

## **Review of Loss of accumulation zone exposes dark ice and drives increased ablation at Weißseespitze, Austria**

### **Overview**

The paper addressed the relevant topic of understanding changes related to glaciers and their accumulation/ablation zones and surface albedo, which can be a challenge to model, especially for future glacier evolution. The study fits well within the scope of TC. The novelty of the paper, although focused on one specific glaciers, is the utilization of remotely sensed albedo and details related to spatial distribution of albedo. The paper is well structured, the figures are clear and easy to follow/read.

I like the way field data and remote sensing is fused and suppose one to another. The introduction reads well and builds the topics well together with ample references. The figures are clean and draw attention to the data. Well made and readable. Much detail to the errors and influencing impacts on observed albedo, both in the paper and the supplemental material, which is very nice to see but perhaps more could have been done to detail the impacts of these errors on the modelled energy balance ? The title of the paper describes well what the paper presents and discusses.

Figures 12 and 13 are very good figures that clearly detail the changes, clean and easy to read. Good work!

Overall the paper is a good read with interesting analytics, clear figures and tells an important story.

### **COMMENTS**

The authors might want to review the verb tense throughout the paper, as there are a few instances where it doesn't seem to be used consistently. I'm not an expert in the English language though. A few of such are pointed out in the minor comments.

Overall, I think more could have been done with the Cosipy model since it was setup for the glacier with the unique AWS dataset. This would have provided more insight into various possible changes, details related to the winter mass balance and what would need to happen for the glacier to regain its accumulation area, etc. I think this is one of the shortcomings of the work, which could easily be improved. I also miss some insights to what winter mass balance does for the glacier. Are the low/bare ice albedo years coincidence with winters with little snow ? Could high snow winters help the glacier "back on track" or is it doomed ?

For the References list there are no DOI numbers at any of the references. I assume TC would like some DOI numbers.

Section 2.4 needs some input on the spatial resolution of Sentinel 2 albedo and as well how the buffered pixels are handled. If multiple pixels are covering the buffer what is done ?

Ideally the configuration files for Cosipy and the modified code to account for albedo directly should be included in some repo for reproducibility.

Somewhere in the introduction or in the description of the study site there should be a mention of the winter mass balance, how much it is in context to the melt. Even ballpark numbers if measurements are not available.

In figure 4 there is a very nice comparison of the observed and remotely sensed albedo. For me it seems to be or might be different comparing statistics between seasons or months. Overestimation during the melt seasons and underestimation during winter. Would it be valuable, also in relation to future studies that would like to adopt the methodology, to provide some statistics for this comparison on a monthly basis ? This could be an additional column to table 1.

## MINOR COMMENTS

L004: feedback or relationship would be better than connection

L007: remove conditions ...low albedo values...

L007: Recorded by what ? AWS or S2 ?

L008 Is this only ice ablation? Or just general ablation for the location ? Winter snow + firn + ice?

L016: The new Glambie paper in Nature would be a good additional reference here

L021: More context is needed. For example: "...bare ice becomes exposed with lower surface albedo than firn" This is then referred to in the next sentence.

L026: glacier albedo might be better here. Or snow and ice albedo. Same in L027

L039: Drive is not a good word here. Force or input data

L056: ...during extreme years... extreme years of what ? Rewrite this sentence so it is clear what is extreme.

L057: In the following of what? In this study... could be used

L070: For non-native Alps people writin Gepatschferner *glacier* would be helpful

L071: I am a bit confused by this number, 0.05 km<sup>2</sup>, as the red area highlighted in Fig.1 showing the ice covered mountain seems to be more than ~1km ? Are you referring to the absolute peak of the mountain ? Perhaps, if this number is not important you could skip it to reduce confusion ? Is it possible that this is the area all the stakes are aggregated in fig 1 panel c ? Perhaps a small box there would be useful.

L073: what is cal BP ? Please write out.

L073: change ice depth to ice thickness.

