

Simulation of the Asian Monsoon in a Super-parameterized AOGCM

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Climate simulations using a multi-scale modeling framework (MMF), or “super-parameterization” may offer new insights into the role of convection, air-sea coupling, and equatorially-trapped waves on the simulation of the Asian monsoon system. In this study, we compare the monsoon simulation in the Community Climate System Model (CCSM, v3.0), which uses a traditional cumulus parameterization, to super-parameterized coupled and uncoupled versions of CCSM, in which the traditionally parameterized effects of cumulus convection are explicitly simulated with multiple realizations of a cloud resolving model. The atmosphere-only super-parameterized model is referred to as SP-CAM, and the fully coupled super-parameterized model is SP-CCSM. The traditionally-parameterized CCSM simulates a very weak monsoon. The monsoon in SP-CAM is more robust, with improved simulation of the eastward- and westward-propagating components, but the variability is too high. SP-CCSM offers the best simulation of the monsoon, including the signature NW-SE tilted rainband structure that arises from the combined eastward- and northward-propagating components of the monsoon.

We focus on the role of the $n=1$ equatorial Rossby (ER) and mixed Rossby-gravity (MRG) waves in the northward-propagating component of monsoonal precipitation. In observations, Indian Ocean ER and MRG waves both contribute to northwestward (NW)-propagating monsoon precipitation, with an MRG/ER variance ratio of $0.4 \sim 0.8$. Similar behavior is observed in SP-CCSM but not in SP-CAM or CCSM, where individual MRG waves propagate southwestward (SW).

Comparison of each model’s basic state climate and high-frequency wave activity lead us to conclude that successful simulation of the Asian monsoon depends on a model’s ability to simulate a realistic basic state climate, as well as a variety of wave types, especially ER and MRG waves. Explicitly simulating convection is important for increasing variability, but convection only organizes into modes similar to those seen in nature when the resulting waves propagate through a realistic basic state atmosphere.