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Stability and sensitivity analysis of the Indian monsoon under climate change

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We present a box model of the Indian monsoon which reproduces key features of the observed monsoon dynamics such as the annual course of precipitation and the transitions between winter and summer regimes. With this model we perform an extensive sensitivity analysis of the Indian summer monsoon rainfall to changes in parameters and boundary conditions which are influenced by human activities. Because of its transparency and computational efficiency, this model is highly suitable for exploring the effects of anthropogenic perturbations such as emissions of greenhouse gases and sulfur dioxide, and land cover changes, on the Indian monsoon. Results of a systematic sensitivity analysis indicate that the sign of precipitation changes over India will be dependent on the direction and relative magnitude of different human perturbations. Emissions of greenhouse gases, e.g., lead to an increase in Indian summer rainfall. In contrast, all parameters related to higher atmospheric aerosol concentrations lead to a decrease in Indian rainfall.

Under extreme human perturbations, e.g. changes of the albedo, a saddle node bifurcation with the existence of two stable regimes - a wet and a dry monsoon - is observed. This finding is remarkable insofar as it indicates that anthropogenic perturbations of the planetary albedo, such as sulphur emissions and/or land-use changes, or natural variations in insolation and CO2 concentration could trigger abrupt transitions between different monsoon regimes.