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Satellite Estimates of Extreme Rainfall at the Global Scale through a Metastatistical Approach

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The study of rainfall extremes is essential for designing most water-related infrastructure and to optimally manage water resources. Statistical inferences regarding the distribution of rainfall Extreme Values (EV) is currently hinged on the Generalized Extreme Value (GEV) distribution, derived either under hypotheses of stationarity and in the limit of a large number of rainfall occurrences, or by assuming the Poisson occurrence of Peak Over Threshold (POT) values. These foundational assumptions imply, among other things, that inter-annual fluctuations, now widely detected and studied globally, cannot be incorporated in traditional EV statistical models. Here we illustrate a new approach to EV analysis, the Metastatistical Extreme Value Distribution (MEVD), which relaxes the above assumptions. In this framework, statistical inference is not solely based on a sample of annual maxima (or on a small set of values over a high threshold), but on the whole probability distribution of measured rainfall events (e.g., at the Daily scale). Moreover inter-annual variations observed in the probability distribution of daily rainfall values are explicitly accounted for in the MEVD framework by acknowledging that the parameters defining such distributions vary stochastically. We show, by means of a Monte Carlo approach applied to a global dataset of daily rain gauge observation, that the MEVD on average outperforms GEV-based methods when the return time of interest is longer than the length of the available sample. This property suggests MEVD to be particularly suited for applications to satellite rainfall retrievals, which only cover the past few decades. Here we apply MEVD to version 7 TRMM Multi-satellite Precipitation Analysis (TMPA), a 18-year long remotely-sensed daily rainfall dataset that provides quasi-global coverage with remarkable spatial (0.25°x0.25°) and temporal (up to 3-hour) resolutions. The approach we propose here overcomes some limitations of the traditional EV analysis methods, particularly when applied to satellite-sensed extremes. In fact, not only are intense events poorly sampled in TMPA datasets for they low frequency of occurrence and sensor detection limitations, but their quantification is also particularly affected by estimation uncertainty. MEVD, by exploiting the entire set of recorded values, reduces the estimation uncertainty with respect to GEV-based methods that only fit few and more uncertain large values. The new approach, applied to TRMM rainfall estimates, leads to i) an optimal use of the short TMPA datasets in estimating the tail of the probability distribution of daily rainfall, and ii) global mapping of daily rainfall extremes and distributional tail properties. The optimal estimation of satellite-observed extreme events potentially provides unprecedented global-scale coverage, promising to bridge the large gaps in ground-based networks.