Using CERES data to evaluate clouds and radiative fluxes in the CCCma AGCM

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Introduction

- Cloud feedback source of uncertainity in climate change
- Cloud-Aerosol Feedback and Climate (CFAC)
  - Focused on improvements in the CCCma GCM
- Want to characterize clouds and radiation in the current GCM
- Cloud feedbacks $\Rightarrow$ CFMIP
- Compare clouds and radiation with CERES

GCM configuration and monthly CERES data

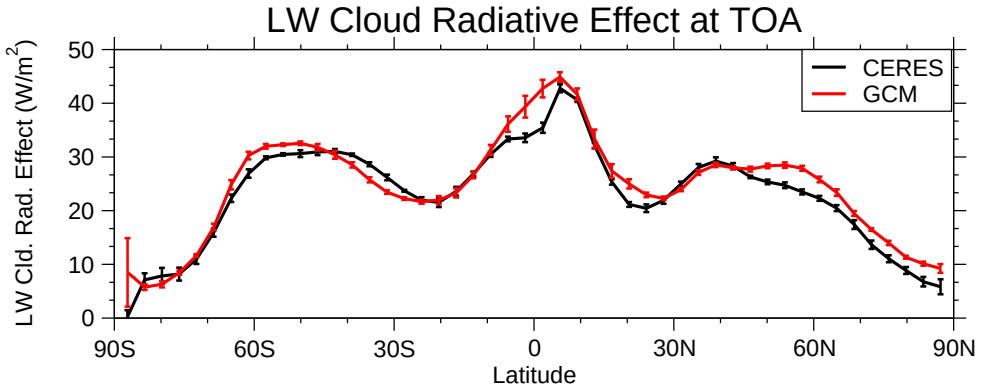
- GCM15F (developmental version)
- T47 ($\sim 2.8^\circ$x2.8°) with 35 levels
- Time varying Had. Centre SSTs
- Jan. 1999-Aug. 2005
- ISCCP simulator
- Monthly CERES data (1°x1°)
  - Radiation (SRBAVG) from Mar. 2000 - Oct. 2005
  - SRBAVG2 GEO cloud data Oct. 2000 - Oct. 2005
- Averaged 1°x1° CERES data to T47 grid
- Set points on T47 grid to missing if $< 50\%$ CERES data
- Generated month by month masks, applied to GCM fields

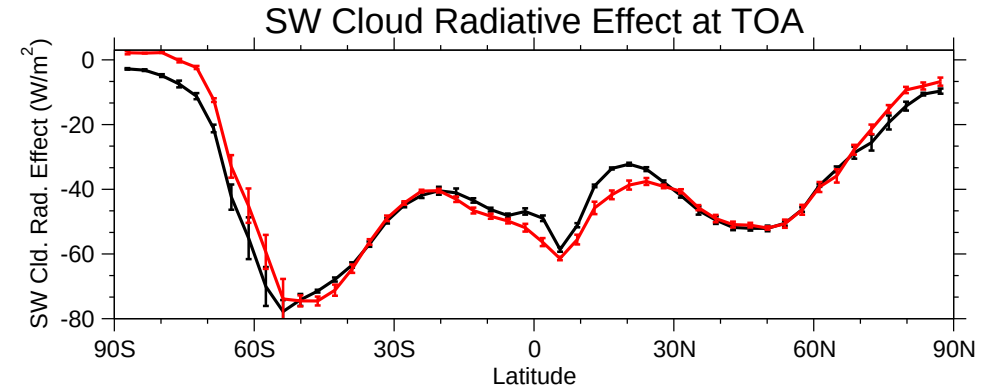
TOA cloud radiative effect (2000/08 - 2005/08)

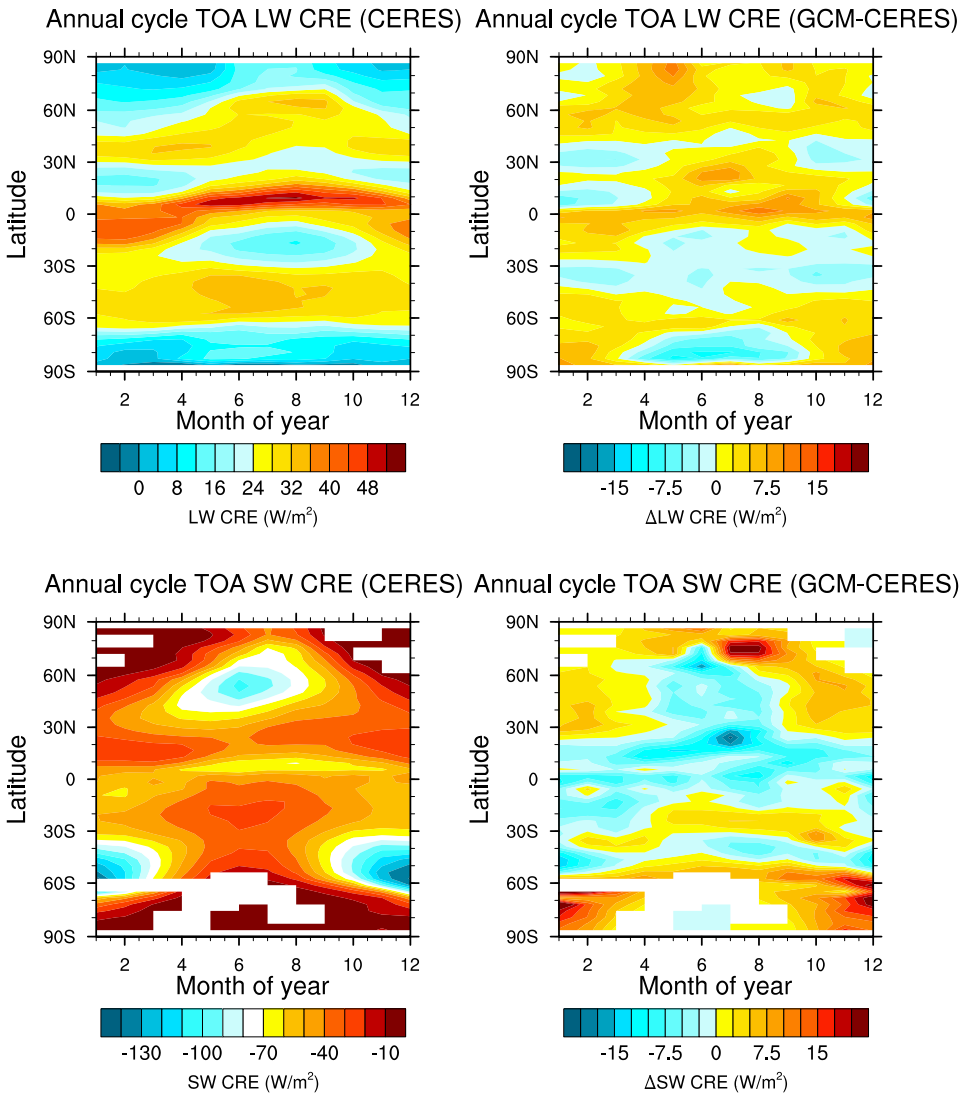
Global means

Variable	CERES	GCM
SW CRE TOA	-45.87	-46.89
LW CRE TOA	26.75	27.98

CRE = F(all-sky)-F(clear-sky)

