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Extreme rainfall from Tropical Cyclones described through the Metastatistical Extreme Value Distribution

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Tropical Cyclones (TCs) represent a threat in several areas of the world, among which the Eastern/South-Eastern United States are one of the highly impacted regions. In addition to the frequently analyzed hazards related to the strong winds and storm surges associated with TCs, they are also responsible for heavy rainfall, which can affect areas located very far from the storm center. The accurate estimation of rainfall extremes is crucial in several TC-related impacts, such as engineering design of buildings and prevention/protection measures, flood mapping, risk estimation and mitigation, insurance and re-insurance purposes, policy-making support. Statistical approaches considering the physical drivers of hydrological phenomena, besides their conceptual relevance, can help reducing the estimation uncertainty of extremes. Under these premises, here we use the Metastatistical Extreme Value Distribution (MEVD), a recent approach that improves the estimation of high-return period values over the traditional Extreme Value Theory. We leverage the property of the MEVD to explicitly include in the statistical formulation different rainfall-generating phenomena and we examine the potential advantage of distinguishing TC-induced and non-TC rainfall events in the estimation of extremes. Hence, we apply the MEVD both in a single-component formulation (i.e., assuming that all rainfall events are generated by one single mechanism, so that they can be described by the same probability distribution) and a mixed-population formulation (i.e., separating non-TC and TC-induced rainfall events) to long time series of daily precipitation in six American metropolitan areas, historically known for being impacted by TCs. Moreover, due to the characteristic time scale of these mechanisms, which can significantly influence precipitation for several days, we focus also on aggregated values of rainfall on consecutive days. We find that the mixed approach is advantageous in some cases when looking at daily rainfall, especially when there is a rather uniform frequency of TC events over years. When considering cumulative rainfall on time windows of three days, we show that the reduction of the estimation error by the mixed MEVD is generally higher than in the case of daily rainfall and it is consistent for all the cases studied, except for Houston. A possible reason for the mixed MEVD not to outperform the single-component MEVD in this area is the presence of tornadic supercell convective mechanisms, which also generate heavy rainfall though concentrated in short time intervals.