Reply on RC2

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Dear Reviewer,

Thank you very much for your detailed and helpful comments. We address them point by point below.

Main comments

1.

The article is quite long and there are mainly repetitions. In particular the "Discussion" section is very mainly an extended summary of the results. There are actually few sentences of discussion. Would it be possible to drastically shorten this part?

Answer: You are right, there are many repetitions in the discussion. We believe they could be avoided by merging the sections results and discussion (as suggested in RC3) and we will change the manuscript accordingly.

2. I'm a bit puzzled by the fact that a constant xi is considered in the d-GEV distribution. As Fig. 8 shows, the xi parameter seems to be decreasing with duration (as expected). The authors claim that the shape parameter in difficult to estimate, which is true, but don't you think that a simple model on xi (e.g. log-linear wrt duration) could be managable?

Answer: Thank you for this interesting remark. For the dependence of the GEV parameters on duration in equations (5)-(7), we followed the assumptions of Koutsoyiannis et al. (1998). These assumptions are derived on the basis of an empirical formulation for the relationship between precipitation intensity, duration, and frequency, which is not based on any theoretical reasoning. Based on annual maxima, it is difficult to find an alternative formulation for the dependence of the shape parameter on duration $\xi(d)$, since the estimation of this parameter is associated with large uncertainties. This is also evident in our manuscript from Figures 7(c) (red squares) and 8(a). To the best of our knowledge, previous studies on estimating IDF curves have therefore always used a constant shape parameter $\xi(d)$ =const. within a duration-dependent extreme value distribution (Koutsoyiannis et al., 1998; Van de Vyver and Demarée, 2010; Lehmann et al., 2013; Van de Vyver, 2015; Van de Vyver, 2018). One important outcome of our study is that when monthly maxima are used, the reduced uncertainties in the estimation of ξ allow further investigation of the dependence of ξ on duration. We find that ξ decreases with duration when taking the average of the investigated stations in Germany. We believe that this finding provides a good basis to explore a potentially more suitable formulation of $\xi(d)$ in future studies.

References

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Specific comments

l 4:

"IDF curves are steeper": I think this is not understandable in the abstract

Answer: We suggest to rephrase the sentence to: "The monthly IDF curves of the summer months exhibit a more rapid decrease of intensity with duration, as well as higher intensities for short durations than the IDF curves for the remaining months of the year."

l 5:

"short convective events occur very likely in summer" : the "very likely" may be confusing because it is stille rare (probability vs conditional probability)

Answer: We suggest to change the sentence to: "Thus, when short convective extreme events occur, they are very likely to occur in summer everywhere in Germany."

l 24:

Kuntz et al is in german so I could not check

Answer: The book "Klimawandel in Deutschland" (Climate Change in Germany) summarizes results from a wide range of studies on the observed and projected effects of climate change in Germany. Chapter 7 discusses changes in precipitation. Unfortunately, there is no English edition. Non-German speaking readers are referred to Moberg and Jones (2005) and Łupikasza (2017).

l 95:

you consider both 1 and 2 minutes. As shown later in your figures, the distributions for 1 and 2 minutes are very similar so I'm not sure that the 2 minute is necessary.

Answer: We chose to cover a wide range of durations, with the aim of having equidistant durations on the logarithmic scale. Therefore, both one minute and two minutes are included in the analysis. Although the distributions have very similar characteristics, we do not consider removing either of these information as beneficial. Especially since the information about the short durations is crucial for the estimation of the duration offset parameter θ.

l 178:

Actually to the best of my understanding, Jurado et al 2020 conclude that accounting for dependence gives better results when d<=10h, which is the case for 10/14 (71%) of the considered durations. So I'm not convinced by your justification (but I agree that accounting for dependence increases much model complexity)

Answer: You are correct that Jurado et al. (2020) have shown that the estimation of the higher quantiles for short durations improves when dependence is taken into account. However, this improvement is rather modest considering the increased complexity of the model. In addition, sub-hourly durations were not included in the study. We suggest rewording the sentence as follows: "Jurado et al. (2020) have shown that accounting for asymptotic dependence between durations yields a modest improvement in the estimation of quantiles of short durations $d \leq 10\,\mathrm{h}$, but comes at the cost of increased model complexity. We therefore decide to neglect the dependence between durations when estimating the d-GEV parameters using equation (12)."

l 205-206:

I'm not familiar with the cross-validated likelihood method so I missed this part. E.g. what is the number of folds? Please consider being more specific here.

Answer: Thank you for pointing this out. We will elaborate more on this part.

l 233-238:

to be sure: do you use the same sampling years also for deriving the annual GEV from the monthly GEV ? (i.e. do all monthly GEV use the same sampling years?)

Answer: Yes, all monthly maxima (for all durations) from a particular year are jointly sampled.

l 297-303:

If I understood correctly, the sum of the ordinates of the dots of a given duration is equal to 0.1 (due to the 0.9-quantile). So dividing the ordinates by 0.1 gives the proportion of exceedances that occur a given month. Wouldn't it be easier to interpret Fig 4 this way? For example in Bever 45% of the exceedances occur in July.

Answer: Thank you for this helpful comment. Yes, the product of the monthly probabilities is 0.1, so when dividing by 0.1 we obtain the conditional probabilities. We will include this as additional information in the text and caption.

Fig 5:

I don't understand the legend for Pr max. For example what do you mean by "$< 2\%$"? Isn't it "$1 - 2\%$"? Also I would find it easier to interpret if you divide Pr by 0.1, as said above.

Answer:

You are right, we will change the legend to $1 - 2\%$. We will mention the information about the conditional probabilities in the caption.

l 364-366

I don't understand how you deal for cases p>1-1/T. What is the observed quantile in this case? I guess you consider the maxximul value by I don't thin that's correct. So I suggest removing the cases without dots in Fig 6.

Answer: The Quantile Score is defined as

$$\mathrm{QS}(p) = \frac{1}{N}\sum_{n=1}^{N} \rho_p(o_n - q_p), \quad \text{where } \rho_p(u) = \begin{cases} pu & , u \geq 0 \\ (p-1)u & , u < 0, \end{cases}$$

where $u = o_n - q_p$ is the difference between an observation o_n and the quantile q_p estimated from (in this case) the d-GEV model. Therefore the model is always compared directly to all data and no empirical

quantile estimation is necessary. A common problem in the verification of extreme value models is the lack of data to verify the model for high non-exceedance probabilities. However, even if no observations are above the estimated quantile, QS still provides an estimate of the model performance. We decided to indicate the length of the time series available for verification, since the estimate might be less reliable if the length of the time series T is shorter than the period corresponding to the non-exeedance probability $p = 1 - 1/T$ being verified. One should therefore be more cautios when interpreting these results. However, we do not agree that this information should be completely removed.

l 426:

I agree that Fisher information matrix is correct in this case but for comparison puropose, I suggest using a bootstrap method as for the other cases.

Answer: Thank you for pointing this out. You are correct that it is better for reasons of comparability to estimate all uncertainties using the same method. We will change this and estimate all uncertainties via the boostrap method in Figure 7.

Fig 8:

As said above, the monthly GEV seems log-linearly decreasing with duration

Answer: See above.

Section 4:

As said above, this is actually almost only an extended summary. Please consider shortening it.

Answer: See above.

l 562-563:

As a first try, I wouldn't try the multi scaling model but I'd rather consider xi function of d.

Answer: We agree. We were just suggesting multiscaling could lead to similar results. We will make it more clear in the manuscript, that future studies should investigate the dependence of ξ on duration.