

## ***Interactive comment on “Projection of future glacier and runoff change in Himalayan headwater Beas basin by using a coupled glacier and hydrological model” by Lu Li et al.***

### **Anonymous Referee #2**

Received and published: 4 January 2018

The manuscript by Li et al. investigates the impact of climate change on glacier melt contribution to discharge in a medium-sized catchment in the Indus basin. To this end, a calibrated glacio-hydrological model was driven by statistically downscaled climate projections from one GCM under two GHG concentration scenarios. The simulations build on ensemble projections of glacier extent derived from a previous study by Lutz et al. (2016) who have already provided a more comprehensive assessment for the entire Indus basin. The manuscript mainly reports on model application in a particular basin and generally lacks novelty.

Major comments

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The glacio-hydrological modeling capitalizes on projections of future glacier extent from Lutz et al. (2016). Data derived from the Lutz et al. study should be moved to Materials and Methods and should be separated more clearly from the GSM-WASMOD modeling results obtained in the current study. This concerns section 4.3 including figures 10 and 11.

The manuscript has a poor structure and is more often than not hard to follow. For example, modeling results are presented and superficially discussed in “Results and discussion” which is however followed by a “Discussions” section that in fact introduces a completely new modeling experiment including data, methods, results and discussion. The additional material addresses the issue of uncertainty in precipitation data in high altitudes. This topic is without question relevant for hydrological modeling in the study region, however falls largely out of the scope of manuscript. In the remainder part (section 5.2) this topic is further discussed while a critical discussion of the main results presented in sections 4.2 - 4.4 is largely missing.

It is only mentioned by the end of the results section that only one GCM was down-scaled to drive the glacio-hydrological simulations while all previous sections give the impression that a GCM ensemble was used. A plethora of previous studies has shown that GCMs contribute a large share to total uncertainty in simulated hydrological impact and it is consequently common practice to drive (an ensemble of) impact models with a GCM ensemble. In this regard, the study clearly falls behind the state of the art and the material does not support significant conclusions.

The manuscript contains a large amount of figures and tables, 21 in total, of which some seem redundant and the authors should make an effort to streamline the material. For example, Table 4 listing all possible combinations of GCM, RCP and method of bias correction is largely identical in content to Table 2.

The standard of English needs to be improved throughout the manuscript. While the meaning is usually (but not always) clear, there are a lot of grammatical errors (far too

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many to list) and diction is often poor.

Specific comments

L. 11: Why would the glacier melt lead to extreme rainfall?

L. 13: I strongly disagree with the use of the term RCM when referring to the two methods of GCM bias correction/downscaling applied in this study. The term RCM describes numerical prediction models.

L. 30-32: Colloquial, please rephrase.

L. 36: Please correct to “CMIP5”

L. 67: Correct to “Mishra 2015”

L. 88: Unclear, please rephrase.

L. 115-117 : This section describes the study basin/region; information on the model and data used should be moved to the corresponding sections.

L. 115: Please correct to “meteorological”

L. 130: Was the GSM module developed in the scope of this study? If not, please add the reference to the original publication.

L. 148: What was the reason for choosing a modeling resolution of 10 km? Most of the input data sets do seem to support a higher modeling resolution; please clarify.

L. 149: It was mentioned earlier that potential evaporation was only available from one station. Were these station values used for the entire basin? Please clarify.

L. 155-156: Unclear, please rephrase.

Section 3.4: 1) The authors miss to describe and reference the 21st century GCM ensemble data used in the study. Please add a section or paragraph. 2) Lutz et al. (2016) applied the same GCM ensemble but a different downscaling approach

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to simulate the future glacier extent used in this study. Why did the authors choose a different downscaling technique? Given that the downscaling technique is found to have a profound effect on projected precipitation and temperature (which drive both the simulated glacier extent and melt), how does this inconsistency affect the results for the Beas river basin and the conclusions drawn? 4) Sections 3.4.1 and 3.4.2 need to be rewritten to enhance comprehensibility. In the current version, it is impossible to understand how both downscaling approaches work.

L. 209-215: “SSVM is directly used to construct the relationship between hydrological data and atmospheric variables” and “The calibration of downscaling models used the station-scale hydrological data and GCM historical atmospheric variables to construct the relationship”: I understood from the earlier text that both techniques were used the downscale GCM simulated atmospheric variables to station-scale meteorological data which subsequently were used to drive the glacio-hydrological simulation. Did the authors establish a direct statistical relationship between atmospheric variables and hydrological fluxes? Please clarify.

Section 3.5: 1) In L. 220, Li et al. 2013a or Li et al. 2013b? 2) Glacier mass balance data were apparently used for calibration, but this data-set has not been described or mentioned yet. Please add a description to the data section. 3) The efficiency criteria listed seem to refer to simulated discharge only. How was model efficiency evaluated with respect to glacier mass balance? 4) Were discharge and glacier mass balance calibrated simultaneously?

L. 242 “worked fine”: Colloquial, please rephrase. Further, I cannot see how Fig. 5 adds important new information. If its only purpose was to show that the model “worked fine”, the figure can be removed.

L. 245: It was mentioned earlier that glacier mass balance data were used to calibrate GSM-WASMOD; are those the same data as used here for validation?

L. 250: Table 4 formally belongs to the methods section and should be referenced

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there.

L. 255-265: The two downscaling methods seem to introduce a large uncertainty with respect to future climate in the region. How does this uncertainty compare to the spread between the different GCMs?

L. 294 “It shows that the summer peak of runoff shifts to the other seasons in Beas river basin”: Cannot be inferred from the figure.

L. 300 and following: It is mentioned here for the first time that only GCM was down-scaled to drive the glacio-hydrological model. This should have been made clear in the methods section.

Tab. 2: Please rephrase the caption and correct to “glacier evolution”; “Selected model” in the table heading is rather ambiguous and could be replaced by “GCMs”

Table 3: Please correct to “validation”, “Nash-Sutcliffe coefficient” and “NS\_d” (row 6); topographical error in the last row; missing space before table number.

Table 5: Please provide a more informative caption. I assume ensemble median and range are shown. “Change” should be spelled lower case. Does the table show changes over the glacierized area or for the entire river basin?

Fig. 2: In the legend, please correct to “Simulated dis”

Fig. 3: Please add the observed discharge for reference

Fig. 4: Please correct to “Monthly hydrographs”. The quality of the Figure should be improved.

Fig. 6: The observed data shown seem to be mean values over certain time periods rather than estimates for a single year (e.g. 1999–2004 in Vincent et al. 2013), but are depicted as points in the figure which is misleading. Please correct. Further, please add a table listing all external glacier MB data including reference period and estimation method.

Fig. 7+8+9: I strongly disagree with the use of the term “RCM” when the authors actually refer to bias correction methods, please correct. Please revise the captions. Do the figures show the ensemble mean? If yes, please add the ensemble range.

Fig. 10: Y-axis label should read “Glacier”

Fig. 11: Is this the ensemble mean?

Fig. 12: The figure needs profound revision. 1) I can only guess that the numbers in the legend refer to the index given in Table 4. Listing all ensemble members in the legend is somewhat obsolete since they are not distinguishable in the plot. 2) The caption claims that results for only one GCM are shown (CANESM2) while the figure apparently shows the whole ensemble. 3) Are both RCPs shown? If yes, please color-code accordingly. 4) In all simulations glacier melt discharge approaches 0 by the end of the century while according to Table 5 glacier cover remains larger than 0. Please explain. 4) Why is glacier-melt discharge given in negative numbers?

Fig. 14: The two subfigures seem to show exactly the same data with respect to the single ensemble members. Please double-check.

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