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Discussions

Interactive comment on "Impacts of climate change on extreme floods in Finland – studies using bias corrected Regional Climate Model data" *by* Noora Veijalainen et al.

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Dear Reviewer

We would like to thank you for your useful comments on our manuscript. Here are our replies to the comments.

General comments:

The reviewer expressed concern on the choice of the study basins. To address this issue we added the study site of Hypöistenkoski to the study basins to better enable the evaluation of impacts of the method used on floods caused by daily precipitation

on small catchment. Hypöistenkoski is a small river in south-western Finland with 325 km2 catchment area and 1 % lake percentage. The results of Hypöistenkoski (see attached Figure) show that there is no significant difference in the performance of the single gamma and double gamma distribution in correcting of the snowmelt floods as expected. However, the double gamma method corrects the maximum annual rain induced floods better than the single gamma method. Typically the annual maximum floods in Finland have been snowmelt floods, but in the future in southern and coastal part of Finland the annual maximum floods will be more frequently rain induced floods due to climate change. Therefore we will add the results of Hypöistenkoski catchment and discussion about the importance of the performance of the bias correction methods for producing snowmelt and rain induced floods separately.

We will also reformulate the objectives of the study to put more emphasis for the testing of adequacy of the RCM simulations.

1) This section of the manuscript concerning delta change and bias correction methods could indeed be improved and it will be revised including a more comprehensive and up to date literature review.

2) We have looked into the method proposed by Hempel et al. and believe it would indeed help retain the trends in average precipitation. However, as demonstrated by Olsson et al. 2015 (the first part of this study), the trends in average precipitation did not change significantly by either single or double gamma distribution. The trends in extreme precipitation, which changed differently with double gamma distribution than in the uncorrected data, may change differently also in the method proposed by Hempel et al. While this would be an interesting topic to compare, we unfortunately do not have the resources or the space to carry out this comparison in this study and this paper.

3) ENSEMBLES data was used because at the time the first part of this research (published in Olsson et al. 2015) was carried out the EURO-CORDEX data was not yet available and we wanted here to use the same data as in the earlier paper. Prein et

al. 2015 have concluded that the largest improvements with higher resolution can be found in regions with substantial orographic features. Finland is relatively flat country and therefore the added value of fine resolution is smaller than in some other parts of Europe. Casanueva et al. (2016) found only limited added value of higher resolution in the precipitation frequency and intensity. The text regarding the choice of RCM data will be modified and comparison of ENSEMBLES and EURO-CORDEX data will be added.

4) The focus of this article has been in the changes of the extreme floods. The changes in mean high discharges and mean low discharges were studied in previous article (Olsson et al. 2015), but the adequacy of the bias correction method was not tested. In this paper we have proposed to test the adequacy of the bias correction method basing on 95 % confidence limits of the 100 year floods of the control simulation. This test could be improved by extending it to the lower return periods (2-10 years) for testing the performance of the bias correction method in more frequent floods and distribution of the annual maximum floods. The testing of adequacy of the RCMs will be further demonstrated and

5) The likelihood test was applied to the observed discharges and to the control floods (discharges simulated with hydrological model using observed temperature and precipitation). More comprehensive analysis of the GEV vs. Gumbel issue will be added to the manuscript and the changes in the skew parameter of GEV distribution fitted for the simulated floods will be analyzed. In future work the changes for snowmelt floods and rainfall floods should maybe be estimated separately.

Minor comments

The necessary changes will be made to the manuscript. These include:

1) Language of the paper will be checked. 2) Title will be re-evaluated and modified to e.g. Bias correction of Regional Climate Model data in estimation of extreme floods in Finland- comparison of two gamma distributions and evaluation of adequacy of results.

3) Information on the 67 catchments will be added, possibly in a table in an appendix (since these take up quite a lot of space). 4) The sentence will be reformulated. 5) In Olsson et al. 2015: “The areal values of the meteorological observations are calculated for each sub-basin of the hydrological model from three closest observation stations by inverse distance weighting taking into account the elevation differences. The areal values were converted to the same regular 0:25lat*0:25 long grid as the RCM data.” This information will be added to this paper. 7) The discussion section will be restructured.

Best regards

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Juho Jakkila

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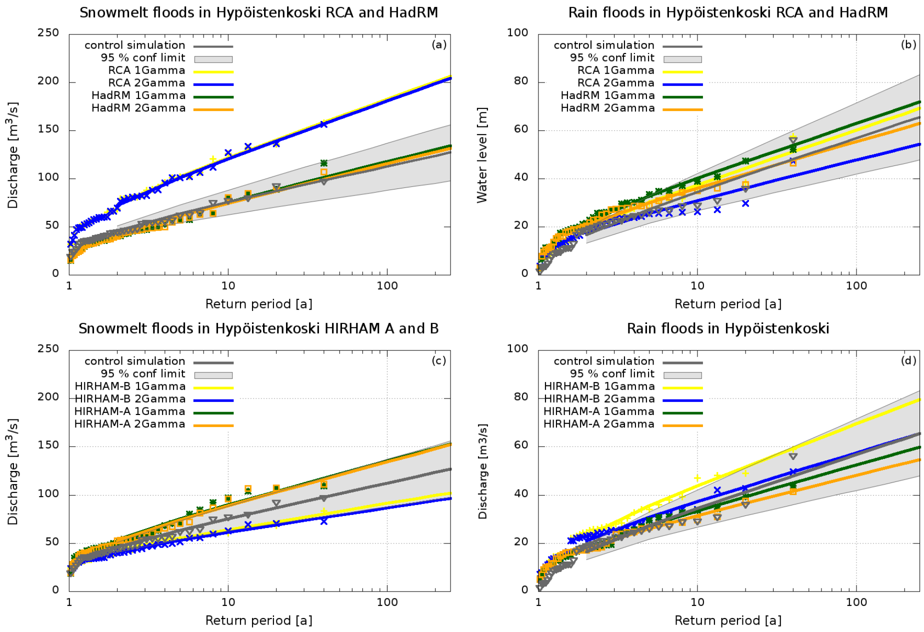

Fig. 1. Comparison of simulated maximum discharges and Gumbel distribution of Hypöistenkoski for snowmelt floods (a and c) and rain induced floods (b and d) in 1961-2000 for bias corrected RCM scenarios.