RC2:
Thank you for the helpful feedback and comments and the time spent on the review! We will address the points raised to the best of our abilities in the revised manuscript. Please see below for responses to specific comments (blue text).
-Lea Hartl on behalf of the authors

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.
Thank you!

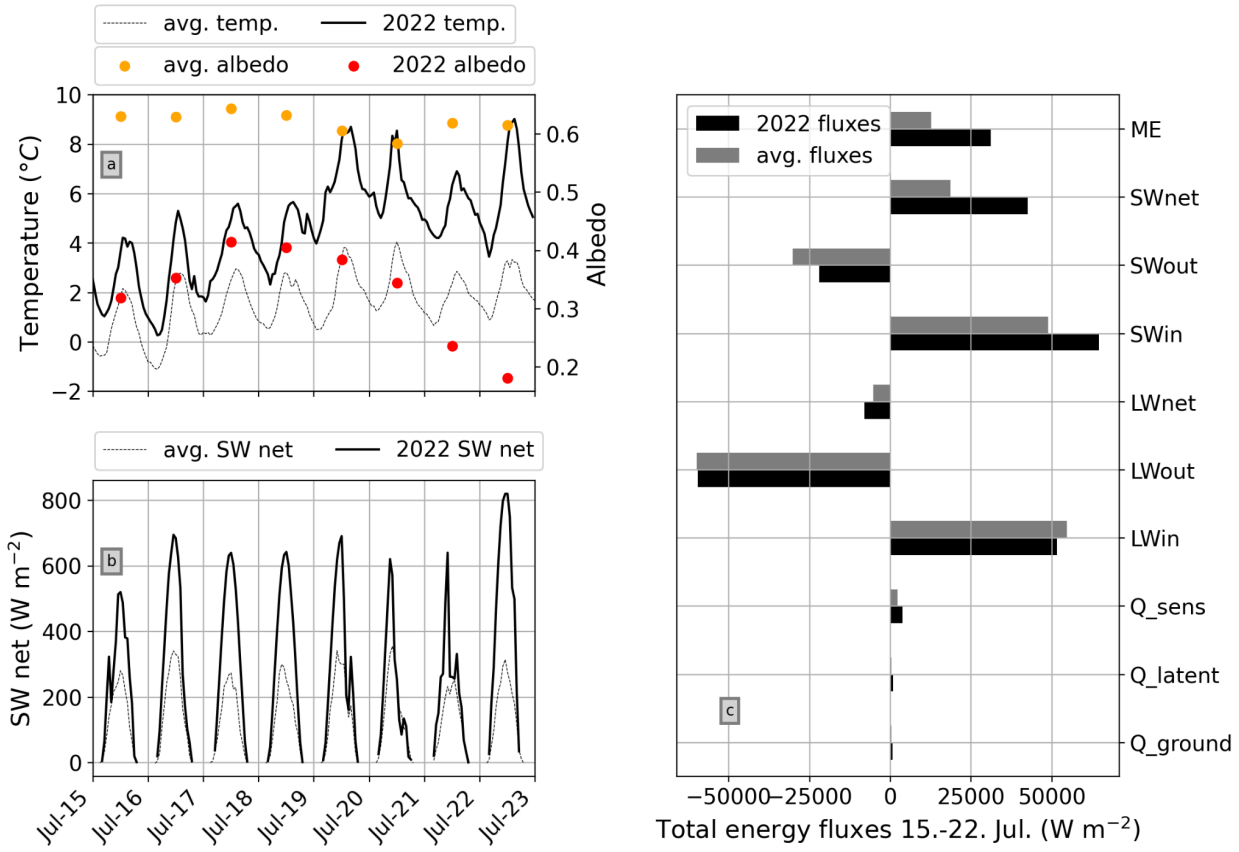
COMMENTS
The authors might want to review the verb tense throughout the paper, as there are a few instances where it doesn't seem to be used consistently. I'm not an expert in the English language though. A few of such are pointed out in the minor comments.
We have revised the manuscript to improve the consistency of tenses. We aim to generally use past tense for the methods and results and present tense for time invariant content and interpretations. We are also not experts in the English language and are happy to correct instances we may have missed during this round of revisions.

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.

Based on this and comments by R1, we added a figure to the results section partitioning the fluxes for average 2018-2024 summer conditions and the 2022 heatwave. This shows that shortwave radiation is a key driver of energy balance at this site.

