Responses and Actions taken on Reviewers' Comments

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Title: Evolution of multivariate drought hazard, vulnerability and risk in India under climate change.

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We thank the Reviewer for reviewing our revised manuscript and providing valuable feedback that have helped improve the quality of the work significantly. In this document, we provide a point by point response and actions taken on the comments and suggestions from the reviewers. (Figure, line, table and page numbers referred to in this document are with respect to the revised manuscript unless mentioned otherwise.)

Responses to comments from Referee #1

General comment

I think the authors presented a valuable and interesting study about the future development of the drought hazard, vulnerability and risk in India. The revision of the description of the datasets and the methods is satisfactory and the authors improved the manuscript significantly. Before the acceptance of the manuscript, I think the authors should consider the following minor comments and technical corrections. A revision of the English language is also recommended.

We thank the reviewer for the positive and constructive feedback on our work. We have implemented the minor and technical corrections suggested by the reviewer. Further, we have proof-read the manuscript again and corrected for grammar and language wherever necessary. We have addressed the comments provided by you in the below sections.

Minor comments

L refers to the lines in the revised manuscript with the highlighted changes.

1. L77: Please replace ‘deficiencies’ with ‘data’.

Line 76, Page 3

“…analysis of precipitation as well as soil moisture data”

2. L84: Please replace ‘frequencies’ with ‘resolution’.

Line 83, Page 3

“….to monthly resolution for the historical drought hazard assessment.”

3. L102-107: The authors could discuss in Section 3 the limitations due to uncertainty in the simulated precipitation and, particularly, in soil moisture data. Similarly, the authors could discuss the uncertainty in the socio-economic scenarios.

We agree with the reviewer that the uncertainties in the simulated datasets may affect the drought risk assessment. We have now explained this point in the revised manuscript.

Lines 338-341, Page 13

“It is to be noted that the four GCMs considered in the present study for precipitation and soil moisture simulations are bias-corrected for precipitation, and covers more uncertainty in temperature and precipitation changes compared to other GCM subsets (McSweeney et al., 2015). However, inclusion of other skilled GCMs can account for wide range of uncertainty in the drought hazard assessment.”

Lines 384-387, Pages 16-17

“Further, the socio-economic challenges for adaptation and mitigation in different SSP narratives are lead by different development pathways (O’Neill et al., 2017). Therefore, adoption of other SSPs in drought vulnerability assessment may unveil other plausible drought vulnerability projections.”

4. L124: ‘comprise sensitivity…’ instead of ‘comprises of’.

Line 119, Page 4

“…comprise sensitivity, exposure and adaptive capacity indicators.”

5. L190: Unclear what the authors mean with ‘deficiencies’. Please use another term such as ‘deficit’.

Replaced.

Line 154, Page 5

“…based on the deficits in precipitation and soil moisture.”

6. L197: ‘are’ instead of ‘is’.

Line 198, Page 7

“…chosen grid are given in Table S2”

7. L199: Please explain the meaning of small ‘r’ and ‘s’.

Here ‘r’ and ‘s’ represents the value of the random variables R and S respectively.

Lines 164-165, Page 6

“where r and s represents the value of the random variables R and S respectively, and p represents the joint probability of the precipitation and soil moisture.”

8. L201-204: Based on this sentence it is unclear how ‘sk’ and ‘rk’ were computed. Please explain.

r_k and s_k here denote the kth observation for precipitation and soil moisture respectively. The number of joint occurrences (m_k) of precipitation and soil moisture pair below r_k and s_k from the whole set of observations is used to calculate empirical joint probability for kth observation based on bivariate Gringorten plotting position (Gringorten, 1963). This is clarified in the revised manuscript.

Lines 166-169, Page 6

"r_k and s_k here denote the kth observation for precipitation and soil moisture respectively. The number of joint occurrences (m_k) of precipitation and soil moisture pair below r_k and s_k from the whole set of observations is used to calculate empirical joint probability for kth observation based on bivariate Gringorten plotting position (Gringorten, 1963)."

9. Tables 2 and 3: Please add in the caption the thresholds or the definition for the transition or the no transition. This should be explained in the main text as well.

The meaning of transition term adopted in Tables 2 is as follows. The baseline and projected scenarios of drought hazard are represented using five different classes – very low, low, medium, high and very high. Every region (grid) of the country may transit from one class in the baseline scenario to another class in the projected scenario, or remain in the same class for both baseline and projected scenario. This transition area is presented as percentage values in Figure 4. Similar definition of transition in vulnerability and risk classes are adopted and are shown in Figures 6 and 8 respectively. This is explained in the revised manuscript.

Lines 305-307, Page 12

"The baseline and projected scenarios of drought hazard are represented using five different classes – very low, low, medium, high and very high. Every region (grid) of the country may transit from one class in the baseline scenario to another class in the projected scenario, or remain in the same class for both baseline and projected scenario."

References:

Gringorten, I. I.: A plotting rule for extreme probability paper, J. Geophys. Res., 68(3), 813–814, doi:10.1029/JZ068i003p00813, 1963.

McSweeney, C. F., Jones, R. G., Lee, R. W., and Rowell, D. P.: Selecting CMIP5 GCMs for downscaling over multiple regions, Clim Dyn, 44, 3237–3260, https://doi.org/10.1007/s00382-014-2418-8, 2015.

O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., van Ruijven, B. J., van Vuuren, D. P., Birkmann, J., Kok, K., Levy, M., and Solecki, W.: The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century, Global Environmental Change, 42, 169–180, https://doi.org/10.1016/j.gloenvcha.2015.01.004, 2017.