

Interactive comment on “Hydrological impacts of climate change on small ungauged catchments-results from a GCM-RCM-hydrologic model chain” by Aynalem T. Tsegaw et al.

Aynalem T. Tsegaw et al.

aynalem.t.tasachew@ntnu.no

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Hydrological impacts of climate change on small ungauged catchments-results from a GCM-RCM-hydrological model chain

We would like to thank the reviewer for the thoughtful comments and efforts towards improving our manuscript, which have helped us to improve the quality of the manuscript. In the following, we give responses to the comments/concerns the reviewer raised.

Reviewer 2 This study aims at assessing the impacts of climate change on flow patterns and patterns and frequency of floods in small ungauged rural catchments in Norway.

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It is an interesting manuscript that is mainly well prepared and structured. The study reveals that higher mean annual discharges are expected at the end of the 21st century. Mean annual floods are projected to increase compared to the baseline period. The manuscript's results contribute to the knowledge of climate change impacts in terms of river discharges in western Norway.

Three Main comments/concerns: 1. Only one RCM has been used that was driven by bias-corrected input of only one GCM. Nowadays, a state-of-the-art climate impact study should not base its results solely on one climate simulation, but on an ensemble of climate model simulations. Moreover, the results are only discussed for RCP8.5 at the end of the 21st century. In the discussion section, the authors address this issue and put their results into a larger context (Norway study), which is important, but not done in sufficient detail. Plotting precipitation and temperature projections of the NorESM1-M / WRF model in the context of the CMIP5 or CORDEX ensemble would be helpful here. However, I am not sure whether putting the results into the context of another study justifies the approach of using only one climate simulation as input.

Answer Since the new climate simulation is specially made for southwest coast of Norway with a time resolution of 3 hours and 4km by 4km spatial resolution, the comparison with other studies is interesting to see how the new method performs compared to what we know before and if it seems reasonable. Therefore, we believe that putting our results into the context of another study justifies the approach of using only one climate simulation as input.

We agree that the state-of-the-art of climate impact study normally is based on an ensemble of climate model simulations; however, for climate impact studies on small catchments, we have used only one GCM-RCM model simulations. We have used a single GCM-RCM model simulation as we actually can not find sub-daily data which is required for small catchments (< 10km²) study. We know that improvement is needed for the west coast of Norway so that we provide something brand new sub-daily climate data and bias corrected GCM data as input. The reasons for using a single GCM-RCM

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model simulation are summarized as follows: i) The single GCM-RCM simulation used in this study was generated based on the need to improve the precipitation distribution for the west coast of Norway, this was done through the new bias correction method and by utilizing kilometre-scale resolution.

ii) Limited computational resources to conduct ensembles of downscaling. This 60-year GCM-RCM downscaling alone has used approximately 650,000 cpu hours on a national hpc machine.

We have discussed in detail the results obtained using a single scenario and single climate model into a larger context in the discussion section of the revised manuscript. The discussions are found on lines 446 to 484 and lines 621 to 649 in the discussion section.

2. The description of the hydrological model and the regionalization approach in the Method chapter is quite long (6 pages). I think, this is not appropriate for a manuscript claiming to investigate climate impacts. In between I wondered whether the main focus of the manuscript is actually on climate impacts or on the methodology to be applied in ungauged catchments. What I would expect to read instead is something like this: "The DDD model is a lumped, conceptual hydrological model with a module simulating the slow flow component (subsurface) and the quick component (runoff dynamics)." Additionally, something about the temporal and spatial scales, it can be applied to, that it is not fully, or semi distributed...

Answer Thank you. We have revised and shortened significantly (from 6 to 2.5 pages) the hydrological model and regionalization approach in the method section of the manuscript (section 2.3). We have included only the main points about DDD model and the regionalization methods.

Revised Manuscript The revision is found in section 2.3 of the revised manuscript, lines (242 to 295).

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3. Especially in the discussion and conclusion sections, the authors mention many times the novel bias correction method that has been applied. From my point of view, instead of providing a lengthy description of the hydrological model, a description of the novel bias correction method would be much more valuable in the context of a climate impact study.

Answer Thank you. We have shortened the lengthy description of the hydrological model (from 6 pages to 2.5 pages) and expanded the novel bias correction method (from 0.5 page to 2.5pages) under section 2.3 and 2.2 respectively.

Revised Manuscript The revisions are found in section 2.3 and section 2.2 respectively in the revised manuscript.

Besides these three main concerns I have made a lot of comments on the attached RC2-supplement-pdf file.

General comments 1. The introduction is a bit lengthy, particularly the section between rows 70-87. Answer The introduction is shortened. Particularly, section 70-87 is reduced significantly (from 70-87 to 72-83).

2. English is usually adequate, but some sentences are incomprehensible or poorly expressed, e.g. following sentence: "The regional impacts of climate change (e.g. on local flooding) come out with the necessity of orienting adaptation measures to local climatic, geographic, economic and social conditions." Answer We went through the manuscript and corrected the poorly expressed sentences.

3.The authors should consider having the manuscript revised by a native speaker. Answer We revised the language, and we believe that the language is enough for publication.

4.The authors use the term "hydroclimatic elements" meaning variables, such as precipitation and discharge. I recommend calling these "hydro-climatic variables" not elements. Answer Thank you. We have changed hydroclimatic elements to hydro-climatic

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variables in the revised manuscript.

Technical 1. Multiple citations should be ordered by year. Answer Thank you, we have revised accordingly.

2. Equations. Many variables in the equations are not explained or mentioned in the text, some examples: Eq.2: $Q(t)$; Eq.5: C_{ea} ; Eq.6: M Answer We have explained the variables of the equations in the revised manuscript.

Following articles might be worth citing in some contexts in the manuscript. [Blöschl, G. et al. \(2019\). Changing climate both increases and decreases European river floods. Nature](#) [Blöschl, G. et al \(2017\). Changing climate shifts timing of European floods. Science, 357, 588-590](#) C3 Answer Thank you. We have included the references in the introduction (lines 46-48), study area (lines 144-147) and discussion (lines 555-557) sections of the revised manuscript.

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