"Using A-Train observations to evaluate cloud occurrence and radiative effects of tropical clouds in the Community Atmosphere Model"

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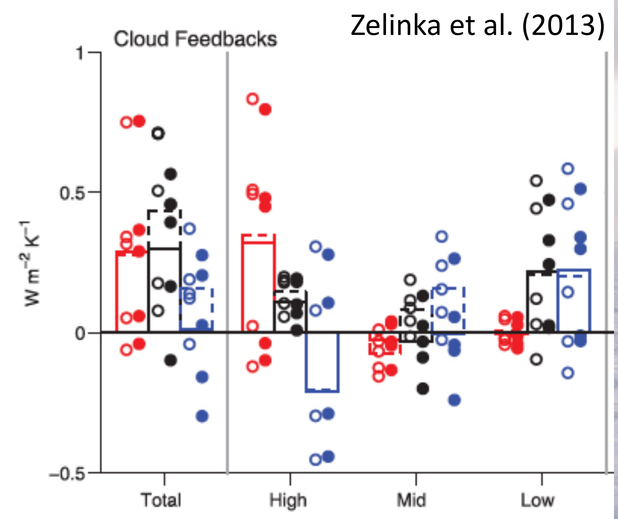
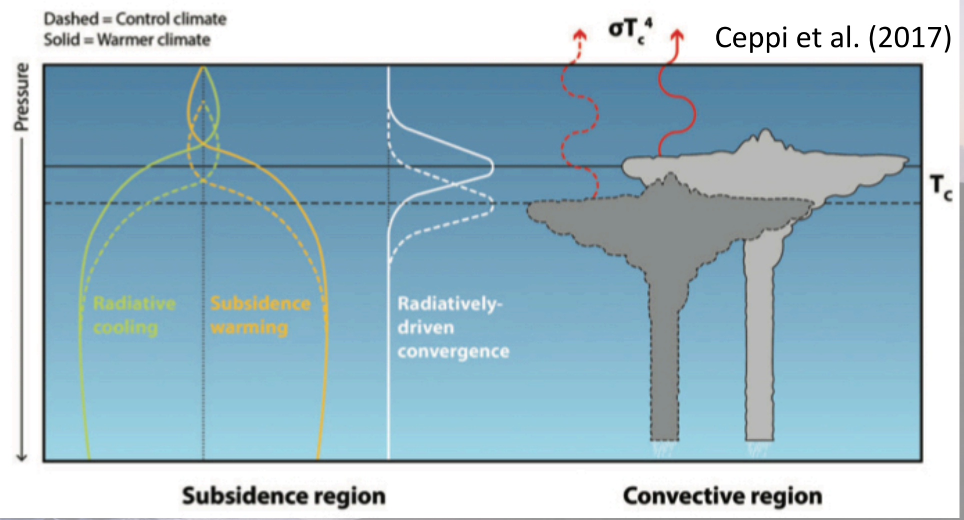
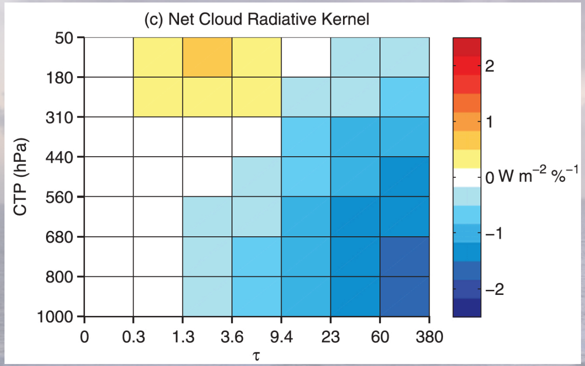
High Cloud Feedbacks



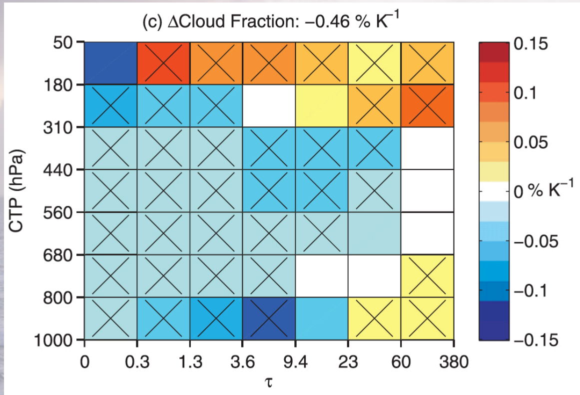


- Net cloud feedback for high clouds is positive and robust among models (Soden and Vecchi, 2011); although high clouds have the largest spread in shortwave and longwave feedbacks (Zelinka et al., 2013)
- "Proportionately Higher Anvil Temperature" (Zelinka and Hartmann, 2010) describes mechanism for the positive tropical high cloud feedback

