The Earth’s Radiation Balance Inferred from A-Train Observations

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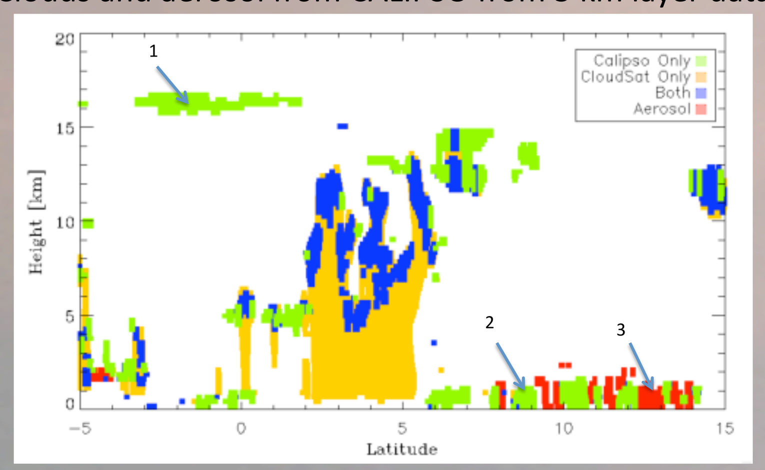
INTRODUCTION

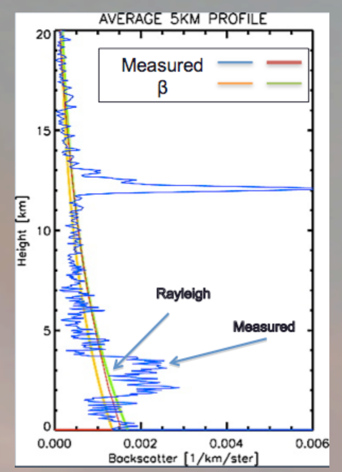
- It is important to understand the the radiative budget of the Earth (ERB)
  - Affects global circulations on both large and small time scales
  - Heating due to cloud albedo (reflection of shortwave (SW) radiation to space) or trapping longwave (LW) radiation back to the surface.
- The 2B-FLXHR product from CloudSat (L’Ecuyer et al., 2008) can be used to study the ERB and the distribution of fluxes within the atmosphere, but does not include all clouds or aerosol.
  - Cannot detect all clouds due to interference with ground clutter, or if clouds are below CloudSat’s minimum detectable signal of -30 dBz.
- Using a combination of CloudSat, CALIPSO, and MODIS, locations of clouds and aerosols and their properties are identified.
- Input new cloud and aerosol properties into radiative transfer model, which outputs upwelling and downwelling fluxes and vertical profiles of heating rates.
  - Time of study from January 2007 – February 2008
  - Compare fluxes with CERES FLASH Flux data
  - Find heating impacts and radiative effect of undetected clouds
  - Find radiative effect of aerosol
  - Calculate global average of ERB

CLOUD/AEROSOL DETECTION AND PROPERTIES

Clouds from CloudSat from 2B-Geoprof
Clouds and aerosol from CALIPSO from 5 km layer data



1. Thin cirrus detected by CALIPSO
   - Optical Depth from lidar-transmission method (below) and CALIPSO 5km layer product



•Thin Cirrus clouds given R_e=30µm

•Exponential fits for Rayleigh and Measured taken from CALIPSO backscatter to get OD