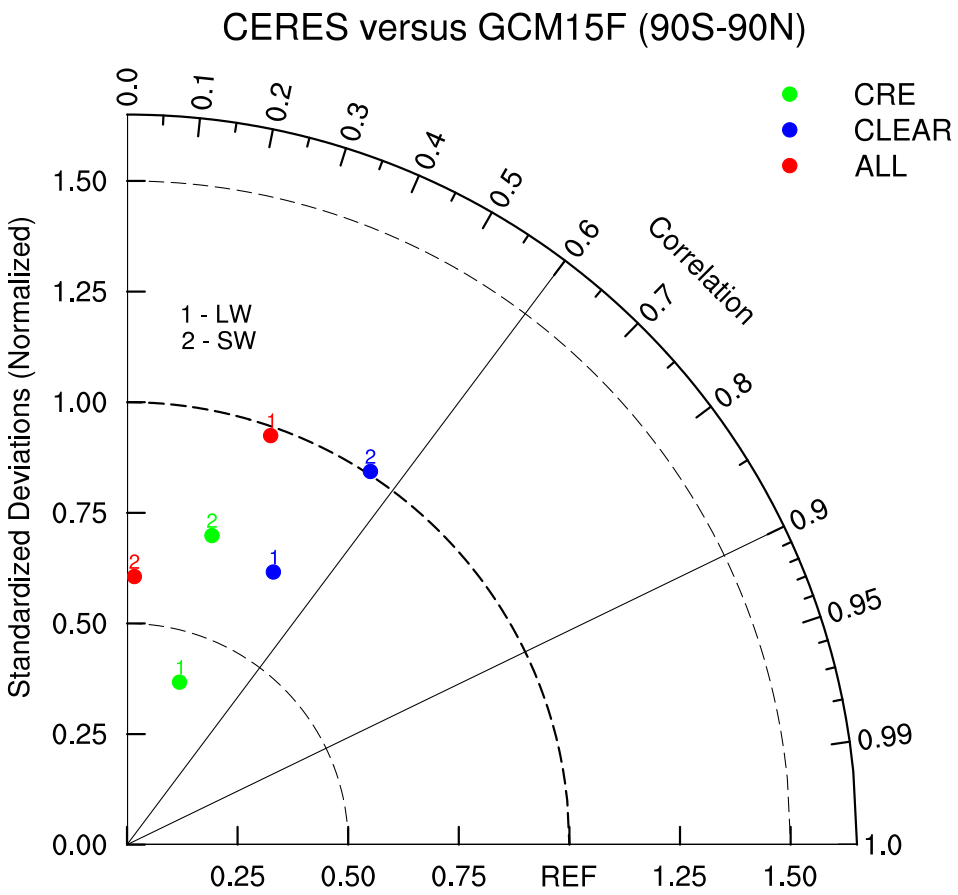


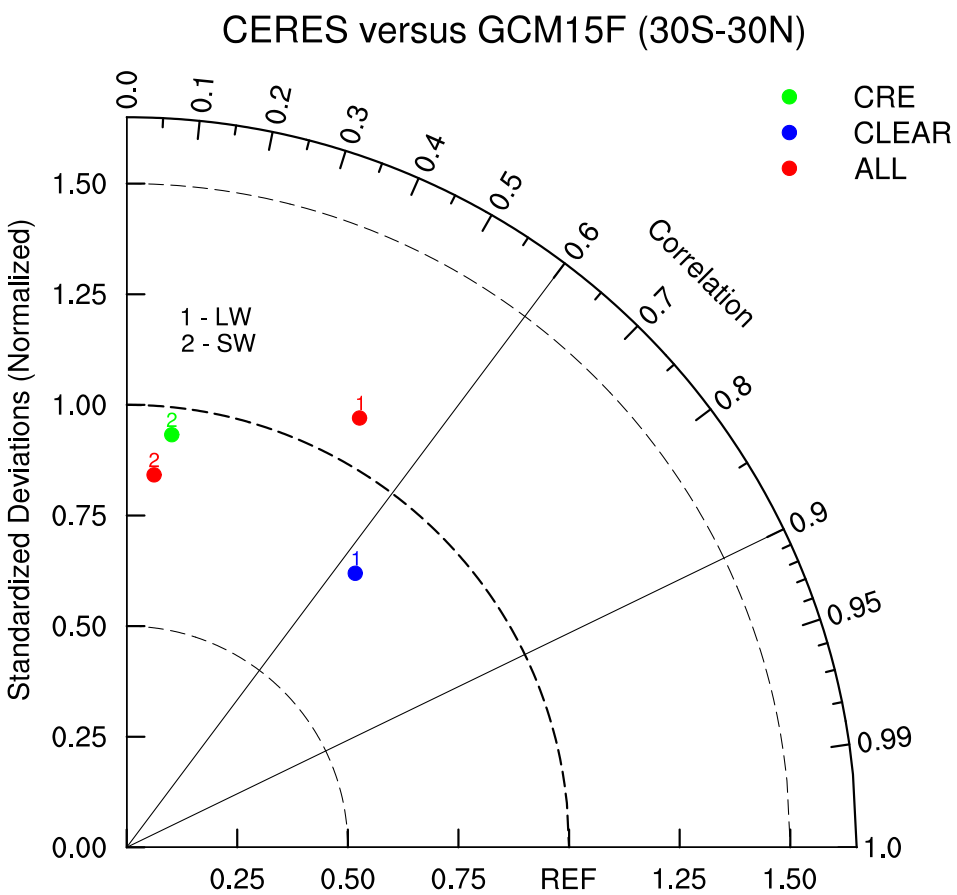




Monthly anomalies (2000/08 - 2005/08)

$$\text{Radius} = \sigma_{GCM}/\sigma_{CERES}$$
$$\text{Angle} = \text{Correlation}$$





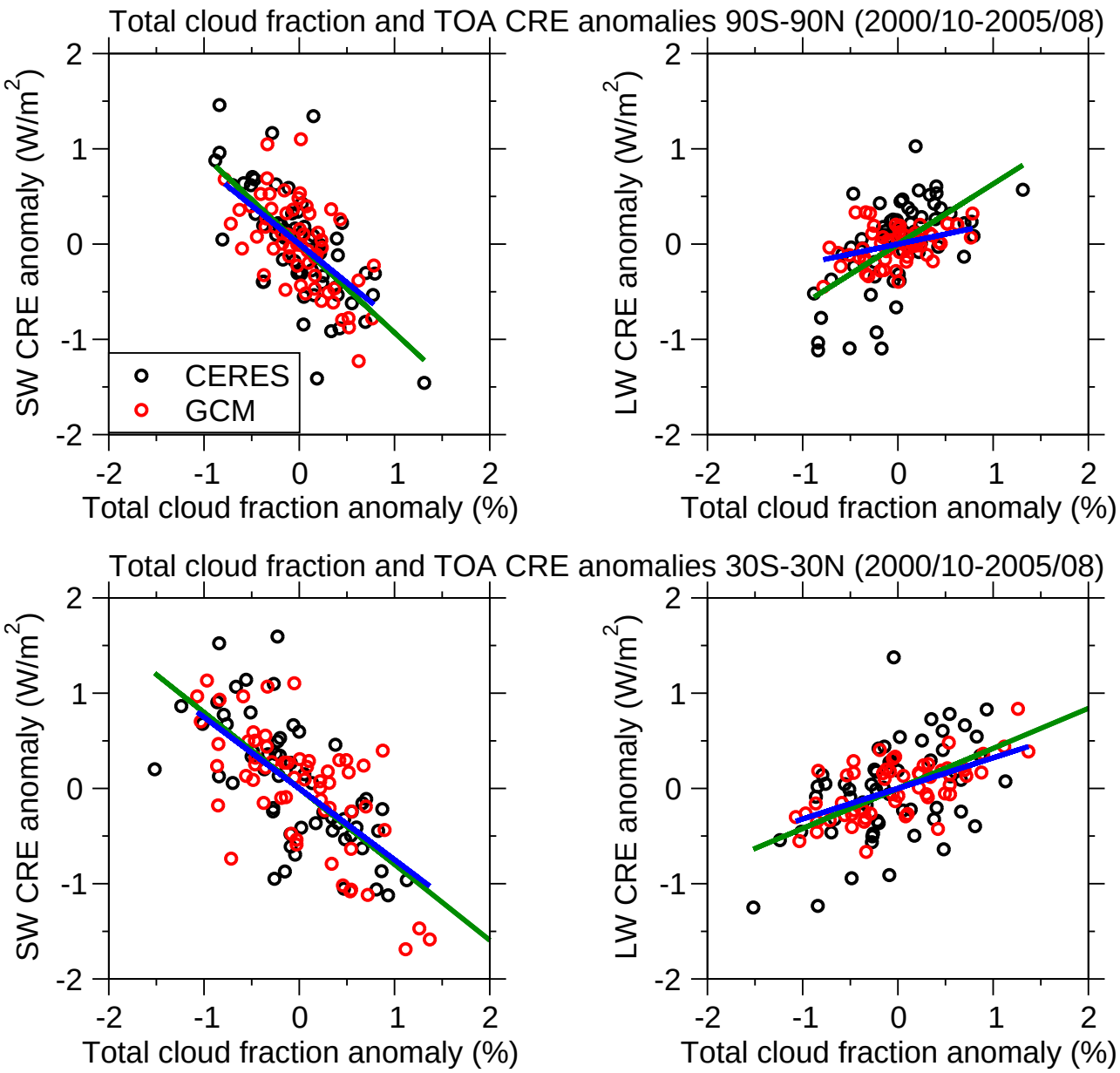
ISCCP (90°S-90°N), Ratio=1.96, Corr.=0.19

