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The role of atmospheric diagnosis and Big Data science in improving hydroclimatic extreme prediction and the merits of climate informed prediction for future water resources management

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The threats that hydroclimatic extremes pose to sustainable development, safety and operation of infrastructure are both severe and growing. Recent heavy precipitation triggered flood events in many regions and increasing frequency and intensity of extreme precipitation suggested by various climate projections highlight the importance of understanding the associated hydrometeorological patterns and space-time variability of such extreme events, and developing a new approach to improve predictability with a better estimation of uncertainty. This clear objective requires the optimal utility of Big Data analytics on multi-source datasets to extract informative predictors from the complex ocean-atmosphere coupled system and develop a statistical and physical based framework. The proposed presentation includes the essence of our selected works in the past two years, as part of our Global Floods Initiatives. Our approach for an improved extreme prediction begins with a better understanding of the associated atmospheric circulation patterns, under the influence and regulation of slowly changing oceanic boundary conditions [Lu et al., 2013, 2016a; Lu and Lall, 2016]. The study of the associated atmospheric circulation pattern and the regulation of teleconnected climate signals adopted data science techniques and statistical modeling recognizing the nonstationarity and nonlinearity of the system, as the underlying statistical assumptions of the classical extreme value frequency analysis are challenged in hydroclimatic studies. There are two main factors that are considered important for understanding how future flood risk will change. One is the consideration of moisture holding capacity as a function of temperature, as suggested by Clausius-Clapeyron equation. The other is the strength of the convergence or convection associated with extreme precipitation. As convergence or convection gets stronger, rain rates can be expected to increase if the moisture is available. For extreme rainfall events in the mid-latitudes, tropical moisture sources related to strong convection from equatorial oceans were identified together with atmospheric circulation conditions that in favor of consistent transport and convergence of moisture [Lu et al., 2013; Lu and Lall, 2016]. Further, [Lu et al., 2016a] linked the influence of the slowly changing oceanic boundary conditions with the development of the global atmospheric circulation and showed that (1) strong convection over the oceans and the atmospheric moisture transport and flow convergence indicated by atmospheric pressure fields can determine where and when extreme precipitation occurs; and (2) the time-lagged spatial relationship between teleconnected oceanic signals and synoptic atmospheric circulations can improve the predictability of extreme precipitation globally over the next 30 days; such a forecast would be potentially very useful for flood preparation at a lead time that is well beyond the lead time of meteorological forecasts, and it corresponds to a gap in the predictability between quantitative precipitation forecasts and seasonal-to-interannual climate prediction. Lastly, we will demonstrate our most recent results showing the merits of utilizing climate informed forecasts for water resources management, considering irrigation supply, hydropower and flood control, with marked-based financial instruments [Lu et al., 2016b].