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A spatial bootstrap technique for parameter estimation of rainfall annual maxima distribution

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Comments to Authors

Paper summary

The reviewed manuscript presents a novel methodology, based on multiple-station probability weighted spatial bootstraping, to estimate the parameters of a GEV distribution model for rainfall maxima at different (ungauged) locations in a geographical region. The applied probability weights are proportional to the product of two Gaussian kernels: the first accounts for the reduced influence of rainfall observations with increasing distance from the location were the GEV parameters are estimated, while the other accounts for orographic effects.

Assuming simple scaling of the annual rainfall maxima, the authors: a) standardize rainfall averages at any measuring location by the sample mean, b) construct synthetic samples at ungauged locations inside the catchment (i.e. by probability weighted spatial bootstrap resampling from the standardized data), and c) use the synthetic samples to obtain the spatial variation of GEV parameters, as duration independent. The authors proceed one step further and derive depth-duration-frequency relationships.

Technical soundness

The bootstrap approach and probability weighted scheme are technically sound. I have only one comment concerning the assumption of simple scaling of annual rainfall maxima, which requires some discussion; see below.

General comment

The authors make a direct assumption on the scaling of annual rainfall maxima. It is my opinion that, rather than making direct assumptions on the scaling of extremes, one should better obtain such properties starting from the scaling of the rainfall process itself; see below.

Several studies (see e.g. Schertzer and Lovejoy, 1987; Tessier *et al*., 1993; Gupta and Waymire, 1993; Menabde *et al*., 1997; Deidda *et al*., 1999; Deidda, 2000; Veneziano and Langousis, 2005, 2010; Veneziano *et al*., 2006, 2009; Langousis and Veneziano, 2007; Langousis *et al*., 2009, 2013; Langousis and Kaleris, 2013) have shown that rainfall fields follow a more general scale invariance condition, than simple scaling, known as stochastic self similarity or multifractality; see the reviews in Veneziano *et al*. (2006) and Veneziano and Langousis (2010). Under this hypothesis, and based on arguments from large deviation theory, the limiting distributions of rainfall maxima scale in a self similar way, as either the return period $T \to \infty$ or the averaging duration $d \to 0$. More precisely: $i_{d,T} \propto d^{-\gamma}\, T^{\delta}$, where $i_{d,T}$ is the maximum rainfall intensity averaged over duration d with return period T, and γ and δ are positive constants that differ significantly in the two limiting cases (see Veneziano and Furcolo, 2002; Veneziano and Langousis 2005, 2010, and Veneziano *et al.*, 2006). Two recent studies, Veneziano *et al.* (2009) and Langousis *et al.* (2013) used arguments from large deviation theory and simulation results to show that, for finite values of d and T, one can approximate $i_{d,T}$ using a GEV distribution model with shape parameter that decreases with increasing duration d. Note that dependence of the shape parameter of the GEV distribution on the duration d originates from the fact that, for finite samples, the distribution of rainfall maxima has not yet fully converged to a GEV shape. Dependence of GEV parameters on the averaging duration d, as implied by multifractal theory, is discussed by the authors as a possible future refinement of their approach.

Overall, I believe that the authors should provide a brief introduction to multifractal rainfall models, while discussing the issue of self-similarity of rainfall maxima at the limit as either $T \to \infty$ or $d \to 0$. In order to keep their approach as simple as possible for practical applications, the authors can refer to the non-asymptotic results of Veneziano *et al.* (2009) and Langousis *et al.* (2013), and assume that for ranges of the return period T relevant to practical applications (e.g. from 10-1000 years; see e.g. Langousis *et al.*, 2013) the standardized rainfall maxima can be approximated by a GEV distribution model with constant parameters.

An alternative option is that the authors abandon the simple scaling hypothesis and allow the GEV parameters to vary, also, with the duration of rainfall accumulation d. While more general and accurate, the latter approach would require some additional effort.

Contribution and audience

Apart from the issue of simple scaling (see discussion above), which can be easily addressed, the presented work is solid and of interest to a wide audience of hydrologists and engineering practitioners.

Prior publication

To my knowledge, neither the same nor very similar work has been published elsewhere.

Recommendation

For the reasons mentioned above, it is recommended that the paper is published in *HESS* after minor revisions.

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