Replies to Reviewer #2

January 2021

We would like to thank the Reviewer for carefully evaluating our revised manuscript, and for their suggestions for further improvement. We provide a detailed reply (in red) to the individual comments (in *italics*) below.

Main points

1. *Section 2.1 I overall approve of the "raindrop" analogy although it does become a little strained when the vegetation is added. Unfortunately I don't have a better idea either. Maybe it would have been more consistent to show a stylized image of a raindrop flowing down a rock instead of the Lorenz attractor in Figure 1. The zoomed in parts of the trajectories could easily represent paths of rain drops instead of the abstract trajectory along the "butterfly". On the other hand most readers with any kind of climate science background are probably familiar with L63.*

We understand the Reviewer's viewpoint, and have opted to add a figure (new Fig. A1) showing a schematic of raindrops flowing down the side of a valley. We hope that this makes the raindrop analogy (including the vegetation component) clearer, while also leaving the familiar reference of the Lorenz '63 attractor for the readers with a background in dynamical meteorology.

2. *Answer to reviewer #2 major comment 2: I would like to clarify my original comment because I don't think it came across properly. If the prp field contains only ones and zeros, the distance between such fields is effectively an integer. Regardless of the regular or fractal nature of the binary point set, the distance d is a fundamentally different kind of random variable than for slp and z500 because its density consists of a finite number of point masses at whole numbers. The members of the GEV family, on the other hand, are continuous functions. I appreciate that your methodology may nonetheless be applicable but I do not see the "robust theoretical arguments": In Lucarini et al. (2012), the attractor of the system is a fractal but the considered distance measure is continuous and not discrete. Faranda et al 2017a present an empirical study which may give evidence that this strategy for precipitation differences is appropriate in practice but they do not give theoretical arguments for its validity. I therefore believe that intermittent variables like precipitation are not ideal targets for your kind of analysis.*

We thank the Reviewer for this clarification, as we had indeed partly misunderstood their original comment. Our estimation procedure is based on fitting the exponential member of the GPD family in the context of dynamical systems theory. Hitz (2016) showed that discrete variables which yield the same mixing properties of continuous variables can still be approximated by GPD distributions. Here, we

implicitly use this result which, as shown by Hitz, may be applied to modelling geophysical data. In the new version of the manuscript, we have expanded our discussion of this theoretical, yet very important point. In view of the clarification provided by the Reviewer, we have also revised our previous statement and now write that there is no complete theoretical framework for the application of extreme value theory to recurrences of discrete fields, although studies such as Hitz (2016) and Faranda *et al.* (2017a) support the physical relevance of the results .

3. *L.136, equation (3): What do you actually mean by the "U"-symbol? I thought this was the symbol for the union of two sets but the expressions left and right of it are not sets but logical statements in which case you probably mean "v" for a logical "or"? In either case I think what you actually want is a logical "and" which would be an inverted "v" (in Faranda et al. 2020 it is formulated in terms of conditional probability using the "|" symbol which also means that both thresholds must be exceeded): If you actually meant "or", the numerator would be the number of cases where either g(x) or g(y) exceed their thresholds which is at least as large as the number of cases where only g(x) is above s_x; alpha would then be bounded from below by 1.*

We thank the Reviewer for spotting this typo; we should indeed have used the "|" symbol, and have now corrected this in the paper.

4. *L. 306. "significantly increased precipitation across the southern portion of the domain [are] favored by negative SLP and Z500 anomalies to the North of the strongest precipitation anomalies [...]. These are likely the footprint of a strengthened heat low [...]" Heat lows are generally shallow structures with negative pressure anomalies in the lower levels and divergence with associated positive pressure (or geopotential) anomalies above. In their discussion of West African heat lows, Lavaysse et al. (2009) explicitly state that "A heat low is an area of low atmospheric pressure near the surface resulting from heating of the lower troposphere and the subsequent lifting of isobaric surfaces and divergence of air aloft." If anything, I would expect a positive geopotential anomaly at 500hPa associated with this kind of pressure system. Your interpretation of the negative Z500 anomaly as an indicator of increased heat low activity is therefore questionable.*

The Reviewer is absolutely correct; we had mistakenly written "negative [...] Z500 anomalies" instead of "positive [...] Z500 anomalies." Indeed, Fig. 7a clearly shows negative Z500 anomalies in the south of the domain, and positive Z500 anomalies to the North of the negative SLP anomaly core in Fig. 6a, much like what is shown in Fig. 2b in Lavaysse et al. (2009). We have now rephrased this passage to: "In MH_{CNTL}, this takes the form of significantly increased precipitation across the southern portion of the domain, favoured by negative SLP anomalies to the North of the strongest precipitation anomalies (Fig. 6a) and positive Z500 anomalies to the North of the negative SLP core (Fig. 7a). These are likely the footprint of a strengthened heat low (see e.g. Fig. 2b in Lavaysse *et al.*, 2009), which favours a northward progression of the monsoonal precipitation." We have further reformulated some of the sentences in the rest of the paragraph to ensure a more accurate description of the observed Z500 anomalies.

References

Hitz, Adrien. Modelling of extremes. 2016. PhD Thesis. University of Oxford.