Effects of Interactive Cloud Radiation on the Development of Tropical Convection

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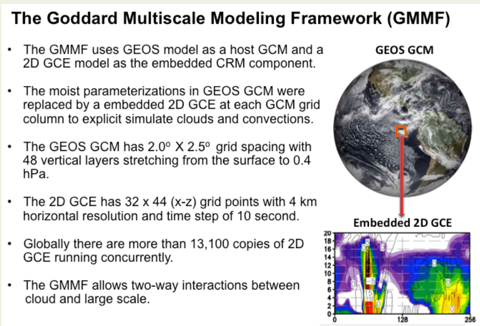
1.Overviews

Objectives: To examine the impacts of cloud-radiation interaction on to the maximum organization of tropical convection (MOTC) and extreme precipitation events (EPEs), and to better understand the dynamics of MOTC and potential predictability of EPEs.

Approaches:: Goddard MMF experiments with and without cloud-radiation feedback.



Experiment setup: Effects of cloud-radiation interaction are examined based on the differences between two 10-year (2007-2016) GMMF simulations with (Control) and without (NoCRF) cloud-radiation feedback.

Annual mean precipitation simulated by MMF

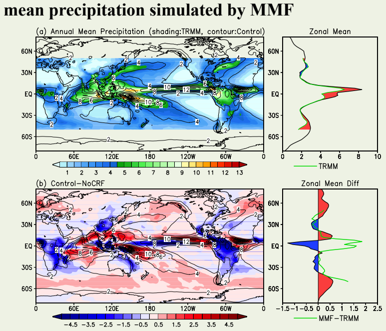


Figure 1. (a) Annual mean precipitation from TRMM 3B43 (shading) and MMF Control experiment (contour). (b) Precipitation difference between Control and NoCRF experiments.

2. Results: Impact of cloud-radiation interaction

Radiative Forcing and Balance

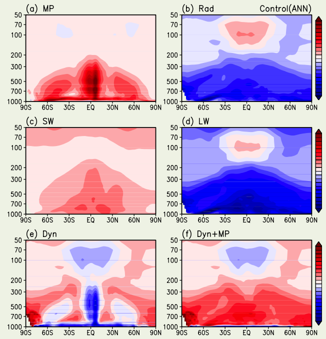


Figure 2. Zonal mean diabatic heatings (a-e) and dynamic heating (f) averaged over the 10-year perid simulated by MMF control experiments

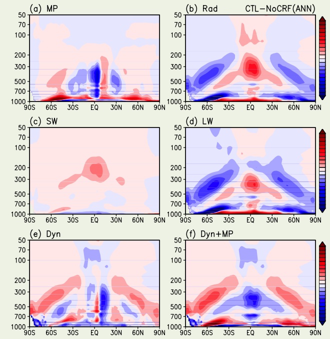


Figure 3. Same as Figure 2, but for the difference between Control and NoCRF experiments.

Dynamic Adjustment

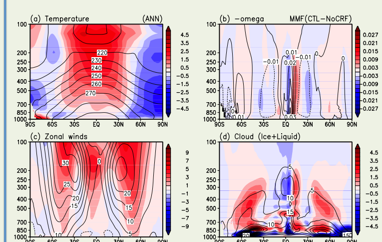


Figure 4. Impacts of cloud-radiation feedback on zonal mean (a) temperature, (b) pressure velocity, (c) zonal winds, and (d) cloud mixing ratio. Contour indicate mean values from the Control experiment.

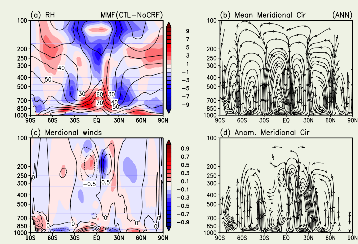
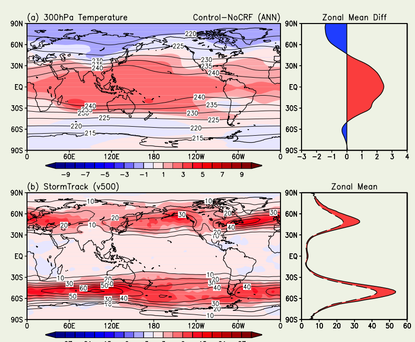


Figure 5. Impacts of cloud-radiation feedback on zonal mean (a) relative humidity, (c) meridional winds, and (d) meridional circulation. Climatological mean from the Control experiments are shown as contours on (a) and (c) and streamline on (b).

