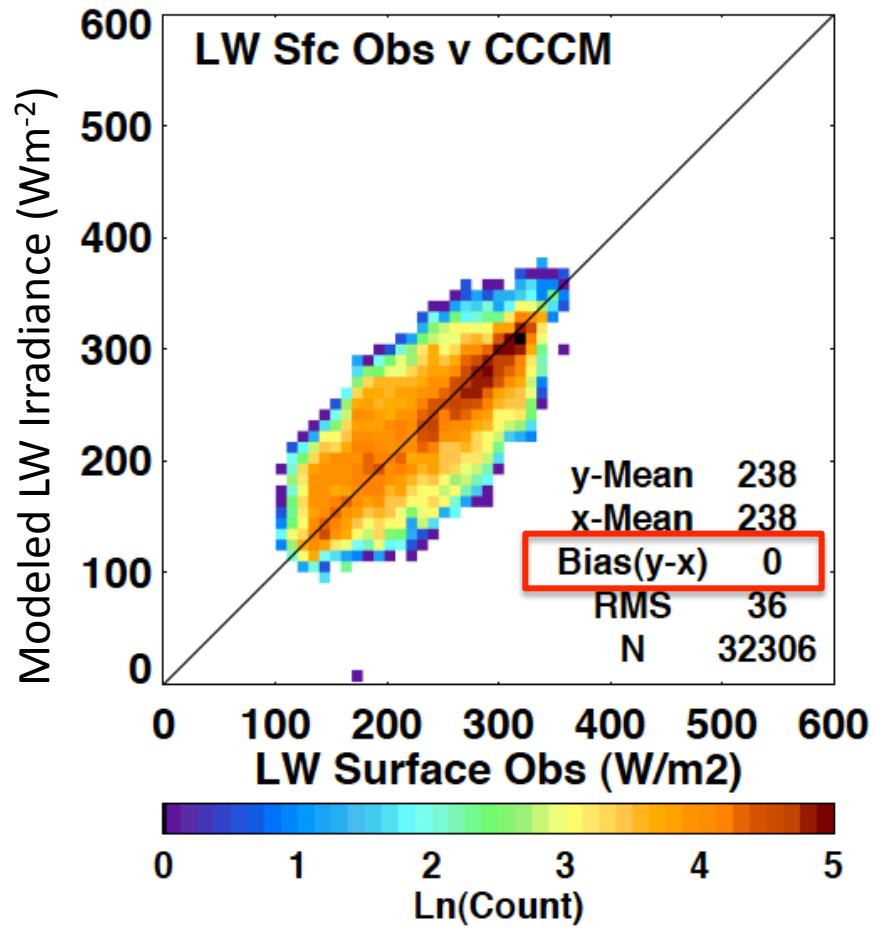
1 year mean (200607 to 200706)

Comparison with surface observations (Polar)

