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Dynamically Downscaled Climate Projections of the Indian Monsoon: Physics Parameterization Impacts and Precipitation Extremes

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The complex orography of South Asia, including both the Himalayas and the Tibetan Plateau, renders the regional climate complex. How this climate, especially the monsoon circulations, will respond to the global warming process, is important given the large population of the region. Here, as a contribution to the understanding of the expected impacts, a series of dynamically downscaled climate projections for the Indian subcontinent are presented. Global simulations based upon the Community Earth System Model (CESM) are employed to drive a dynamical downscaling pipeline in which the Weather Research and Forecasting Model (WRF) is employed as regional climate model, in a nested configuration with two domains at 30- and 10-km resolution, respectively. To investigate the sensitivity of the South Asian summer monsoon simulation to different parameterization schemes, a small physics ensemble consisting of 4 members with different physics parameterizations is employed. The entire ensemble was integrated for a historical validation period (1980-94) and for a mid-21st-century (2045-59) and an end-21st-century (2085-99) projection period. The global model represents a complete integration from the onset of northern hemisphere industrialization and assumes the representative concentration pathway 8.5 (RCP8.5) for the future scenario of radiative forcing. Compared to CESM, WRF substantially improves the representation of orographic precipitation. The Noah-MP land surface scheme reduces the summer warm bias compared to the Noah LSM. Compared with the Kain-Fritsch cumulus scheme, the Grell-3 scheme produces an increased moisture bias at the Western Ghats rain barrier, whereas the Tiedtke scheme produces less precipitation over the subcontinent than observed. Precipitation extremes are also characterized using Extreme Value Analysis based on combined data from climatologically similar stations and are successfully verified by comparison of the results with observations for the historical period, after which the same analysis method is applied to future projected precipitation. The Noah-MP land surface scheme performs slightly better in capturing the distribution of extreme precipitation intensity than the Noah LSM. Compared with the other 2 cumulus schemes, the Grell-3 scheme has the best quality of fit to observational extreme precipitation distribution over South India. Independent of the physics configuration employed, all projections are characterized by an increase in summer average precipitation and a fattening of the tail of the daily rainfall distribution. Both the average rainfall intensity changes and the extreme precipitation increase are projected to be slightly larger than the Clausius–Clapeyron thermodynamic reference of 7% per degree Celsius of surface warming in most parts of India. This further increase can be primarily explained by the fact that surface warming is projected to be smaller than the warming in the mid-troposphere, where a significant portion of rain originates, while dynamic effects related to increased moisture flux from the Arabian Sea also plays a secondary role.