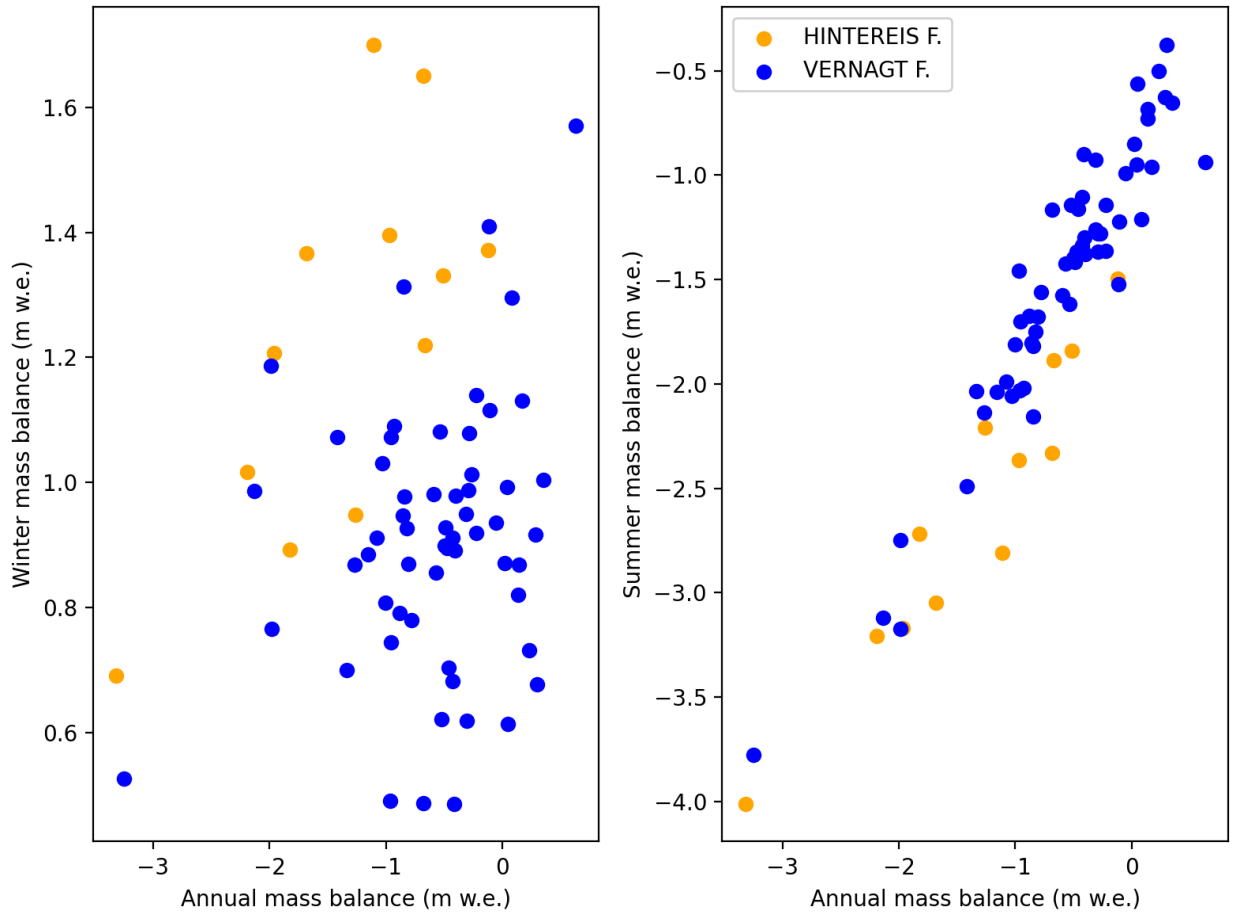
The focus of this study is the relationship between summertime melt and the duration of ice exposure and ice albedo at high elevations, hence the COSIPY experiments target this aspect. The snow height data from the AWS is very noisy (as detailed in the supplement) and we do not have snow density measurements, hence it is not possible to fully quantify winter mass balance. In the revised manuscript, we have added general information on the relationship between winter and annual mass balance to the study site description (see also responses to below comments), and expanded the discussion of this issue.



