

The Cryosphere Discuss., referee comment RC2
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Comment on tc-2022-69

Anonymous Referee #2

Referee comment on "Spatio-temporal reconstruction of winter glacier mass balance in the Alps, Scandinavia, Central Asia and western Canada (1981–2019) using climate reanalyses and machine learning" by Matteo Guidicelli et al., The Cryosphere Discuss., <https://doi.org/10.5194/tc-2022-69-RC2>, 2022

Guidicelli et al propose an interesting method to downscale and bias-correct reanalysis precipitation data to the elevation and sites of glaciers in 4 regions of the world. 2 reanalyses are used : ERA5 and MERRA2. The method is based on gradient boosting regressions, a technique from the field of artificial intelligence. The performance of this method is evaluated through cross-validation and discussed in terms of both temporal and spatial extrapolation. Finally, precipitation trends on glaciers are derived for each 4 regions based on the bias corrected and downscaled reanalysis data.

The study tackles the very interesting and yet unsolved issue of high-altitude precipitation amounts, with tools from machine learning. It adds to the existing literature by focusing on glacier winter mass balances, used as a proxy for winter precipitation at high altitudes. In my opinion, this makes the topic of this study very relevant. While the analyses displayed are in general sound, I advise a revision of the paper with respect to concerns regarding the spatial generalization capability of the models and the derivation of trends, see below.

MAIN COMMENTS

1 - Comparison/justification with respect to other AI techniques for bias correction and downscaling in literature : Even though the introduction describes well the existing literature on AI-based downscaling/bias correction methods, the choice of GBR is barely justified with respect to other techniques. I would have expected elements in that direction in the manuscript, especially since a section of the Discussion is entitled : '5.1 Advantages and disadvantages of gradient boosting regressors'.

2 - Limits inherent to the number of available learning data :

Some of the regions of interest, e.g. Canada and Central Asia, have in total less than 20 glaciers used in this study, which is an extremely low percentage of the number of glaciers that they truly host.

This in my opinion strongly impedes the (spatial) generalization capability of the GBR models learned on these data, to the region of interest as a whole. Although this is not what the authors do in the paper, this is what the title suggests while mentioning the world's glaciers. I would strongly recommend to modify this misleading title, as the developed technique is in practice not applied to derive precipitation data over any glacier of the world, but is limited to (i) the regions of interest and (ii) the few glaciers with data in these regions..

On top of the low sampling level for application of machine learning techniques in general, there may be furthermore a strong sampling bias in the glaciers data from WGMS, for instance towards large glaciers in the European Alps, so that the representativity of the glaciers with data w/r to the regions of interest is questionable. It follows that it is hard to know whether models or conclusions inferred solely based on these very few glaciers, are representative of the region as a whole.

I very much would like the authors to comment on this.

"The good performance of the GBRs in terms of bias suggests that they can be used for SWE estimates over glaciers where no ground observations are available (site-independent GBRs)". Despite being better than the benchmark, the performance of site-independent GBR models is limited (Fig 9) and decreases when data of neighbouring glaciers are excluded from the training. Considering that, and the likely sampling biases of WGMS data, I think the authors could revise this sentence.

3 - Trends :

In my opinion the derivation of trends based on the GBR modelled precipitation, should be accompanied with sensitivity tests to ascertain the robustness and uncertainties of this method. Typically, data-withdrawal techniques could be used on the longest time-series to evaluate the robustness/uncertainty of the trends derived when missing data are encountered. The distribution of the data gaps within the time-series (= for instance one missing season every two year, vs 20 years with data and nothing for the following 20 years) may also play a role, and it would be good to have an insight into this and possibly only derive trends for glaciers with a sufficient number data (seasons). The strong limitation of temporal extrapolation for some glaciers is highlighted I 350-I355, hence making a derivation of trends on these glaciers meaningless.

MINOR COMMENTS

- the GBR consider as predictors both elevation differences between reanalysis pixel and glacier site, and downscaled variables like temperature, whereby the downscaling of temperature itself mostly relies on this altitude difference. Hence there is a high redundancy in the chosen predictors. Did you test suppressing the downscaled predictors ?

- the predictors in the PCA figures (4 and 5) are often barely lisible. Fig 5 could maybe join the supplemental material.

- I 264-274 : could the different magnitude in factors relate to known biases / weaknesses of the reanalyses in representing different types of precipitation events ?
- I 311 : "their performance is worse than the site-independent models". It is not so clear for me why : could you please explain ?
- I 448 : why were more topographic predictors used in the ERA-5 GBRs than in the MERRA-2 ones ?
- Fig 2 could join the Supplemental material
- Fig 6 : could the absolute biases also be mentioned ?
- Fig 7: a ranking of the glaciers with respect to altitude, or to the number of seasons with Bw_data, would enable to more efficiently support the analysis related to this figure, please consider this. The same applies to Fig 11.
- Tables 1 and 2 could join the supplemental material
- Section 5.2 : this recent literature could also be of interest : <https://doi.org/10.5194/hess-24-5355-2020>; <https://doi.org/10.5194/essd-14-1707-2022> (update of Durand et al., 2009).