

Response to reviewer comments

Long-term firn and mass balance modelling for Abramov glacier in the data-scarce Pamir Alay

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Dear Editor,

We appreciate the interest in our study and thank you for editing our study. We would like to thank the reviewer for his constructive comments and suggestions on the revised manuscript. Below, we respond point by point to all comments, and state how we accounted for them in a revised version of the paper. The responses (normal font style) to the reviewers' comments and updated paragraphs (in quotation marks) are written directly into the reviews (displayed in italic font style).

Marlene Kronenberg

Fribourg, November 7, 2022

Summary

The authors apply an energy and mass balance model for firn and ice to a glacier in High-Mountain Asia (HMA) using the almost 50-year record of meteorological weather station data (AWS) together with down-scaled reanalysis data from ERA5. There is no significant trend in the annual mass balance found, though differences in space and time exist.

There is a significant improvement of the manuscript compared to the initial submission. The current manuscript is easier to follow and much more streamlined, some unnecessary figures have been moved to the supplement. Clear answers and adjustments have been made and the restructuring was to the benefit of the overall quality of the work. However, there are still some more minor changes to make which fall in line with the previous comments.

General remarks

Ask yourself again what does the figure show and why do you show it. Does it show relevant info or just proves that the model works (its not a model development paper)? For example, Figure 11 shows subsurface temperatures being too high in the model for June 2018. The plot is shown, the results about it are briefly mentioned, but there is not really a discussion linked to it. Why is there disagreement or not between model and observations. One could speculate about the effect of fresh snow fall albedo increase in the model, you mention that during observations it fresh snow often melts early, etc. I am wondering if during 4.2 the discussion, fig. 11 could be linked more to the discussion or else why is it shown for this particular time period (2018) or at all.

Figure 11 nicely shows that the EBFM is able to reproduce temperate firn conditions and we therefore decided to show it. The misfit between modelled and measured subsurface temperatures in June 2018 indicates that firn warming the modelled firn warming at the beginning of the melt season is somewhat accelerated compared to the measurements. This might be due to a reduced modelled subsurface refreezing (cooling effect) caused by the lack of liquid water and/or the lack of cold content. Due to the relatively coarse spacing of thermistor measurements it is not possible to track melt water percolation and single refreezing events in the measurements. A discussion of the processes would thus remain rather speculative and we therefore decided not to discuss this further in Section 4.2.

All correlation/regression plots show regressions of data points with larger modeled than measured SMBs (away from the line of equality) (Fig 6,14, S4). This is seems to be a systematic effect from the modeling. Could you comment on this, and mention and discuss it in uncertainty/discussion. Why is this observed? It is only briefly mentioned that the model does underestimate ablation as well as accumulation, but does it, or only extreme values?

Several reasons for the misfit between modelled and measured mass balances are discussed in section 4. The reasons include grid resolution, model simplifications and the choice of constant parameter values (e.g. albedo) but also the distribution of point measurements. We completed section 4.2. with the following statements:

”The linearly updated glacier surface might thus be a reason for the underestimation of melt rates on the glacier tongue as visible from Figs. 6a,b and S4b.”

and

”The lack of considering those processes also explains the misfit between modelled and measured accumulation as visible from Figs. 6a,b and S4a,b to some extent. Other reasons for the misfit are likely related to the limited spatial representativeness of the rather low number of accumulation observations.”

There are still some vague statements for quantities: “a certain threshold” etc. Try to avoid those and provide numbers.

The threshold values are given in the supplementary material (see also answer to specific comments below).

Specific comments

Figure 5a: The colors are updated now from gray shading, which makes it easier to see, but from my understanding of how the plot is composed it still plots the later years on top of the earlier so if the maximum glacier extent was observed at a later time scale one cannot see the extent of earlier times? So the problem remains, could transparency solve this?

The glacier area reduced over the decades shown in Figure 5a. This is now specified in the caption:

“The largest glacier area was observed for the first decade (shown in dark blue) and reduced over time.”

