Forcing Mechanisms for Tropical Rainfall in GCMs

a proposal by
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Abstract

Biases, or errors in the simulated climatologies of general circulation models (GCMs), lead to error in dynamical seasonal to interannual climate prediction and in assessment of future climate change. Most present-day coupled GCMs have particularly large biases in tropical rainfall. While the biases in uncoupled atmospheric GCMs are smaller, they are still significant, and often resemble the coupled biases enough to suggest that the atmospheric bias is the root, or at least a major part of the coupled problem. Ameliorating the biases in the atmospheric components of CGCMs is thus an essential prerequisite step for improving simulation and prediction of interannual variability and climate change.

The deficiencies in GCMs simulations are a reflection of deficiencies in our understanding of the forcing mechanism for tropical rainfall. Observations show that a rainfall maximum is always accompanied by a maximum in surface convergence, but the reverse is not true. Surface air that converges just south of the equator in the East Pacific can be vented out of the boundary layer by a shallow, non-precipitating circulation, rather than by deep ascent associated with precipitating convection. Observations also show that warm SST is necessary for rainfall, but a warm pool such as the Caribbean Sea can be quite dry. Both dynamical (surface convergence) and thermodynamical (SST) forcings are important in nature, but we lack an understanding of their relative importance, and how this balance can change from basin to basin.

We propose to investigate the relative importance of dynamic and thermodynamic forcings over the global tropics in a set of GCMs that present opposite behaviors with respect to precipitation biases. We will conduct (i) a detailed diagnostic analysis of the statistical relationship between rainfall and its environment, (ii) a momentum budget analysis that distinguishes between SST-induced (à la Lindzen-Nigam) and tropospheric-heat-induced (à la Gill) boundary layer convergence, (iii) a moist static energy (MSE) budget analysis that distinguishes between the role of local forcings (i.e. vertical heat and moisture fluxes) and the role of boundary-driven shallow circulation (i.e. lateral advection of MSE) in forcing the deep ascent in the ITCZ.

Finally, we will complement our diagnostic analysis with idealized GCM experiments that aim at testing the hypothesis that arise from the above analyses (i) on the origin of biases and (ii) on the characteristics of the SST field that determine the relative importance of thermodynamic and dynamic forcings.