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Tropical Precipitation Responses to Surface Warming in a CRM

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This work is part of a larger effort to elucidate the response of convective-scale characteristics of a modeled tropical atmosphere to surface warming. A large-domain (10 000 km x 180 km) cloud-resolving model (CRM) with explicit, though moderate, resolution of convection (2.4 km) is run in radiative convective equilibrium for a long time integration (55 days). This combination of high resolution and long integration will be used to assess cloud climatologies. The model utilized is the Regional Atmospheric Modeling System (RAMS). Sensitivity to surface warming is assessed through the use of fixed sea surface temperatures of 298 K, 300 K, and 302 K (termed SST298, CONTROL, and SST302, respectively). Several results common to general circulation model climate warming scenario integrations are found: rain rate is found to increase less than total precipitable water; sensible heat fluxes decrease; clear-sky longwave cooling increases. However, results differing from general circulation model integrations are also found. Included among them are an increase in relative humidity and a cooling of deep convective anvil emission temperature.

The work to be presented will focus on precipitation in this high-resolution model as there are many reasons to be skeptical about the simulation of rain in general circulation models. An examination of precipitation rates binned by percentile of precipitation rate is conducted. It is found that while at most percentiles rain rates are actually less in SST302, at the highest percentiles, rain rates are higher. The partitioning between rain and drizzle and how this changes with surface temperature will be discussed. The model results indicate a shift in drizzle away from simulated boundary layer cumulus overlain by clear sky to one in which drizzle is produced by shallow or congestus cumulus at the edges of deep convection. Rain is seen to shift in the way predicted by saturation-fraction theory. The mechanisms contributing to the shifts in rain accumulation and rain rate are examined through the use of probability density functions of the components of the column-total moist static energy. From this analysis, clouds will be suggested to modulate column energy in a nonlinear way with respect to surface warming.

While general circulation models are likely to accurately represent the mean of many of these effects, we suggest that the kinds of statistical distributions of quantities examined in this work are unlikely to be simulated well in general circulation models. As such, we argue that the results of this experiment contribute uniquely to our understanding of earth system responses to surface warming.