Without CALIPSO and CloudSat

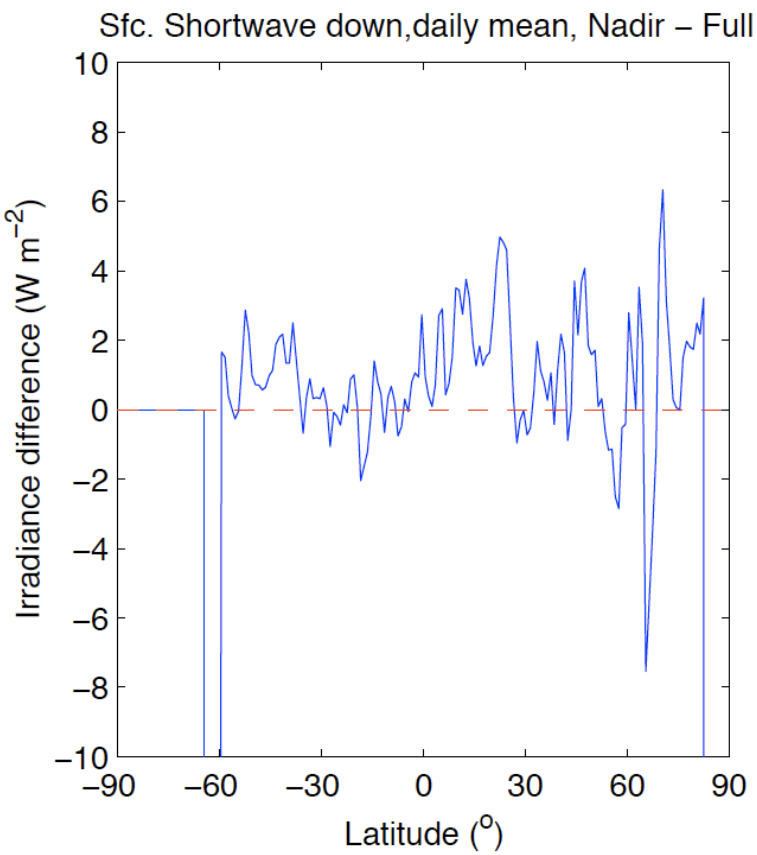


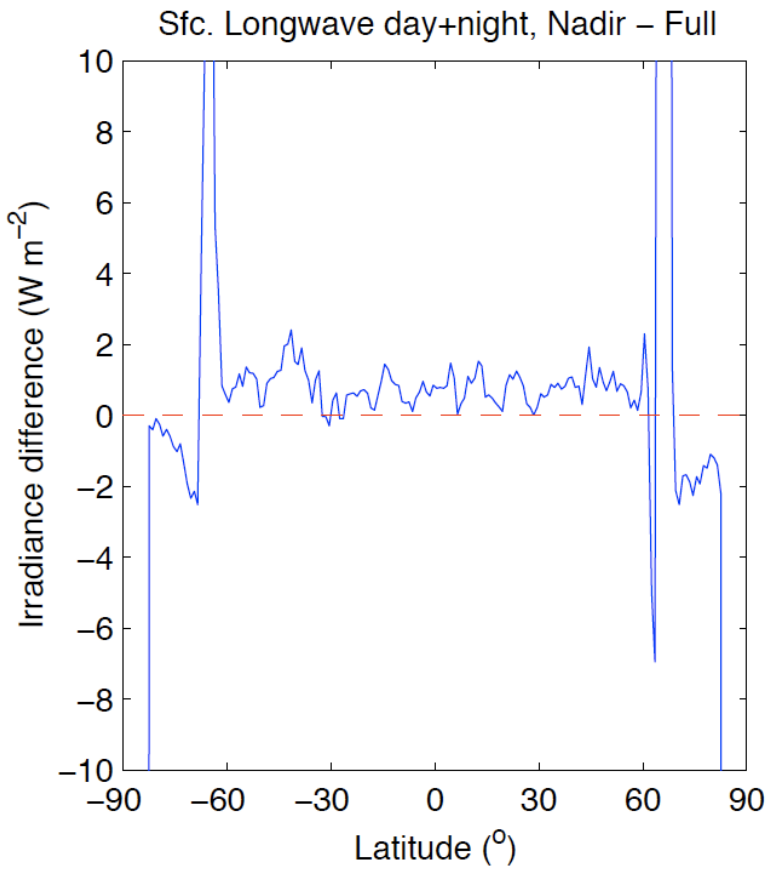
With CALIPSO and CloudSat



Nadir view only, within 150 km from surface sites, 2 years of data
http://snowdog.larc.nasa.gov/rutan/cccm/

Nadir vs. Full swath surface Irradiance difference (June 2002)





	Daily SW (W m^{-2})	LW day + night (W m^{-2})
Nadir – Full (global)	0.95	-0.13

Global annual mean surface downward longwave irradiance
(Rough estimate)

	With (C3M)	without	CERES AVG	Scaled
LW down (W m^{-2})	352.8	344.7	342.2	350.2
LW up (W m^{-2})	403.7	402.8	379.9	380.7
SW down (W m^{-2})	272.9	274.6	189.0	187.8
SW up (W m^{-2})	27.3	28.4	23.1	22.2