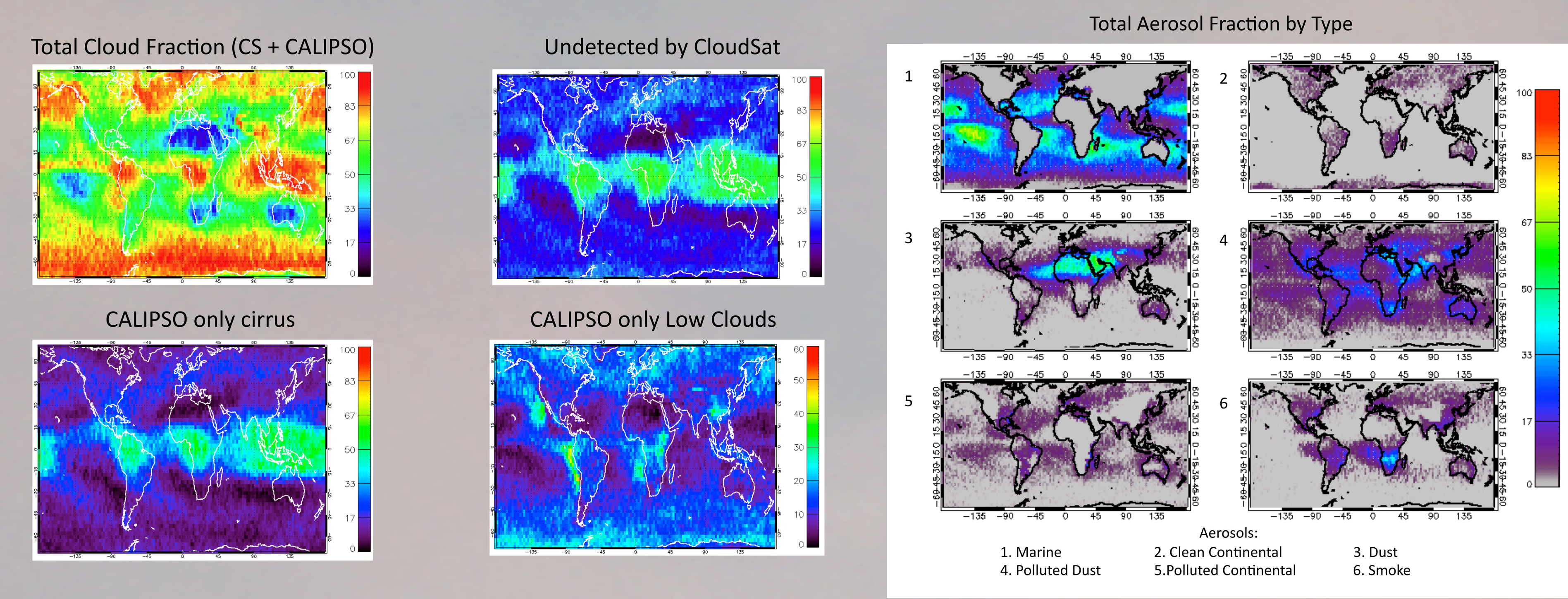
$$\beta = A\, e^{-z/H} \longrightarrow \frac{A_M}{A_R} = e^{-2\tau_{cld}}$$

