Precipitation extremes on multiple time scales - Bartlett-Lewis Rectangular Pulse Model and Intensity-Duration-Frequency curves

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Reply to Comments from Reviewer #1

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We are very grateful to three anonymous reviewers for carefully reading and commenting thoroughly on our manuscript. We received highly valuable and constructive comments which very much helped to improve our work and led to new insights. We additionally got plenty ideas for further investigations.

In the following, we go point by point through all the comments and reply to them. Reviewers' comments are all repeated in this document, typeset in black. They are individually addressed, typeset in blue. Changes to the original manuscript as resulting from the reviewers comments are repeated here to ease the comparison with the original version; they are typeset in *blue italic*.

Due to some comments from the reviewers, we decided to exchange the abbreviation *BLRPM* to *OBL model* in order to distinguish the original Bartlett-Lewis model (*OBL*) from a modified version (*MBL*).

Reviewer #1

General Comments:

This paper investigates the ability of the original Bartlett-Lewis model for estimating extreme rainfall at various levels of aggregation. Unfortunately, the paper is not very novel. It is already known for a long period that the Bartlett-Lewis (BL) models have problems in reproducing extremes, especially at shorter aggregation levels. It is not clear why the authors chose for the Original Bartlett-Lewis (OBL) model, while the Modified Bartlett-Lewis (MBL) model or one of the later versions (e.g. Onof and Wheather, 1994) that were further optimized for addressing the problem of the undergeneration of extremes. An important part of the paper is dealing with the fact that using a short time series for calibration may have an important impact on the statistics described by the observed extremes: the highest extreme may have a much larger return period than the one estimated from the time series. This, of course, is not surprizing, and the shorter the time series used, the higher the potential becomes of facing with extremes that have true return periods much larger than the length of the time series. Yet, this example may be of interest for the scientific community, especially for young researchers starting in the domain of stochastic hydrology. Therefore, I believe this part of the paper may be of interest, though not very novel.

Remarks:

Yet, I would like to give some suggestions that may improve this section:

Mayor (1) using the model with 12 extremes, calculate the return period of the highest extreme that was omitted (i.e. the one in year 2007) to frame how extreme this event in 2007 was?

We added the following sentence and table to Section 5.3: *Based on the model with parameters estimated from observations without the year 2007 (observed), we obtain return periods for the event "Kyrill" for different durations and find this event to be very rare, especially on short time scales (1-3 hours), see Tab. 1.*

Duration [h]	Probability of exceedance without Kyrill [%]	Return period without Kyrill [years]	Probability of exceedance including Kyrill [%]	Return period including Kyrill [years]
1	1.8×10^{-6}	560000	5.6×10^{-4}	1790
2	4.3×10^{-5}	23000	2.4×10^{-3}	420
3	2.2×10^{-4}	4400	5.4×10^{-3}	185
6	1.6×10^{-3}	630	1.6×10^{-2}	63
12	1.7×10^{-3}	590	2.0×10^{-2}	49
24	3.5×10^{-3}	280	3.5×10^{-2}	29
48	2.0×10^{-2}	50	9.5×10^{-2}	11

Table 1: Return period for the event *Kyrill* as estimated from the observational time series with this particular event left out and included for parameter estimation for different durations.

Mayor (2) Why not redo the same exercise with the Peak-Over-Threshold method, where the threshold is put quite low to ensure a larger number of extremes? This may reduce the uncertainty on the IDF curves as more data are used to fit the parametric model?

The POT approach might have given us a larger number of extremes. However, we are not sure to what extend the consistent estimation using all durations simultaneously can be performed for the GPD as it can be (and we do it here) for the GEV. Koutsoyiannis et al. [1998] suggested the duration dependent GPD as well as a model for IDF curves but explicitly states that parameter estimation would have to be carried out via annual maxima and the asymptotic equality of GEV and GPD for extremes, rendering the GPD based approach less interesting for us. Our argument here is that uncertainty can be reduced due to borrowing strength from neighbouring durations by using the *duration dependent* GEV approach.

Minor

- Line 11-12: here it is not clear what is meant with a singular event. Context is not sufficiently provided.