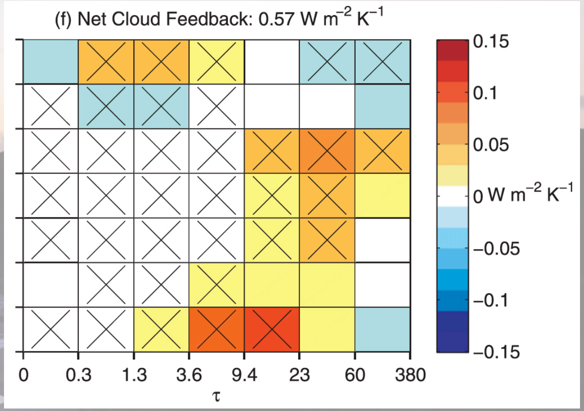
Cloud feedbacks by cloud type (Zelinka et al., 2012a)



Cloud Radiative Kernel (K) Sensitivity of TOA fluxes to perturbations in cloud fraction [$Wm^{-2}\%^{-1}$]



Change in cloud fraction, expressed as a joint function of cloud top pressure (CTP) and optical depth (τ)



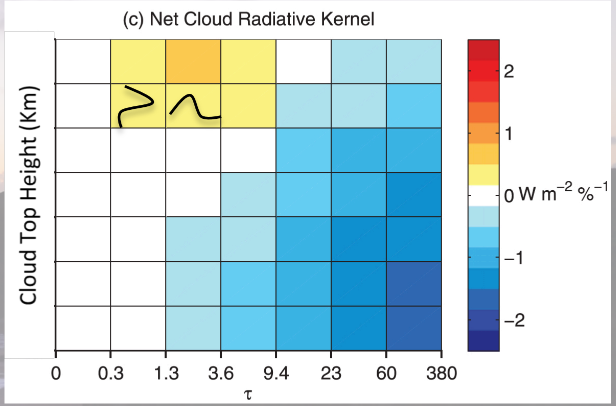
$$K\Delta C = \Delta R$$

Contribution of each cloud type to the change in TOA radiation associated with climate change

Feedback, $f = \frac{\Delta R}{\Delta T_s}$

Data-based Cloud Radiative Kernels

- Adapt this to methodology to create data-based kernels, derived from populations of observed and modeled single-layer clouds
- Use data-based kernels to compare observed clouds to modeled clouds
  - Present-day distribution of single-layer clouds (C)
  - The sensitivity of the TOA radiation to changes in cloud fraction (K)
  - Cloud forcing (R)



$$K * C = R$$

Focus on Southeast Asia [5S-25N,80-120E]
summer monsoon June-September 2007-2008

Data

CloudSat and CALIPSO (CC)

- Overpass time ~1:30a/p
- Footprint 1.4 x 1.7 km

Cloud layers identified from 2B-Geoprof-LIDAR CloudSat dataset

↓

Ice microphysics from 2C-ICE dataset; liquid from Z-tau/Z-LWP algorithm (Mace, 2010)

↓

T and Q from ECMWF-AUX CloudSat dataset

CAM5 2005-2008 climate run

- 3hrly output (sampled at overpass time)
- Grid box 1.9° x 2.5°

Apply downscaling to create subcolumns from grid box cloud fraction profile

↓

Model water content and size for all species (snow included)

