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Critical review and hydrologic application of threshold detection methods for the generalized Pareto (GP) distribution

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Estimation of extreme rainfall from data constitutes one of the most important issues in statistical hydrology, as it is associated with the design of hydraulic structures and flood water management. To that extent, based on asymptotic arguments from Extreme Excess (EE) theory, several studies have focused on developing new, or improving existing methods to fit a generalized Pareto (GP) distribution model to rainfall excesses above a properly selected threshold u. The latter is generally determined using various approaches, such as non-parametric methods that are intended to locate the changing point between extreme and non-extreme regions of the data, graphical methods where one studies the dependence of GP distribution parameters (or related metrics) on the threshold level u, and Goodness of Fit (GoF) metrics that, for a certain level of significance, locate the lowest threshold u that a GP distribution model is applicable. In this work, we review representative methods for GP threshold detection, discuss fundamental differences in their theoretical bases, and apply them to 1714 daily rainfall records from the NOAA-NCDC open-access database, with more than 110 years of data. We find that non-parametric methods that are intended to locate the changing point between extreme and non-extreme regions of the data are generally not reliable, while methods that are based on asymptotic properties of the upper distribution tail lead to unrealistically high threshold and shape parameter estimates. The latter is justified by theoretical arguments, and it is especially the case in rainfall applications, where the shape parameter of the GP distribution is low; i.e. on the order of 0.1 ÷ 0.2. Better performance is demonstrated by graphical methods and GoF metrics that rely on pre-asymptotic properties of the GP distribution. For daily rainfall, we find that GP threshold estimates range between 2÷12 mm/d with a mean value of 6.5 mm/d, while the existence of quantization in the empirical records, as well as variations in their size, constitute the two most important factors that may significantly affect the accuracy of the obtained results.

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