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Multisite drought risk assessment using extreme Gumbel Copula

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The presentation investigates the change of drought risk appraisal when analyzing a drought index by pairs of locations, rather than in one single location independently from its surrounding. The study is based on the drought indicator SMDI (Soil Moisture Deficit Index) and the spatial approach of drought risk assessment is developed using Copula analysis. SMDI was proposed by Narasimhan and Srinivasan (2005) based on the estimation of the weekly soil moisture deficit, using SWAT hydrological model coupled to the SWAT crop growth model, at a spatial resolution of 16 km^2, for two watersheds in the Texas region. They found that SMDI time series compare favorably to NDVI satellite observations. They concluded that SMDI derived from an entire soil profile could be a good indicator of long-term drought conditions. In the present study, we analyse time series of SMDIs simulated using a lumped water balance model with a single soil layer (the BBH model from Kobayashi et al., 2001). To calibrate the BBH model, we consider series of daily rainfall and runoff observations for several basins and we adopt for each case the absolute relative error on the annual runoff as well as the dekadal (10 days) and monthly runoff Nash coefficients to select the best model parameters. For Copula analysis, the Gumbel model is assumed (as drought is an extreme event) and the maximum likelihood is adopted to estimate the copula parameter. By construction, SMDI is scaled between -4 to +4. Extreme drought conditions correspond to SMDI$\leq$-3, moderate drought is identified with -3<SMDI$\leq$ -2 and mild drought with -2<SMDI$\leq$ -1. Thus, to fit the Gumbel model SMDI series are first ranked and the non parametric Weibull formula is adopted to transform SMDI values into percentiles. The methodology is achieved using five watersheds from Northern Tunisia (not nested), having a common simulation period of 8 years (1967- 1975). It is found that SMDI=-2 corresponds to a percentile around 0.23 while a percentile 0.05 is attached to SMDI=-3.8. Using the estimated copula parameters, the SMDI contours are plotted for the following combined drought risk values: p=0.2; 0.1; 0.05; 0.01. It is found that for situations when SMDI percentile is less than 0.20 in both basins (moderate to extreme drought conditions are prevailing in both basins), the combined risk falls to percentiles equal to 0.05 or less, indicating more severe drought conditions. When both basins present a percentile of SMDI less than 0.40, the combined risk falls under the threshold 0.20. Moreover, situations where the SMDI percentile is less than the threshold 0.20 in one basin (extreme to moderate drought conditions) and greater than 0.2 in the other basin (mild drought to no drought conditions) result in a combined risk less than 0.15 (0.15 corresponds to SMDI= -2.5 in the univariate case, which means moderate drought conditions). Thus, such an approach would be helpful to assign a multisite drought risk when analyzing a given geographic or an administrative area.