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Rainfall extremes from TRMM data and the Metastatistical Extreme Value Distribution

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A reliable quantification of the probability of weather extremes occurrence is essential for designing resilient water infrastructures and hazard mitigation measures. However, it is increasingly clear that the presence of inter-annual climatic fluctuations determines a substantial long-term variability in the frequency of occurrence of extreme events. This circumstance questions the foundation of the traditional extreme value theory, hinged on stationary Poisson processes or on asymptotic assumptions to derive the Generalized Extreme Value (GEV) distribution.
We illustrate here, with application to daily rainfall, a new approach to extreme value analysis, the Metastatistical Extreme Value Distribution (MEVD). The MEVD relaxes the above assumptions and is based on the whole distribution of daily rainfall events, thus allowing optimal use of all available observations. Using a global dataset of rain gauge observations, we show that the MEVD significantly outperforms the Generalized Extreme Value distribution, particularly for long average recurrence intervals and when small samples are available.
The latter property suggests MEVD to be particularly suited for applications to satellite rainfall estimates, which only cover two decades, thus making extreme value estimation extremely challenging. Here we apply MEVD to the TRMM TMPA 3B42 product, an 18-year dataset of remotely-sensed daily rainfall providing a quasi-global coverage. Our analyses yield a global scale mapping of daily rainfall extremes and of their distributional tail properties, bridging the existing large gaps in ground-based networks.
Finally, we illustrate how our global-scale analysis can provide insight into how properties of local rainfall regimes affect tail estimation uncertainty when using the GEV or MEVD approach. We find a dependence of the estimation uncertainty, for both the GEV- and MEV-based approaches, on the average annual number and on the inter-annual variability of rainy days. In particular, estimation uncertainty decreases 1) as the mean annual number of wet days increases, and 2) as the variability in the number of rainy days, expressed by its coefficient of variation, decreases. We tentatively explain this behavior in terms of the assumptions underlying the two approaches.