Systematic model errors in Asian-Australian monsoon precipitation climatology: process-based diagnostics to identify error sources

H. Annamalai

IPRC/Department of Oceanography, University of Hawaii, USA

In climate models, simulating the monsoon precipitation climatology remains a grand challenge. Compared to CMIP3, the multi-model-mean (MMM) errors for the Asian-Australian-Monsoon (AAM) precipitation climatology in CMIP5, relative to GPCP observations, have shown little improvement. One of the implications is that uncertainties in the future projections of time-mean changes to monsoon rainfall may not have reduced from CMIP3 to CMIP5. Despite dedicated efforts by the modeling community, the progress in monsoon modeling is rather slow. This leads us to wonder if there are fundamental limits to realistically simulating the AAM monsoon?

The model errors persist, partly due to our lack of understanding the interactive dynamic and thermodynamic processes that shape monsoon precipitation climatology. We hypothesize that these processes are non-local. A conceptual model of mean monsoon is proposed and a suite of physically based diagnostics has been applied to available observations and a suite of reanalysis products to identify dominant processes that lead to organization of large-scale monsoon convection. Then, we examine if these processes are faithfully represented in models. Diagnostics include sensitivity of observed precipitation to SST, column relative humidity, and low-level versus free-troposphere moisture. Then, vertically integrated moist static energy (MSE) budget diagnostics are performed to quantify various processes that anchor moist convection. Specifically, feedbacks among moisture-convection and cloud-radiations are identified. Finally, models' skill in representing boundary-layer quasi-equilibrium hypothesis for moist convection over open oceans is examined.

From a suite of process-based diagnostics, a set of metrics is presented to evaluate climate models' fidelity in representing AAM precipitation climatology. Our results provide pathways for model improvement and make a case for the need of high-quality direct observations of thermodynamic variables to constrain model physics.