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Lognormal Upper Tail of Rainfall Intensity and POT Values: Implications on the IDF Curves

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Let $I(d)$ be the average rainfall intensity in an interval of duration d and denote by $I(d;i^*)$ the peak-over-threshold (POT) value of $I(d)$ for threshold i^* and by $I_{max}(d)$ the annual maximum of $I(d)$.

Hydrologic risk assessment and design depend critically on the upper tail of the distribution of $I_{max}(d)$. Since the events $I(d) > i$ in non-overlapping d-intervals become independent as i becomes large and for even moderate thresholds i^* the excursions of $I(d)$ above i^* may be considered Poisson, the upper tail of the distribution of $I_{max}(d)$ may be estimated from the upper tails of $I(d)$ and $I(d;i^*)$ as

$$P[I_{max}(d) > i] \approx \{P\left[I\left(d\right) > i/\gamma\right]\}^{1/d} \quad (1)$$

$$P[I_{max}(d) > i] \approx \; e^{-\lambda_{i^*} P[I(d;i^*) > i - i^*]} \quad (2)$$

where d is in years, γ is a continuity correction factor around 1.15, and λ_{i^*} is the average annual exceedance rate of threshold i^*. Based on (1), it has been argued that the distribution of $I_{max}(d)$ should be of the GEV type, with recent propensity for EV2. This is consistent with results from (2) if $I(d;i^*)$ has GP distribution. However, the GEV claim follows from (1) under asymptotic conditions that may not be attained for the upper tail of $I_{max}(d)$ and from (2) under the assumption that $I(d;i^*)$ is GP-distributed, which may not hold.

We take another look at the distributions of $I(d)$ and $I(d;i^*)$ and their implications on the upper tail of $I_{max}(d)$ through (1) and (2). Specifically we show that there is

empirical and theoretical evidence that for durations $d \leqslant 1$ day the upper tail of $I(d)$ has a lognormal behavior over a wide range of intensities and that also the distribution of $I(d;i^*)$ has a significant lognormal range. These conclusions are supported by both historical and simulated rainfall records and theoretical analysis. For the simulations we use a partly theoretical model in which storm occurrence times and durations are extracted from a historical record but the storm intensity and within-storm fluctuations are generated randomly, the latter using a beta-lognormal multifractal process.

Results on $I_{max}(d)$ obtained from (1) and (2) by fitting distributions of $I(d)$ and $I(d;i^*)$ with upper lognormal tails are compared to results from directly fitting a GEV distribution to the observed annual maximum intensities and from using (2) with a fitted GP distribution of $I(d;i^*)$.

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