Geophysical Research Abstracts
Vol. 18, EGU2016-16251, 2016
EGU General Assembly 2016

Land–Climate Feedbacks in Indian Summer Monsoon Rainfall

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In an attempt to identify how land surface states such as soil moisture influence the monsoonal precipitation climate over India, a series of numerical simulations including soil moisture sensitivity experiments was performed. The simulations were conducted with a nonhydrostatic regional climate model (RCM), the Consortium for Small-Scale Modeling (COSMO) in climate mode (CCLM) model, which was driven by the European Center for Medium-Range Weather Forecasts (ECMWF) Interim reanalysis (ERA-Interim) data. Results showed that pre-monsoonal soil moisture has a significant impact on monsoonal precipitation formation and large-scale atmospheric circulations. The analysis revealed that even a small change in the processes that influence precipitation via changes in local evapotranspiration was able to trigger significant variations in regional soil moisture–precipitation feedback. It was observed that these processes varied spatially from humid to arid regions in India, which further motivated an examination of soil-moisture memory variation over these regions and determination of the ISM seasonal forecasting potential. A quantitative analysis indicated that the simulated soil-moisture memory lengths increased with soil depth and were longer in the western region than those in the eastern region of India. Additionally, the subsequent precipitation variance explained by soil moisture increased from east to west. The ISM rainfall was further analyzed in two different greenhouse gas emission scenarios: the Special Report on Emissions Scenario (SRES: B1) and the new Representative Concentration Pathways (RCPs: RCP4.5). To that end, the CCLM and its driving global-coupled atmospheric–oceanic model (GCM), ECHAM/MPIOM were used in order to understand the driving processes of the projected inter-annual precipitation variability and associated trends. Results inferred that the projected rainfall changes were the result of two largely compensating processes: increase of remotely induced precipitation and decrease of precipitation efficiency. However, the complementing precipitation components and their simulation uncertainties rendered climate projections of the Indian summer monsoon rainfall as an ongoing, highly ambiguous challenge for both the GCM and the RCM.