ISCCP (30°S-30°N), Ratio=1.41, Corr.=0.43

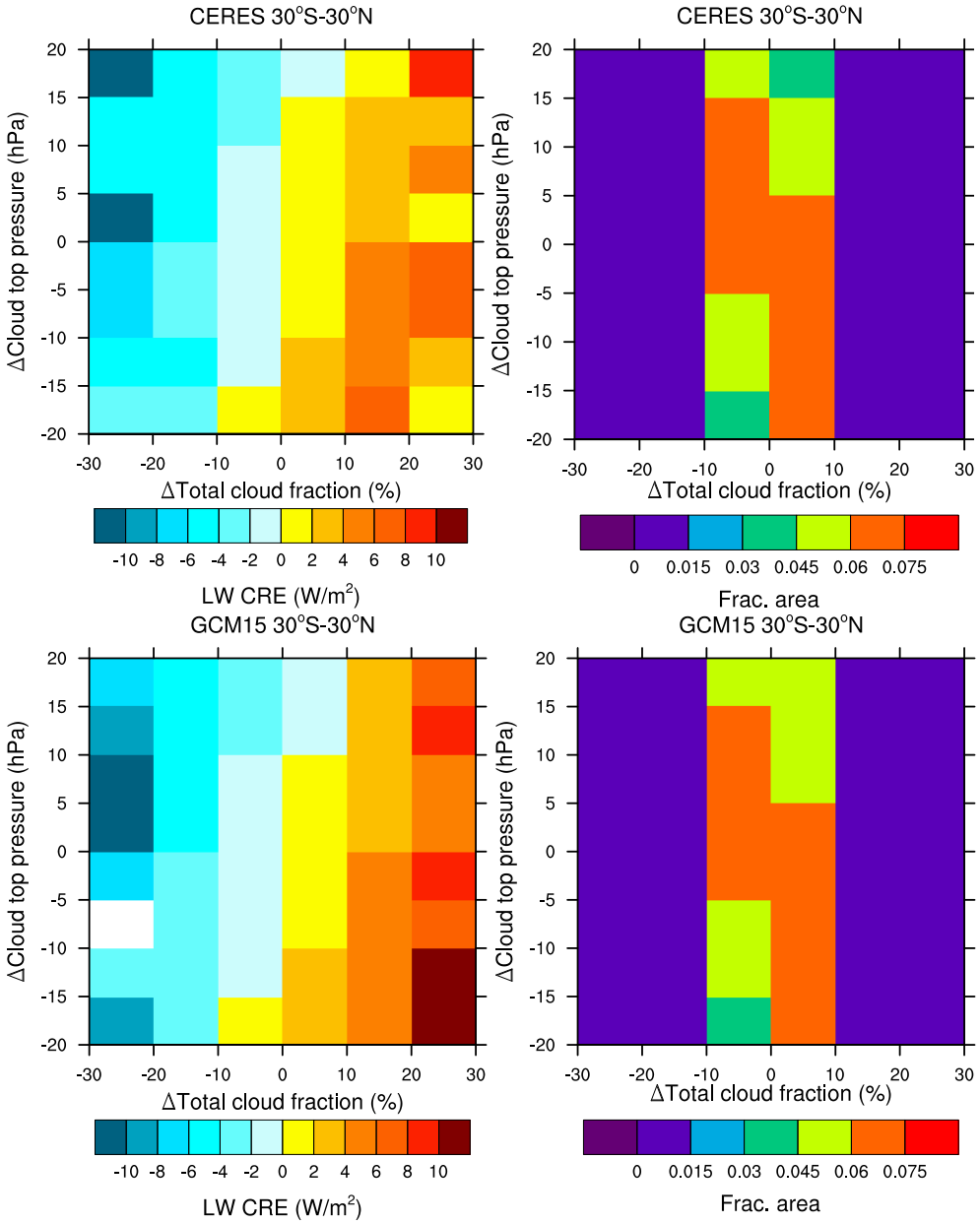
Clr SW - Ratio=1.04, Corr.=-0.01

LW CRE - Ratio=0.573, Corr.=-0.149

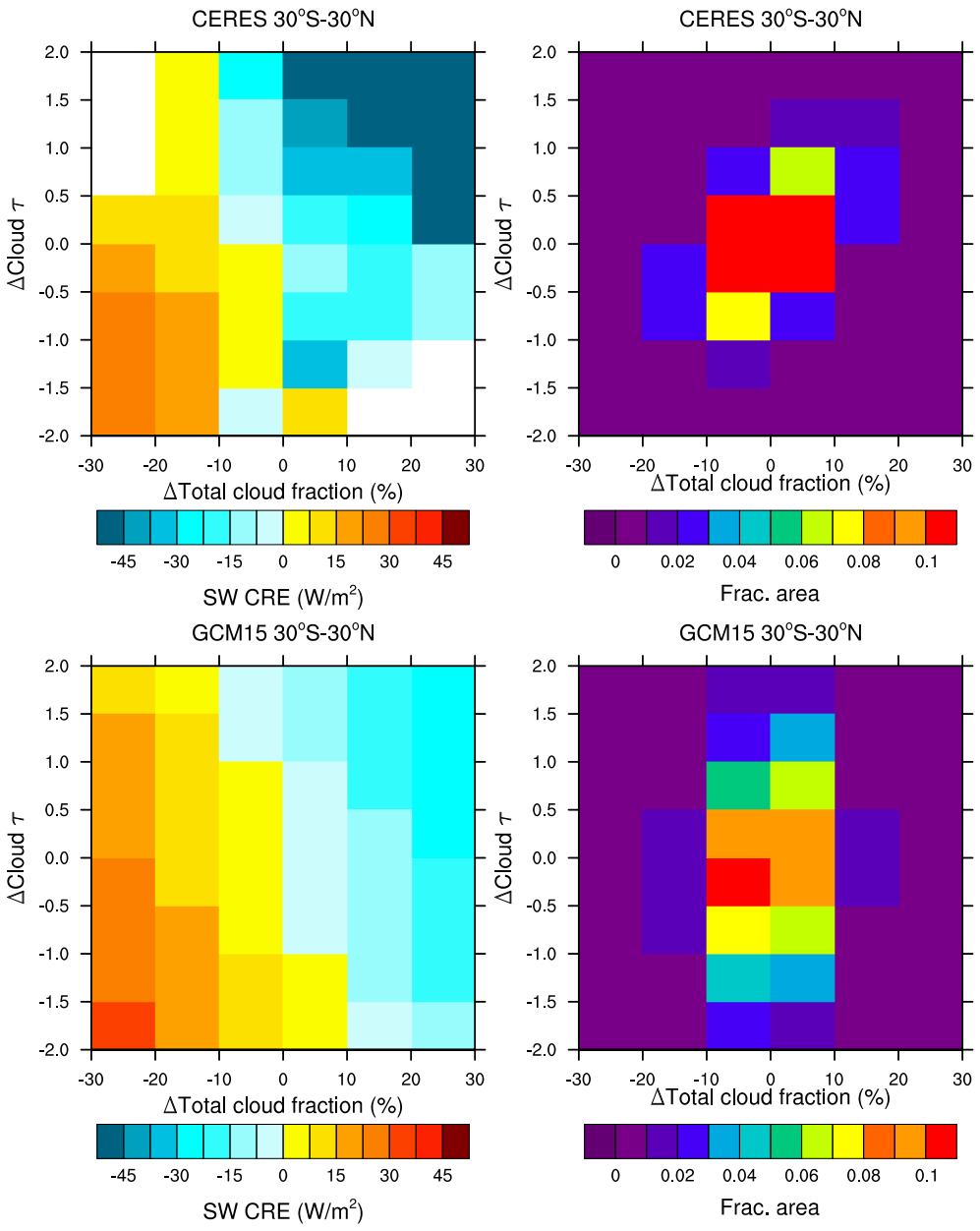
TOA CRE and cloud fraction anomalies



LW TOA CRE and cloud properties anomalies



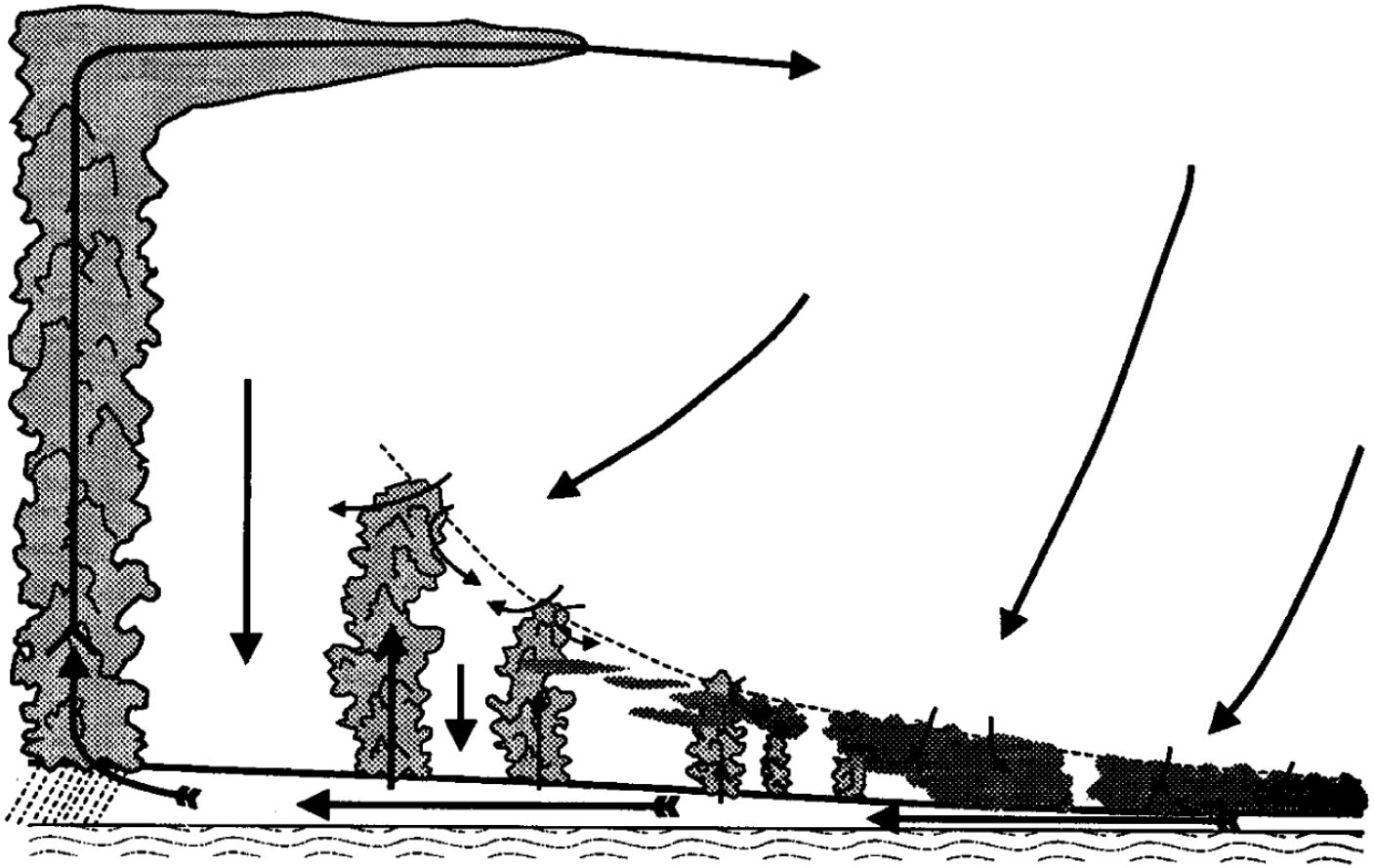
SW TOA CRE and cloud properties anomalies



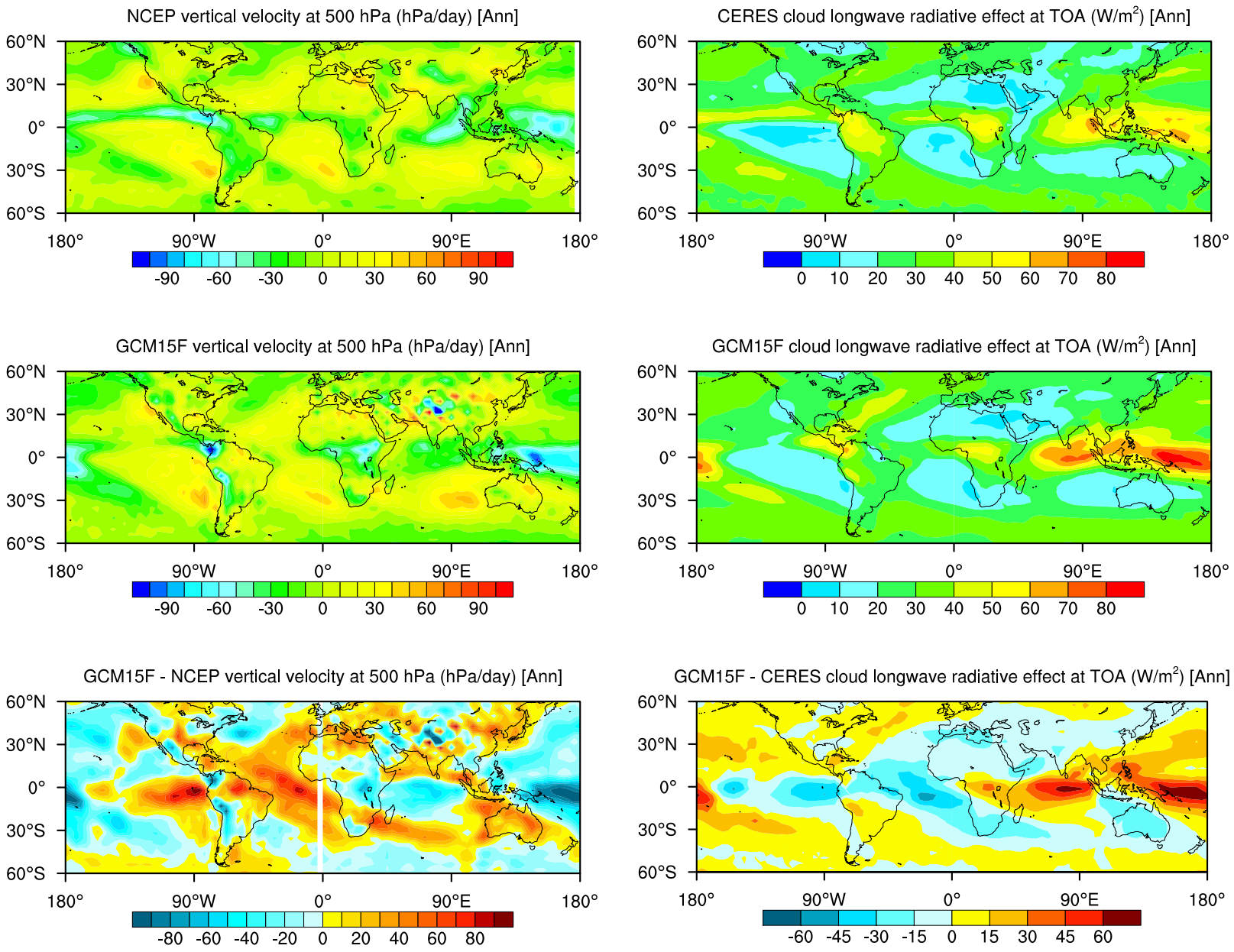
Compositing by dynamical state (Bony diagrams)

