Evaluate the Diurnal Cycle in the Multiscale Modeling Framework Using Satellite and ARM Data

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Research Highlight

Processes of convection and clouds are usually parameterized in traditional general circulation models (GCMs), which contribute to uncertainties in predicting climate. Recently the Multiscale Modeling Framework (MMF), also called ``superparameterization'', was proposed to resolve these processes at their native scales by embedding a cloud resolving model (CRM) at each grid column of a GCM. Using a "model-to-satellite" approach, we evaluated diurnal cycles of deep convection, high-level clouds and upper troposphere relative humidity in MMF. Specifically, we applied an infrared (IR) brightness temperature and a precipitation radar (PR) reflectivity simulator to the MMF CRM column data to measure cloud condensates and precipitation, respectively. Simulator results were then compared with IR radiances from Geostationary satellites and PR reflectivities from the Tropical Rainfall Measurement Mission (TRMM).

While the actual surface precipitation rate in the MMF has a reasonable diurnal phase and amplitude when compared with TRMM observations, the IR simulator results indicate an inconsistency in the diurnal anomalies of high-level clouds between the model and the Geostationary satellite data.

Primarily due to its excessive high-level clouds, the MMF overestimates the simulated precipitation index (PI, an indicator for deep convection) and fails to reproduce the observed diurnal cycle phase relationships among PI, high-level clouds, and upper troposphere relative humidity (Figure 1). The PR simulator results show that over the tropical oceans, the occurrence fraction of reflectivity in excess of 20 dBZ is almost one order of magnitude larger than the TRMM data at altitudes above 6 km (Figure 2). Both results suggest that the MMF oceanic convection is overactive. Furthermore, the joint distribution of simulated IR brightness temperature and PR reflectivity indicates that the most intense deep convection is found more often over tropical land than ocean, in agreement with previous observational studies.

We will further evaluate MMF using long-term observations at the ARM Climate Research Facility (ACRF) Southern Great Plains (SGP) site. Available ARM data are categorized into different cases based on diurnal cycles of precipitation and clouds. By so doing, we try to improve our understanding on conditions and processes responsible for occurrence of shallow cumulus, and transition from shallow to deep convection. Such knowledge from observations will later be applied to the evaluation on CRM simulations with three-year ARM continuous forcing at SGP to distinguish model deficiencies and further feedback on both CRM and MMF development.

Reference(s)

Zhang, Y, SA Klein, C Liu, B Tian, RT Marchand, JM Haynes, RB McCoy, Y Zhang, and TP Ackerman. 2008. "On the diurnal cycle of deep convection, high-level cloud, and upper troposphere water vapor

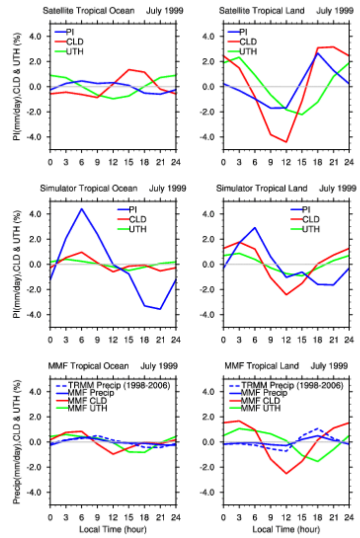

Figure 1: Diurnal anomalies for tropical (left) ocean and (right) land: (top) the precipitation index (PI), high-level cloud (CLD) and upper troposphere relative humidity (UTH) based on Geostationary satellite data; (middle) PI, CLD, and UTH from the IR simulator applied to the MMF; (bottom) the MMF actual surface precipitation rate, CLD, and UTH calculated without a simulator. TRMM surface precipitation rates are also shown (blue dashed lines in bottom).

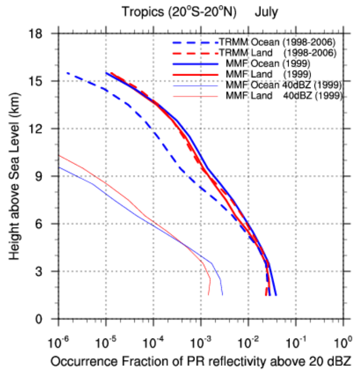

Figure 2: The occurrence fraction of precipitation radar (PR) reflectivity >= 20 dBZ in July in tropics. Blue (red) lines are for tropical ocean (land). Solid lines are from the PR simulator applied to the MMF. Dashed lines are from the TRMM PR data in July averaged over the years 1998 to 2006. The MMF 40-dBZ or greater occurrence fractions are shown in thin lines. Note that the X-axis is in logarithmic scale.

Office of Science
U.S. DEPARTMENT OF ENERGY

in the Multiscale Modeling Framework." J. Geophys. Res., 113, D16105, doi:10.1029/2008JD009905.

Working Group(s)
Cloud Modeling