↓

Model T and Q

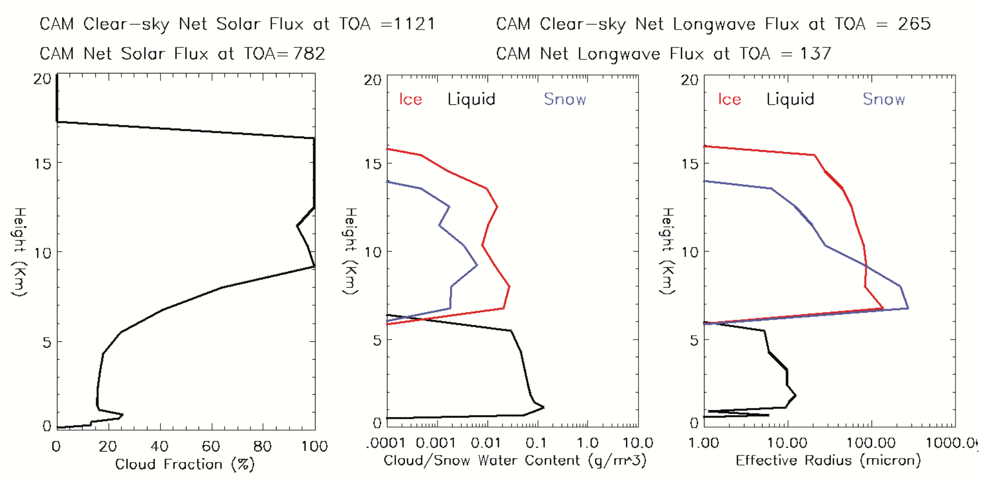
↓

Calculate radiative properties (ω, τ, g) using parameterizations for ice cloud (Fu 1996; Fu et al. 1998) and liquid cloud (Slingo 1989; Kiehl et al. 1998)

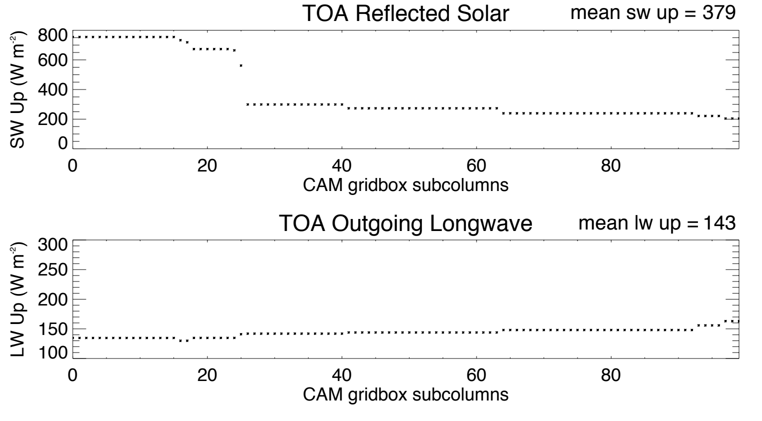
↓

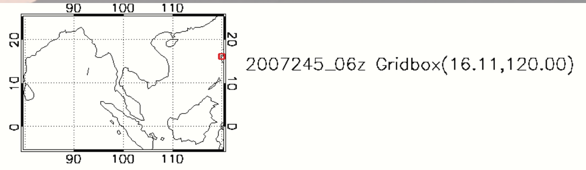
Run two-stream radiative transfer model that uses the k-distribution method and correlated-k assumptions (Toon et al. 1989; Kato et al., 2001; Mlawer et al. 1997)

