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Interactive comment on "Return Levels of Temperature Extremes in Southern Pakistan" *by* Maida Zahid et al.

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We would like to thank anonymous Referee # 3 for the critical review and comments. The step-by-step responses (*) to the main reservations of the referee are as follows.

Why we did not analyze the overall increasing trends in the frequency or intensity of extremes related to daily maximum temperatures?

(*)We did not analyze the increasing trends in the frequency and intensity of extremes related to daily maximum temperatures, and considers the stationary extreme value analysis due to short duration of the data (33 years) and to have reliable estimates with less uncertainty. Moreover, the study domain is one of the hottest region in the world as mentioned in the paper with the highest record-breaking temperature of 52°C in 2010. This region is a hub of agriculture activities and 50% of the population work outdoors.

The local administrations have limited resources, so they want to prioritize the region for the adaptions like, early warning systems, introducing new the temperature tolerant crops, water management and providing shelters for the outdoors workers etc. Therefore, the information of return levels is good for the planning and adaptation strategies. So, a stationary analysis is already a pretty relevant contribution for the region. Clearly, considering non-stationarity is a good idea for future work. We might consider using the centennial NCEP reanalysis (Compo et al., 2011).

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The motivation: It does not become clear, why the re-analysis data are relevant here, except that they might be used to fill gaps with missing observations. In this respect, it appears important to correct the re-analyses for biases. That would, however, require a more advanced method as the one used here, combining local information at the stations with information on large-scale conditions.

(*) It is common practices among meteorologists to use ERA Interim (or NCEP) data to study the local to regional to large scale climatic properties. These datasets are also often used to assess the skill of climate models. Therefore, it seems reasonable to include them here. Additionally, the ERA Interim reanalysis data was proved to be very good at replicating trends in percentile-based measures of temperature (Cornes and Jones, 2013). However, it is still not clear that ERA data can simulate well meteorological extremes. This is why we use ERA Interim data to see how well it performs in the target area against observations. We are well aware – this is clearly explained in the text – that one could used more advanced bias correction methods. But here we want to show whether if we reduce to zero the bias in the first two moments (note that most scientists and practitioners focus only on these two statistical properties), we are still able to have a good representation of the tail of the distribution. In some stations like Nawabshah, Karachi etc, even the standard bias correction show very good agreement with observations. However, we agree with reviewer that if ERA data has to be used in the region (and elsewhere) to study extremes, a more advance method is needed. We

wish to underline the need to loon into actual station data. We have added this detail in the revised version of the paper.

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The presentation of the methodology: The presentation of the methodology fills a rather large part of the manuscript, although much of it is widely used. Therefore, this part of the manuscript could be shortened. The presentation of the results: The presentation of the results is not very concise. Numerous numbers and maps are included in the manuscript, but often they are not properly presented.

(*) We agree that the statistical methods used here method is widely used, but, we prefer giving some details in order to address an audience that might be not so familiar with extreme value theory. We agree that the presentation includes a lot of maps and figures, but we remind the reviewer that, as mentioned in the paper, this is the first analysis for extremes using extreme value theory in Pakistan. Therefore, we consider giving all the possible details, to provide a thorough picture of the methodology and results to the fellow researches in Pakistan and neighboring countries.

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The discussion of the results: The results of the study are not really discussed, neither with respect to the scientific literature nor with respect to the underlying physical mechanisms and, only partly, with respect to the representativeness of the results for southern Pakistan for the rest of Pakistan or the rest of the wider region.

(*) The results are discussed with respect to the available scientific literature. Please see the following cited references in results and discussion.

Sacrrott and MacDonald, 2012 (line 17, page 7), Coles, 2001 (line 19, page 7), Furrer et al., 2010 (line 20, page 7), Davison and Smith, 1990 (line 26, page 7), Hatfield and Preuger, 2015 (line 29, page 9).

The scientific literature regarding extreme value theory and return levels is not available

(mentioned between line 13 -14 page 3) for this specific region, therefore we could not discuss it in results. Understanding the meteorological mechanisms behind heat waves is well beyond the scope of this paper, which is only mostly statistical in nature. Much more work at this regard would be needed. Note that we have clearly explained why the statistical properties analyzed here are relevant for human welfare and economy in the region.

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Concluding section: The concluding section is just a repetition of the main results of the study, and no conclusions of this study are given.

(*) The concluding section is named as “Summary and Conclusion”, therefore we have summarized the results in the beginning and conclusions are given between lines 4-17 page 11. However, it is customary to summarize the results of the paper at the beginning of the last section, especially for a paper where statistical properties are analyzed.

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Tables: As for Table 2, it is not clear, why monthly mean values of the daily minimum and mean temperatures are presented here. As for Table 3, I am puzzled by the substantially different behaviour of the p-values according to the KS-test and the p-values according to the AD-test. As for Table 4, I am missing the units.

(*) Table 2: shows the mean monthly climatic characteristics of the region from 1980-2010. It is there to describe the climatology of the region. This is a useful complement to the analysis of the extremes performed in the rest of the paper.

Table 3 : shows the different behavior of p-values because KS test and AD test are two different methods, and are used here to see the goodness-of-fit at each station. For details please see line 9-12 page 8.

Table 4 : show the estimated parameters shape ξ, scale σ and standard error $\Delta\xi$ of all

the data sets.

Shape parameter ξ has no unit. Scale parameter σ has the unit "degree Celsius" like temperature.

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Figures: Generally, the figures and/or figure captions are lacking units. Also, in many cases the use of different plotting ranges for panels, which show the same kind of estimates for different data sets or different locations make it difficult to draw firm conclusions from these figures. As for Figs. 8 and 9, it layout of the panels makes is very hard to extract the relevant information from the map, since it the information on the magnitude is hidden in the respective column including the symbols.

(*) The units are placed inside the figures, but now we have written them in figure captions as well. Regarding Figure 8 and 9 we think two different colors clearly distinguish between observations and bias corrected ERA Interim return levels, also different symbols are used to differentiate among the cities and return level values. In our point of view, the information on the magnitude of extremes is quite obvious here. However, suggestions to improve Figure 8 and 9 are welcome. Unfortunately it is never easy to find optimal solutions for that kind of figures. We have relied on interactions with colleagues and practitioners in multiple poster and oral presentations to gain inputs on that.

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References: Most of the references to the scientific literature are used in the Introduction and in the methodology section, also highlighting the fact that the sections on the results and the discussion are not properly done.

(*) Given the nature of the paper (first analysis of extremes in the region), it seems quite natural that most of the referencing goes in the introduction and in the methodology. In results and discussion, following references are cited, highlighting the fact that it is

properly done.

Sacrrott and MacDonald, 2012 (line 17, page 7), Coles, 2001 (line 19, page 7), Furrer et al., 2010 (line 20, page 7), Davison and Smith, 1990 (line 26, page 7), Hatfield and Preuger, 2015 (line 29, page 9).

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