Impact on storm tracks

Figure 6. Impacts of cloud-radiation feedback on (a) 300hPa temperature and (b) storm track activity. Storm track activity is define as the variance of high-pass filtered meridional winds at 500hPa.



Impact of Cloud-Radiation Interaction on the Characteristics of MOTC

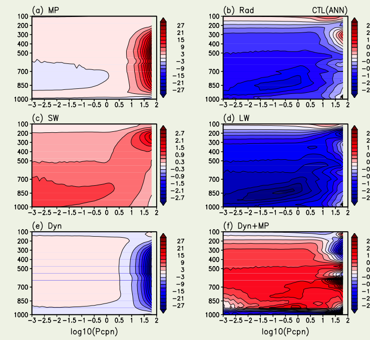


Figure 7. Zonal mean diabatic heatings (a-d) and dynamic heating (e) as a function of rain intensity, based on the Control experiment.

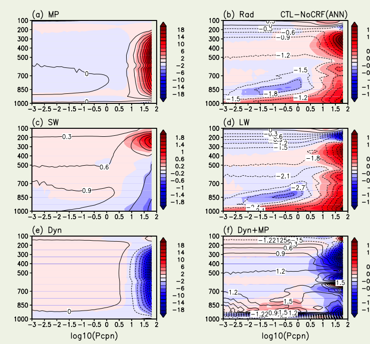


Figure 8. Same as Figure 7, but for the difference between Cotnrol and NoCRF.

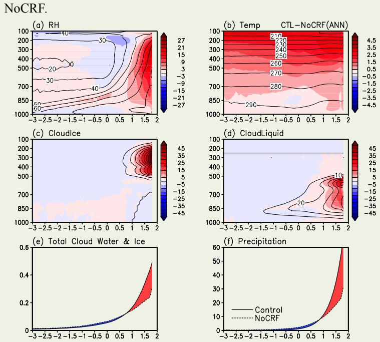


Figure 8. Simulated differences in (a) relative humidity, (b) temperature, (c) cloud ice, (d) cloud liquid mixing ratio, (e) total cloud watr and ice, and (f) precipitation.

3. Summary

Impacts of cloud radiation feedback (CRF) on organization of tropical convection, and large-scale circulation on climatic time scales are examined by conducting two sets of 10-year simulations using the Goddard MMF (GMMF), with (Control) and without CRF (NoCRF) with prescribed SST from 2007-2016. Changes in clouds, precipitation and circulation, heating due to moist physics, shortwave and longwave radiation, and dynamical tendency are examined based on the differences between Control and NoCRF experiments. Preliminary results show that:

- CRF improves the simulation mean precipitation distribution, reducing excessive equatorial precipitation in GMMC.
- CRF warm mid- to upper-tropospheric temperature, shifts deep convection to the warmer hemisphere (NH), increases equator-to-pole temperature gradient, and enhances mid-latitude storm tracks.
- Both SW and LW contribute to warming of the tropical troposphere, while LW cooling dominates in the subtropics and extratropics above clouds.
- Anomalous heating by deep convection in the tropics is strongly balanced by dynamics (adiabatic cooling) in the tropics, while anomalous LW cooling in the extratropics balances the heating due to increased poleward heat transport by the enhanced extratropical storm track.
- In the tropics the overall effect of CRF is to enhance heating by SW and LW in regions of heavy precipitation, and increase LW cooling in drier, less cloudy regions, increasing the heat contrast between wet and dry regions.

Roles of CRF in affecting organization of tropical convection on intraseasonal time scales will be explored.