L095: Are they operated only during summer ? Redrilled in each spring. In L096 it is indicated the stakes are visited over the full year or is this inly for the summer. In the ablation stakes section (2.2) it might be clear if these stakes only survey summer mass balance or if the survey winter mass balance as well ?

L111: I would suggest to use SW<sub>in</sub> and SW<sub>out</sub> which I believe is pretty standard ? Or provide some insight in why *ref* is used. *Reference or reflected ? On most other locations in the paper SW<sub>in</sub> and SW<sub>out</sub> is used. Please systematically go though the paper and make these the same in text and figures.*

L149: In this sentence "Multi-spectral reflectance was converted to broadband

150 reflectance using the conversion developed by Liang (2001), following prior work addressing broadband albedo of glacier surfaces (Naegeli et al., 2017)." A bit more insight into what equation is used would be beneficial and what bands are input.

L174: are => were and in L115

L179: the word model or simulate is missing after the citation, “to **model the** surface mass balance...”

L182: take => use

L186: To Cosipy, is the snowfall in height units or w.eq. ? Is there a conversion with density done ?

L189: Could you explain a bit what idealised runs actually are ? Observed met data with 0.05 incremental changes in albedo to the full period from and to ? Running from fall to fall or during summer ? What is the timestep of the model runs needs to be added.

L191-192: What does this sentence mean ? What assumptions for the subsurface are assumed ? Is something in the model skipped ? I would assume that there are some sort of initial conditions for the model ?

L198: *“However, running the model with input as recorded by the AWS for a sub period with SR50 data of acceptable quality shows good agreement between the modeled and measured surface height (Fig. S8, supplementary material) during the phase of snow melt and subsequent ice ablation at the station.”* This sentence would improve by being re-written for clarity, it is a bit . Surface height should be surface height changes.

L198: For me it is a bit too simple to say: *“Detailed validation exercises are beyond the scope of this study.”* The authors mention a good comparison to observed and modelled surface height changes which in a sense is a good calibration metric. Since there is a figure in the supplements please add some simple stats in the text of this agreement, i.e. rmse, R2 and bias for example.

L206: Add the years (2018 - 2024) in the text so it is clear that these are mean values for the whole study period.

L211. Are these anomalies ? See comment for figure 3

L246: Cumulative ice ablation. This is summer mass balance right ? No only ice, but ice and snow is it not ? Or skip the word “ice”

L256: is => was

L261: mm w.e => mm w.e. (a dot is missing)

L353: “broadband conversion of Liang (2001) is suitable for ice albedo.” Not for snow albedo ? Perhaps expand this a bit so it is clear.

L373: observation => observations

**Figure 1:** In the map (b) of Gepatschferner there are a lot of green outlines. I would suggest highlighting what is defined as Gepatschferner with another color for context and then either skip the other outlines or have them in an alternative color. A lot of ice patches and small glaciers are in the area. Also, there are parts of glaciers that seem to have no outline, i.e, in the south west part of the image. It also seems like parts of the Gepatschferner are missing its outline ?

**Figure 3.** I am a bit confused by the figure. I understand that the long term mean albedo is shown in each subplot but for each individual year are the anomalies shown (data minus the long term mean) or the change compared to the mean ? For example, for the big grey period in 2024 in September is the anomaly about 0.4 lower than the long term mean or is the observed albedo about 0.2 ? I would change this figure to true anomalies (data minus mean). That would also highlight better the

deviations as positive or negative. The AWS and S2 validation/comparison is already done in Figure 4 and 5 so there is no need to repeat that here with the black dots.

**Figure 7:** In the b-panel the color needs to be different for SWin and SWout. It is very hard to see what is what. Perhaps change to SWnet ? Or have SWin and SWout with different sign as often is done?

**Figure 8** is a very nice figure.

Figure 10: It would be a good idea to have the same names for radiation components as mentioned earlier, SW/LW in/out here but different earlier in the text.

Figure 11: Meam should be mean