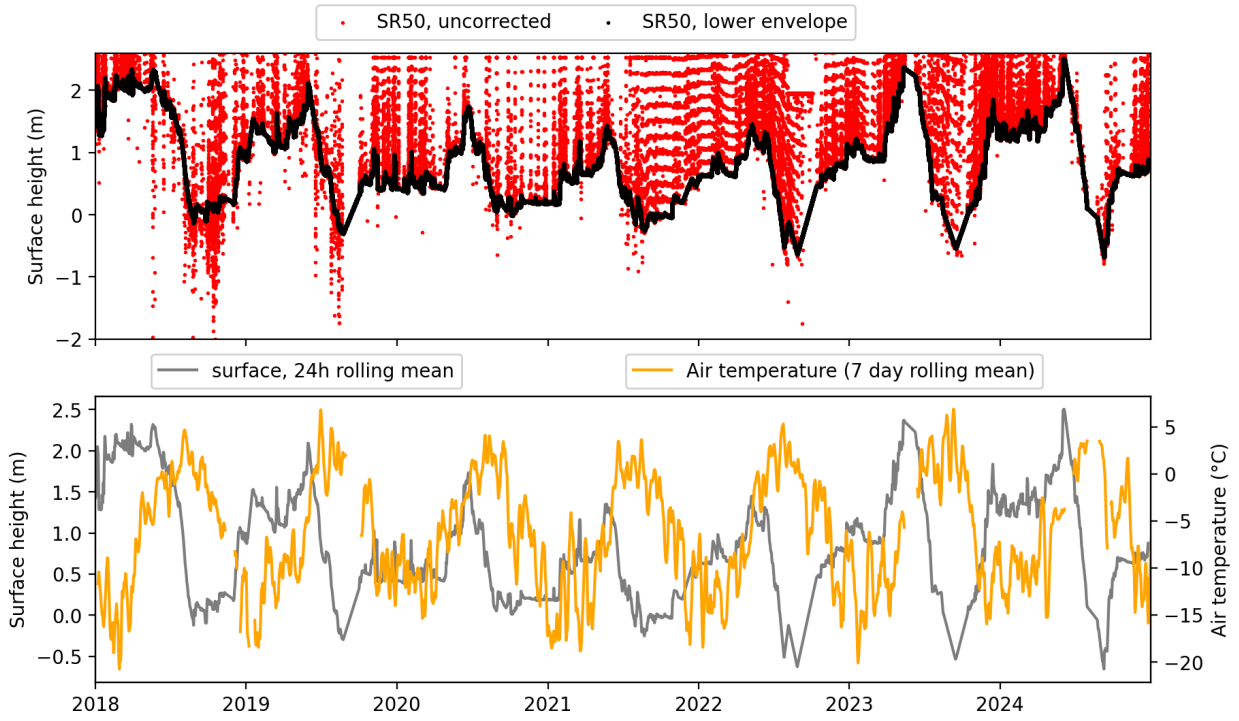
Additional figure showing the 2022 heat wave and average 2018 to 2024 conditions during the same time of year and associated energy fluxes in panel c: ME: Energy available for melt. Q_sense: Sensible heat flux. Q_latent: Latent heat flux. Q_ground: Ground heat flux.

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 ?

There are no winter mass balance data for this site. Two WGMS reference glaciers very close by do have seasonal records. Based on those time series, it is apparent that the trend in ablation (summer mass balance) drives the annual trend in this region. The below figure shows winter and summer mass balance vs. annual mass balance for the two closest WGMS reference glaciers, Hintereisferner and Vernagtferner, to illustrate this. We have added commentary on the questions posed by the reviewer in the discussion section (sec. 4.4.) and added a figure to the supplement showing the time series of 2018-2024 snow depth. Summers with few "low albedo" days, such as 2020 and 2021, were not preceded by exceptionally snowy winters. Strong melt years with long periods of exposed ice have occurred in seasons with relatively little snow in late spring (2022) and in seasons with above average spring snow depths (2024). A deep spring snow pack can undoubtedly delay the onset of ice ablation and reduce annual ice loss, but recent years indicate that it cannot prevent substantial ice melt under otherwise unfavorable conditions.



Winter and summer mass balance vs. annual mass balance at WGMS reference glaciers Vernagtferner and Hintereisferner.



Cleaned SR50 data showing surface height evolution at the AWS. The lower panel shows smoothed surface height and air temperature. This figure was added to the supplement in the revised manuscript and is referred to in comments on the role of winter snow pack for the ablation season added to the revised discussion section.

For the References list there are no DOI numbers at any of the references. I assume TC would like some DOI numbers.
Added DOIs, thanks for pointing this out.

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 ?
We have added the spatial resolution (10x10m) and an explanation of the buffer. The value for each point corresponds to the pixel whose centroid is within the buffer. If there are multiple pixel centroids in the buffer, the average is taken.

Ideally the configuration files for Cosipy and the modified code to account for albedo directly should be included in some repo for reproducibility.
Yes, we will prepare a repo to accompany the revised manuscript.