•Optical depth used to calculate IWC

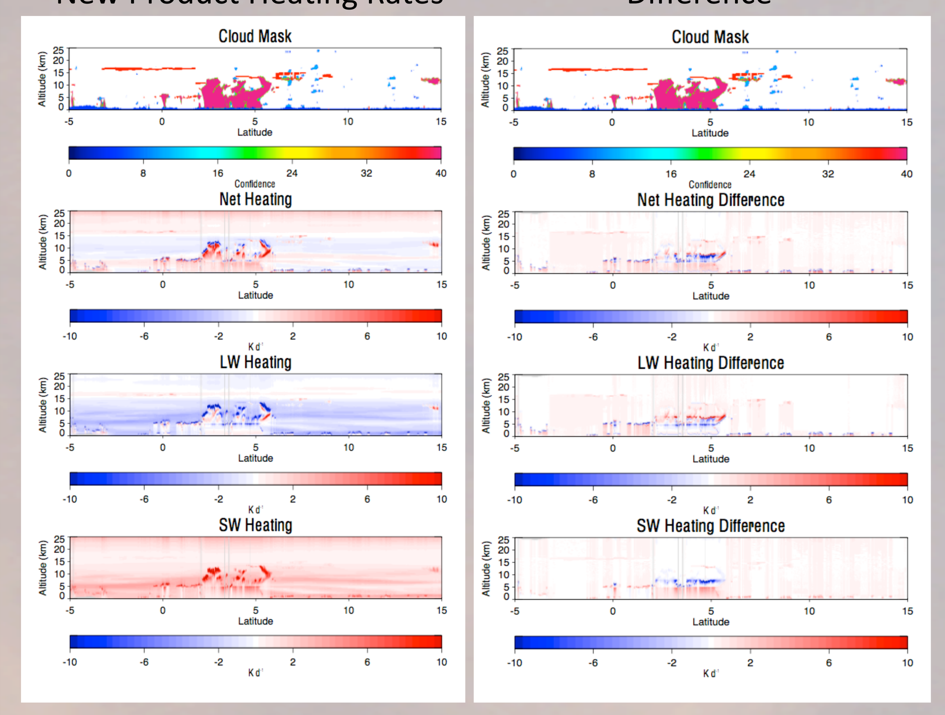
$$\tau_{cld} = \frac{3\, IWC}{2\, \rho_i R_e}\Delta z$$

2. Low Boundary Layer clouds detected by CALIPSO
   - Where MODIS is available, R_e is calculated from 2B-Tau
   - Else, R_e=13µm (Mean from MOD 06)
   - $LWC_{>1km}$=120mgm^{-3} (From CPR) or $LWC_{<1km}$=50mgm^{-3} (Miles et al., 2000)
3. Aerosol detected by CALIPSO
   - Species and aerosol OD from CALIPSO 5km Aerosol Layer Product
   - Radii and OD from CALIPSO matched to SPRINTARS optical properties (Takemura et al., 2002)
4. Precipitation
   - Drop sizes given by the LWC and Marshal-Palmer distribution
   - Cloud water added in precipitation with R_e=18µm
5. CloudSat Clouds, Atmosphere, and Surface
   - Vertical distributions of LWC, IWC, and effective radii are inputted from CloudSat’s 2B-CWC Product
   - Temperature and relative humidity profiles from ECMWF
   - Surface albedo and emissivity from the International Geosphere-Biosphere Programme (IGBP)