- "Bony" diagrams (Bony et.al., 2004, Climate Dynamics)
- Composite tropical (30°S-30°N) means using ω at 500 hPa

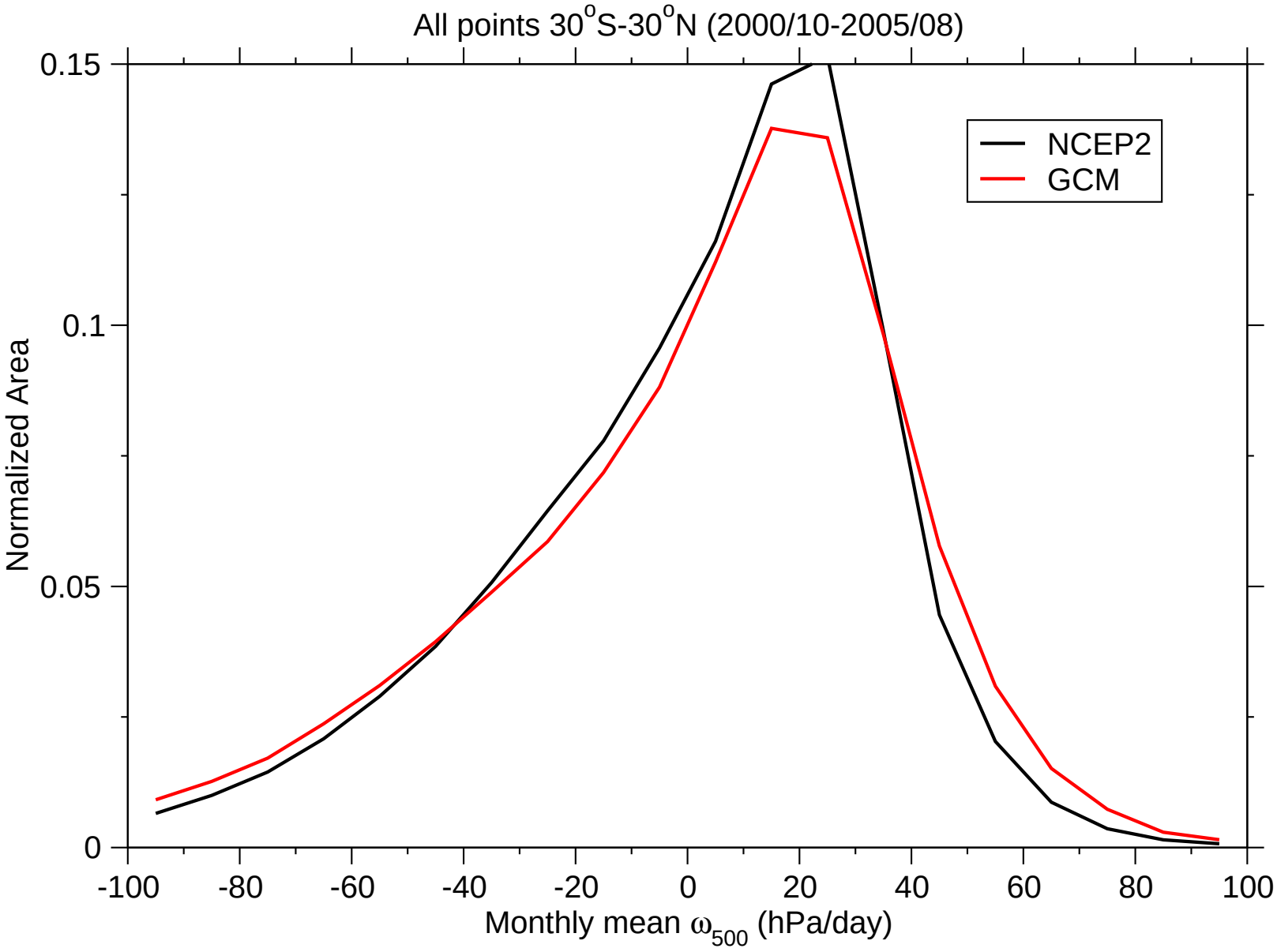
$$\overline{C} = \int_{-\infty}^{\infty} P_\omega C_\omega d\omega$$



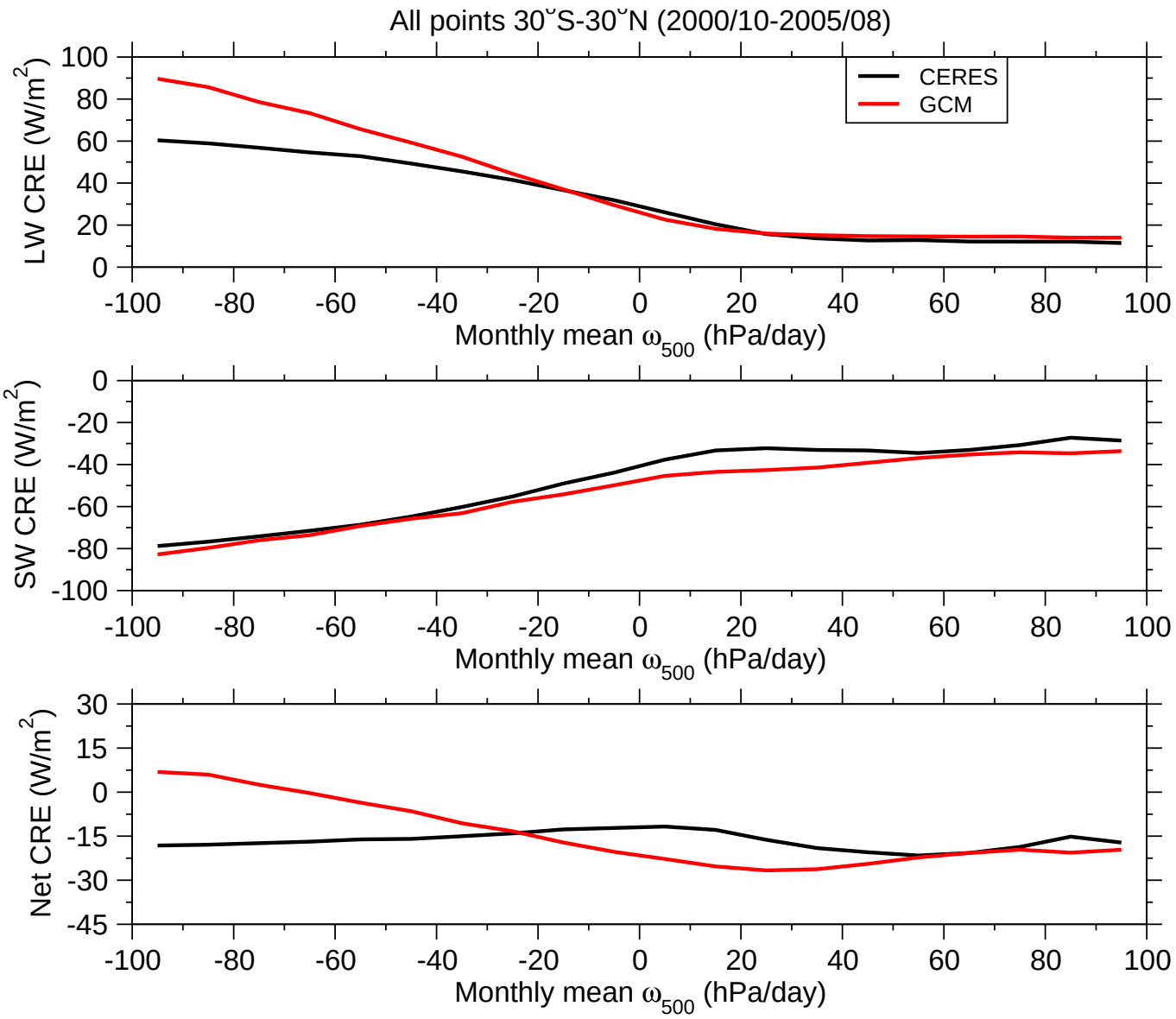
Vertical velocity and TOA LW CRE (2001/01-2004/12)



