A Generalized Spatio-temporal Framework for Climate Informed Extreme Precipitation Analysis

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Abstract. Numerous modeling and empirical studies indicate increasing trend in the occurrence and intensity of climate extremes under a warmer climate. These extremes have a significant socio-economic impact therefore, a strong need to investigate changes in frequency and intensity of climatic extremes in space and time is being called to enable hazard mitigation and resources planning strategies. Here, we present a generalized spatio-temporal framework using Bayesian Hierarchical Modeling approach for modeling climate extremes which incorporates covariates such as large-scale climate drivers (e.g., ENSO and PDO). The first level of hierarchy uses an elliptical copula to model the joint distribution of observed in-situ extremes, whose marginal follows a generalized extreme value distribution (i.e., GEV). The second level models the variability of extremes in space and time through Generalized Linear Model, which links distribution parameters (i.e., location and scale) of GEV to climate indices or other covariates. The regression residuals from the second layer are assumed to be realizations from a Gaussian spatial field and modeled using spatial model which allows transferring estimates from gauged to ungauged sites, and improves the accuracy of regression parameter estimation. The copula layer makes this a novel approach compared to other hierarchical models for spatial extremes. An example is illustrated to explore regional frequency (i.e., the risk analysis) in estimating return level of wintertime extreme rainfall over 50 sites in Arizona. By pooling data and sharing information from multiple sites, the result shows significant reduction of uncertainty in estimating the shape parameters, which is useful for rigorously quantifying the extremal tail behavior of rainfall; as well as in reducing the uncertainty of the return level estimates. The temporal variability layer enables modeling the nonstationarity in the rainfall extremes driven by climate variables, and the copulas capture the spatial correlation structure very well.