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New Extreme Rainfall Statistical Models: Optimization and Comparisons with Traditional Approaches

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Extremes in geophysical processes are a central issue in Earth science. The traditional Extreme Value Theory (EVT) is based on assumptions that limit the amount of information used to infer the probability distribution of extreme values and are ill-suited for non-stationary processes. A new approach to extreme value theory has recently been proposed, the Metastatistical Extreme Value (MEV) distribution, that relaxes some key assumptions of the classical EVT, makes full use of the observations and lends itself to describing extremes in the presence of inter-annual variability and a fluctuating climate.
The MEV distribution has been shown to significantly outperform the traditional Generalized Extreme Value (GEV) distribution when applied to daily rainfall (50% reduction in the predictive uncertainty). However, no systematic understanding exists as to how to optimally apply the new MEV framework depending on the statistical properties of observed rainfall. Here we comparatively examine the performance of the MEV and GEV distributions applied to daily rainfall data, either real or synthetic, spanning a variety of statistical structures in terms of 1) clustering of events (from under-dispersed, to Poisson, to over-dispersed rainfall occurrences) and 2) inter-annual variability of rainfall properties.
We find that the plotting position formula used to estimate probabilities has a significant impact on the predictive uncertainty for both the MEV-Weibull and GEV distributions; the Weibull plotting position and the Landwehr formula are respectively those that allow a better estimation of the distribution parameters via PWM and give therefore a higher accuracy in the quantiles computation. The computation of the estimation error for different rainfall statistical structures confirmed that the Root Mean Square Error (RMSE) is much reduced when using MEV rather than GEV to estimate large quantiles.

The MEV is applied to daily rainfall by fitting a Weibull distribution to the ordinary rainfall depths over several subsets of the available time series (1-year windows in the original formulation). We find that, while the choice of a 1-year window in most cases (about 70%) leads to the minimum predictive uncertainty, a longer window decreases uncertainty when rainfall inter-annual variability is low. Hence, when using the MEV distribution, there is a trade-off between accurately describing the effects of inter-annual variability, which requires short windows, and improving parameter estimation of the ordinary rainfall distributions, which requires longer windows. We were able to identify the conditions leading to a longer optimal window, and found that first order controls are the variability in the parameters of the “ordinary” value distribution and in the average number of rainy days. Overall, our results confirm that the MEV distribution outperforms the traditional EVT when applied to daily rainfall, and suggest that this superior performance is due to the inter-annual variability of rainfall properties and to the non-Poisson nature of the rainfall occurrence process.