ARM Summer Training and Science Applications

Using Large-Eddy Simulations of Cloud and Boundary Layer Processes to Test Modeling Factors Report

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1.0 Using Large-Eddy Simulations of Cloud and Boundary Layer Processes to Test Modeling Factors

Large-eddy simulations (LES) of cloud and boundary layer processes provide a convenient way to test model sensitivities, relationships between simulated fields, and hypothetical observational strategies.

We tested the ability of different domain sizes and resolutions to simulate cloud properties on a case from the Rain in Cumulus over the Ocean (RICO) field campaign. Horizontally averaged cloud properties such as cloud base and cloud top height showed similar values across the different size domains. However, the temporal variability in the simulated cloud fraction was much greater for the smallest domains (1.9 km in each horizontal dimension); a 7.7 km domain had much lower variability in the cloud fraction, suggesting a reasonably homogeneous cloud field was produced.

Using these results, we simulated the same RICO case with a large (~50x50 km2) domain and a 25 m horizontal grid spacing. The three dimensional model output for this case showed a high potential to find relations of cloud properties. The volume and mass of individual clouds indicate the available energy for cloud growth and can be related to the lifecycle of cloud or precipitation properties. For example, the dependency of the cloud overlap ratio to the thickness of clouds was illustrated; this relationship could help future researchers understand cloud radiative feedbacks.

To test the variability of the cloud field captured by a Ceilometer, we sampled the cloud fraction from the LES model outputs for RICO using a simple forward model. The synthetic ceilometer was placed at 10,000 random locations within the model domain, giving 10,000 synthetic observations of cloud-fraction time series. The mean cloud fraction resulting from this experiment converges to the domain mean cloud fraction relatively quickly; substantial variance remains even at the end of the 3-hr sampling period.

Finally, we performed model simulations of a dry-convective case. The initial conditions were derived from atmospheric profile observations, surface fluxes, and large-scale tendencies from global weather model analyses. The model was able to capture the boundary layer height and its growth reasonably well in comparison to the observations. We found that initializing the large-scale tendencies in the model was essential in reproducing the observations. We found the largest model uncertainty n the entrainment layer, indicating the importance of microphysical processes in this layer.

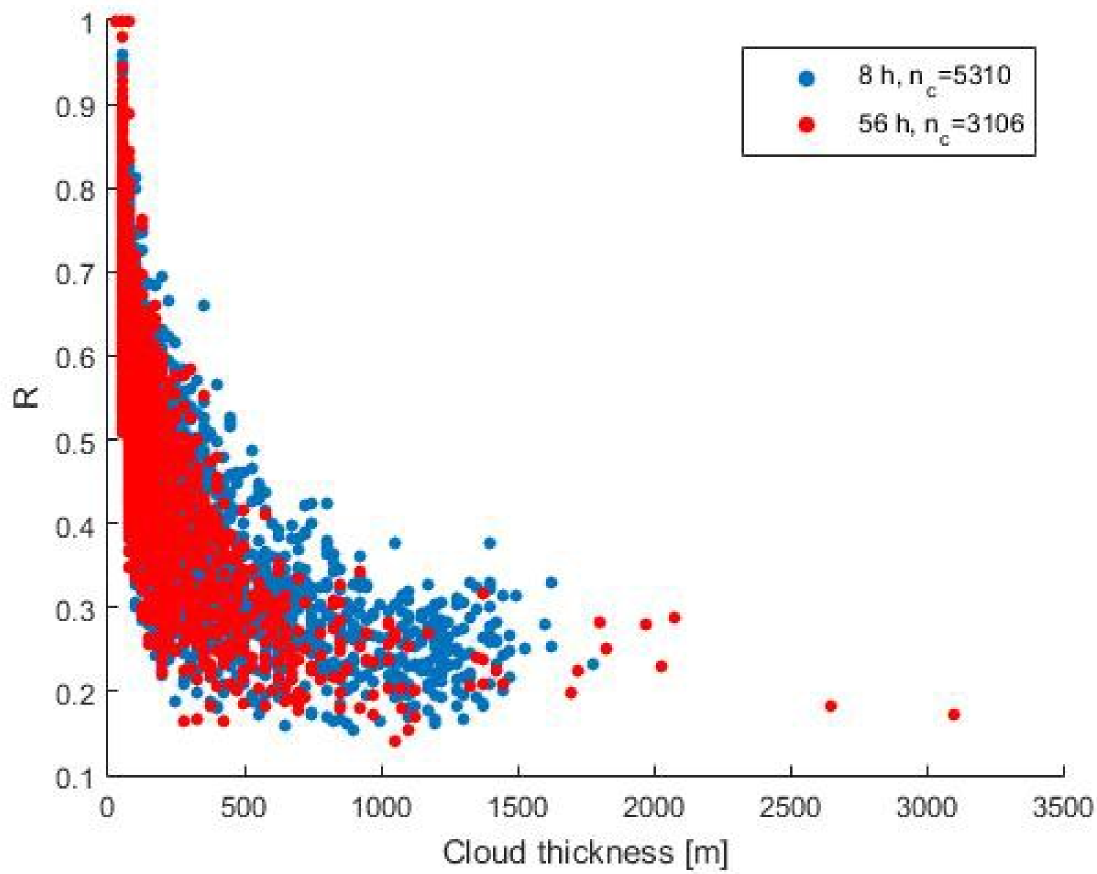

Figure 1. Scatter plot of simulated cloud overlap ratio vs. cloud thickness for (blue) 8 hours after model initialization and (red) 56 hours after model initialization. This simulation was performed using the UCLA Large-Eddy Simulation code.