Interactive comment on "Estimating changes of temperatures and precipitation extremes in India using the Generalized Extreme Value (GEV) distribution" *by* Kishore Pangaluru et al.

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Reviewer #1 replies

Pangaluru and co-authors quantify extreme temperatures (maxima and minima) and precipitation over India using climate models with historical forcing and CRU data. They show biases between the two datasets spatially over India. I may not have a lot of comments, but overall I find that the analysis is shallow and I fail to grasp what the significant contribution of this paper is. There is already a lot of literature comparing historical and future temperature using climate models. For example, the IPCC report, but also many other papers, often on a global scale. Therefore, I strongly doubt whether

the manuscript in its current (or even updated) form meets the standards of HESS. Here I provide some key points that need to be addressed:

Reply: The authors thank the reviewer for his/her comments/suggestions which increases the quality of manuscript drastically. We will partly agree with the reviewer's comment on a lot of literature on historical and future temperature extremes over the globe but very few articles are available over particular regions like India. In this revision, we have provided point-by-point replies to the reviewer's comments and information concerning how we handled the revised manuscript while also considering the other reviewer comments/suggestions.

None of the figures actually provides information on future changes in the extremes over India. All that can be seen is that there are biases between the climate models and CRU. This should be analyzed because that is the analysis that was suggested in the title of the paper and even what is concluded on, for example, L316 and L356-359. It would probably also require carrying out bias-correction for the climate models.

Reply: The authors apologize for this mistake. We applied the bias correction and downscale method (BCSD) and discussed in the revised manuscript. For our analysis purpose, we consider the common period of Historical model and CRU observational datasets (1901-2005) and adjust the biases in CMIP5 RCPs (2.6, 4.5, 6.0, and 8.5) output for projected the time period (2006-2099) by assuming a constant model bias. We also included these lines are incorporated in the revised manuscript. Our main intension was to show the temperature and precipitation extremes of observational and model datasets during the 20th and 21st centuries using generalized extreme value (GEV) statistical distribution.

The CRU data is monthly. Most literature for extremes is on daily or sub-daily scale. I am not sure if it is very useful to do extreme value analysis on monthly data. Essentially you probably have 2 or 3 months each year that can have the highest temperature or precipitation. You could also take the month which generally has to highest temperature

and do a trend analysis. I would like to see some analysis by the authors that showed that the assumption of GEV-distribution is useful or use references to explain that this is a useful approach.

Reply: Thanks for your comment. We used monthly average daily maximum and minimum temperatures and precipitation datasets and we corrected in the revised manuscript. We have gone through several published papers, from the literature we found daily, monthly and yearly temperature and precipitation datasets are used for the GEV statistical distribution with different periods. Previous literature we found that:

Wen et al. (2015): They utilized for their GEV analysis purpose the monthly average daily maximum and minimum temperature and precipitation datasets during the period from 1901 to 2005 over China. Ashouri et al. (2016): They examined both the annual maximum precipitation events and precipitation peaks above a certain threshold using CPC and MERRA datasets. Fernado et al. (2006): The datasets are considered monthly maximum for each year, exceedances over large thresholds are used for GEV analysis. Kharin et al. (2013): They considered annual extreme of daily maximum and minimum surface air temperatures of CMIP5 models during the years 1850-2005. Kumar et al. (2017): They examined the annual maximum peak flood data that vary over the period 1957-1989 for 115 bridge sites. Naima et al. (2017): For their GEV analysis purpose the annual maximum of daily precipitation in different regions northern Algeria from 1936 to 2009. Shashikanth et al. (2017): They examined Indian summer monsoon (JJAS) each year peaks are utilized for their analysis purpose. None of the studies explain the non-stationary GEV model spatial structures of temperature and precipitation extremes using Historical model and CRU observations (1901-2005), and all scenarios (RCP2.6, 4.5, 6.0, and 8.5) of CMIP5 models (2006-2099), especially over India.

Regional averaging: is this done before or after the application of the GEV model? Explain why?

Reply: Thanks for your comment. The regional temperature and precipitation mean values are estimated for the 10-, 20-, and 50-year return periods of GEV model results. The regional mean values are estimated using all seven regions over India. The regional mean is the same as the spatial average over India, but we used the word 'regional mean' in the text.

Extreme value theory is normally used to estimate extremes with return period beyond the window of training data. With 100+ year of data, you could just get the 10, 20 and 50 year return levels directly from your data, without fitting and GEV model, so what is the point in doing that?

Reply: Thanks for your comment. To the best of our knowledge, for estimating the extremes with return period the window is little more than the required period. However, we checked the literature most of the researchers are extracted the time periods between 10 to 50 years using little more length than the required time period. In our analysis, we used Historical (1901-2005=105 years) for 2oth century purpose, and RCPs (2006-2099=93 years) used for the 21st-century purpose. I hope this length is enough to estimate the temperature and precipitation extremes for three different (10, 20, and 50-year) periods.

