Review of:
Sub-surface processes and heat fluxes at coarse-blocky Murtèl rock glacier (Engadine, eastern Swiss Alps)

Submitted to: *Earth Surface Dynamics*
Reviewer: Benjamin Hills

Summary.

Amschwand et al. present a new and unique dataset which constrains the thermodynamics of a rock glacier in the Swiss Alps. To interpret their data, they also design thermodynamic models for heat fluxes in and out of the rock glacier system. I believe this dataset is of great interest to the readership of *Earth Surface Dynamics*, and after revisions I believe the article will fit well in the journal. As written, I worry that the importance of this work could be lost in the complexity of its presentation. Most of my requests below aim to help refine the narrative of the article and to elevate its impact.

General Comments.

I believe you are underselling your work by focusing on details and skipping over some of the high-level impact/importance of your work on rock glaciers. For instance, there is no introductory statement (not in the abstract or introduction section) to explain *why* the reader should care about rock glaciers to begin with. The final statement in the conclusion effectively states that "more work needs to be done" which could leave a reader confused on what they are meant to take away from your article. Even the title could be changed to increase the interest in the article, bringing in something about the climate resiliency or the 'semiconductor' effect that you mention (see my comment on that below). I do realize you want to keep consistency with the title in your previous article (Amschwand et al., 2024), so maybe it is too late for that change.

Some of the analysis is thorough to the point of redundancy. I do appreciate the full exploration of every aspect of the data, but I feel that much of it could be moved to a supplementary text for the sake of preserving the clearest narrative possible in the main article. Some examples:

- Thermal conductivity, thermal diffusivity, and thermal resistance are all presented as material properties of interest. I understand that each is slightly different, but they are all related and trying to get at the same thing. That is, "how long does it take to heat up or cool down the active layer". I would focus on one material property within the main text (probably the thermal diffusivity since it contains the conductivity and since I believe Figure 10 is one of the more important takeaways). Then, move any other discussion to the supplement.
- There are *many* variables, and many different fluxes to keep track of. I suggest a table to list all the notation.
- The two temperature models, degree-day model and Stefan model, give effectively the same result (e.g., in figure 13 a and b). I argue it is not worth the confusion it adds to

explain each of them separately. Instead, just use the model which is best suited to your narrative (probably the Stefan model in my opinion).

- The data presented in the appendix is not critical to the main article and it is not presented as a significant component of the study. I believe these figures could be moved to a supplement which would reduce the length of the article with no drawback to the narrative.
- How important are the "short-lived events" to the overall energy balance of the rock glacier? My sense is that this is additional information which could be kept to the supplement (e.g. move figures 15 and 16 there) to leave the reader with the most important takeaways (e.g. I think that Figure 14 is quite important).

Most of the measurements critical to the interpretation presented in the article are from a single subsurface cavity. It is not clear that this single cavity is representative of the AL over the entire area or especially to other rock glaciers. Some explanation within the Discussion section (even if speculative) could help the reader to understand whether the measurements made there can be extended away from the one cavity.

Specific Comments.

Abstract – I believe the second thaw-season mechanism is the most new and interesting result in the entire study. I would like to see it elevated and described more clearly in the abstract. As it is written, it is not clear to the reader that the 1.2 W/m/K vs. the 10 W/m/K are in opposite directions (i.e., that the increased conductivity actually acts to cool down the AL which is perhaps counterintuitive and a strong result). You mention the "thermal semiconductor" here in regard to this as well which I do not believe is explained in the text. Perhaps this is a known phenomena, but I had never heard of it and I think it is a useful analogy to talk about your system. Please discuss this semiconductor analogy more clearly in the text if you are going to use that term in the abstract.

L16 - Intro gets into detail very quickly. Maybe one more sentence to describe what the coarse-blocky active layer is in plain language?

L21 – I believe a comma after "Snow" would help readability.

L 31 – Not sufficiently clear yet what the term "undercooling" is referring to.

L70-82 – This paragraph feels more like methods to me.

L99 – Missing unit on the "2"

L163 and 180 – I think either make these subsections or just make it clear in the paragraph what you are talking about.

L170 – I am confused about this Nu parameterization, is it used later? If not, I think it only adds confusion to define it here.

L174 – Have you defined the Richardson number?

L197 - I would move all of section 4.1 into the Flux section 4.3. What is currently section 4.2 can be the explanation in words and then what is currently 4.3 serves to explain all the variables in a mathematical context.

L286 – seems to be a missing word? “on melting ground ice the AL”

L289 – citation for the Stefan equation. Also, could be worth stating in words that this is sensible/latent heat comparison.

L309 – make it clearer that this is an update to eq 11 and drop the parenthetical unless it is seen as necessary.

L341 – is this the first time Tal has been defined? It was used above.

L343 – Do you mean Tal<0.5C? I don’t see how temperatures close to the melting point would minimize latent heat exchange.

L354 – need a citation on the “rarely been occurring in the last ~15 years”

L402 – not sure what the exclamation mark is for.

L415 – I believe you mean Figure 8b.

L431 – I believe there is a typo with the log-mean variable “alpha_alpha”, shouldn’t that bee kappa?

Figures

Overall, the figures are beautiful, very nice aesthetic.

Figure 1 – Beautiful map. Can you give a projection for the Northing/Easting that you show on the x/y axes, I assume it is UTM? Please describe the red lines in the caption, Does the latitude line correspond to both the inset and the main map? Unclear.

Figure 3 – I assume that the horizontal scale is equal to the vertical in the illustration. Is the same scale used in the “schematic horizontal section”? If not, a scalebar there would help.

Figure 4 – Shouldn’t the t0 schematic go on the left with (a)?

Figure 5 – Indicate what the red and black contours are in the caption.

Figure 6 – Having the legends for b-d spread out through all the panels is confusing. I would make it one legend to the right of all the panels.

Figure 8 – Is the data on the x-axis the same for both (a) and (b)? If so, I am confused why the extents for the axes are different and why the net longwave extends into the range of 20-25 W/m2 for (a) but not for (b).

Figure 14 – I would remind the reader which of these fluxes are meant to sum together. That is, from equation (3) the purple, cyan, and black lines sum to equal green, but don't assume the reader will be able to remember eq (3). You do a good job of explaining this in the text 6.1.1, add some indicator either to the plot or the caption on how a reader should interpret this figure (perhaps redefining the flux terms in words instead of only the symbols, its hard to keep track of all of them).

Table 3 – This should be presented closer to where it is first introduced.

References

Amschwand, D., Scherler, M., Hoelzle, M., Krummenacher, B., Haberkorn, A., Kienholz, C., & Gubler, H. (2024). Surface heat fluxes at coarse blocky Murtèl rock glacier (Engadine, eastern Swiss Alps). *Cryosphere*, *18*(4), 2103–2139. https://doi.org/10.5194/tc-18-2103-2024