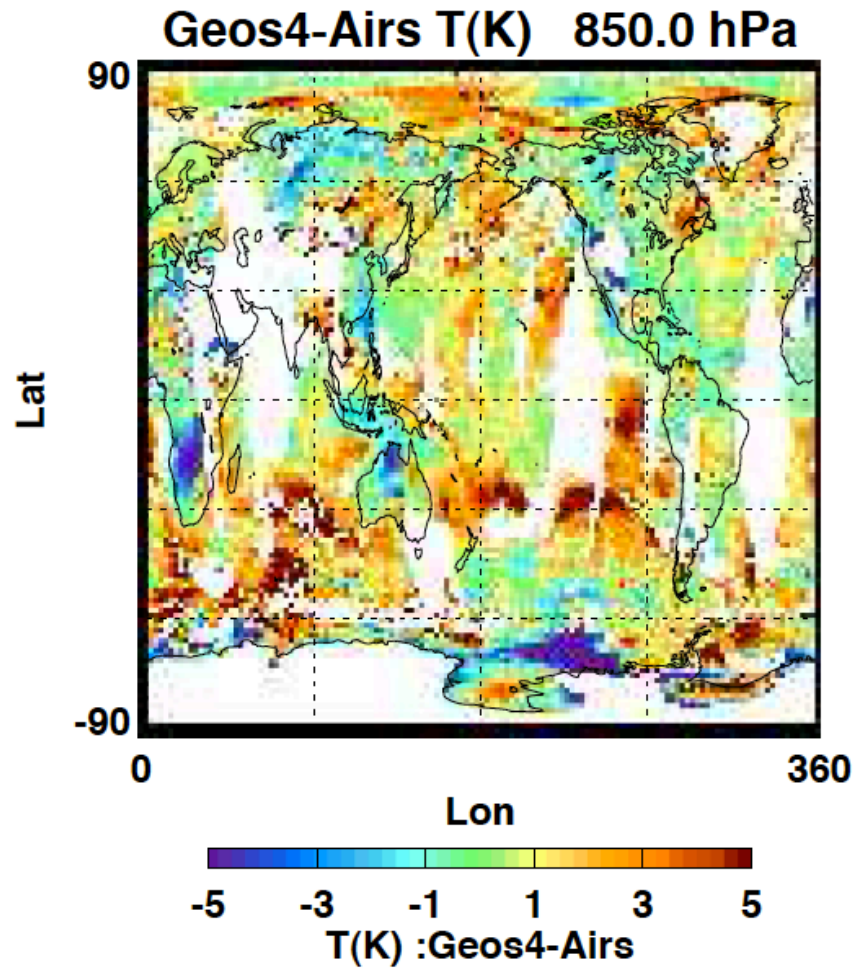
$$AVG\frac{C3M}{CRS}$$

Downward Longwave is increased by 8 Wm^{-2}

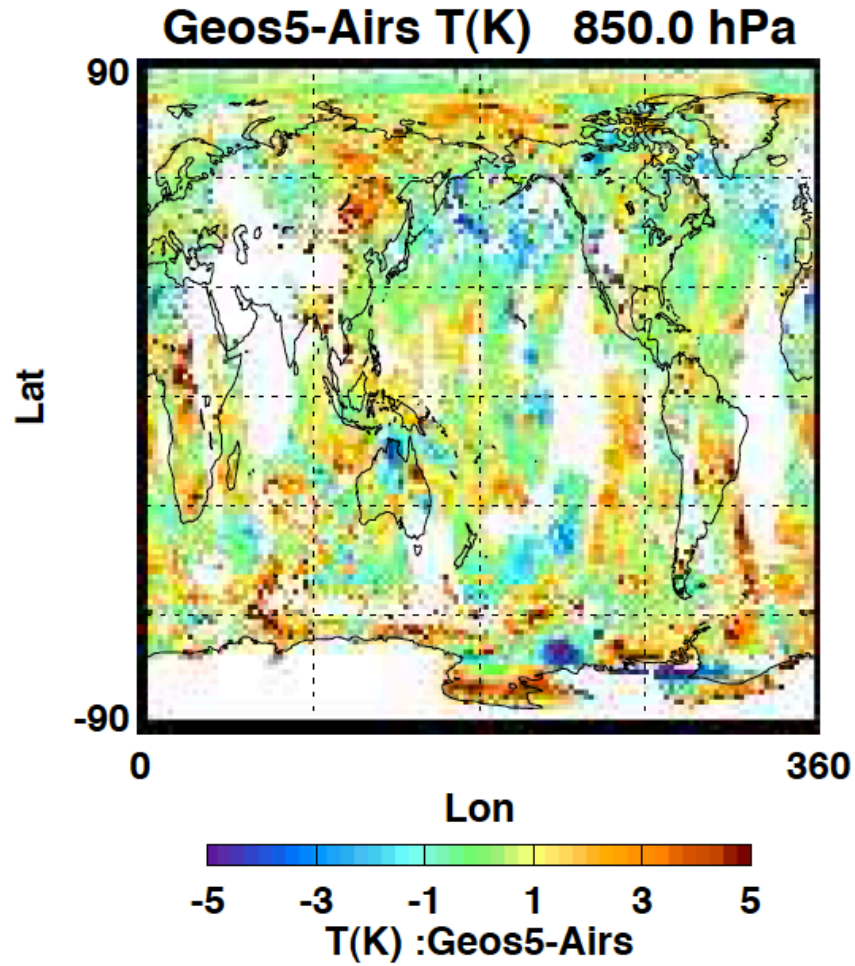
Effects of clouds introduced by the CALIPSO problem is small because:

