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Beyond Traditional Extreme Value Theory Through a Metastatistical Approach: Lessons Learned from Precipitation, Hurricanes, and Storm Surges

Marco Marani (1,2), Enrico Zorzetto (3), Arianna Miniussi (1), Seyed Reza Hosseini (4), and Marco Scaioni (4)

(1) University of Padova, Dept. of Civil, Environmental and Architectural Engineering, Padova, Italy, (2) Division of Earth and Ocean Sciences and Department of Civil and Environmental Engineering, Duke University, Durham, NC, USA (marco.marani@duke.edu), (3) Division of Earth and Ocean Sciences, Nicholas School of the Environment, Duke University, Durham, USA (enrico.zorzetto@duke.edu), (4) Deptartment of Environmental, Hydraulic, Infrastructures and Surveying Engineering, Polytechnic Milan, Milan, Italy

The Generalized Extreme Value (GEV) distribution is widely adopted irrespective of the properties of the stochastic process generating the extreme events. However, GEV presents several limitations, both theoretical (asymptotic validity for a large number of events/year or hypothesis of Poisson occurrences of Generalized Pareto events), and practical (fitting uses just yearly maxima or a few values above a high threshold). The Metastatistical Extreme Value Distribution (MEVD, Marani & Ignaccolo, 2015) relaxes asymptotic or Poisson/GPD assumptions and makes use of all available observations. We illustrate here the flexibility of the MEVD by applying it to daily precipitation, hurricane intensity, and storm surge magnitude.
Application to daily rainfall from a global raingauge network shows that MEVD estimates are 50% more accurate than those from GEV when the recurrence interval of interest is much greater than the observational period. This makes MEVD suited for application to satellite rainfall observations ($\sim$20 yrs length). Use of MEVD on TRMM data yields extreme event patterns that are in better agreement with surface observations than corresponding GEV estimates.
Applied to the HURDAT2 Atlantic hurricane intensity dataset, MEVD significantly outperforms GEV estimates of extreme hurricanes. Interestingly, the Generalized Pareto distribution used for “ordinary” hurricane intensity points to the existence of a maximum limit wind speed that is significantly smaller than corresponding physically-based estimates.
Finally, we applied the MEVD approach to water levels generated by tidal fluctuations and storm surges at a set of coastal sites spanning different storm-surge regimes. MEVD yields accurate estimates of large quantiles and inferences on tail thickness (fat vs. thin) of the underlying distribution of “ordinary” surges.

In summary, the MEVD approach presents a number of theoretical and practical advantages, and outperforms traditional approaches in several applications. We conclude that the MEVD is a significant contribution to further generalize extreme value theory, with implications for a broad range of Earth Sciences.