I did not comment on the captions, because the author have made it too difficult for reviewer to assess them as the captions and the figures are given separately. Please fix this in a revised manuscript.

Reply: As per reviewer suggestion, we have added the figure caption at the bottom of each figure in the revised manuscript.

The precipitation analysis is carried out much less rigorously compared to the temperature analysis. I think this should be extended.

Reply: We sincerely appreciate the reviewer's suggestion in this regard. In the revised version we extended non-stationary GEV statistical distributions of precipitation

Interactive comment

extremes using different scenarios of CMIP5 models (RCP2.6, RCP4.5, RCP6.0, and RCP8.5) and we have added two figures (See Figures 1 and 2) of extreme precipitation results along with the description. The revised manuscript covers the 20th and 21st-century extreme precipitation non-stationary GEV results using Historical model (1901-2005), CRU (1901-2005), and CMIP model (2006-2099).

SPECFIC AND TECHNICAL COMMENTS

Are the temperatures monthly average temperatures (day+night), or are they monthly averages of daily maxima/minima or something else?

Reply: Thanks for your comment. For our analysis purpose, we utilized monthly average daily maximum and minimum temperatures.

L31-32: " The GEV statistical distribution is a time-dependent distribution" The GEV distribution in itself is not time-dependent. Only if you make the parameter non-stationary (e.g. Wilcox et al., 2018). Later on in the methods the authors (falsely) suggest a time-dependency of the parameters (L136), but I actually think that they applied GEV non-stationary for different time periods, which is different from applying a time-dependent (i.e. non-stationary) method.

Reply: We agree with the reviewer's concern and we used the non-stationary GEV statistical distribution. In the revised manuscript, we discussed the stationary and non-stationary GEV distributions and the importance of the non-stationary method. We also included more information on non-stationary GEV model and we have provided references for important statements.

L31-34: "The GEV statistical distribution is a time-dependent distribution with different time scales of variability bounded by a precipitation, maximum (Tmax) and minimum (Tmin) temperature extremes and also assessed their possibility changes are evaluated and quantified over India is presented" There is something wrong in this sentence.

Reply: We are sorry for the mistake. In the revised manuscript, we have avoided these

flaws sentences.

L37-40: "The regional means of historical warm extreme temperatures are 34.89, 36.42, and 38.14 C for three different (10, 20, and 50-year) periods, respectively; whereas the cold extreme mean temperatures are 7.75, 4.19, and -1.59 C". Since there has not been given a definition of a regional mean extreme temperature this information is not very helpful in the abstract. This word period is somewhat misleading here. I suggest to use always (throughout the manuscript) include the word 'return' when talking about return periods. Period could just refer to a certain length of time.

Reply: We sincerely appreciate the reviewer's suggestion in this regard. We will agree the "regional" word is misleading in the abstract. We modified the sentence accordingly in the abstract. The regional mean values are estimated using all seven regions over India. We have explained how we did the regional mean in the revised manuscript. We have included the word "return" throughout the manuscript in the revised manuscript when talking about return periods.

L46-47: "The CRU precipitation extremes are larger than the historical extreme precipitation in all three (10, 20, and 50-year) return-periods. What does this mean? CRU is historical precipitation right?

Reply: Thanks for your comment. Yes, CRU precipitation extremes are larger than historical model ensemble precipitation extremes. Here, the Climate Research Unit (CRU) is the observations and historical is model datasets. The CRU temperature and precipitation datasets are collected from 1901 to 2005 over land areas, based on daily values from rain gauge measurements provided by more than 4,000 weather stations distributed around the world with the horizontal resolution of 0.5x0.5 grids. The CRU and historical precipitation datasets are considered the same period (1901-2005). Nearly 20 historical models are used for our analysis purpose (see Table 1).

L56-57: "India is the third most influenced nation by weather related by disasters, which can largely be attributed to both higher occurrences of extreme temperatures and pre-

cipitation" Does this statement include or exclude the effect of risen CO2-levels in the atmosphere, or is it because of the fact that people simply live very close (perhaps very close) to rivers for example.

Reply: Thanks for your suggestion. We included the statement in the revised manuscript.

L58-60: "Trenberth (2005) showed that climate change due to increased greenhouse gas emissions leads to changes in extreme event behavior in terms of precipitation and temperature all over the world. Really? The title of the paper suggest that it looks at uncertainties in hurricanes. perhaps other references are more appropriate.

Reply: We also agree your suggestion, now we added the relevant reference in the revised manuscript.