- CALIPSO and Cloudsat derived clouds are neglected if the CERES MODIS cloud algorithm does not detect clouds within a 20 km horizontal distance.
- Clouds introduced by the problem are optically thin

GEOS versus AIRS temperature

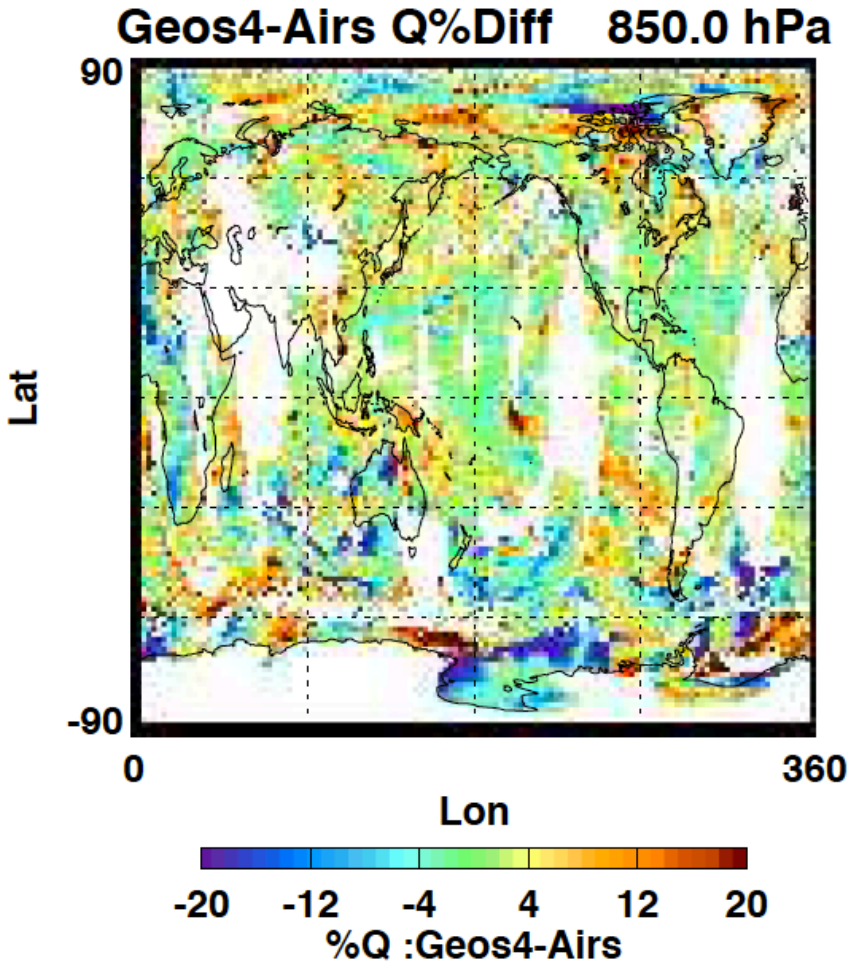


N= 137332. Mean (StdDev)
T(K) :Geos4-Airs 0.815(2.46)

