

Response to reviewer #1

The authors have adequately addressed my comments in the revised manuscript; however, I recommend some minor revisions before considering it for publication.

Language refinement is advised for the manuscript, and a grammatical check is necessary. Some statements may be challenging to understand even for professional readers.

Examples for improvements in the abstract (but not limited to):

Should "glacier dynamics" be replaced with "glacier mass balance" in line 17 of the abstract?

Consider revising line 19-20: "apply ... to ..."; in line 20, use "coupled with."

In line 24-25, consider revising: "This, in turn, reducing the melt laterdt reduce?"

In line 26, consider changing: "which primarily attributes to..." to "is attributed to..." or "is associated with..." - the latter is preferable.

Reevaluate line 29-30: "Thicker debris cover ... contrast between ... -contact zone, hard to understand."

Review line 32-33: "The last sentence is hard to understand."

Additionally, a general check for clarity and coherence throughout the manuscript is recommended to enhance overall readability.

Thank you for your suggestions. We have thoroughly checked the manuscript and made some changes to the grammar and unprofessional expressions. Please see the revised version for details.

Response to reviewer #2

I applaud the authors for the detailed response and thorough revision. The manuscript is now coherent and provides important insights into the energy fluxes and mass balance of the debris-covered Batura glacier and debris-free Pasu glacier in the Karakoram. I only have of a few minor comments before publication.

1) I am still wondering to which degree the resampling of the original debris thickness map of Rounce et al. (2021) from 35 m to 300 m spatial resolution (this processing step is not yet mentioned in the methods section and should be added) affected the modelling results. Considering the high spatial debris thickness variability across the ablation zone and the non-linear effect of debris thickness on glacial melt, the chosen resolution of 300 m is very coarse (I understand that the spatial resolution was constrained by the computational costs). Hence, the impact of the spatial resolution on the modelled energy fluxes and ice melt should have been explored, at least for a subsection of the debris-covered tongue. I would be happy if the authors could implement such an experiment. If that's not feasible, I encourage the authors to compare at least the statistical distribution of the in-situ debris thickness measurements (the ones from the authors plus those from WAPDA), the original debris thickness map and the aggregated debris thickness map, and discuss the potential impacts on the EB/MB modelling in case there are any considerable differences in the debris thickness distribution of the three data sets. A figure with a histogram or boxplot for each of the three debris thickness data sets could be added (to the supplements).

Thank you for your comments. We have added the method of resampling the Rounce et al. (2021) data to 300m in the Methods section. According to your suggestion, we conducted a comparative simulation experiment with different resolutions on a small part of the terminus of the Batura Glacier. The results showed that the energy flux and ablation of the 100m resolution simulation results have significant differences in spatial distribution compared with the 300m results, but the mean results of the region are relatively small, which can be specifically seen in the third paragraph of Section 4.5 and Figure S7.

2) Please check all figure captions. Most of them are very short and do not necessarily contain all relevant information to understand the figure content. Add additional information where necessary. Thank you for your suggestions. We have revised the title of the figures and added more information.

Line 290/291: "We validated the simulated debris thickness using observed data, which showed an average deviation of 6 cm." I still don't understand how a coarse debris thickness map can be validated with a few in-situ measurements. Please clarify or rather compare the statistical debris thickness distributions (see general comment).

Thank you for your comments. We compared the results using interpolation, which is explained in the methods section of the revised version.

Line 299: Indicate Pasu glacier in Fig. 1

Thank you for your suggestions. We have incorporated this information into Figure 1.

Line 659: Update the reference to the correct Figure (S3 is not showing mass balance...)

We appreciate you bringing the errors to our attention. We have made the corrections and have also

reviewed the entire manuscript to prevent similar errors from occurring in other part.

Line 725: “we propose that the primary factor influencing the comparatively low negative mass balance of the Batura Glacier is the substantial inhibitory impact exerted by the surface debris on the process of ablation” Please see the respective comments in my previous report. Your simulations do not support such a conclusion.

Thank you for your suggestion. We are trying to express that the presence of debris cover is an important guarantee for Batura Glacier to maintain a relatively low negative mass balance under the background of warming compared with other mountain glaciers. We have now changed the sentence to "we propose that the presence of debris on the glacier surface effectively reduces the amount of latent heat available for ablation by absorbing solar radiation and preventing it from reaching the ice surface, which creates a favorable condition for the Batura Glacier's relatively low negative mass balance."

Line 753: “...discussed and investigation.” => discussed and investigated
Revised it already.

Line 800 and thereafter: as precipitation increases considerably with elevation in the Karakoram, lapse rate is not a suitable term here. Better replace lapse rate by “(altitudinal) gradient”.

Thank you for the suggestion. We have made revisions throughout.

Figure 2 appears two times. Update figure numbers.

Revised it already.

Figure 2 (model scheme): I appreciate that a model scheme was added, but to me the arrangement of the energy fluxes and symbols is a bit confusing. I know that this was not the intention, but in this visualisation it appears that only the atmospheric flux shown at the top (shortwave, longwave and turbulent fluxes) is relevant for the processes in the “column” listed below. Can you make it more clear that the radiative and turbulent fluxes are relevant for all physical processes listed below. Moreover, I think the figure and caption could be improved overall. Some notations are not explained (e.g. T_{snow} , T_{debris} , T_{b}). It should also be mentioned (in the caption) that the figure shows the energy fluxes for three different setting (bare ice + snow cover, debris-covered ice + snow cover, debris-covered ice; what about just bare ice?).

Thanks for your comments. Figure 2 has been improved for better clarity. The captions now provide detailed explanations of energy fluxes and the symbols used. Additionally, the connections between atmospheric flux and surface/subsurface flux were labelled in the figure. The critical role of surface temperature in linking these fluxes is emphasized. Any essential details that couldn't be visually represented in the figure are included in the caption. For a more comprehensive picture, the figure now also includes a scenario with only bare ice.

Figure 2 (mass balance comparison): You state several times in the manuscript that the simulated MB and geodetic MB agree relatively well. If I recall correctly, you used the geodetic MB for the calibration of certain model parameters. Please clearly state this in the caption and text. The simulated MB and geodetic MB are not completely independent in your case.

Thank you for your suggestion. We have already explained it in the figure caption and the text.

Figure 3: Please state the measuring interval (daily?), the approximate debris thickness at the location of the weather station and the depth of the thermistor for the surface temperature measurements.

We have added the measuring interval. In fact, we have already explained in the main text about the debris thickness at the location of the weather station and the depth of the thermistor for the surface temperature measurements, see Line 272 "the observed debris thickness was approximately 1.13 m", line 313-314 "The temperature probe is buried ~ 2 centimeters below the surface layer".

Figure S4: The axes are missing and the caption seems to be incomplete.

We supplemented the missing information in Figure S4 and made necessary additions to the figure caption.