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Reply to Jonathan D Mackay (Reviewer #1)

Sarah Shannon et al.

Author comment on "A snow and glacier hydrological model for large catchments – case study for the Naryn River, central Asia" by Sarah Shannon et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2022-51-AC1, 2022

We would like to thank the reviewer #1 Jonathan D Mackay for taking the time to provide comments on the manuscript. Please find our replies below.

Reply to reviewer #1

A well written and clearly presented manuscript that introduces an updated version of the DECIPHeR hydrological model which includes a simple energy balance model to simulate snow and ice ablation and accumulation. Overall, only a few comments from me which should be easy for the authors to address (see attached PDF with comments). Of these comments, two are slightly more "major" points which I hope the authors can address in their response and manuscript revisions. The first is on the question of novelty. It's not entirely clear from the introduction what the novelty of the work is exactly. In the Conclusions section it states that:

"The motivation for this work was to develop hydrological model that can be used to simulate discharge in very large glaciated and snow-fed catchments, at a high spatial resolutions, whilst maintaining the ability to explore model uncertainty."

So I'm assuming that the novelty is the model itself, but my understanding is that there are already models out there that can be used to do this (I've mentioned some in the attached). Could the authors please spell out what the novelty of the work is in the introduction. If the novelty is the model then I think the manuscript would really benefit from a more explicit explanation of the limitations of current models available and what exactly this model offers to address these. A good starting point might be the review of Van Tiel et al. (https://wires.onlinelibrary.wiley.com/doi/full/10.1002/wat2.1483).

To clarify the novelty of the work is in using the DECIPHeR model.

We added the following text (L69) of the introduction to highlight the reasons we used DECIPHeR, instead of one of the other glacio-hydrological models in the literature.

“Many glacio-hydrological models already exist in the literature (van Tiel et al., 2020; Horton et al., 2022), however, we integrate a snow and glacier melt model into DECIPHeR for the following three reasons. Firstly, DECIPHeR uses hydrological response units (HRUs) to model water flow in hydrologically similar parts of the catchment which allows the model to be run as a fully distributed (HRU for every single grid point), semi-distributed (multiple HRUs) or as a lumped model (1HRU). Depending on user requirements and the corresponding degree of complexity, topographic, land use, geology, soils, anthropogenic and climate attributes as well as points of interest (any gauged or ungauged point on the river network), can be supplied to define the spatially connected topology and thus differences in model inputs, structure and parameterization (Coxon et al. 2018). Other HRU based glacio-hydrological models exist, for example, SWAT (Omani et al., 2017), PREVAH (Koboltschnig et al., 2008) and HBV (Finger et al., 2015) but they don't offer this level of flexibility within a single modelling framework.

Secondly, DECIPHeR is computationally efficient, which makes it suitable for modelling very large catchments. Many of the glacio-hydrological models in the literature are distributed (grid point based) for example, TOPKAPI (Pellicciotti et al.,2012), DHSVM (Frans et al., 2018), VIC (Schaner et al., 2012), GERM (Farinotti et al., 2012). The computational expense of modelling processes with adjacent grid points makes distributed models more suited to studying small catchments. Furthermore, computationally efficiency makes it possible to quantify uncertainties and run large ensembles which is important for understanding the uncertainties in future predictions.

Thirdly, the DECIPHeR code is open source which allows opportunities for further community development. In contrast, the glacier enhanced version of SWAT (Omani et al., 2017; Luo et al., 2013) is not open source."

The other point regards the application of GLUE and the use of the top 0.5% of model simulations to represent a population of behavioural models. The 0.5% seems arbitrary and, therefore, it's not clear to me what the merit of including these in the analysis is. What do the uncertainty bounds of an arbitrary population of models mean? Could the authors please justify the use of using the top 0.5% of simulations rather than, say, defining a more objective set of "good behaviour" criteria e.g. based on the different metrics of model performance used in the study.

We added this to the discussion section "

In this study we set the behavioural models to the best 0.5% simulations in the ensemble as it was important in our analysis to rank models according to their ability to capture seasonal discharge, particularly from spring snow melt and summer glacier melt. Often behavioural models are selected using threshold values for guidelines metrics. These metrics are calculated over the complete discharge timeseries, rather than for individual seasons. For example, metrics from Moriasi et al. (2007) are commonly used in the literature to categorise 'acceptable', 'good', or 'very good' simulations based on threshold values for NSE, PBIAS and RSR. Metrics calculated over the complete discharge time series are not a strong test of the model's ability to predict seasonal discharge. To our knowledge, there are no standardised guideline thresholds in the literature for seasonal metrics, therefore we selected the best 0.5% of the ensemble. If we decided to define the behavioural models using a threshold for the seasonal RSR, then this would also be based on an arbitrary choice of value. A high threshold for seasonal RSR would be required to categorise the behavioural models because the summer values are high (See RSR_{JJA} in Table 4).