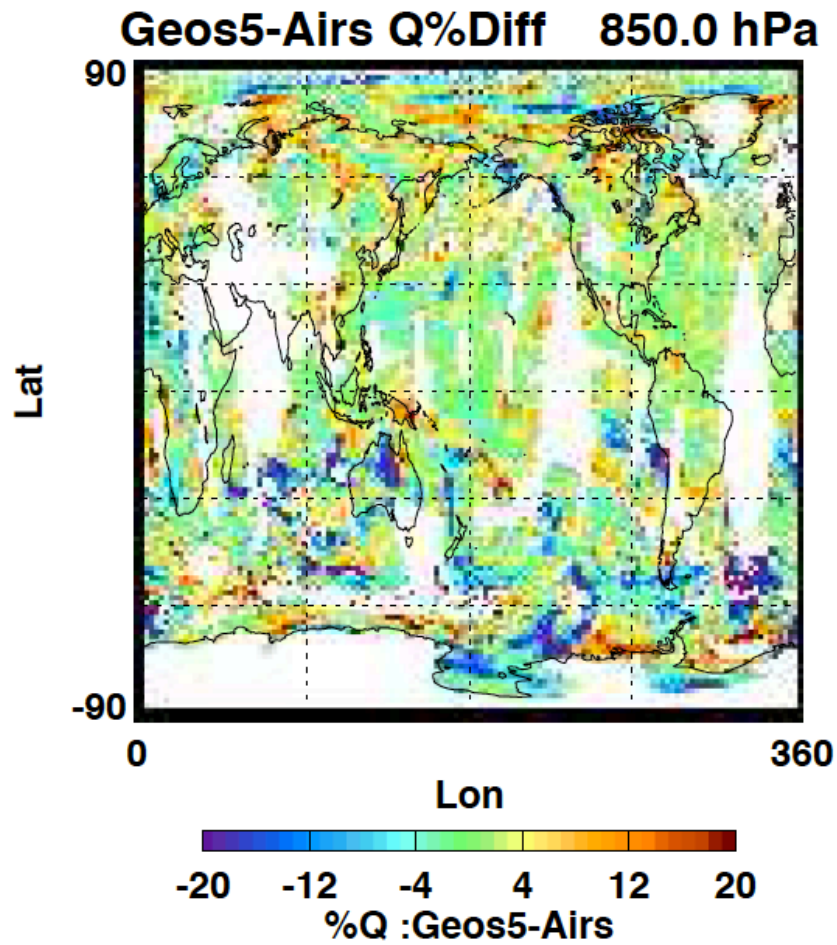


N= 137634. Mean (StdDev)
T(K) :Geos5-Airs 0.646(1.98)

