The general circulation model precipitation bias over the southwestern equatorial Indian Ocean and its implications for simulating the South Asian monsoon

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Abstract

Most of current general circulation models (GCMs) show a remarkable positive precipitation bias over the southwestern equatorial Indian Ocean

(SWEIO), which can be thought of as a westward expansion of the simulated IO convergence zone toward the coast of Africa. The bias is common to both coupled and uncoupled models, suggesting that its origin does not stem from the way boundary conditions are specified. The spatio-temporal evolution of the precipitation and associated three-dimensional atmospheric circulation biases is comprehensively characterized by comparing the GFDL AM3 atmospheric model to observations. It is shown that the oceanic bias, which develops in spring and reduces during the monsoon season, is associated to a consistent precipitation and circulation anomalous pattern over the whole Indian region. In the vertical, the areas are linked by an anomalous Hadley-type meridional circulation, whose northern branch subsides over northeastern India significantly affecting the monsoon evolution (e.g., delaying its onset). This study makes the case that the precipitation bias over the SWEIO is forced by the model excess response to the local meridional sea surface temperature (SST) gradient through enhanced near-surface meridional wind convergence. This is suggested by observational evidence and supported by AM3 sensitivity experiments. The latter show that relaxing the magnitude of the meridional SST gradient in the SWEIO can lead to a significant reduction of both local and large-scale precipitation and circulation biases. The ability of local anomalies over the SWEIO to force a large-scale remote response to the north is further supported by numerical experiments with the GFDL spectral dry dynamical core model. By imposing a realistic anomalous heating source over the SWEIO the model is able to reproduce the main dynamical features of the AM3 bias. These results indicate that improved GCM simulations of the South Asian summer monsoon could be achieved by reducing the springtime model bias over the SWEIO. Deficiencies in the atmospheric model, and in particular in the convective parameterization, are suggested to play a key role. Finally, the important mechanism controlling the simulated precipitation distribution over South Asia found here should be considered in the interpretation and attribution of regional precipitation variation under climate change.