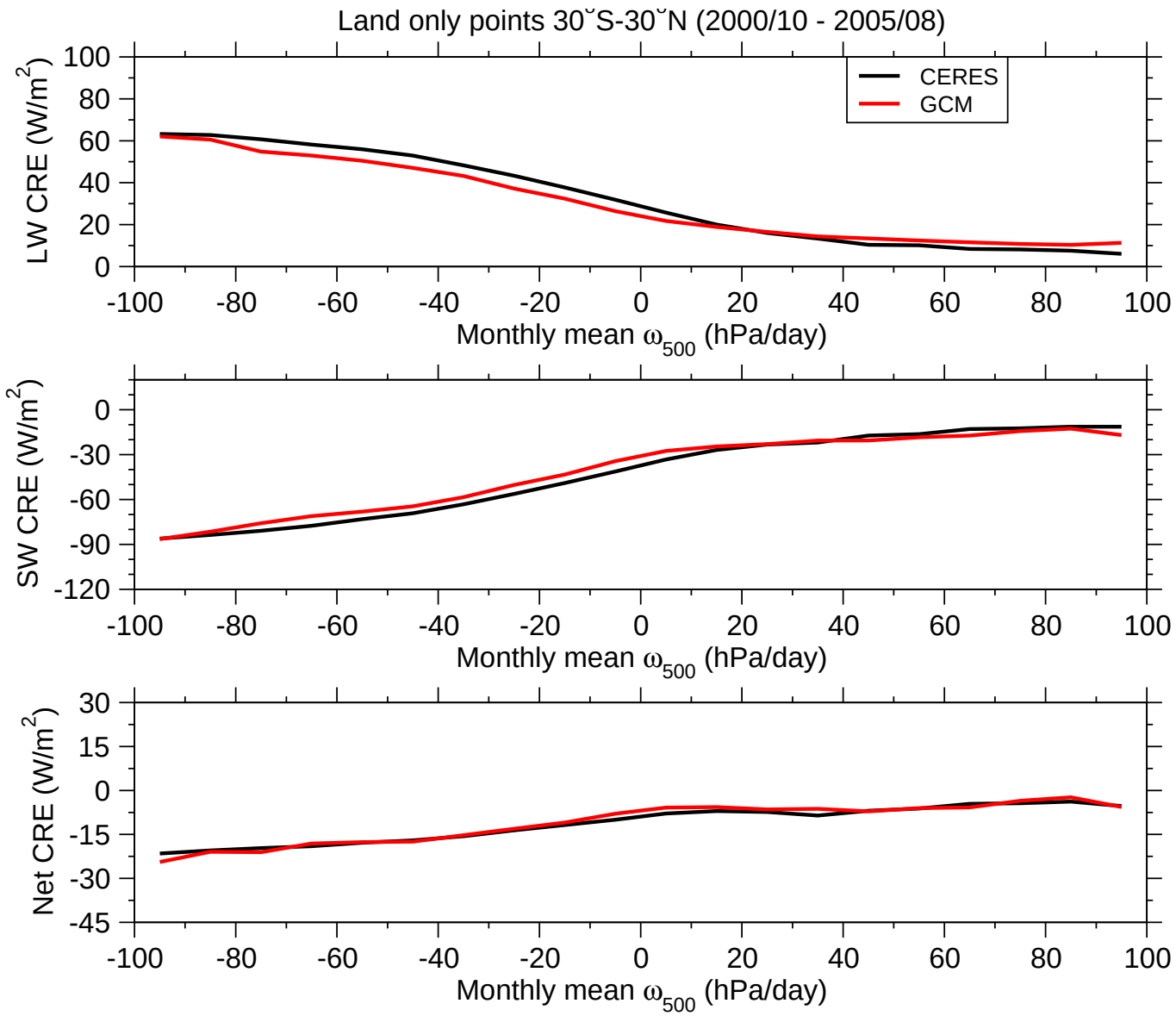
Fractional area of vertical velocity



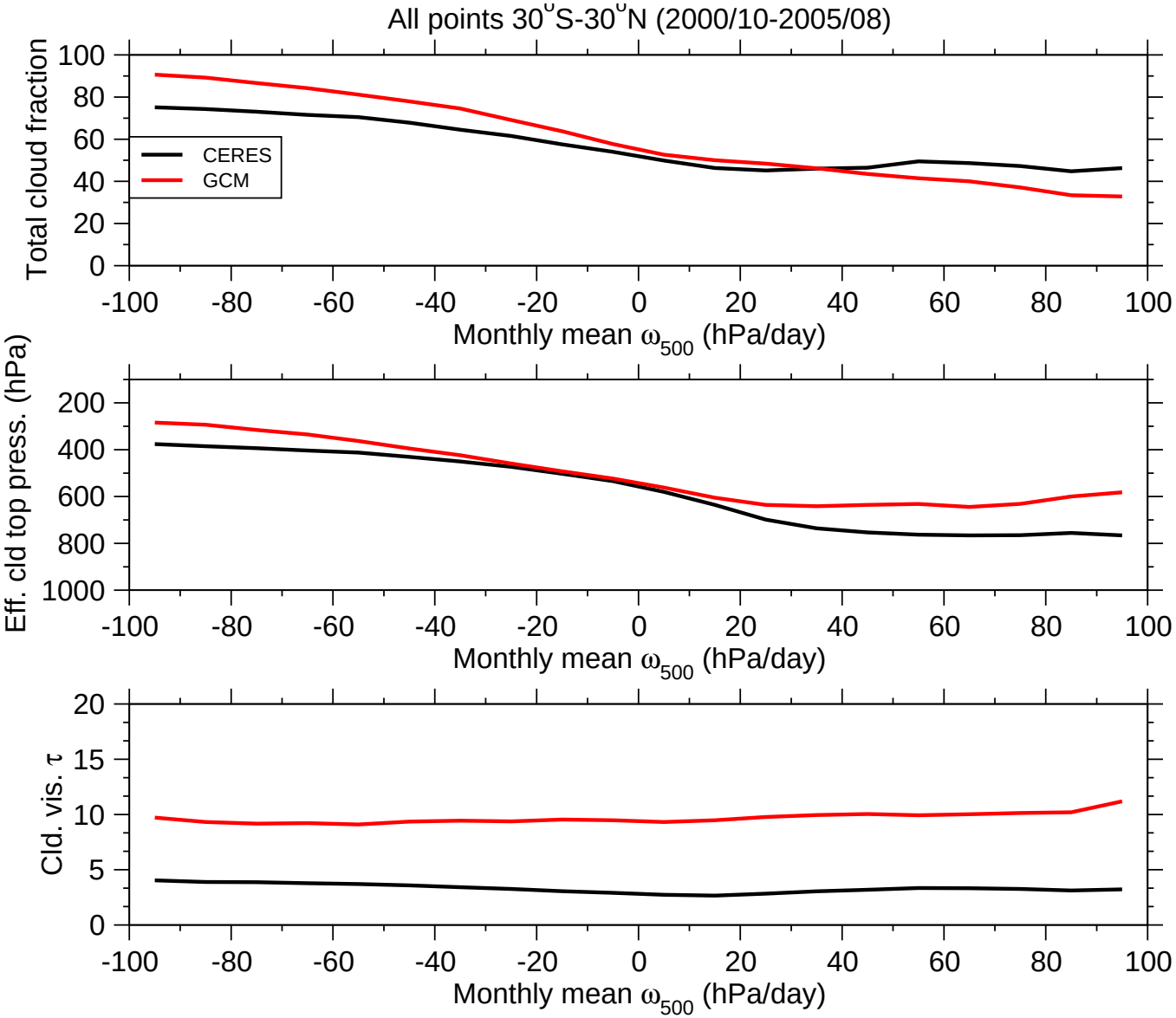
TOA CRE function ω (30°S-30°N)



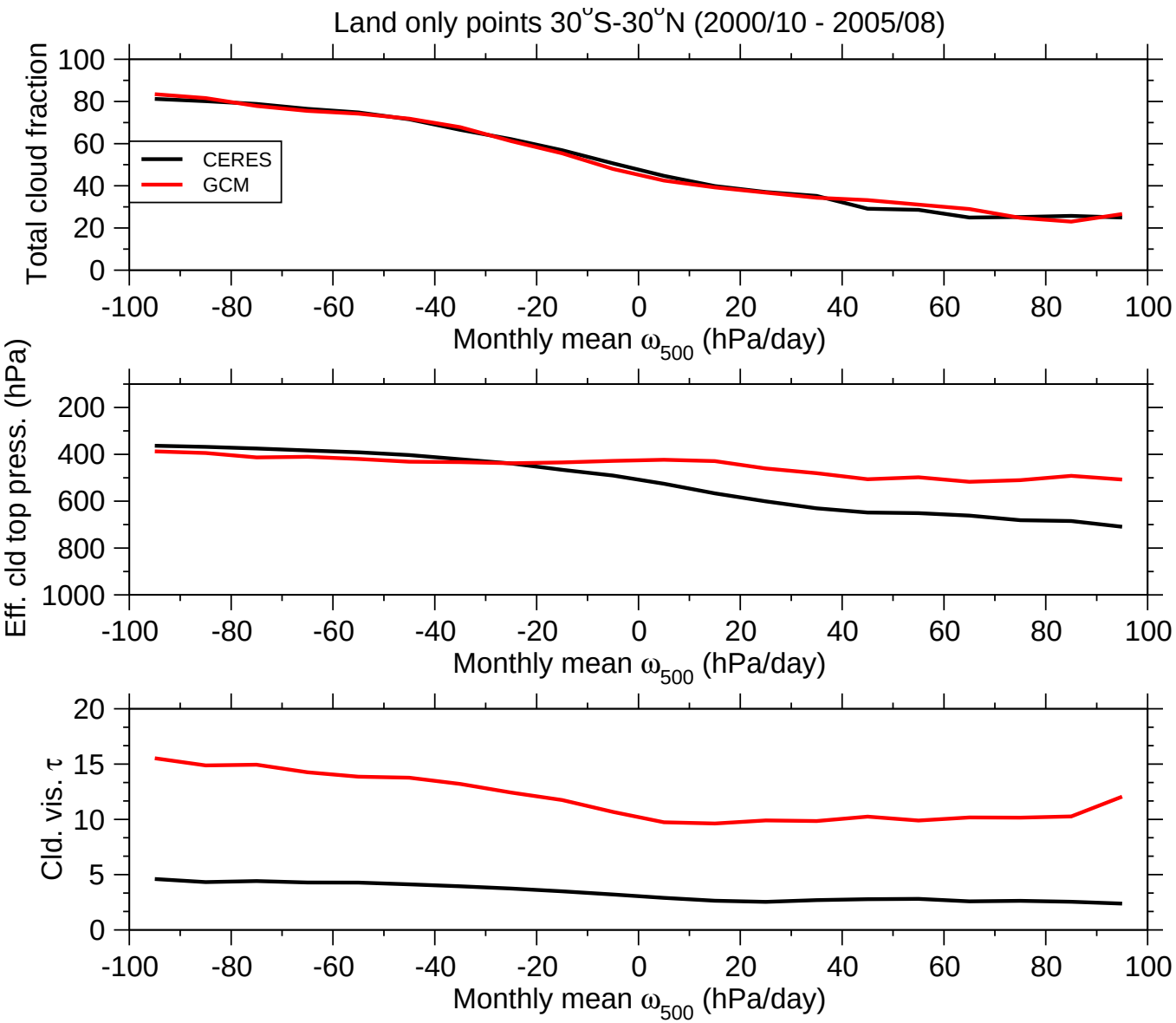
TOA CRE function ω over land (30°S-30°N)



Cloud props. function ω (30°S-30°N)



Cloud props. function over land ω (30°S-30°N)

