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Comment on hess-2021-499

Anonymous Referee #2

Referee comment on "Climate sensitivity of the summer runoff of two glacierised Himalayan catchments with contrasting precipitation regimes" by Sourav Laha et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-499-RC2, 2021

In this manuscript the climate sensitivities of runoff (catchment, glacierized and non-glacierized parts) in two contrasting glacierized Himalayan catchments are analyzed. The obtained climate sensitivities are then used to derive a measure for the standard deviation of streamflow and to make projections of how streamflow will change under climate change. A hydrological model combined with a glacier melt model is used to simulate streamflow timeseries for the two catchments. Instead of deriving the streamflow variability and the future changes directly from the model output, the model simulations are used to get the climate sensitivities of summer runoff to annual precipitation and summer temperature. This step is likely needed because the hydrological model only includes a static glacier. The study comes to the (not very novel) conclusion that glacierized parts of the catchment are sensitive to temperature and that the non-glacierized parts are sensitive to changes in precipitation. It also suggests that climate sensitivities can be used to estimate magnitude and timing of peak water, but it is unclear how climate sensitivities should be derived for ungauged catchments and what the advantages are of not directly estimating peak water from (glacio)-hydrological models. Overall, I think that, despite the interesting topic of climate sensitivity of glacierized catchments which is suitable for HESS, the study does not do a good job in addressing a clear research gap. Besides, I have some doubts about some parts of the methods, there are some unclear descriptions and there is a lack of discussion on the simplifications, interpretation of the findings and the implications. Please find below my major and minor comments.

Novelty and research gap

The introduction of the manuscript is very minimal, it touches on a few topics but does not show how this study fits in between previous studies and it does not clearly explain the

research gap and what the study aims to achieve and why. The sentence 'Due to a lack of long-term data…. may still be lacking' does not do justice to all the studies that exist on streamflow and its projections of Himalayan catchments. Here I would expect to read what climate sensitivities can add to the existing (modelling) studies. Then in the second part of the introduction, the explanation of how climate sensitivities are related to long-term changes and the glacier compensation effect are very unclear. What to do with the sentence 'Climate-sensitivity based predictions for future changes in runoff are reliable ……..over the calibration period'? How does that match with the peak water exercise in the manuscript? The relation between climate sensitivity and glacier compensation effect is also not clear and requires more explanation. In the last sentence 'We also attempt to do this and that (glacier compensation effect and peak water)' I miss reasoning on why these attempts are needed.

Methodology

The workflow in this manuscript is not completely clear to me. The aim of the study is to assess climate sensitivities, because those can help to understand the variability and changes of streamflow. Since there is only limited streamflow data available, timeseries of streamflow are simulated with the VIC model. However, in theory, such models can also provide information on variability and change, so as a reader I need some argumentation why climate sensitivities are a useful alternative route, especially when there are no or only few streamflow observations available.

The simulations of streamflow are crucial here for the derivation of climate sensitivities, and I am surprised by the similar sensitivities of the two catchments, while their precipitation seasonality and mass balance type are so different. How is snowmelt simulated in the VIC model? Is there a different parameter for snow and glacier melt? If there is snow falling on the summer accumulation type glacier, is melt then also reduced in the model (albedo effect)? Have you tested if there is a difference in summer runoff sensitivity to summer precipitation in the non-glacierized parts? How is ET modelled? This should be important for the non-glacierized runoff sensitivity to temperature. Regarding the parameter sensitivity tests, were the optimized DDF and ap parameters fixed? Low parameter sensitivity may suggest that the model is not very suitable to model the system. Also, summer runoff may not be the optimal variable to test with, as timing of melt and snow/rain ratio will be important to model right to extract the sensitivities in a meaningful way. Could Qg and Qr for the 40 year of simulations be easily plotted, and compared with other modelling studies?

Climate sensitivities are derived for catchment runoff, glacier runoff and non-glacierized runoff. There is a formula given (eq4) for how to derive catchment runoff sensitivity from the glacier and non-glacier runoff, but, if I am right, it is not used for the results. Has this been tested for?

In Eq. 8, the changes in runoff due to changes in glacier cover are estimated by the recent difference in runoff from the glaciers and the non-glacierized parts. This, however, neglects the process of usually increasing precipitation with elevation. For large changes of

glacier cover this may become quite relevant. Also, assuming 'the recent ratio of winter to summer runoff remain unchanged' contradicts many previous studies of increased winter flow and decreased summer flow. If these assumptions need to be made, I wonder how the results could be used, as many of the models do actually include these kinds of feedbacks.

