Modelling the Point Mass Balance for the Glaciers of Central European Alps using Machine Learning Techniques

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We are grateful for the editor's thorough review and suggestions on manuscript number **egusphere-2022-1076**: 'Modelling the Point Mass Balance for the Glaciers of Central European Alps using Machine Learning Techniques'. Please find enclosed a marked-up version of the manuscript incorporating the suggested changes and the revised manuscript. The point-by-point response to the comments is provided below. The comments by the editor are presented in a ***bold italicised*** font style. The author's response is in normal font style. Text quoted from the revised manuscript is *italicized*.

COMMENT 1:

Could you please clarify what is meant by forecast albedo?

Forecast albedo is a measure of the reflectivity of the surface. It is represented as a fraction of incident shortwave radiation that is reflected by the surface across the spectrum. It is different from the broadband albedo given by

$$1 - \frac{Net\ Solar\ Radiation}{Downward\ Solar\ Radiation}$$

. To clarify the importance of forecast albedo as observed using the machine learning modelling, we include the following at lines 389-393 (Section 4.3) in the revised manuscript:

In the case of ERA5 Land, the forecast albedo variable represents both the direct and diffuse radiation incident on the surface with values dependent on the land cover type. It is calculated using a weight applied to the albedo in the UV-visible and infrared spectral regions. The *albedo of snow and ice land covers is different in the UV-visible spectral region and the infra-red spectral region. This makes forecast albedo more important than broadband albedo, which depends only on the surface net solar radiation and the surface solar radiation downwards.*

<u>**COMMENT 2:**</u>

Section 4.1: Although the focus of the paper is intercomparison of ML approaches, this section would benefit from the inclusion of available literature on ERA5-Land performance in complex terrain. Some relevant papers might be:

- ***https://doi.org/10.1016/j.jhydrol.2023.129384***
- ***https://doi.org/10.3389/feart.2022.907730***
- ***https://doi.org/10.1016/j.jhydrol.2021.127353***
- ***https://www.sciencedirect.com/science/article/pii/S0169809520313028***
- ***Specific to downscaling: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021WR031294***

Thank you for this suggestion. We have updated Section 2.2 Data and Methods and Section 4.1 Comparison of Model Performance and Associated Errors to reflect this. The changes are in lines 140-145 in the revised manuscript (Section 2.2):

"The network of weather stations is sparse over much of the Alpine terrain; hence, reanalysis datasets are recommended (Hersbach et al 2020). We used the ERA5-Land reanalysis dataset (Muñoz Sabater, 2019, 2021). This data set was chosen primarily due to its comparatively high spatial resolution. This is in line with the findings of Lin et al 2018 and Chen et al 2021 that suggest that datasets with higher spatial resolution effectively represent the orographic

drag and mountain valley circulation which in turn results in improved performance for orographically complex terrain."

The lines 335-343 are modified in the revised manuscript's Discussion Section 4.1 Comparison of Model Performance and Associated Errors.

"Further, the use of input meteorological reanalysis data can result in bias, especially in locations without sufficient ground stations (Zandler et al 2019, Guidicelli et al 2022). Specifically for the use of ERA5 Land data in complex terrain, Wu et al 2023 reports that while ERA5 Land represents the intra-annual variations in precipitation characteristics, there is a positive bias in the precipitation variables. Similarly, in the case of temperature, Zhao et al 2022 show through correlation and RMSE analysis that while the ERA5 Land dataset captures the temperature trends effectively, the magnitude of the values is not well represented. Thus, we suggest using a bias correction step such as that proposed by Cucchi et al 2020 in the case of RF, GBR and SVM models. Moreover, the reanalysis data do not fully reflect point scale data as it has a coarse resolution. Lin et al 2018 depicts the impact of resolution in simulating drivers of local weather in complex terrain and shows that coarser resolutions do not account for orographic drag. "

COMMENT 3:

Section 4.3: Consistent with Reviewer 2's comments, I suggest mentioning the caveat that using only annual mass balance data could impact the analysis of feature importance for the accumulation and ablation months. I also suggest explicitly discussing what is known or expected about orographic precipitation in ERA5-Land as opposed to referring to data scale.

We have incorporated the suggestion on orographic precipitation in lines 384-386 in the revised manuscript.

"This is possibly a result of the scale of the meteorological variables used not sufficiently

representing the influence of orographic water vapour transport that results in precipitation (Lin et al 2018, Chen et al 2021).”

The suggestion on mentioning the caveat of using annual mass balance datasets is accepted and presented in Section 4.4 (lines 434-437) of the revised manuscript.

“ An important factor to note is that through this study, we have considered annual mass balance measurements as opposed to seasonal measurements due to the paucity of sufficient datasets to fully train a multi-parameters machine learning model. The role of ablation and accumulation variables will be better represented in the case of seasonal measurements and is an avenue to explore through future studies.”

COMMENT 4:

Please provide a more descriptive name for the supplementary sheet as well as a small caption for the data that are presented. I suggest also mentioning any sensitivity studies that were performed (e.g., using Leaky ReLU) and their results in the supplement.

A revised supplementary zip file with a text file containing captions is uploaded to https://github.com/RituAnilkumar/pt-gmb-ml

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References

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