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.
There are no measurements of winter mass balance from the study site. As mentioned above, annual mass balance in the region is driven by ablation and not strongly correlated

with winter mass balance. To give some more context on the general setting, we added the following to the study site section:
“This is in line with trends towards increasingly negative annual mass balance at three World Glacier Monitoring Service (WGMS) reference glaciers in close proximity to Gepatschferner (Hintereisferner, Vernagtferner, Kesselwandferner). Annual mass balance at these sites is strongly correlated with summer mass balance and trends in ablation dominate the overall mass balance trend in the region (WGMS, 2025). Winter mass balance at the reference glaciers shows no clear trend over time.”

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.
S2 derived albedo is on average slightly lower than AWS albedo from October through December but this is not the case in the remaining winter months. Below are various statistics comparing the different months. We feel that this is not very conclusive regarding seasonal over- or underestimation and would prefer to keep the table in the manuscript as is. If the reviewer feels differently or has suggestions on other metrics to compute here we would be happy to explore this further.

month	rms	Abs. mean bias	Mean difference	Median difference
10	0.119	0.085	-0.027	-0.027
11	0.109	0.082	-0.01	-0.02
12	0.117	0.087	-0.044	-0.027
1	0.088	0.073	0.017	0.021
2	0.099	0.079	0.041	0.043
3	0.093	0.08	0.056	0.072
4	0.099	0.082	0.065	0.064
5	0.081	0.062	0.054	0.039
6	0.083	0.066	0.041	0.055
7	0.085	0.069	0.056	0.049
8	0.072	0.06	0.022	0.028
9	0.068	0.054	0.012	0.013

MINOR COMMENTS
L004: feedback or relationship would be better than connection
Changed to relationship

L007: remove conditions …low albedo values…
Changed as suggested.
L007: Recorded by what ? AWS or S2 ?
Changed to : “recorded by the weather station”
L008 Is this only ice ablation? Or just general ablation for the location ? Winter snow + firn + ice?
It is only ice ablation.
L016: The new Glambie paper in Nature would be a good additional reference here
Yes - added.
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.
Changed to: “As snow lines rise and multi-year firn is depleted, bare ice becomes exposed. The newly exposed ice surfaces have a lower albedo than snow and firn, which affects the surface energy balance by increasing the amount of absorbed solar radiation, thereby creating a positive melt-albedo feedback”
L026: glacier albedo might be better here. Or snow and ice albedo. Same in L027
Changed to “overall glacier albedo and the albedo of bare ice have increasingly come into focus” - we specifically discuss ice albedo in the following sentences, hence we’d like to keep this distinction.
L039: Drive is not a good word here. Force or input data
Changed to force.
L056: …during extreme years… extreme years of what ? Rewrite this sentence so it is clear what is extreme.
Rephrased to simplify the sentence: “The continued loss of firn and reduced seasonal snow cover increases the relative importance of bare ice and the potential albedo variability of bare ice surfaces for glacier-wide albedo.”
L057: In the following of what? In this study… could be used
Changed to “in this study”.
L070: For non-native Alps people writin Gepatschferner glacier would be helpful
We added “Gepatsch Glacier” in parenthesis in the previous paragraph where the name is first introduced to clarify this. Ferner is a German word for glacier so “Gepatschferner glacier” translates to Gepatsch glacier glacier and we’d rather avoid that.
L071: I am a bit confused by this number, 0.05 km2, 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.
We removed the number. It is indeed confusing and not essential to anything that follows.
L073: what is cal BP ? Please write out.
Calibrated years before present - added to the text.
L073: change ice depth to ice thickness.
OK!

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 ?
The stakes are redrilled when they are close to melting out. They remain in the ice throughout the year and are only used for ablation measurements. We have added the following explanation here: “Seven ablation stakes were drilled on the Weißseespitze summit ice cap between 2017 and 2019. Another stake was added in 2022. The stakes consist of 2 m long wooden poles connected to each other with tubing to achieve total stake lengths of 6 to 8 m. The stakes are periodically redrilled when they are close to melting out” and clarify that winter mass balance is not measured at the end of the section.

L111: I would suggest to use SW_in and SW_out 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 SWin and SWout is used. Please systematically go though the paper and make these the same in text and figures.

Included “reflected” here to clarify this and revised the manuscript to ensure consistent usage of terms.

L149: In this sentence “Multi-spectral reflectance was converted to broadband 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.
We have specified the input bands in the text: “Multi-spectral reflectance was converted to broadband reflectance using the conversion developed by Liang et al 2001, where broadband reflectance is a function of the blue, red, NIR, SWIR1 and SWIR2 bands.”