  Thanks for the hint! Singular is indeed unclear here. We replace occurrences of *singular* in the text by *rare in the sense given in Tab. 1* or *...rare event (here an event with a return period larger than 1000 years on the hourly time scale)* before the table is introduced *in section 5.3.*

- Line 73: mention what version of the BL models is used (i.e. the Original BL model)

  We added *original* and *(OBL)* to line 73 and change the notation *OBL model* instead of BLRPM throughout the text.

- Line 147: remove the footnote after the equation as it reads as if (1-p) is put to the power "1". The text in the footnote can easily be introduced in the sentence.

  We changed the sentence to *An IDF curve for a given return period* $T = 1/(1-p)$*, with* p *denoting the non-exceedance probability,...*

- Lines 227-228: please introduce a figure to illustrate this.

  Thanks for the hint. It should (and does now) read in the text *For January, IDF curves from observations and OBL model simulations ...* and not February. The figure for January is provided.

- Line 232: True, but this is a typical problem occurring for too short time series used for extreme value analysis: fitting a distribution to 13 points is questionable!

  Here we expect that using the simultaneous fit to 9 durations makes this approach more robust. We fit one duration dependent GEV to 117 extreme values (13 years multiplied by 9 durations). They are, however, clearly not independent.

- Line 299: "which may not be reproduced by the BLRPM": this may be reproducible! Only, its occurrence may be very low causing that this event was never modelled during the short time series generated! What is the return period of this "singular" event based on the model built from all extremes excluding this event?

  From Tab. 1, one can see that the return period for a comparable event (for 2h duration) is several thousand years. However, we do only simulate 1000 years and probabilities of getting such a strong event in this short time period are low. We suggest a better formulation for this sentence in the introduction: *2) How are IDF curves affected by very rare extreme events which are unlikely to be reproduced with the OBL model for a reasonably long simulation?* and the conclusion *2) How are IDF curves affected by very rare extreme events which are unlikely to be reproduced with the OBL model for a reasonably long simulation? When the year 2007 is excluded from the analysis, the aforementioned discrepancy in January disappears. We conclude that an extreme event which is rare (return period of 23000 yrs) with respect to the time scales of simulation (1000* $\times$ *13 yrs) has the potential to influence the dd-GEV IDF curve as 1 out of 13 values per duration – i.e. one maximum per year out of a 13 years time series – does change the GEV distribution.*

- Line 330: define "relative difference"

  To define this term, we changed the beginning of the paragraph to: *Figure 11 shows the relative difference*

$$\Delta = \frac{dd\text{-}GEV_{OBL} - dd\text{-}GEV_{obs}}{dd\text{-}GEV_{obs}} \cdot 100\% \tag{1}$$

  between IDF curves (dd-GEV) derived from the OBL model $dd\text{-}GEV_{OBL}$ *and directly from the observational time series* $dd\text{-}GEV_{obs}$.

- Appendix A: please provide information to the reader of what should be learned from the figures presented in the appendix. Nor the appendix or the text sufficiently elaborates on this.

Appendix A is referred to twice in the text and gives an overview on estimated OBL model parameters. We consider the information in the table as necessary for reproducible research.

With the Figures in Appendix B, we suggest another way of looking at differences in IDF curves which aims to provide a better understanding of model deficiencies in terms of over- or underestimation of return levels. We changed the sentence referring to Appendix B in Sec. 5.2 to *The relative differences in IDF curves given in Fig. 11 (Appendix B) suggest a tendency for the OBL model to underestimate extremes, particularly for large return levels and short durations, similar to results found by, e.g. Verhoest et al. [1997] and Cameron et al. [2000].*

References

D. Cameron, K. Beven, and P. Naden. Flood frequency estimation by continuous simulation under climate change (with uncertainty). *Hydrology and Earth System Sciences Discussions*, 4(3):393–405, 2000.

D. Koutsoyiannis, D. Kozonis, and A. Manetas. A mathematical framework for studying rainfall intensity-duration-frequency relationships. *J. Hydrol.*, 206(1):118–135, 1998.

N. Verhoest, P.A. Troch, and F.P. De Troch. On the applicability of bartlett-lewis rectangular pulse models in the modeling of desing storms at a point. *J. Hydrol.*, 202:108–120, 1997.