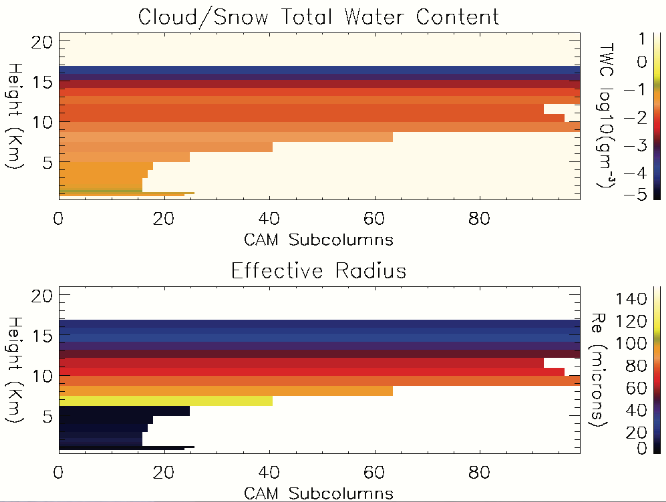
Methodology for CAM5



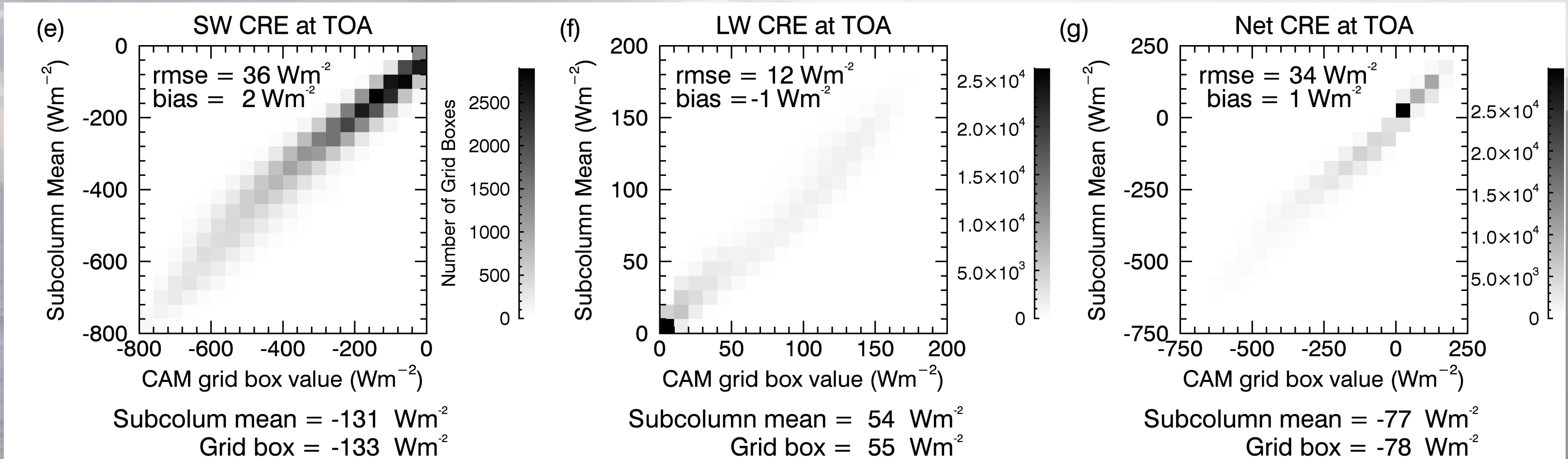
Maximum random overlap assumption (Jacob and Klein 1999) to create 100 subcolums within each grid box





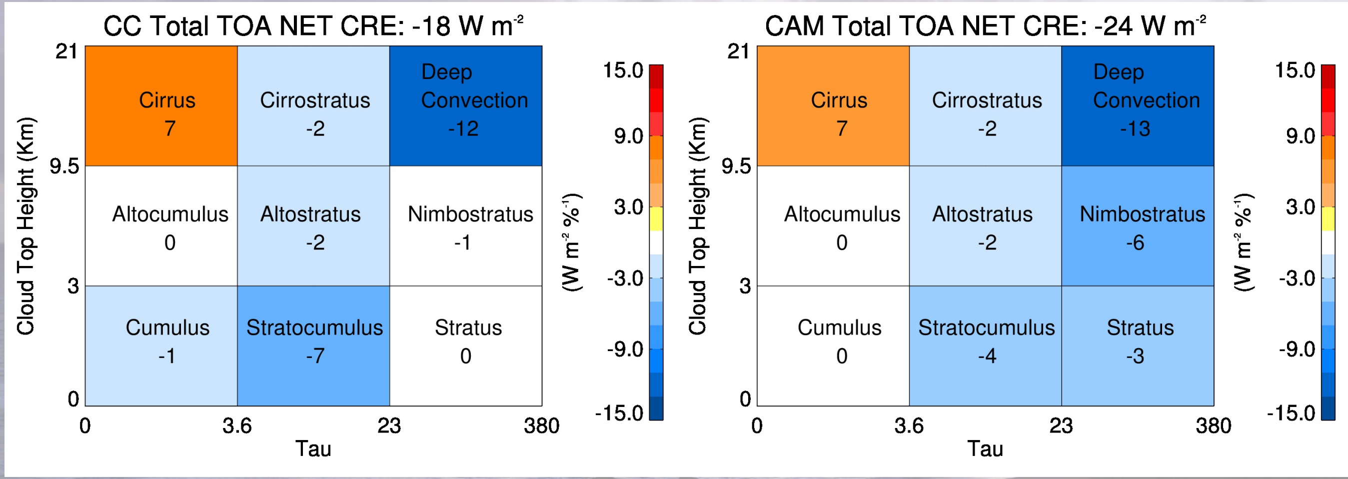


Comparison of calculated radiative fluxes for model subcolumns vs. CAM5 internally generated fluxes