L64: "Jaruskova and Rencova (2008)" Not sure why this reference singled out. There are probably hundreds of papers using GEV. A reference that should probably not be missed is Papalexiou and Koutsoyiannis (2013), since that does global analysis and this includes India as well.

Reply: We agree with the reviewer's concern in this regard. Papalexiou and Koutsoyiannis used maximum rainfall datasets of 15,137 records from all over the world, with lengths varying from 40 to 163 years. We modified the manuscript and we have provided this reference in the revised manuscript. Thanks for giving the reference, which helped while revising the manuscript.

L124: "Generally, the value of ξ is greater than zero for precipitation data" Can you provide reference?

Reply: Thanks for your suggestion. In the revised manuscript we added the reference.

L161: "return time periods" I think this should be return period or return time and not return time period.

Reply: Thanks for your suggestion. In the revised manuscript we used the term "return period" throughout manuscript.

L215-217: " Moderately warm regional mean temperature changes are observed in RCP2.6 and RCP8.5 scenarios at about 1.15, 1.28, and 1.28oC for the three (10, 20 and 50 year) periods, respectively." Where can I see these numbers back?

Reply: Thanks for your comment. In the revised version of the manuscript, moderately warm spatial mean temperatures are observed in RCP8.5 than RCP2.6 scenarios at about (37.51-36.36=1.15), (39.28-38.00=1.28), (41.18-39.90=1.28oC) for the three (10, 20, and 50-year) return periods, respectively. The spatial mean value over India for each return period is mentioned on the top of each panel in Figure 5 (Figure 4 in the old version).

L228: " warming of more than 2oC over the western Himalayan region in the 50 year period." The word 'Warming' suggests a trend in time of 2 degrees Celsius over 50 years, but I think the authors are just discussing the biases between CRU and CMIP5 for the 50-year return period or something like that. Please provide more details of what you actually did and better explain what you mean exactly.

Reply: Thanks for your comment. We mean to say that compare to the CRU warm extremes, the RCP8.5 simulation fitted warm extreme results are more than 3oC over three regions (NW, NC, and IP), and 1.5-2oC higher over the western Himalayan region in the 50-year return period. The results indicate that rising temperature in the 50-year return period may be due to global warming or other external forcings may influence the long-term precipitation pattern, in addition, an increase in the frequency of drought severity in several regions over India. These are discussed clearly in the revised manuscript.

L322: " Extreme warm values in Historical Tmax in India appear to be rather moderate." I could be just being from a much colder country, but a regional average monthly value of temperature of 38 degrees Celsius is not something I would classify as moderate.

Reply: We agree with the reviewer's concern in this regard. We modified the sentence in the revised manuscript.

Table 2: clearly provide the considered time period in the caption.

Reply: Thanks fro your suggestion. We have added the time period in the Table 2 caption in the revised manuscript.

Figure 1: axes lack units...

Reply: Thanks for your suggestion. We have added the units in Figure 1 in the revised manuscript.

Figure 2: The word historical is misleading. CRU is historical data, and climate models can simulate the climate of the past, but that does not make them actual history.

Reply: We agree with the reviewer's concern in this regard. We changed has historical multi-model ensemble maximum temperature in the revised manuscript.

TECHNICAL CORRECTIONS

Notation of Italic and non-italic symbols is a mess and not up to the standards as outlined in the HESS manuscript preparation guidelines.

Reply: In the revised manuscript we followed the format of HESS journal.

L60: 'The' Generalized Extreme... (this same error occurs at other places as well)

Reply: We are sorry for the mistake and we corrected in the revised manuscript.

Table 2: 30 year should probably be 50 year

Reply: Sorry for the mistake. We corrected the year in Table 2 in the revised manuscript.

L331: shown -> showed Reply: We are sorry for the typo mistake and now corrected in the revised manuscript.

REFERENCES Papalexiou, S. M. and Koutsoyiannis, D.: Battle of extreme value distributions: A global survey on extreme daily rainfall, Water Resour. Res. 49(1), 187-201, doi:10.1029/2012WR012557, 2013.

Wilcox, C., Vischel, T., Panthou, G., Bodian, A., Blanchet, J., Descroix, L., Quantin, G., Casse, C., Tanimoun, B. and Kone, S.: Trends in hydrological extremes in the Senegal and Niger Rivers, J. Hydrol., 566(Septemeber), 531-545, doi:10.106/j.jhydrol.2018.07.063, 2018.