Throughout the results section, the climate sensitivities are presented as mm change per change in degree C or per change of mm of precipitation. Based on these outcomes, some sensitivities are regarded as zero. However, these results are misleading if they are not communicated in how much T and P varies per year. In general, it would be helpful, I think, to communicate them in percentage from the mean flow, and also present all of them in an overview table.

Unclear descriptions

Throughout the manuscript there are quite some words missing or misspelled (please carefully check!), and unclear descriptions or presentation (see also list below). For example, units are missing in equations, and there is a mix of units in m and in mm.

The bias correction methods description is very unclear. Apparently, temperature is corrected based on station data, but precipitation not and instead is corrected via a calibration parameter. Why is that? How is the meteorological input data used in VIC? Are T and P lapse rates used? If so, how are they obtained? For the VIC modelling, how does the coupling between the glacierized and non-glacierized parts work? Is there snow redistribution from the non-glacierized parts onto the glacier? And does glacier melt contribute to baseflow?

How are the mass balances calculated? Per catchment or per glacier? And how are they compared with available data, per glacier or per catchment? How is the glacier runoff modelled in a similar way to Huss and Hock? Are the same sensitivities as for the non-glacierized parts used for the parts that get de-glacierized?

In general, there are a lot of references to supplementary material, and I would suggest to better describe some of these in the main text.

Lack of discussion

Section 4.9 is quite a deception to read. Basically, it summarizes the methods to obtain streamflow simulations. The approach used in this manuscript is very theoretical, and at least in the discussion section I think a translation again to the glacio-hydrological

processes is needed (e.g. compensation of the glacierized and non-glacierized runoff parts, connecting precipitation importance for mass balance to changes in summer streamflow, describing why temperature is not relevant for non-glacierized parts, interaction of P and T processes).

Also, as mentioned before, it would be good to show what can be learned from these derived sensitivities, how can this approach be implemented to derive sensitivities in other catchments, or how do these results give a different perspective from what we already know?

And last but not least, I think a comparison with other climate sensitivities (also outside the Himalayas) is needed (e.g. He. 2021, Engelhardt et al., 2017, Moore et al., 2020), and some reasoning why there where no differences found between the two catchments (summer acc. types are thought to be very sensitive to temperature) and/or the differences in peak water timing in the two catchments, and the large differences in temperature sensitivities found in the studies that you cite in section 4.5

Minor comments and technical corrections

Title: from – change to 'in'?

L3: catchments – change into glacierized catchments, also remove 'in order', and what is meant with 'the nature'?

L5: semi-distributeD

L22: response OF glacierized

L23: data – do you mean observations?

L27: also BE helpful

L37: An – a

L45: time series is – ARE

L54: is in – is LOCATED in

Table 1: do these values represent catchment mean? Or station values?

L60: solid to liquid or liquid to solid? Text and table say something different

Section 2 Study area – explain here the two glacier accumulation types

L65: bias corrected reanalysis data: bias corrected on what?

L67: relativvely – relatively

L75: concentrate ON

L84: please explain how you go from derivative in Q to anomaly Q

L97: onesdefined

L133: projected future changes in glacier area – How were they arrived? Is this data given per glacier? Or if per basin, do they match with the basins studied here?

L135: Also here, were these timeseries available for the catchment or for individual glaciers? How were they processed for this study?

L137: ignored – if precipitation changes were ignored, it means that in equation 15, change in P is zero and thus non-glacierized runoff is not included in the calculation for change in catchment runoff?

L138: gridded values available: please explain

L140 year 2002 and in L155 year 2002 – how did you derive glacier extent in 2000 then?

L155-156: Please explain how the geodetic mass balances were obtained for the studied catchments

L185: size – elevation range?

L194: shrinkage of glacier fraction – is this value per decade? And is it the decline in catchment glacier cover or the decline in glacierized area?

L202-203: For melt calculations…… data set: very unclear, please rephrase

L236: j denoting individual records – what is meant here?

L280: the sentences have a strange order here, with two times comparing to other studies

L295: th – the

L305: Linear response: what is meant here?

L321-L322: What about ET losses? Or change in storage

L338: has – have

L354: where can I see this effect of stabilizing scaled with glacier fraction?

L390 and 399: to – two

L392: accurate sensitivities – sounds plausible, but how to derive them?

L402 and 472: depndence

L406-407: Do they propose that in this paper?

Section 4.8.3 – Why is peakwater not calculated for catchment runoff?

Figure 1 – It may be an idea to indicate the sub-catchments which were you used in other studies and that you use for comparison of your results

Figure 2 – Please provide the meaning of the parameters

Figure 4 – what do the different dots represent?

References

Engelhardt, M., Schuler, T. V., & Andreassen, L. M. (2015). Sensitivities of glacier mass balance and runoff to climate perturbations in Norway. Annals of Glaciology, 56(70), 79-88.

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