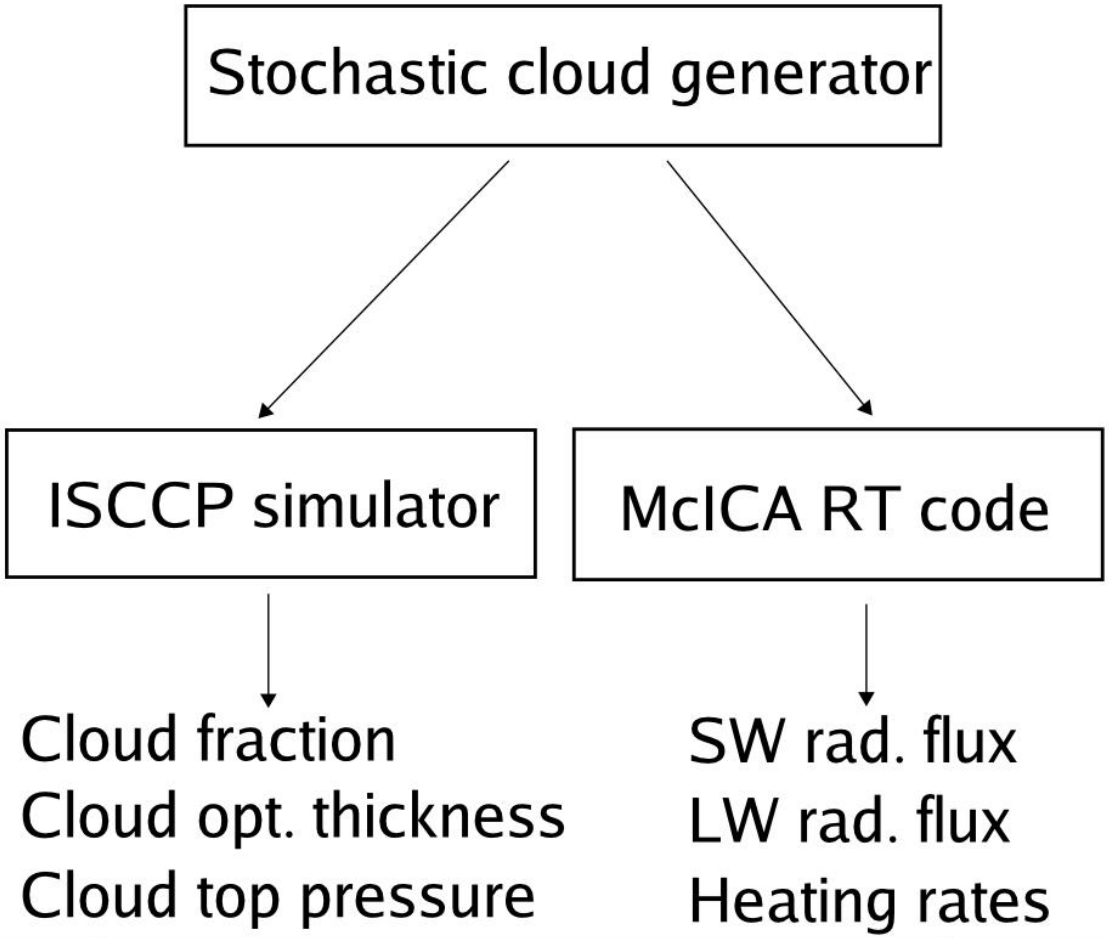


Daily-mean CERES data

- Jan and July 2001-2005
- 1°x1° gridboxes
- Footprints within 1.5 hours of equator crossing time
- Fluxes for LW, SW and WN, clear-sky and cloud
- MODIS narrowband radiance $\Rightarrow$ broadband flux for cloud
- Fluxes for cloudy areas as function of cloud top pressure
  - Low $>$ 680 hPa
  - 440 hPa $<$ Middle $<$ 680 hPa
  - High $<$ 440 hPa
- Compute 24-hour mean using observed meteorology
- Use dependence of albedo on μ

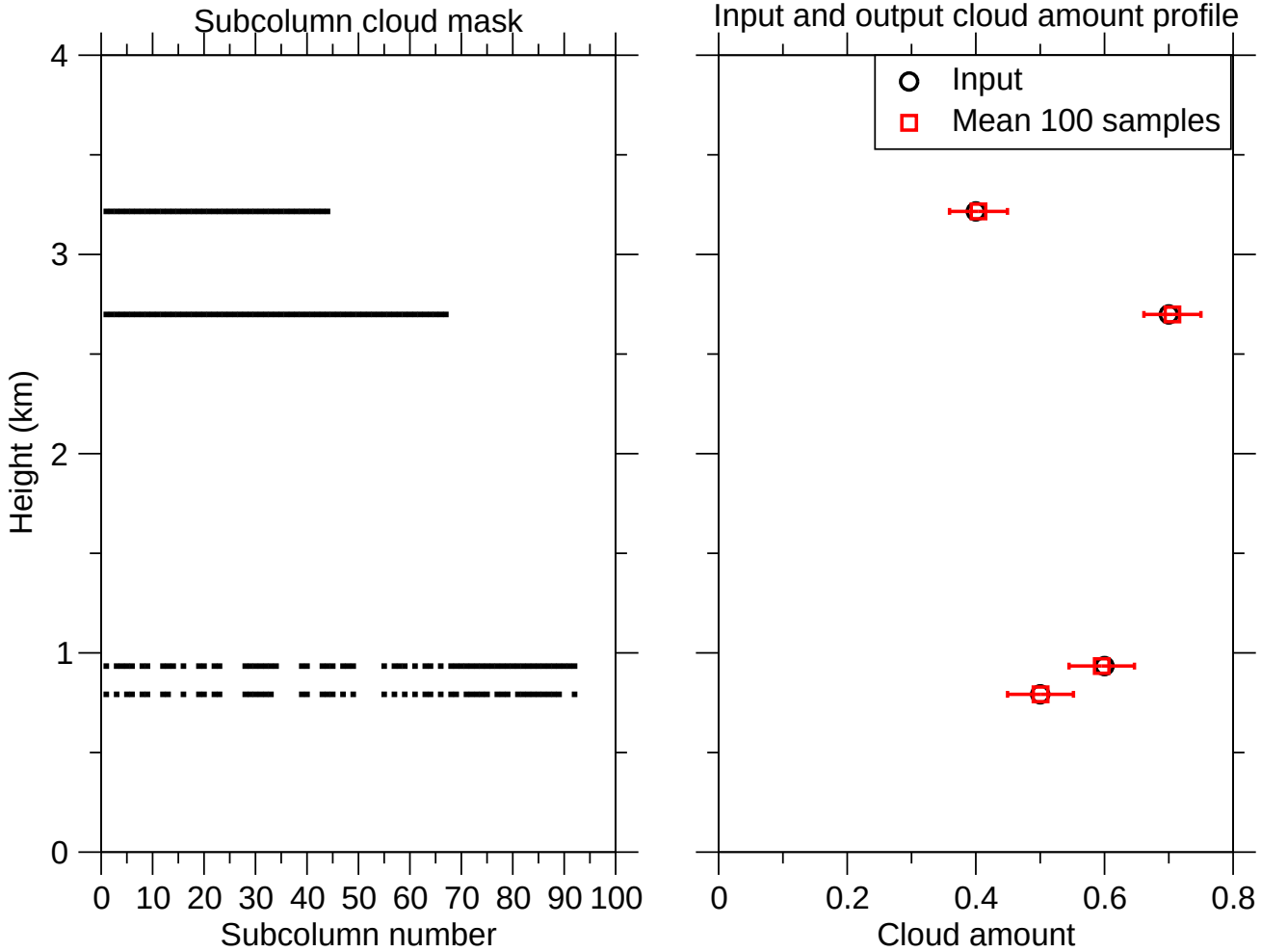
Diagnostic daily GCM calculations

- Try to compute daily means in similar fashion
- Perform diagnostic radiation calculations every hour
  - Grid points within 1.5 hours of 10:30 AM and 1:30 PM
  - Use modified ISCCP simulator for cld. props.



Stochastic cloud generator example

Maximum-random overlap, horizontally homogeneous cloud water



Total cloud fraction $= 1 - \prod_1^{k=K}(1 - max(c_k, c_{k-1}))/(1 - c_{k-1})$

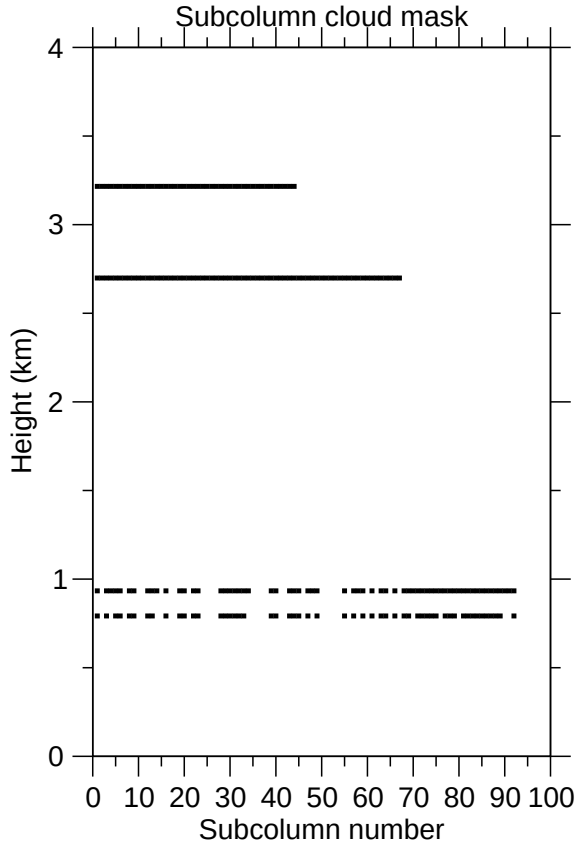
From input profile $= 0.88$, from generator $= 0.884 \pm 0.029$

ISCCP simulator

- For each subcolumn
  - Compute vertically integrated τ
  - Radiance at 11 μm $\Rightarrow$ brightness temp $\Rightarrow$ cloud top pressure
- Average over subcolumns
  - Cloud fraction, cloud top pressure
  - $\overline{\tau} = R^{-1}(\sum_{i=1}^{N} A_i)/N$ (ISCCP)
  - $\overline{\tau} = \exp((\sum_{i=1}^{N} ln\tau_i)/N)$ (CERES)
- Average over daylight periods