The equation is:
$A = 0.356 * \text{blue} + 0.130 * \text{red} + 0.373 * \text{NIR} + 0.085 * \text{SWIR1} + 0.072 * \text{SWIR2} - 0.0018$
We can add it to the manuscript if that would be beneficial but it is the same as in the two references, so we feel that interested readers could refer to those works for further background.

L174: are => were and in L175
Changed the phrasing of the sentence to avoid this.

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

L182: take => use

Changed as suggested.

L186: To Cosipy, is the snowfall in height units or w.eq. ? Is there a conversion with density done ?
We have restructured this section to improve overall clarity. Snowfall is passed to cosipy in height units. A default conversion to density is done with a constant density for freshly fallen snow of 68 kg/m3. This has been added to the revised manuscript. We will add constants and the config file to a code repository that will accompany the revised manuscript.

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.
We have restructured and expanded this section to more clearly explain what was done. The model runs at hourly timesteps for the duration of the time periods used in the experiments, i.e. during summer.

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 ?
We have added information subsurface parameters that are set during initialization (ice thickness and bottom temperature). No part of the model is “skipped” in the sense of modifying the model code. Essentially, the key simplification is that we neglect precipitation (both rain and snow) and snow processes in the calculations and only consider summer conditions. We have rephrased and restructured this section for clarity. The main part now reads:
“We performed idealised sensitivity experiments to isolate the impact of albedo on melt in otherwise unchanged conditions by systematically varying albedo. The model was set up to highlight the influence of surface albedo on overall ablation, considering how “darker” vs. “brighter” bare ice influences mass balance, and how this varies with the time of year. To this end, we considered simplified summertime scenarios with a bare ice surface, omitting considerations of energy balance processes in a seasonal or multi-annual snowpack and energy input from precipitation. Albedo of the ice surface was kept constant over time and varied in increments of 0.05 for each run, so that each model run corresponds to one albedo value between 0.05 and 0.95. For high albedo values that would be indicative of snow, the assumption is that only a minimal amount of snow covers the bare ice, as would be the case for example during a small summer snow fall at high elevation. Subsurface assumptions for model initialization were an ice thickness of 6 m and a bottom temperature of -4°C.“

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.

We have restructured and expanded this section. It now includes a more extensive description of the evaluation procedure and statistics comparing modeled and observed surface change rates. The figure and accompanying text in the supplement was adapted to more clearly show the comparison and explain what was done and the limitations of this evaluation approach (i.e., noise in the SR50 data, no measurements of snow density).

L206: Add the years (2018 - 2024) in the text so it is clear that these are mean values for the whole study period.
Changed as suggested.
L211. Are these anomalies ? See comment for figure 3
Rephrased to match the updated figure.

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"
No, we do actually mean ice ablation. This is further explained in section 2.2 Ablation Stakes. In most cases the ice ablation values are equivalent to annual mass balance but we would like to keep the distinction because we do not explicitly account for snow at the stake locations.

L256: is => was
We think "is" is appropriate here because it is a "time invariant" statement but we are also not english language experts. In the past we have had great support from the language and copy editing team of copernicus journals so perhaps this is something they or the editor could decide. We are happy to correct it if needed and learn how to do this properly.

L261: mm w.e => mm w.e. (a dot is missing)
Fixed, thanks!

L353: "broadband conversion of Liang (2001) is suitable for ice albedo." Not for snow albedo ? Perhaps expand this a bit so it is clear.
Changed to "glacier albedo" to clarify. Naegeli et al (2017)'s findings, which we refer to here, apply to ice and snow on glaciers.

L373: observation => observations

Fixed!

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 ?
Thanks, agreed. We have removed all outlines except for that of Gepatschferner and changed the color and line width to improve visibility. The parts that look like they are missing an outline (southwest section) drain towards the south into the neighboring watershed. The glacier boundary follows the ice divide and this section is not technically considered part of Gepatschferner. We feel that it is valuable to show it anyway since it is obviously part of the same ice mass but adhere to the boundary as per the regional inventory to maintain clear definitions of which part belongs to which glacier.

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.

We have adapted the figure to improve clarity as follows:
Removed black dots showing S2, visually highlighted daily anomalies (black line) and reduced focus on the time series mean (grey line), adapted the caption to more clearly explain what is shown in the figure. We are aiming to show both the daily albedo as measured (black line) and indicate periods with below or above normal albedo (grey and blue shading). Daily anomalies are the vertical extent of the shading. The y-axis shows absolute albedo, as is now stated more clearly in the caption.

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?
Changed the panel to show SWnet, thanks for the suggestion.

Figure 8 is a very nice figure.
Thank you!

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.
Changed the text to ensure consistency.

Figure 11: Meam should be mean
Fixed, thanks!