Indian summer monsoon: Future variability, extreme events and effects of lagged adaptation

Arathy Menon
Potsdam Institute for Climate Impact Research, 14473 Potsdam

The Indian Summer Monsoon (ISM) is one of the major components of the climate system and it shapes livelihood of a large share of the world's population for whom agriculture forms the main source of subsistence. Despite the improvement in numerical models over the past few decades, large uncertainties remain regarding the future projections of ISM rainfall. These uncertainties have significant impacts on risk assessment, development of adaptation strategies and decision making. This thesis covers the future evolution of Indian summer monsoon using the latest ensemble of climate projections prepared for the fifth assessment report of the Intergovernmental panel on Climate Change (IPCC). I use simulations from 20 different models under the four Representative Concentration Pathways (RCPs) which are designed to span the full range of future warming scenarios. I compare these model projections with observations and find that majority of the models capture the Indian monsoon mean rainfall and its spatial distribution quite well. The models project a consistent increase in ISM rainfall under all RCPs. The majority of the models also show an increase in ISM rainfall interannual variability under unabated climate change. Atmospheric circulation associated with Indian monsoon forms a major component of the global circulation system. I further examine the future evolution of the ISM circulation and find a northward shift in the circulation by few degrees during the end of the twenty-first century. In addition to seasonal rainfall, subseasonal variability plays a crucial role in agricultural productivity and flooding. I look at the response of subseasonal precipitation to global mean temperature change and find a consistent positive trend in subseasonal variability of all-India rainfall in all models and under all RCPs. The increase in subseasonal variability per degree change in temperature is of the order of 8% ± 4% K^{-1}. I also find a future increase in the frequency of both heavy and weak rainfall events in the model ensemble, whereas, the frequency of moderate events decreases. Extreme events are a major concern as they can cause huge socio-economic losses. The vulnerability to a heavy precipitation event depends on the availability of infrastructure at place to cope with the event. In this study, I am comparing three different methods, which correspond to three different assumptions about adaptation strategies, in order to quantify the relative changes in daily rainfall extremes under global warming. Under a condition of no adaptation, the relative increase in the annual frequency of wet days is of the order of 100%. But the adaptation measures that base infrastructure on the most recent climatic conditions strongly reduce this perceived increase in the number of wet days to about 5-10%.

In my thesis, I provide a comprehensive analysis of the future evolution of Indian monsoon. While my results indicate an overall increase of the all-India mean monsoon rainfall, also it's variability on interannual and subseasonal time-scales increases and extreme precipitation events as well as dry days will be more frequent. My research illustrates the importance of the substantial increase in variability, when assessing the impacts of climate change and calls for fast adaptation measures to minimize its impact.