Statistical analyses of satellite cloud object data from CERES: Comparison with cloud-resolving model simulations of tropical convective clouds

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The present study attempts to evaluate the ability of a cloud-resolving model (CRM), that is currently being implemented into a multi-scale modeling framework, to simulate the physical properties of tropical deep convective cloud objects identified from a Clouds and the Earth's Radiant Energy System (CERES) data product. The emphasis of this study is the comparisons among the small-, medium- and large-size categories of cloud objects observed during March 1998 (strong El Niño) and the large-size category of cloud objects observed during March 2000 (weak La Niña). Results from the CRM simulations are analyzed in a way that is consistent with the CERES retrieval algorithm and matches with the average scale of the CERES satellite footprints. Cloud physical properties are analyzed in terms of their summary histograms for each category.

Summary histograms of cloud optical depth and top-of-the-atmosphere (TOA) albedo from the CRM simulations of the large-size category of cloud objects do not differ significantly between the March 1998 and 2000 periods, consistent with the CERES observations. However, the CRM is unable to reproduce the significant differences in the observed cloud top height while overestimates the moderate differences in the observed outgoing longwave radiation and cloud top temperature between the two periods. Comparisons between the CRM results and the observations for most parameters in March 1998 show the same consistent larger differences between the large- and small-size categories than between the large- and medium-size, or between the medium- and small-size categories. However, the simulated cloud properties do not change as much with size as observed. In addition, each cloud physical property produced by the CRM exhibits different degrees of disagreement with observations over different ranges of the property, although there are some agreements between the simulations and observations. The simulated cloud tops are generally too high with temperatures that are too low except for the large-size category of March 1998. The probability densities of the simulated TOA albedos for all four categories are underestimated for high albedos, while those of cloud optical depth are overestimated at its lowest bin.

Possible reasons for these disagreements are related to the uncertainties associated with the CRM simulations, such as the spatially averaged forcing data, the one-moment bulk microphysics parameterization, and the empirically determined effective size of ice crystals and application of the independent column approximation for radiation calculation.