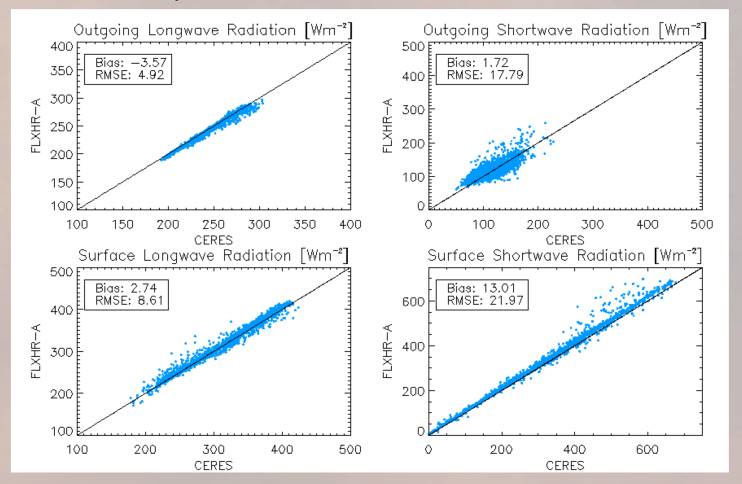
DISTRIBUTIONS OF CLOUD AND AEROSOL



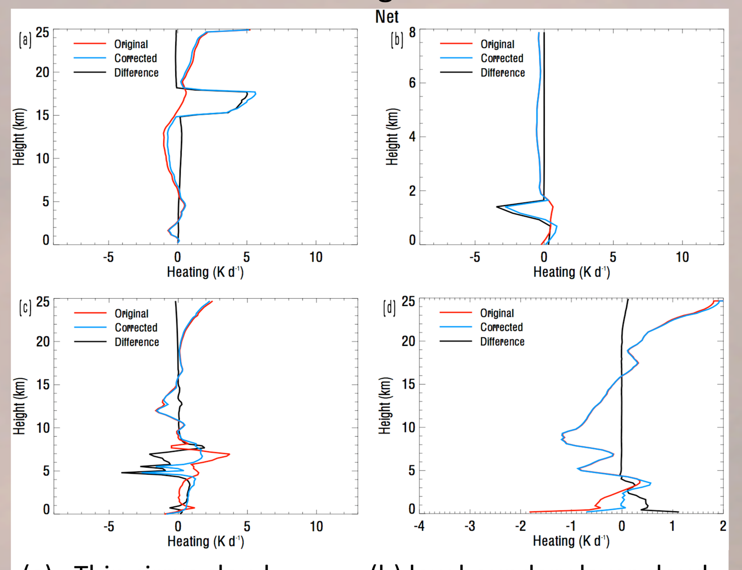
RADIATIVE IMPACTS OF CLOUD AND AEROSOLS



Comparison with CERES FLASHFlux

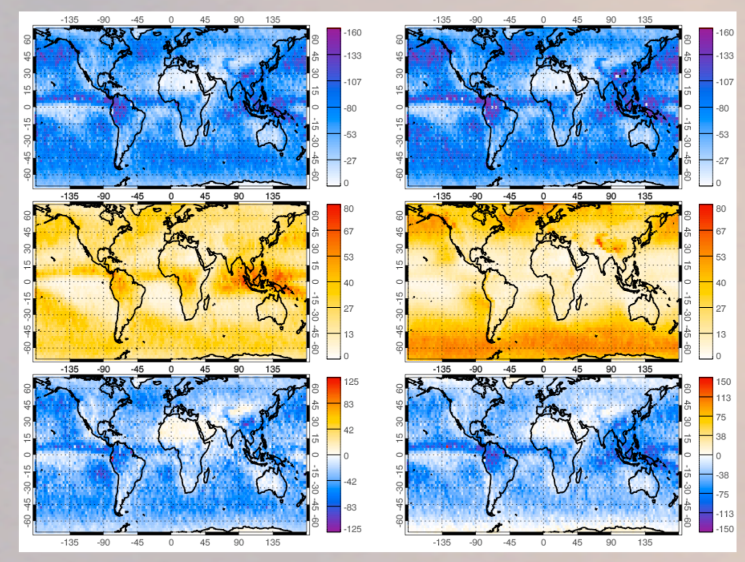


Vertical Heating Rate Profiles



(a) Thin cirrus cloud (b) low boundary layer cloud
(c) Precipitating cloud (d) Saharan dust

Cloud Radiative Effect [Wm^{-2}]



Globally Averaged Cloud Radiative Effect [Wm^{-2}]

CloudSat + CALIPSO Clouds

	DJF	MAM	JJA	SON	ANNUAL
TOA,SW	**-46.7** -53 -51.7	**-43.0** -46 -45.1	**-42.8** -50 -46.7	**-46.2** -50 -50.1	**-44.7** -50 -48.4
TOA,LW	**24.5** 25 30.6	**25.3** 26 **31.3**	**24.6** 25 30.1	**24.3** 25 32.2	**24.6** 25 31.1
TOA,NET	**-22.2** -28 -21.1	**-17.7** -20 -13.8	**-18.2** -22 -16.6	**-21.9** -26 -17.9	**-20.1** -24 -17.3
BOA,SW	**-54.9** -57 --	**-50.7** 49 --	**-50.2** -50 --	**-54.0** -53 --	**-52.5** -52 --
BOA,LW	**23.8** 31 --	**23.6** 30 --	**22.6** 28 --	**24.0** 30 --	**23.6** 30 --
BOA,NET	**-31.1** -26 --	**-27.1** -20 --	**-27.6** -21 --	**-30.0** -24 --	**-28.9** -23 --