We explored the impact of selecting alternative threshold values (1%, 2.5%, 5% and 10%) on the calibrated NSE values (Fig. S24). To obtain NSE values > 0.7 at all the gauging stations requires a threshold smaller than 1%. This is notable at the Alfatun station where the NSE value at the 0.5% threshold is 0.74 but reduces to 0.63 at the 1% threshold (95th percentile limit values). Fig S24 also shows how the uncertainty in the NSE values increases for higher threshold values. At the 10% threshold the uncertainties in the NSE values are much greater than at the 0.5% threshold.”

Please find attached an updated Supplementary material and replies to the minor comments in the zip file.

Additional references

Aizen, V. B., Aizen, E. M., and Melack, J. M. (1995). Climate, Snow Cover, Glaciers, and Runoff in the Tien Shan, central Asia. JAWRA J. Am. Water Resources. Assoc. 31. doi:10.1111/j.1752-1688.1995.tb03426.x

Farinotti, D., Usselmann, S., Huss, M., Bauder, A., and Funk, M.: Runoff evolution in the Swiss Alps: projections for selected high-alpine catchments based on ENSEMBLES scenarios, HYDROLOGICAL PROCESSES, 26, 1909–1924, https://doi.org/10.1002/hyp.8276, 2012

Finger, D., Vis, M., Huss, M., and Seibert, J.: The value of multiple data set calibration versus model complexity for improving the performance of hydrological models in mountain catchments, Water Resources Research, 51, 1939–1958, https://doi.org/https://doi.org/10.1002/2014WR015712, https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2014WR015712, 2015

Frans, C., Istanbulluoglu, E., Lettenmaier, D. P., Fountain, A. G., and Riedel, J.: Glacier Recession and the Response of Summer Streamflow in the Pacific Northwest United States, 1960-2099, WATER RESOURCES RESEARCH, 54, 6202–6225,720 https://doi.org/10.1029/2017WR021764, 2018

Horton, P., Schaefli, B., and Kauzlaric, M.: Why do we have so many different hydrological models? A review based on the case of Switzerland, WIREs Water, 9, e1574, https://doi.org/https://doi.org/10.1002/wat2.1574, https://wires.onlinelibrary.wiley.com/doi/abs/10.7601002/wat2.1574, 2022

Koboltschnig, G. R., Schöner, W., Zappa, M., Kroisleitner, C., and Holzmann, H.: Runoff modelling of the glacierized Alpine Upper Salzach basin (Austria): multi-criteria result validation, Hydrological Processes, 22, 3950–3964, https://doi.org/https://doi.org/10.1002/hyp.7112, https://onlinelibrary.wiley.com/doi/abs/10.1002/hyp.7112, 2008

Luo, Y., Arnold, J., Liu, S. Y., Wang, X. Y., and Chen, X.: Inclusion of glacier processes for distributed hydrological modeling at basin scale with application to a watershed in Tianshan Mountains, northwest China, Journal of Hydrology, 477, 72–85, https://doi.org/10.1016/j.jhydrol.2012.11.005, <GotoISI>://WOS:000313935200006, 2013

Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., and Veith, T. L.: Model evaluation guidelines for systematic825 quantification of accuracy in watershed simulations, Transactions of the Asabe, 50, 885–900, <GotoISI>://WOS:000248036800021, 2007

Omani, N., Srinivasan, R., Karthikeyan, R., and Smith, P. K.: Hydrological Modeling of Highly Glacierized Basins (Andes, Alps, and Central Asia), Water, 9, https://doi.org/10.3390/w9020111, <GotoISI>://WOS:000395435800041, 2017

Pellicciotti, F., Buergi, C., Immerzeel, W. W., Konz, M., and Shrestha, A. B.: Challenges and Uncertainties in Hydrological Modeling of Remote Hindu Kush-Karakoram-Himalayan (HKH) Basins: Suggestions for Calibration Strategies, MOUNTAIN RESEARCH AND DEVELOPMENT, 32, 39–50, https://doi.org/10.1659/MRD-JOURNAL-D-11-00092.1, 2012

Saks, T., Pohl, E., Machguth, H., Dehecq, A., Barandun, M., Kenzhebaev, R., Kalashnikova, O., and Hoelzle, M.: Glacier Runoff Variation Since 1981 in the Upper Naryn River Catchments, Central Tien Shan, Frontiers in Environmental Science, 9, https://doi.org/10.3389/fenvs.2021.780466, https://www.frontiersin.org/articles/10.3389/fenvs.2021.780466, 2022

Schaner, N., Voisin, N., Nijssen, B., and Lettenmaier, D. P.: The contribution of glacier melt to streamflow, ENVIRONMENTAL RESEARCH LETTERS, 7, https://doi.org/10.1088/1748-9326/7/3/034029, 2012

van Tiel, M., Stahl, K., Freudiger, D., and Seibert, J.: Glacio-hydrological model calibration and evaluation, WILEY INTERDISCIPLINARY REVIEWS-WATER, https://doi.org/10.1002/wat2.1483, 2022

Please also note the supplement to this comment:
https://hess.copernicus.org/preprints/hess-2022-51/hess-2022-51-AC1-supplement.zip