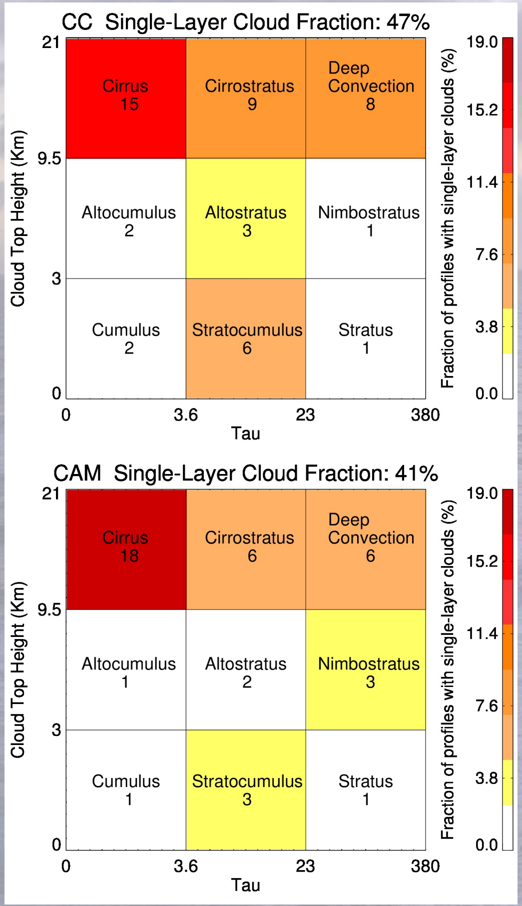
- Average the radiative fluxes for the 100 subcolumns within a grid box and compare that the grid box radiative fluxes from CAM5 output
- N=141,032 grid boxes
- Some scatter, but little bias in the SW, LW and net CRE

Cloud Radiative Effects (R=K*C)



- Very good agreement for the magnitude of the high cloud net CRE; warming by Cirrus; near neutral effects from Cirrostratus; strong cooling from Deep Convection
- Differences for more optically thick low clouds, particularly nimbostratus, but also Stratus and Stratocumulus.

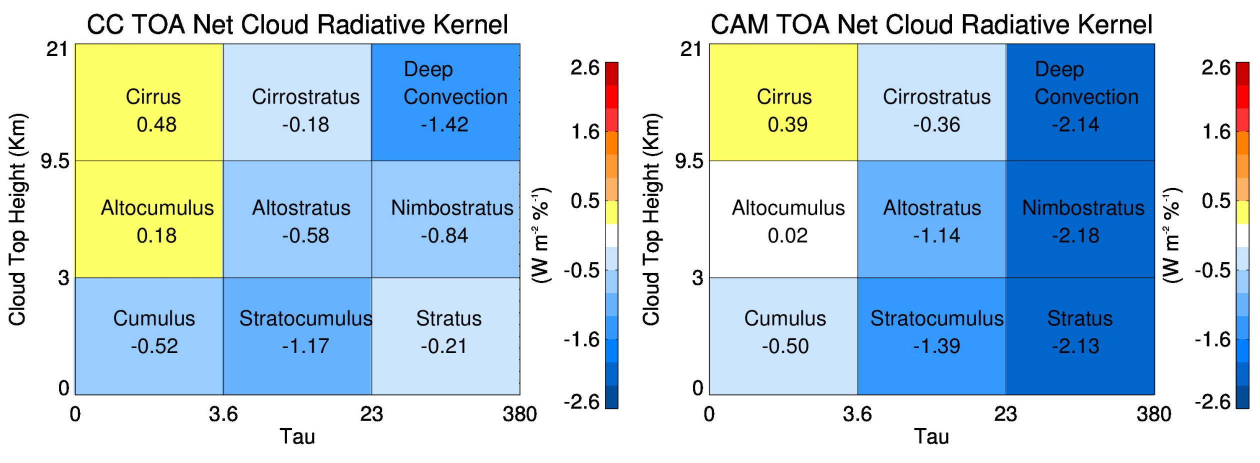
Single-layer Cloud Fraction Histogram (C)



- Cirrus+Cirrostratus single-layer cloud fraction is 24% for both CC and CAM5, however CAM5 tends to have more optically thin Cirrus.
- Stratocu are twice as common in the observations compared to the model. This explains the larger cooling (-7 Wm^{-2}) from CC stratocu compared to CAM5 (-4 Wm^{-2}).