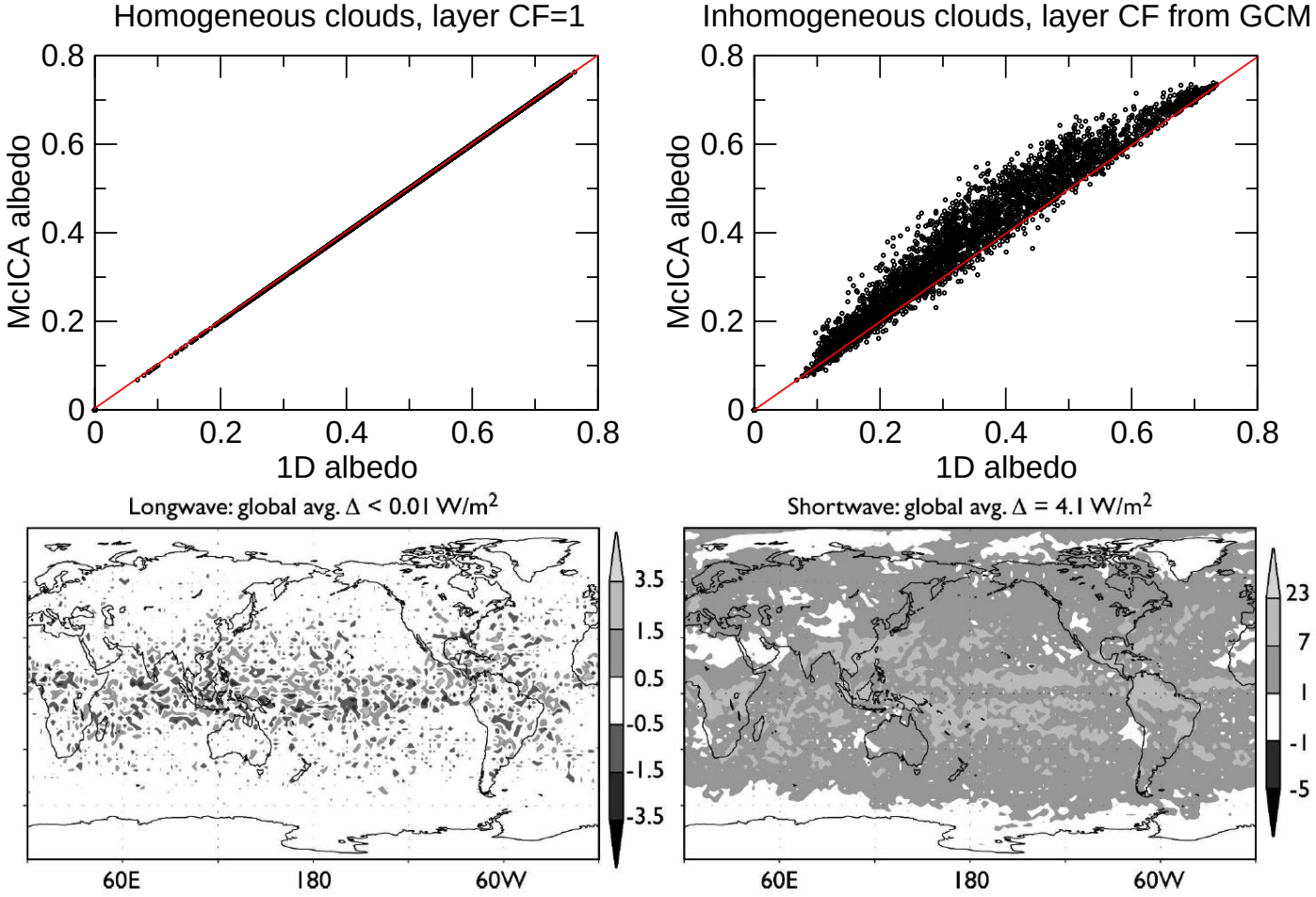
Monte Carlo Independent Column Approximation

- $\widehat{F} = (1 - \widehat{A_c}) \sum_{k=1}^{K} F(s_{\mathrm{clr}}, k) + \widehat{A_c} \sum_{k=1}^{K} F(s_{\mathrm{cld},k}, k)$
- $\widehat{F} = (1 - \widehat{A_c}) \sum_{k=1}^{K} F(s_{\mathrm{clr}}, k) + \widehat{A_c} \sum_{k=1}^{K} \widehat{F_k}$
  - $\widehat{F_k} = \frac{1}{N_k} \sum_{n=1}^{N_k} F(s_{\mathrm{cld},n,k}, k)$
- Unbiased relative to ICA calculations
- Diurnal means by varying $\mu_\circ$, uniform random selection of H



Monte Carlo Independent Column Approximation

- Biases in 1D codes relative to ICA



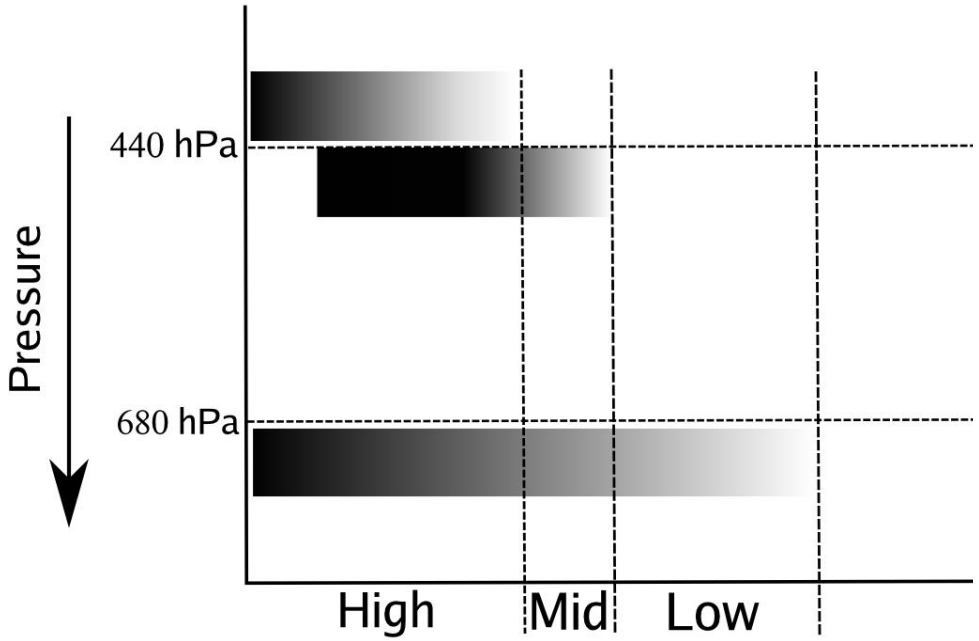
Pincus et. al. 2006 (GFDL, random overlap)

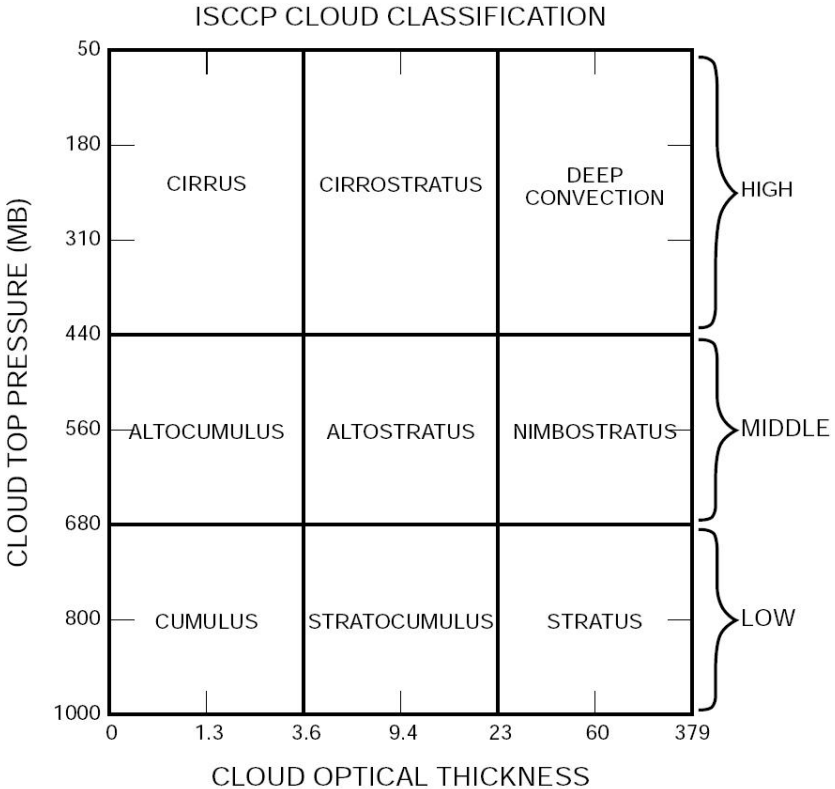
Analysis

$$R = \int_0^\infty p(\tau)R(\tau)d\tau$$

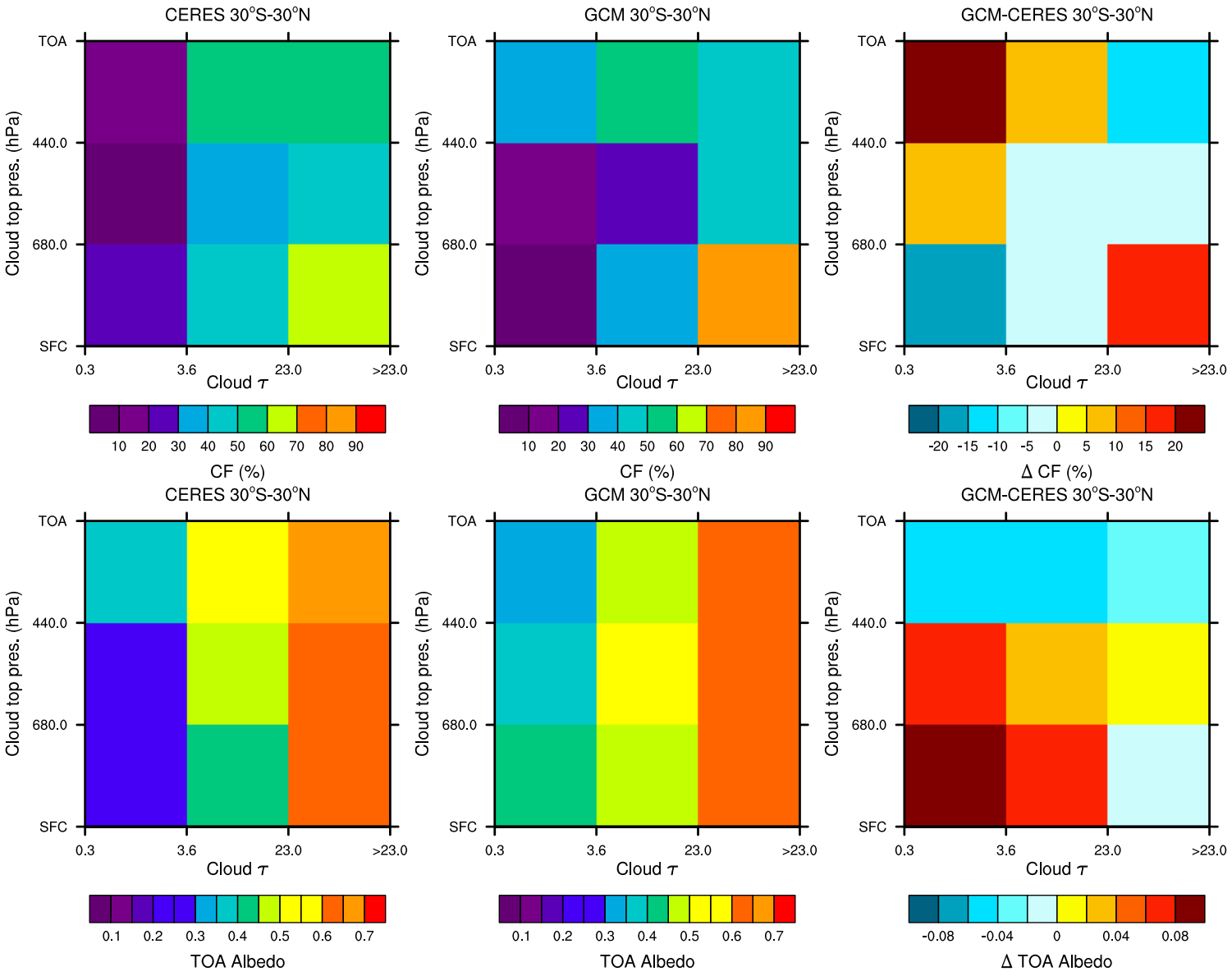
$$R = (1 - A_c)R_{\mathrm{clr}} + A_c \int_0^\infty p(\tau)R(\tau)d\tau$$