Values from this study shown in bold followed below by Raschke et al. (2005) and Harrison et al. (1990)

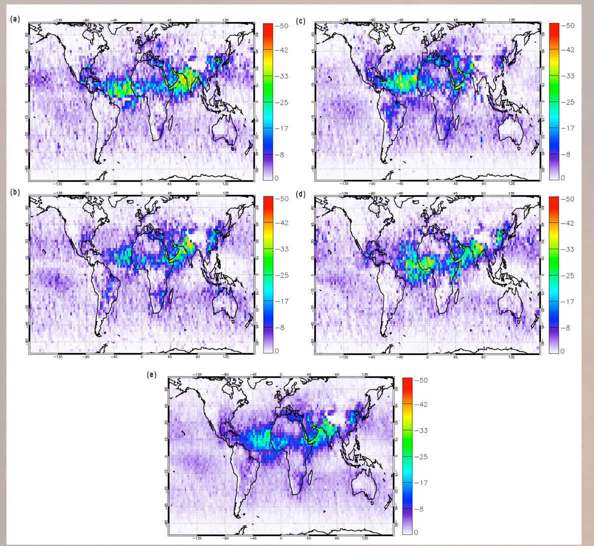
CALIPSO Low Cloud Only

	DJF	MAM	JJA	SON	ANNUAL
TOA,SW	-6.14	-5.19	-5.36	-5.98	-5.67
TOA,LW	2.07	2.08	2.06	2.07	2.07
TOA,NET	-4.07	-3.17	-3.30	-3.91	-3.60
BOA,SW	-6.69	-5.51	-5.77	-6.41	-6.10
BOA,LW	4.97	4.36	4.41	4.82	4.64
BOA,NET	-1.72	-1.15	-1.36	-1.59	-1.46

CALPSO High Cloud Only

	DJF	MAM	JJA	SON	ANNUAL
TOA,SW	-0.12	-0.11	-0.09	-0.12	-0.11
TOA,LW	1.06	1.12	0.92	0.90	1.0
TOA,NET	0.94	1.01	0.83	0.78	0.89
BOA,SW	-0.16	-0.16	-0.12	-0.16	-0.15
BOA,LW	0.09	0.10	0.11	0.10	0.10
BOA,NET	-0.07	-0.06	-0.01	-0.06	-0.05

