PhD Thesis

Time-varying Downscaling Approach for Assessment of Climate Change Impacts on Hydroclimatic Variables Considering Nonstationarity

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Abstract: The impacts of climate change and variability on different hydroclimatic variables is a great concern to the society. The General Circulation Models (GCMs) are able to simulate the climatic variation at continental/hemispheric scale. However, their outputs are not acceptable for the local scale impact assessment studies due to the lack of representation of sub-grid scale features such as topography, convective activity, land use land cover are some of them. Therefore, downscaling techniques are adopted to improve the spatial resolution of hydroclimatic variables from GCM outputs. The usage of dynamical downscaling (e.g., Regional Climate Models) is restricted due to its complexity and demanding of extensive computational facilities. The statistical downscaling (e.g. Statistical Downscaling Model, abbreviated as SDSM) is computationally less intensive but it assumes time-invariant relationship between causal and target variables. The applicability of such assumption in the context of a changing climate is questionable since recent studies confirm the existence of non-stationarity in such relationships. In this regard, development of a new downscaling approach considering the time-varying relationship between causal-target variables and its use of downscaling different hydroclimatic variables is the broad goal of this PhD thesis.

The initial part of the thesis is devoted to investigate the efficacy of an existing time-invariant statistical downscaling approach for the downscaling of precipitation. The SDSM is employed to downscale daily precipitation of different Indian River basins. The future variation of daily extremes is also explored. Next, effectiveness of the downscaled precipitation as input to a rainfall runoff model in simulating the daily inflows to a reservoir and their extremes are investigated.

Realizing the shortcomings due to the time-invariant assumption, a new downscaling approach is developed and named as Time-Varying Downscaling Model (TVDM) which considers the relationship between causal and target variables is time-varying. It is developed based on the parameter updating ability of Bayesian approach. The ability of updating such relationship over time renders TVDM a time-varying approach that is different from other time-invariant downscaling approaches. The potential benefits of the developed time-varying approach (TVDM) are explored in identifying the precipitation extremes and their variation during the future period for different climate change scenarios characterized by different Representative Concentration Pathways (RCPs). The downscaled products are generated for three different hydroclimatic variables, namely precipitation, daily temperature (both maximum and minimum) and soil moisture using the TVDM for the entire India.

The TVDM downscaled data are then compared with the SDSM and Regional Climate Model (RCM) outputs and found superior in estimating means, different quantiles and extreme events of precipitation, temperature and soil moisture in different locations within the country. The results reveal that the precipitation extremes are going to be more in the future period (21st century) and severity is even more as per RCP8.5 scenario. The temperature projected by the TVDM exposes that on an average a rise of ~2 °C is expected by the end of 21st century. The TVDM is also found more effective and reliable approach for assessing the soil moisture and its variability despite of complexity involved in its downscaling. These results indicate that the nonstationary relationship between causal and target variables is unavoidable and TVDM can be able to model it.

In brief, the developed TVDM has shown some potential in its application in a changing climate due to its time-varying characteristics considering the nonstationarity issue that exists in the relationship between the causal and target variables. Adopting the time-varying relationship, the future variability of hydroclimatic variables can be better assessed at basin and continental scale. It can therefore be useful for local scale impact assessment studies and also helpful in better management of available water resources. This information can be further used in many applications, such as the consequences due to hydrological extremes can be averted; the hydraulic structures can be designed considering the extremes obtained from climate change scenarios; useful for design of drainage network; planning for agricultural and other policies for better management of water resources.

Key words: Hydroclimatic Variables, Climate Change, Downscaling, Nonstationarity, Statistical Downscaling Model, Time-Varying Downscaling Model, General Circulation Model, Extreme Events.