Line numbering refers to the markup version:

Line 26: Should it be singular? climates-¿ climate?

Agreed.

Line 285 : “Liquid water is instantly distributed along the depth axis following a normal distribution until a maximum depth z_{lim} unless it reaches an impermeable ice layer before.” how big is z_{lim} roughly?

z_{lim} is 6 m as specified in Table 2.

Line 334 value → valueS

Agreed.

Line 335ff: I am still wondering when you distribute precipitation over the entire day equally but the cloud cover not what effect this has. At least for days with precipitation shouldn't the cloud-cover be correlated with the precipitation. You reason for your choice of cloud cover distribution due to convection effects (“During the melt season, convection is a main driver of cloudiness and cloud formation mainly takes place along the mountain ridges (Suslov and Krenke, 1980).”). On non synoptic scale precipitation events, are you not expecting more in the second half of the day too? Would this play a role? As your albedo due to earlier precipitation on the day may be too high? Or are convective solid precipitation events (snowfall) rare? Your comment specifically also mentions the melt season, is this applied for the entire year – I assume yes, but its not 100% clear out of the manuscript.

Yes, we apply this the entire year. (We refer to the melt season because this is when convective clouds were observed). We agree that non-synoptic scale precipitation events also rather occur later in the day. However, only data are reported. We consider albedo related Uncertainties due to too high precipitation in the morning to be relatively low as precipitation is not frequent during the melt season.

Line 393 which monthly precipitation threshold value, provide a number

The values are given in S1.4 of the supplementary material as specified here.

Line 480: It is not entirely clear what a stronger RMSE is, i.e. stronger wrong word, higher? But what is higher? What is the reference? Higher than bias? Higher than RMSE for winter/summer balance?

We rephrased as follows:

”The comparison of optimized model simulations to surface mass balance observations used for model calibration shows a higher Root Mean Square Error (RMSE) for the annual mass balance than for the accumulation in March...”

line 501 “, and mass loss through runoff “ . I would add an “and “

Agreed.

line 504 Change “other results” to “other (output) variables”

Agreed.

line 505: The sentence does not make sense, though I get what you mean: ... is analysed on a grid/mask corresponding ... for decade-wise updated glacier extents. Until the end of the hydrological year 1978, the entire model output is analysed corresponding to the glacier area of 1975.

We rephrased as follows:

”After modelling, the glacier wide mass balance and other variables are calculated for decade-wise updated glacier extents. Until the end of the hydrological year 1978, the entire model output is analysed. For the next ten hydrological years, ...”

lines 531-535 There are multiple formatting issues with the parenthesis (and which units do the values provided here have? kg/m² (mm w.e.)

The formatting issues were corrected and units were added.

line 621: One of the parenthesis is too much or there is one too little

Agreed.

line707: “EBFM reproduces the observations satisfactorily, as shown by the the comparison of modelled and measured surface mass balances (Fig. 6) and especially the comparison of subsurface properties (Figs. 10, 11). How does 4b fall in line with that, with annual biases around of up to 0.7m w.e.?”

In Figure 4b, we show accumulation and ablation biases separately for single years, whereas the overall bias is given in Fig. 6. Indeed, biases are relatively large for some years. We therefore added the following sentence here:

”Whereas the overall biases between modelled and measured surface mass balances are low (0.05 m w.e. for historical and 0.28 m w.e. for recent years), relatively large biases exist for single years (Fig. 4b).”

Figure 4b: Caption: I am not sure what is meant with bias of surface accumulation and surface ablation. Are those the values of measured accumulation and ablation over the entire glacier over the entire year or for ablation area? i.e. what is exactly compared here? You do not have a continuous height record at your measurement stations I guess?

We clarified the caption as follows:

”Mean annual surface accumulation bias (blue) and mean annual ablation bias (red) between point measurements and model output for corresponding grid points”.