GEOS versus AIRS, humidity

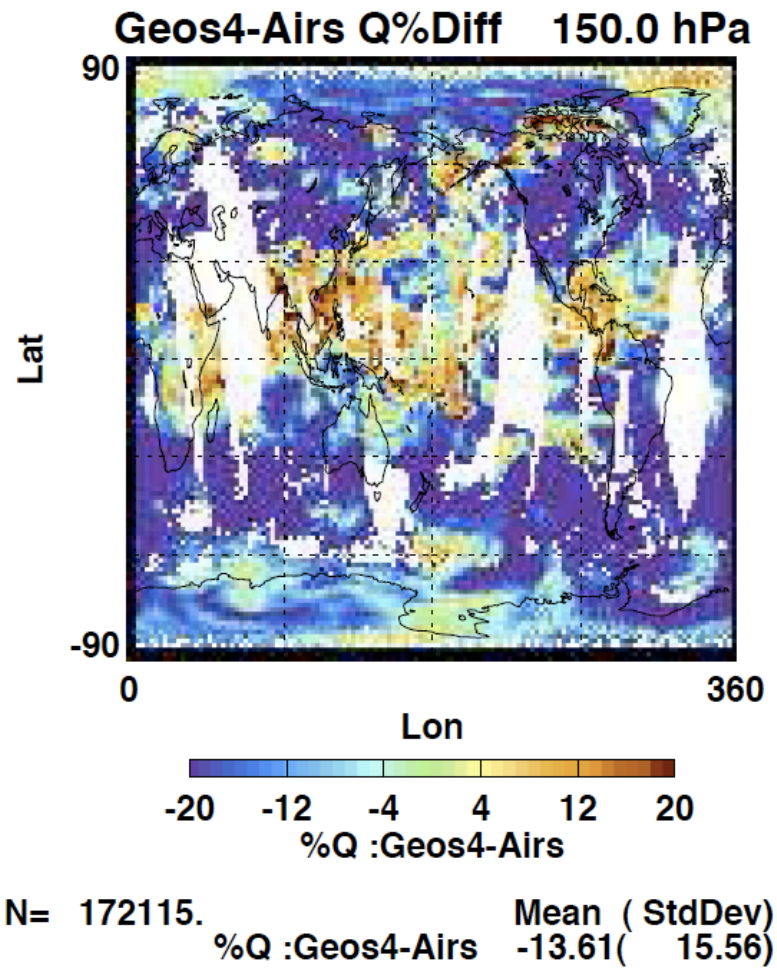


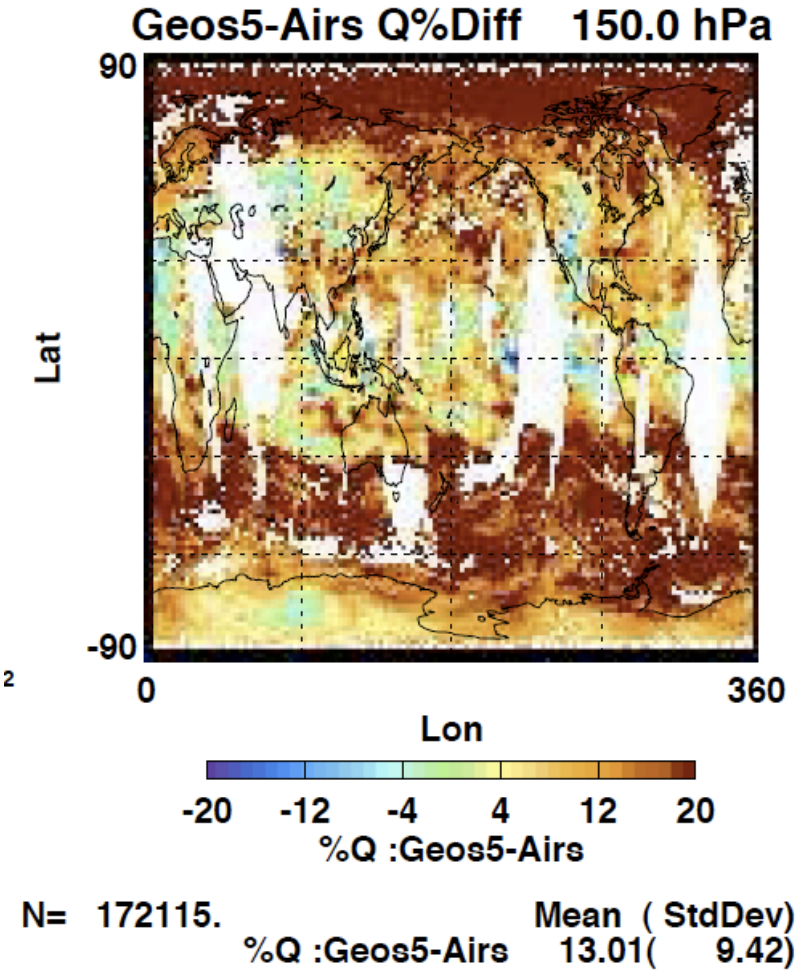
N= 137332. Mean (StdDev)
%Q :Geos4-Airs 0.829(9.52)



N= 137634. Mean (StdDev)
%Q :Geos5-Airs 0.010(8.92)

GEOS-4, GEOS-5, vs. AIRS water vapor





AIRS retrieval accuracy of water vapor in 2 km layers is better than 15%

Summary

- C3M product was developed to understand the process of clouds and aerosols interacting with radiation.
- 2.5 years data has been archived at http://eosweb.larc.nasa.gov/PRODOCS/ceres-news/table_ceres-news.html.
- We start producing the revised product with CALIPSO version 3 data October.
- Global mean surface downward longwave irradiance appears (~8Wm^{-2})to increase when CALIPSO and CloudSat derived cloud vertical profiles are used in irradiance computations.
- We will verify this result with CALIPSO version 3 data.

