Statistical Comparison of CRM-Produced Year-Long Cloud and Radiation Properties with ARM Observations for Evaluating GCM Simulations

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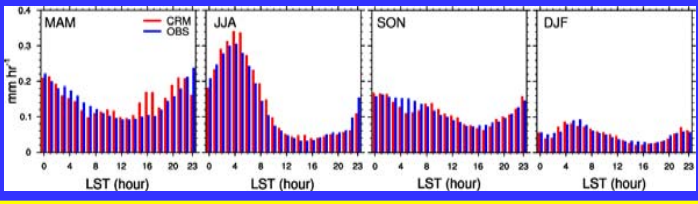
1.Introduction

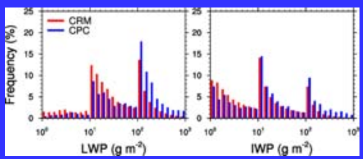
Cloud systems have long been recognized as an important factor in coupled general circulation model (GCM) simulations. However, the lack of observations of *long-term* (multi-year) cloud properties and radiative heating rates under different climate regimes is partly responsible for the slow progress in representing cloud and radiative processes in GCMs as noticed in all four IPCC assessment reports. Most GCMs have to tune ice and liquid water contents in order to maintain the global radiation budget closer to satellite observations. The goal of this project is to improve the simulation and understanding of cloud systems and their impacts on climate mean state and variability using the cloud-resolving model (CRM) and GCM that integrate observations. The ARM measurements at SGP and TWP sites provides a unique opportunity to performing multi-year CRM simulations. The objective of this poster is to compare CRM-simulated year-2000 cloud properties with ARM observational estimates and evaluate GCM-simulated radiative fluxes, heating rates and cloud water against the CRM simulation at the SGP site, which is a step towards constraining and improving the parameterization of subgrid-scale cloud and radiation processes in GCMs.

2. ISU CRM simulations vs. ARM observations

Diurnal variation of precipitation in four seasons: CRM and ARM show an early morning maximum rainfall and an afternoon minimum for summer (JJA) and winter (DJF), and a midnight maximum and an afternoon minimum for spring (MAM) and fall (SON) (Wu et al. 2008, JAS).

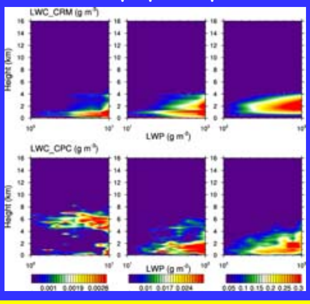


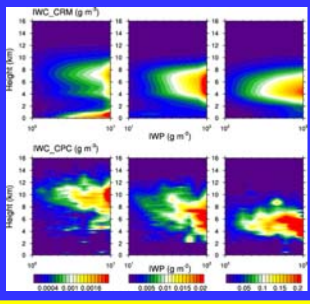
Frequency histograms of liquid and ice water paths (gm^{-2}) for non-precipitating clouds: CRM has less large size of LWP and IWP and more small and medium sizes of LWP than CPC.



Widths of bins are 100, 10 and 1 gm^{-2} for three sizes: large (100-1000 gm^{-2}), medium (10-100 gm^{-2}) and small (1-10 gm^{-2}), respectively. CPC: Column Physical Characterization product (Mace et al. 2006, JGR)

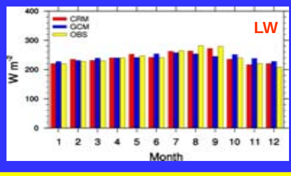
Vertical distribution of liquid and ice water contents (gm^{-3}) for non-precipitating clouds: CRM and CPC display similar peaks of liquid and ice water contents for all three sizes of IWP and LWP except a near-surface peak for small size of IWP in CRM and a mid-tropospheric peak for small size of LWP in CPC.

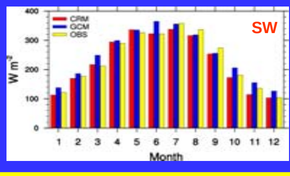




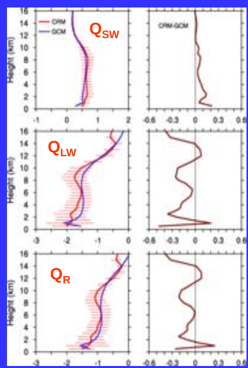
3. GCM simulations vs. CRM simulations

Seasonal variation of net longwave (LW) and shortwave (SW) radiative fluxes at the top of the atmosphere (TOA) over the ARM SGP site: CRM, GCM and ARM observations share similar evolution and amplitude.



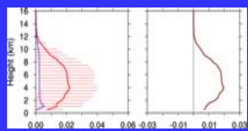


Annual mean profiles of daily radiative heating rates and cloud water:



Radiative heating rates (K day^{-1})

$Q_R = Q_{SW} + Q_{LW}$



Cloud water mixing ratio (g kg^{-1})

Large differences are identified in shortwave, longwave and total radiative heating rates between GCM and CRM under similar TOA radiative fluxes. Much smaller cloud (ice and liquid) water is produced in GCM compared to CRM. This result together with previous diagnostic and single-column model (SCM) studies suggest that the subgrid cloud distribution has to be included in the GCM radiation parameterization scheme in order to improve the heating rate and cloud properties.

4. Summary

* Year-2000 CRM simulation and ARM CPC product over the SGP demonstrate comparable statistics for non-precipitating clouds.
* Initial comparison between GCM and year-long CRM indicates a vastly different radiative heating and cloud profiles.
* GCM simulations that include the improved convection closure, trigger and subgrid cloud-radiation interaction are being conducted, as well as multiple-year CRM simulations.