A Comparison of Simulated Hydrometeor Occurrence Profiles from the Multiscale Modeling Framework (MMF) with ARM observations as a Function of the Large-Scale Atmospheric State

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Introduction

Over the last few years a new type of global climate model (GCM) has emerged in which a two-dimensional or small three-dimensional cloud-resolving model (CRM) is embedded into each grid of a GCM. The embedded CRM removes the need for most of the cloud parameterizations used in traditional GCMs. This new approach is frequently called a Multiscale Modeling Framework (MMF).

Here we present a comparison of output from the MMF model of Khairoutdinov and Randall with ARM ground-based radar profiles of hydrometeor occurrence (that is, the relative frequency that clouds or other hydrometeors, such as rain or snow, are detected by a cloud-radar at a given altitude above ground level).

MMF profiles of hydrometeor occurrence are obtained using a radar simulator (Haynes et al. 2007).

Profiles are shown as a function of atmospheric state, where the atmospheric states are determined using a neural network clustering algorithm on the large scale temperature, pressure, relative humidity and winds fields (Marchand et al. 2006).

The atmospheric state associated with the ARM observations is determined using numerical weather prediction analysis from the Rapid Update Cycle (RUC) model.

Conclusions

- For cold frontal and post-cold frontal conditions (states 5 and 6), the MMF produces profiles of cloud occurrence that compare favorably with radar observations (using either a -40 dBZe or -25 dBZe threshold). There is some indication that low-level (less than 3 km) hydrometeor fractions in post-cold-frontal conditions may be over predicted.
- For warm frontal conditions (as represented by states 1 and 3), the MMF tends to produce hydrometeor fractions that are too large. Below 7 km this is true using either a -40 or -25 dBZe reflectivity threshold.
- The MMF does not appear to correctly capture the formation of a low cloud in those states where low-level moisture is being advected from the Gulf of Mexico over the ARM site (states 2 and 12).
- In several states, including the four states which occur during June, July, and August (states 9, 10, 11 and 12), the MMF produces too much high and thin cloud, especially above 10 km. This result appears to be a common feature of the model in convective regimes.
- The percentage of time each state occupies in the RUC analysis and MMF output is shown at the top of each panel in the figures to the right. It is encouraging that the percentages are similar for most states. A statistical hypothesis test (e.g. based on a moving blocks bootstrap resampling approach) could be designed to assess to what degree these differences are significant. States 5 and 9, however, have rather large percentage differences that are almost certainly significant. State 9, the atmospheric state with the hottest surface temperatures, is particularly troubling in that state occurs about 23% of the time in the MMF compared with about 11% of the time in the RUC analysis. Investigating possible causes of this large difference will be one focus of future research.

Future Work

- In the near future we hope to investigate running SAM (the cloud resolving model in the MMF) using the atmospheric states - or more precisely using composite forcing conditions constructed from the MMF output. If running SAM with such composites is able to reproduce the MMF occurrence profiles, then the atmospheric states can likely be used as test-beds to further understand and correct the model shortcomings shown here.

In the above plots, observations (RUC+ARM) are shown in blue while MMF-simulated output is in red. The label at the top of each subplot shows the percentage of time occupied by each state, along with the p-value from the global similarity hypothesis test (Marchand et al. 2006). The thin black line on the right side of each sub-panel indicates what levels have a sufficient number of samples to make a robust comparison. Individual altitudes where the profiles do not appear to be different at the 95% level of confidence are marked with an asterisk.

Comparison of occurrence profiles

-40 dBZe threshold

- Comparison of occurrence profiles

-25 dBZe threshold