Annual Global Energy Budget

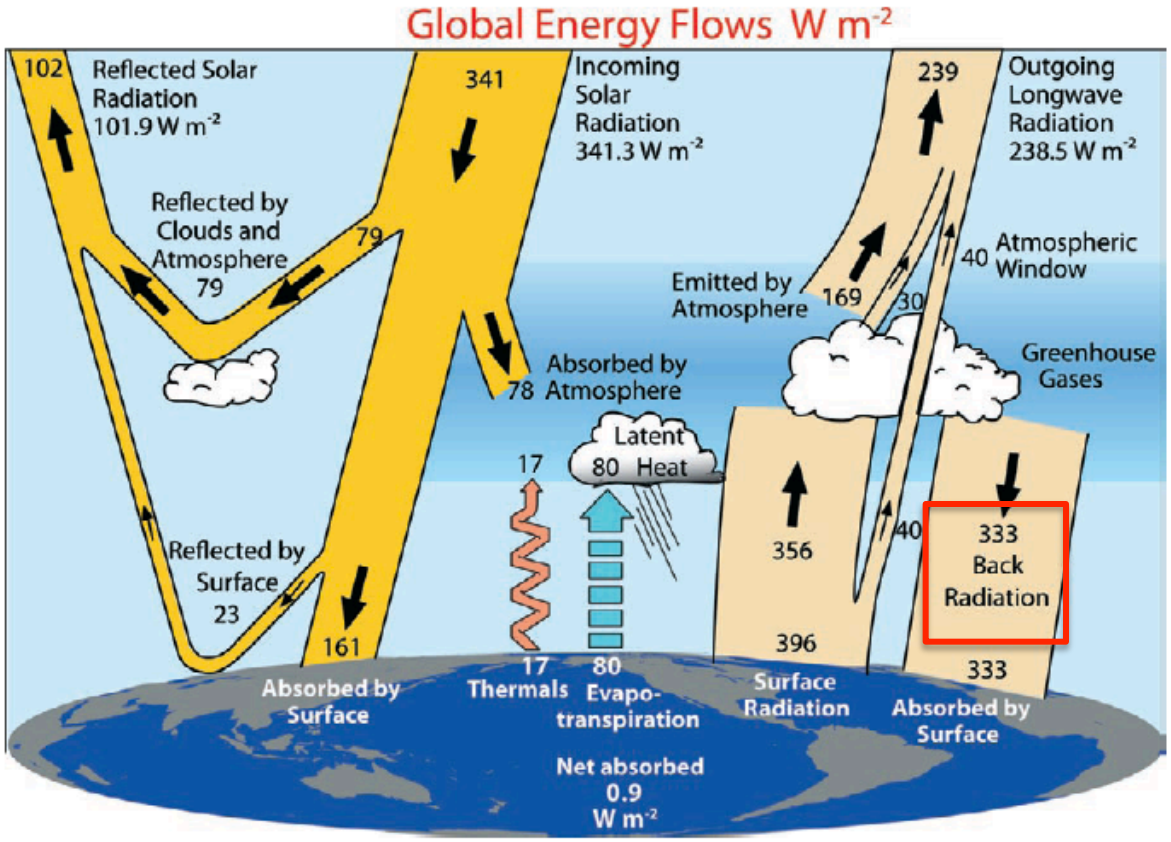
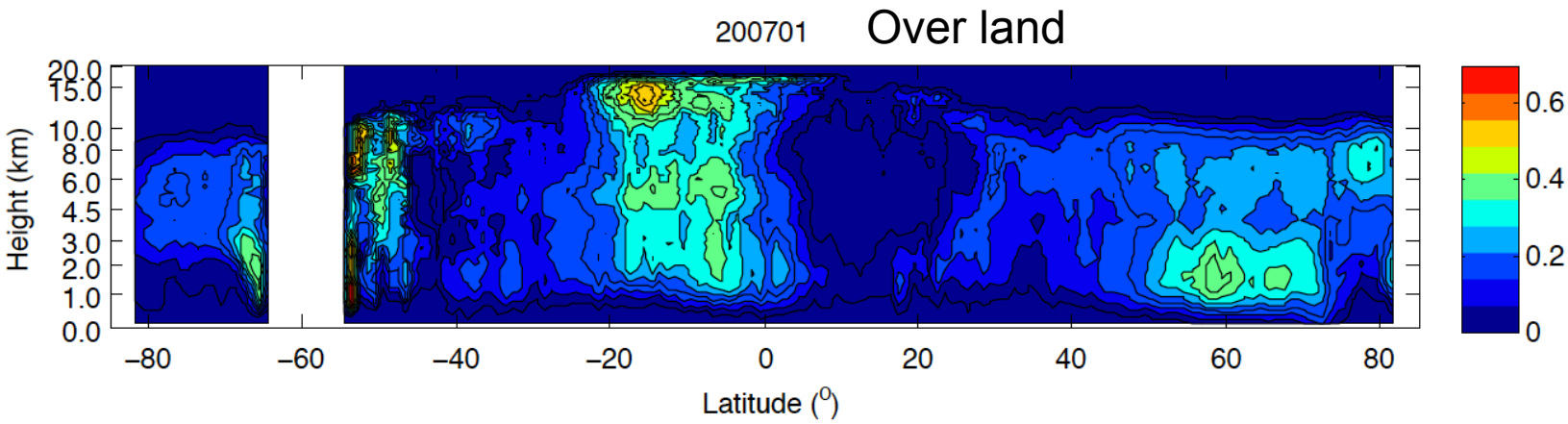


