Geophysical Research Abstracts
Vol. 12, EGU2010-6609, 2010
EGU General Assembly 2010

Using elliptical copulas to model spatial dependence in regional frequency analysis : pros and cons.

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At-site frequency analysis of hydrological extremes (rainfall and runoff) is affected by considerable uncertainty, due to the strong natural variability of extremes and the comparatively short record length. Regional frequency analysis aims to reduce this uncertainty by conjointly analyzing several sites from a homogeneous hydrologic region. In most cases, regional frequency analysis is based on the "index flood" hypothesis: data from all sites are assumed to be realizations from an identical regional distribution, after dividing at-site data by a suitable scale factor (e.g., the at-site median). This regional distribution can then be estimated using data from all sites. However, data are in general spatially dependent. This intersite dependence may bias the inference when ignored.
In this presentation, spatial dependence is explicitly modeled using the family of elliptical copulas, whose properties are well suited to model dependence in high-dimensional spatial problems. Copulas from this family are parameterized by a dependence matrix, whose elements quantify pairwise dependences. The strength of dependence can be assumed to be a function of the intersite distance, thus leading to a natural analogy with methods used in standard geostatistics. Members of the elliptical family differ by their treatment of asymptotic dependence. For instance, the Gaussian copula assumes asymptotically independent data, while the Student t-copula quantifies asymptotic dependence using an additional parameter.
A case study, based on annual maxima of rainfall from sites in the French Mediterranean region, is carried out to evaluate the impact of spatial dependence on regional frequency analysis. In a first step, we evaluate the sensitivity of parameter estimates (e.g., location, scale and shape parameters of a regional Generalized Extreme Value distribution) to the treatment of spatial dependence. Results show that: (i) ignoring the existence of spatial dependence significantly affects parameter estimates. In particular, it leads to an under-estimation of uncertainties. (ii) In comparison, the treatment of asymptotic dependence is of second-order importance, with similar estimates being found with a Gaussian or a Student t- copula.
In a second step, we evaluate the robustness of the framework to estimate the probability of rare spatial events. To this aim, we estimate the probability that several sites exceed high threshold values during the same year. Results demonstrate that such estimates are far more sensitive to the treatment of asymptotic dependence, with different estimates being found with a Gaussian or a Student t- copula. This implies that the choice of a copula (in particular, its treatment of asymptotic dependence) is of prime importance, and has to be based on strong empirical or physical evidence. In the absence of that, there is no guarantee that estimates of spatial events are meaningful, especially in the extrapolation domain.