$$R = (1 - A_c)R_{\mathrm{clr}} + \sum_{i=1}^{i=M} A_{c,i} \int_0^\infty p_i(\tau)R(\tau)d\tau$$

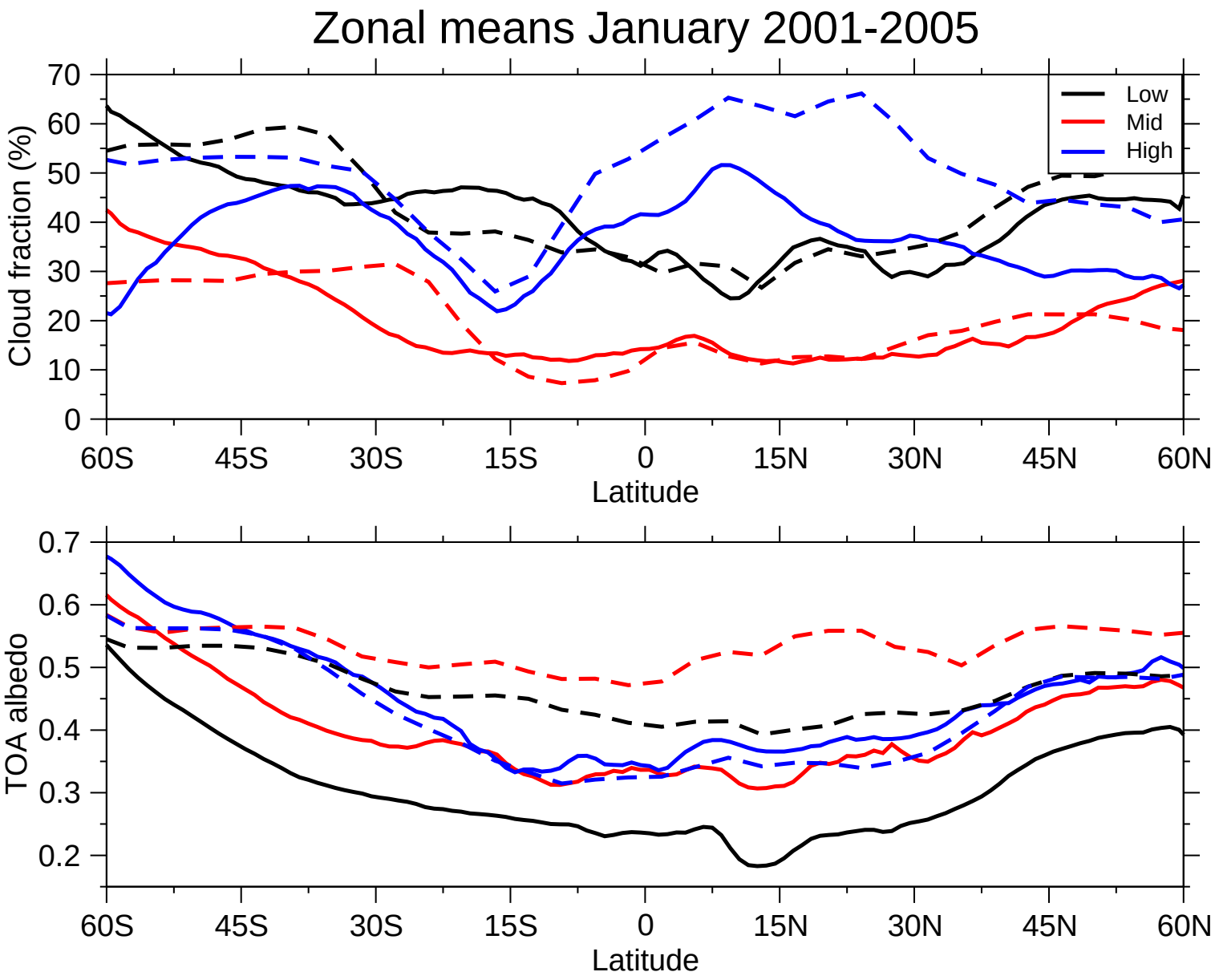




January p-τ (30°S-30°N)

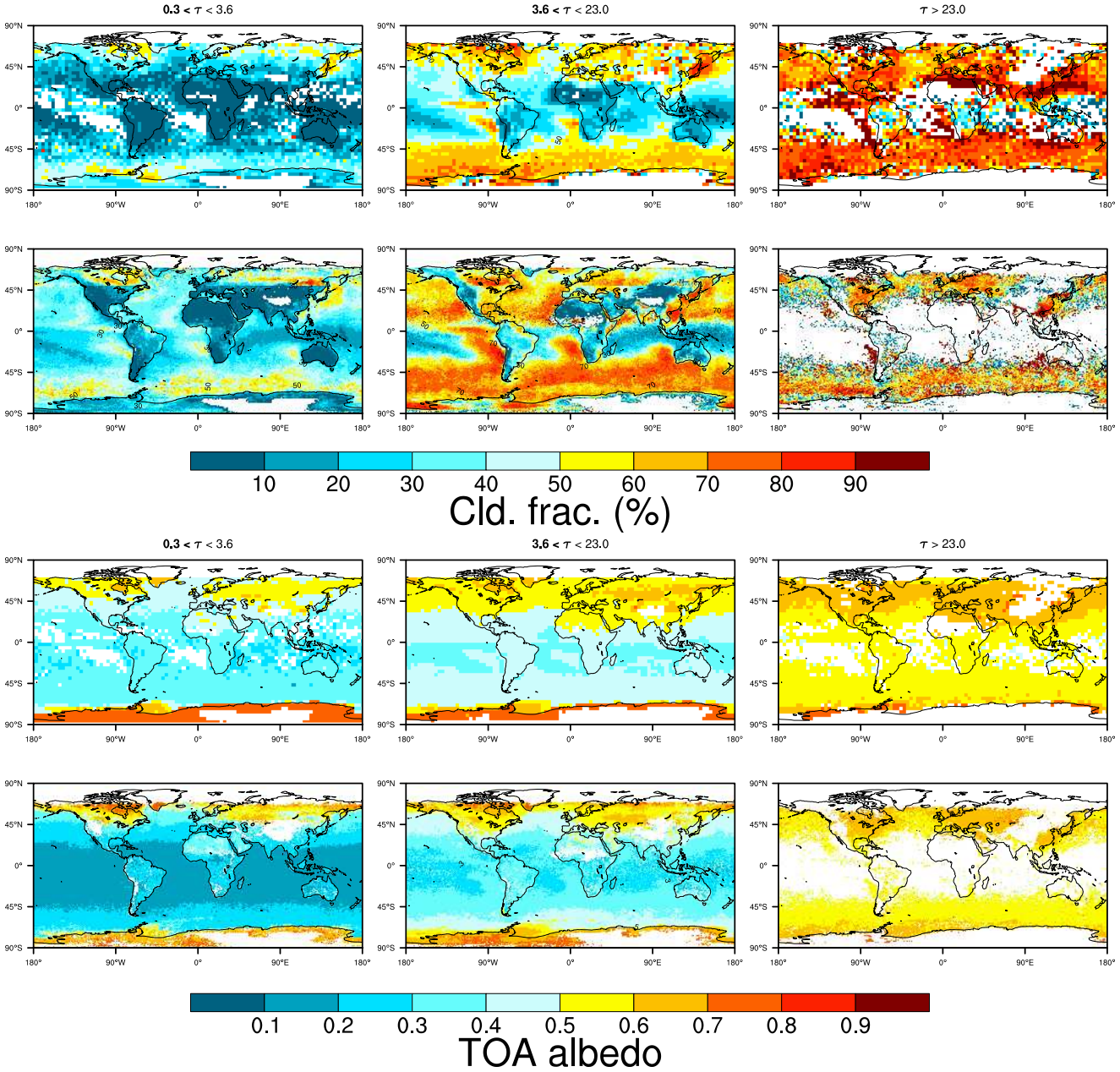


Zonal mean cloud fraction and TOA albedo (January)



Solid - CERES, Dashed - GCM

Low cloud cloud fraction and TOA albedo (January)



Summary

- Compared monthly anomalies of TOA fluxes
- Anomalies between cld. props. and CRE make sense
- Using compositing by dynamic state useful
- Properties for cloud-top exposed to space
  - Can diagnose within a GCM
  - Provides useful information
  - Zhang, 2005 paper (CRE versus cloud props)
- Include monthly surface fluxes
- Can refine the daily diagnostic, i.e., τ threshold
- Redo with T63 version of model (and other models)
- Compare diurnal cycle in GCM with obs.
- Cloud overlap in GCM
  - MRO $\Rightarrow$ decorrelation lengths
- CloudSat/CALIPSO simulator (combination of data)

The End