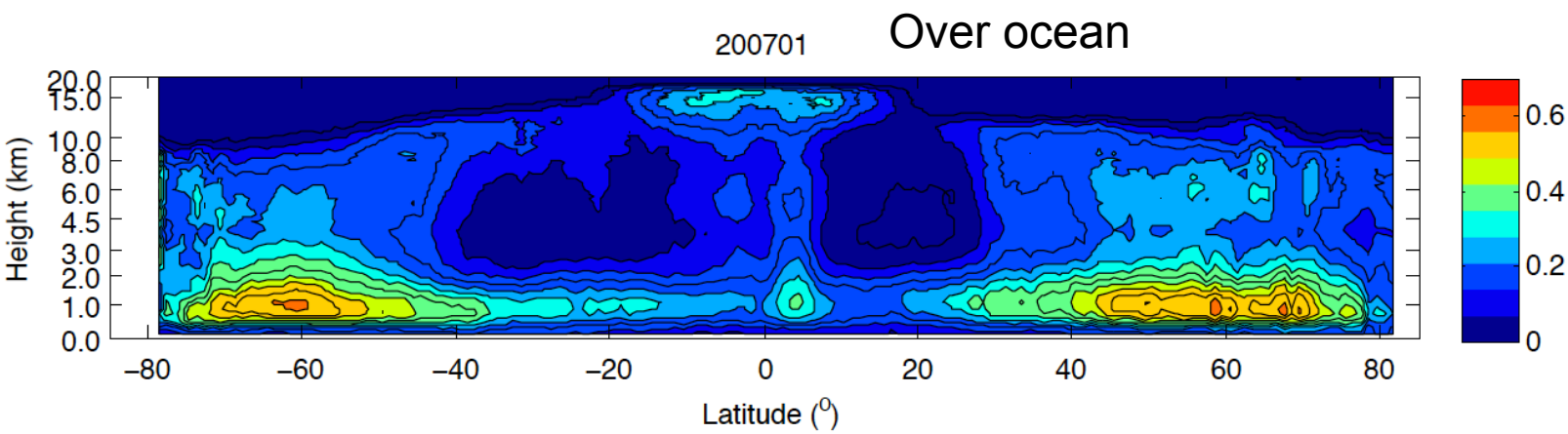
Fig. 1. The global annual mean Earth's energy budget for the Mar 2000 to May 2004 period (W m^{-2}). The broad arrows indicate the schematic flow of energy in proportion to their importance.

333 + 161 ≈ 396 + 80 + 17 + 0.9

Trenberth et al. 2009 BAMS

Land ocean cloud cover





Zonal monthly mean cloud fraction in 1 degree by 200 m volume