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Tropical Convection as a source of Uncertainty in Global Climate Models

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This research seeks to understand the influence of convection on the climate state. The indirect representation of convection through parameterizations introduces biases and errors to the model. This is well known but not well quantified. Of particular importance is the precipitation efficiency that different clouds have in various atmospheric conditions. Precipitation efficiency strongly influences the balance of energy in the system as well as the amount of precipitation that reaches the surface. Mixing of cloudy air with the surrounding air as well as the small scale processes that generate water droplets and ice within the cloud both affect precipitation efficiency. This complexity has made quantification of changes and impacts that are related to precipitation efficiency difficult.

We employ a systematic approach to understanding how convection is modeled over a broad range of scales and domain sizes. The equilibrium state between convection and radiation is examined in an attempt to isolate the critical processes of convection. By comparing experiments with the convection parameterized to experiments that use no convective parameterization we can determine some of the biases that are present in many models. We also compare experiments that use different methods of convective parameterization. Specifically, we look at changes to the entrainment rate and to the microphysics. We explore how the spatial organization of convection influences the climate sensitivity to changes in surface temperatures. The climate sensitivity is thought to be connected to the precipitation efficiency. Results from radiative convective equilibrium experiments across a wide range of spatial scales demonstrate some important elements of the variability of convection.

It is well known that clouds represent the primary source of uncertainty in Earth system modeling. The large uncertainty of cloud effects results from their statistical behavior at the smallest scales and the nonlinearity of cloud dynamics. Therefore simply examining one experiment is not sufficient. Part of this uncertainty in the system is dealt with by looking at clouds which are in a state of statistical equilibrium and part of it is dealt with by looking at many similar scenarios. Because it is not obvious how best to model convection we have chosen to look at several different grid resolutions and several different methods of parameterizing convection. Our research also addresses the possible relevance of the simplifying assumptions we have made. The combined results of these experiments provide some estimate or representation of the inherent variability of tropical convection.