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Hydrology and Earth System Sciences Discussions

Interactive comment on "How extreme is extreme? An assessment of daily rainfall distribution tails" *by* S. M. Papalexiou et al.

S. M. Papalexiou et al.

smp@itia.ntua.gr

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CC: Commenter's comments
AC: Authors' comments

We are grateful to Federico Lombardo (FL) for his encouraging comment.

CC1. *In the interesting Comment by Clauset (2012), it is also stated: "In fact, there must be a physically imposed upper limit on the largest possible rainfall, which means the extreme tail of the distribution must be truncated by finite-size cutoff"; but extreme value theory (EVT) is based on unlimited variates (Gumbel, 1958). This problem refers to the important issue that statistical variates should be consistent with our experience of the real world, and infinity transcends reality. In the classic work by Gumbel (1958),*

it is given an effective defence against this criticism which I endorse: "This objection is not as serious as it looks, since the denial of the existence of an upper or lower limit is linked to the affirmation that the probability for extreme values differs from unity (or from zero) by an amount which becomes as small as we wish. Distributions currently used have this property. The exploration of how unlimited distributions behave at infinity is just part of the common general effort of mathematics and science to transgress the finite".

AC1. We fully agree with this comment and we particularly thank the Commenter for offering this excellent quotation from Gumbel, which also makes a counter argument with respect to the review of Clauset (2012). We include an additional quotation from Feller in our reply to A. Clauset. The second author wishes to add here the following extract from his earlier work (Koutsoyiannis, 2007), which he thinks is relevant to this discussion.

*"The history of infinite goes back to the 6th century BC, with Anaximander, who regarded infinite as the cosmological principle, and continues with Zeno of Elea (c. 490-c. 430 BC) and his famous paradoxes, and later with Aristotle (384-328 BC) who introduced the notion of potential infinite, as opposed to the actual or complete infinite. The Aristotelian potential infinite 'exists in no other way, but . . . **potentially** or by reduction' (Physics, 3.7, 206b16). It is generally claimed that the problem of mathematical infinite was tackled in the late 19th century. According to Bertrand Russell, Zeno's paradoxes 'after two thousand years of continual refutation . . . made the foundation of a mathematical renaissance'. . . In hydrometeorology, however, the concept of infinity is still not understood and this situation has led to fallacies of upper bounds in precipitation and flood, the well-known concepts of the probable maximum precipitation (PMP) and probable maximum flood (PMF) . . . These contradictory concepts are still in wide use, even though merely the Aristotelian notion of potential infinite would suffice to abandon them."*

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CC2. *In EVT, estimates are often required for levels of a process that may not have been observed yet, meaning that EVT provides a class of models to enable extrapolation from observed levels to unseen levels. However, as stated by Coles (2001): "(. . .) extrapolation of models to unseen levels requires a leap of faith, even if the models have an underlying asymptotic rationale". This is especially so when observed values are scarce. Indeed, it is very important to investigate the discrepancy between a large amount of observed values and the values expected under the model in question, because if the model represents badly the extreme values that have already been observed, this behaviour is likely to be greatly magnified on extrapolation. This is why I strongly appreciated the contribution of the paper under discussion, which provided the analysis of such a huge amount of observational data.*

AC2. Again we fully agree with the Commenter's remark. Using data from as many stations as possible, or else "substituting space for time", is in our view the most appropriate way to make safer extrapolations. Perhaps the first who did this systematically was Hershfield (1961, 1965) and his results, despite been formulated in terms of the fallacious PMP concept, can be recovered in a probabilistic framework (Koutsoyiannis, 1999). Hershfield used data from 2645 stations, of which about 90% were in the USA, with record lengths typically from 10 to 70 years (only 11 stations had lengths > 70 years). In our present study we have used much more (15029) daily rainfall records from around the world, with more representative geographical distribution and with much longer records, from 50 to 163 years, and we have treated these data in a probabilistic framework. Therefore, we believe our contribution has some value and usefulness, although some of the other Reviewers and Commenters did not recognize this particular point emphasized by this Commenter.

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