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Links between small-scale dynamics and large-scale averages and its implication to large-scale hydrology

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Changes to the hydrological cycle under a changing climate challenge our understanding of the interaction between hydrology and climate at various spatial and temporal scales. Traditional understanding of the climate-hydrology interaction were developed under a stationary climate and may not adequately summarize the interactions in a transient state when the climate is changing; for instance, opposite long-term temporal trend of precipitation and discharge has been observed in part of the world, as a result of significant warming and the nonlinear nature of the climate and hydrology system. The patterns of internal climate variability, ranging from monthly to multi-centennial time scales, largely determine the past and present climate. The response of these patterns of variability to human-induced climate change will determine much of the regional nature of climate change in the future. Therefore, understanding the basic patterns of variability is of vital importance for climate and hydrological modelers. This work showed that at the scale of large river basins or sub-continents, the temporal variation of climatic variables ranging from daily to inter-annual, could be well represented by multiple sets, each consists of limited number of points (when observations are used) or pixels (when gridded datasets are used), covering a small portion of the total domain area. Combined with hydrological response units, which divide the heterogeneity of the land surface into limited number of categories according to similarity in hydrological behavior, one could describe the climate-hydrology interaction and changes over a large domain with multiple small subsets of the domain area. Those points (when observations are used), or pixels (when gridded data are used), represent different patterns of the climate-hydrology interaction, and contribute uniquely to an averaged dynamic of the entire domain. Statistical methods were developed to identify the minimum number of points or pixels that could be used to represent the temporal dynamic of a large spatial domain. The derived points or pixels allow a decomposition of the average climate dynamic to a number of patterns of the internal variations and change signals. The coupling of sub-sets of climate input to a set of hydrological response units maintains the non-linear nature of the hydrological system. The possibility that the behavior of a large river basin could be studied from a small sub-set of the basin area, indicates that model setup, calibration and evaluation are not necessarily tied with downstream gauges. Instead, local observations could be used to setup and evaluate large-scale models. This work could potentially open up possibilities for better setting up and evaluate large-scale hydrological models, and study the climate-hydrology interaction with limited data. In the same time, the fact that multiple sets of points or pixels could equally well represent the dynamic of a large domain agreed with the equifinality theory: there exist multiple realisms of different climate-hydrology setttings that could lead to same average behavior. The difference among the multiple sets represents the inherent heterogeneity of the domain. This could indicate new ways to bracket uncertainty for current and future hydrological simulations.