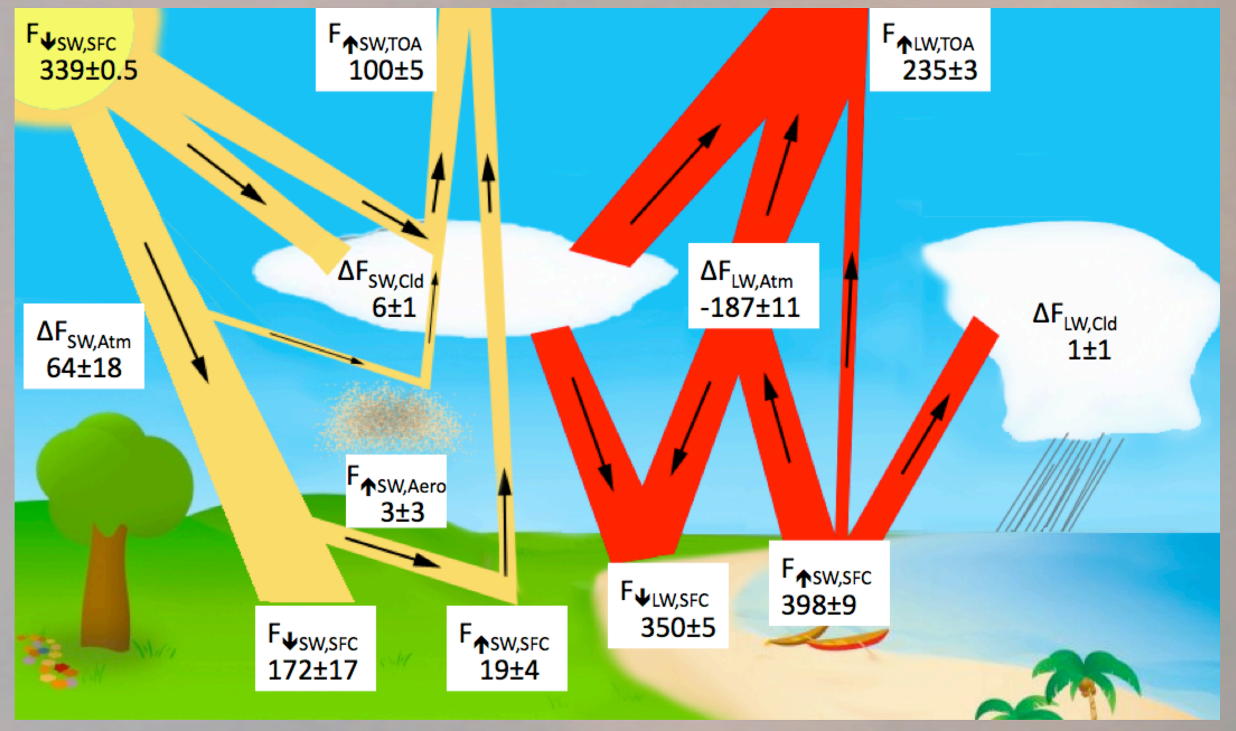
Direct Radiative Effect of Aerosol (SW TOA) [Wm^{-2}]



	(a) MAM	(c) JJA	(b) SON	(d) DJF	(e) ANNUAL
Direct Effect	-3.1	-2.8	-2.8	-3.0	-2.9

GLOBAL RADIATION BUDGET OF EARTH

Globally Averaged Annual ERB [Wm^{-2}]



•Uncertainties in fluxes are calculated by observing the RMS error differences with CERES FLASHFlux TOA and surface fluxes, along with estimated uncertainty in the surface albedo and emissivity. Aerosol error estimates arise from comparisons with studies from the IPCC AR4 report.

•To represent the diurnal cycle the solar zenith angle is changed every 12 CloudSat bins. This method will not change the meteorological properties of the atmosphere, but will increase cloud and aerosol albedo as solar zenith angle increases.

CONCLUSIONS AND FUTURE

By combing CloudSat and CALIPSO data, locations are found of cloud and aerosol. Using data from CloudSat, CALIPSO, and MODIS properties were assigned for new clouds and aerosols, then included in a radiative transfer model

- Validation with CERES FLASHFlux data set shows good correlation at TOA and Surface
- Net cloud radiative effect of -20 Wm^{-2} at TOA
- Clouds and aerosols detected only by CALIPSO show impacts on vertical heating rate profiles
- Clouds and aerosols detected only by CALIPSO affect radiative budget (globally)
  - Low Clouds: 6 Wm^{-2} in SW at TOA
  - Cirrus Clouds: 1 Wm^{-2} in LW at TOA
  - Aerosols: 3 Wm^{-2} in SW at TOA
- Calculated Annual Global Radiative Budget by simulating diurnal cycle
  - Uses information on cloud and aerosol top and base
  - Includes budget at TOA, surface, and atmosphere

- Implement more CloudSat products such as 2C-Precip-Column
- Collocate AMSR-E surface data to get a better representation of sea ice
- Continue to work with aerosol properties, and complete analysis to include different cloud cases
- Continue efforts with looking at the diurnal cycle to improve solar radiation budget
- Work with CloudSat DPC and implement improvements from this research into 2B-FLXHR

REFERENCES

An in depth look at this data-set can be found here:
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