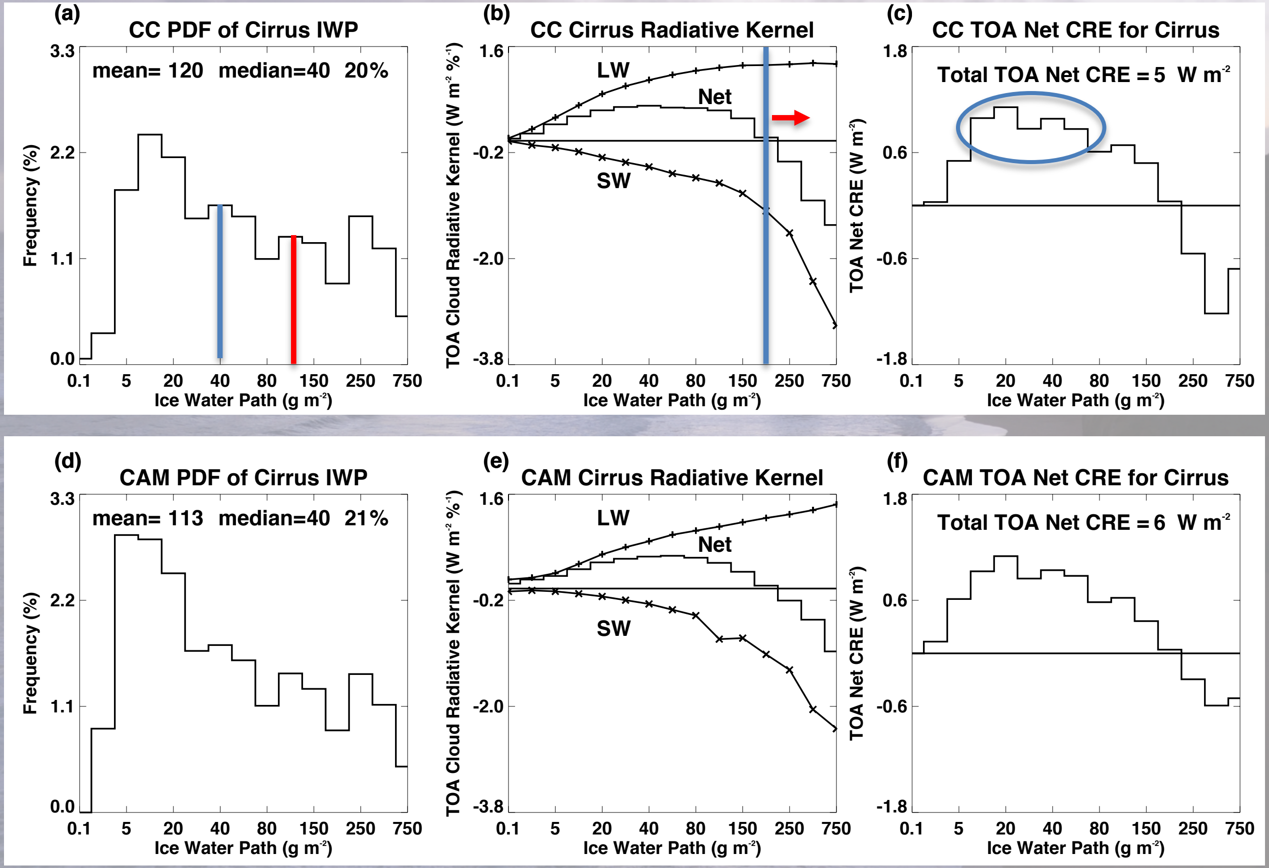
	CloudSat/CALIPSO Single-Layer	CAM5 Single-Layer
High	32%	30%
Middle	6%	6%
Low	9%	5%
Thin	19%	20%
Intermediate	18%	11%
Thick	10%	10%

Cloud Radiative Kernels (K) [$Wm^{-2}K^{-1}$]



- Warming by Cirrus; although CC longwave fluxes show stronger sensitivity to Cirrus
- Slight cooling by Cirrostratus; however CAM shortwave fluxes show stronger sensitivity to Cirrostratus
- These small differences in the kernel for Cirrus and Cirrostratus are compensated by differences in cloud fraction
- Largest differences for Nimbostratus and Stratus due to differences in diurnal cycle

Which cirrus contribute most to heating?



Conclusions

- Data-based kernels show that clouds in the model are heating and cooling like clouds observed by Cloudsat/CALIPSO
- Very good agreement in CRE for ice clouds: optically thin cirrus warm, cirrostratus cool slightly, cirrus layers with IWP ~ 20gm^{-2} contribute most to heating
- Compensating differences between cloud fraction and radiation kernel
  - more Cirrus with weaker warming in CAM5
  - less Cirrostratus with stronger cooling in CAM5

Berry, E., G.G. Mace, and A. Gettelman, "Using Atrain observations to evaluate cloud occurrence and radiative effects of monsoon region clouds in the Community Atmosphere Model," submitted to Journal of Climate