We thank once again for providing thorough review, guidance, and advice throughout the preparation of the paper. Your help and experience were indispensable in pushing us forward to improve our work.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2018-522, 2018.
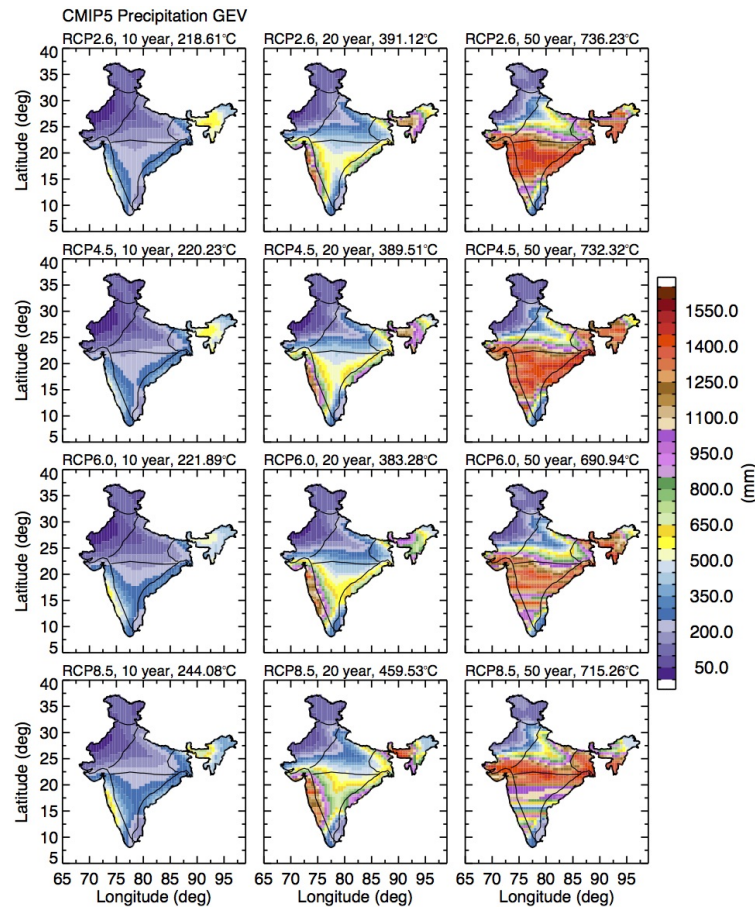
Fig. 1. Spatial structures of CMIP5 multi-model ensemble mean of warm extremes for (left) 10-year, (middle) 20-year, (right) 50-year return periods during 2006-2100 under RCP2.6 (1st row), RCP4.5 (2nd row),
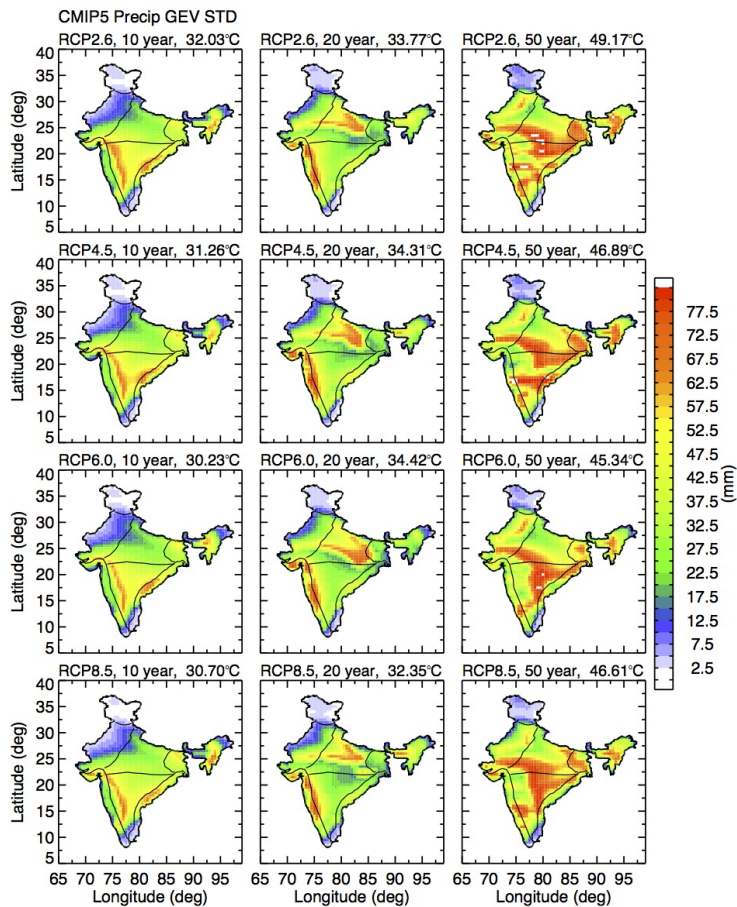
Fig. 2. The CMIP5 inter-model estimated return levels standard deviations for the 10-year (left), 20-year (middle), and 50-year (right) return values of annual maximum of monthly precipitation extremes simula