General comments

The study by Hartl et al. is presenting the results of a new glacier inventory for Austria that has been derived by manual digitisation of orthorectified aerial photography and DEMs along with a detailed comparison to an earlier inventory for glacier-specific assessment of area changes. As the effort required to digitize glacier outlines strongly increases towards higher resolution images, the effort of the authors to create this new dataset must have been tremendous. I also acknowledge the detailed information compiled for each glacier in the attribute table. As numerous outline overlays have been provided in the paper and the suppl. Material, I do not comment on the outlines itself. I have only two larger comments related to the contents and numerous small suggestions for improving the tables and figures (see specific comments). The two larger comments are detailed below. Otherwise, great work, thank you for taking the creation of glacier inventories and the related documentation to this level!

Thank you, Frank, for your encouraging comments and taking the time to go through the manuscript!

I appreciate the detailed discussion and visualization of digitizing variability by different analysts (interpretation uncertainty), yet what is missing is the digitizing uncertainty. This can be determined when the same analyst is digitizing the same glacier independently a few times. Usually this uncertainty is smaller than the interpretation uncertainty, but I think for completely manually digitized outlines it would nevertheless be insightful. I do not know if time is available, but maybe just a few of the colleagues who participated in the digitizing can do it 3 to 5 times for the six glaciers? Contrasting the resulting digitizing uncertainty (e.g. the standard deviation of the obtained areas by one analyst) with the interpretation uncertainty (from different analysts) by the values and outline overlays will likely help in interpreting the deviations across analysts.

The colleagues who participated in the digitizing were mostly volunteers who dedicated their free time to this, so we can't ask for much more. However, following your recommendation, we carried out a smaller experiment in which one analyst mapped three of the round robin glaciers three times on different days (and with different screens). The uncertainties from this are considerably lower than the inter-analyst uncertainties, which confirms our impression from earlier mapping and your statement above. We have added this information to the round robin section in the supplement and refer to it in the discussion section of the main manuscript:

Section 4.1.2:

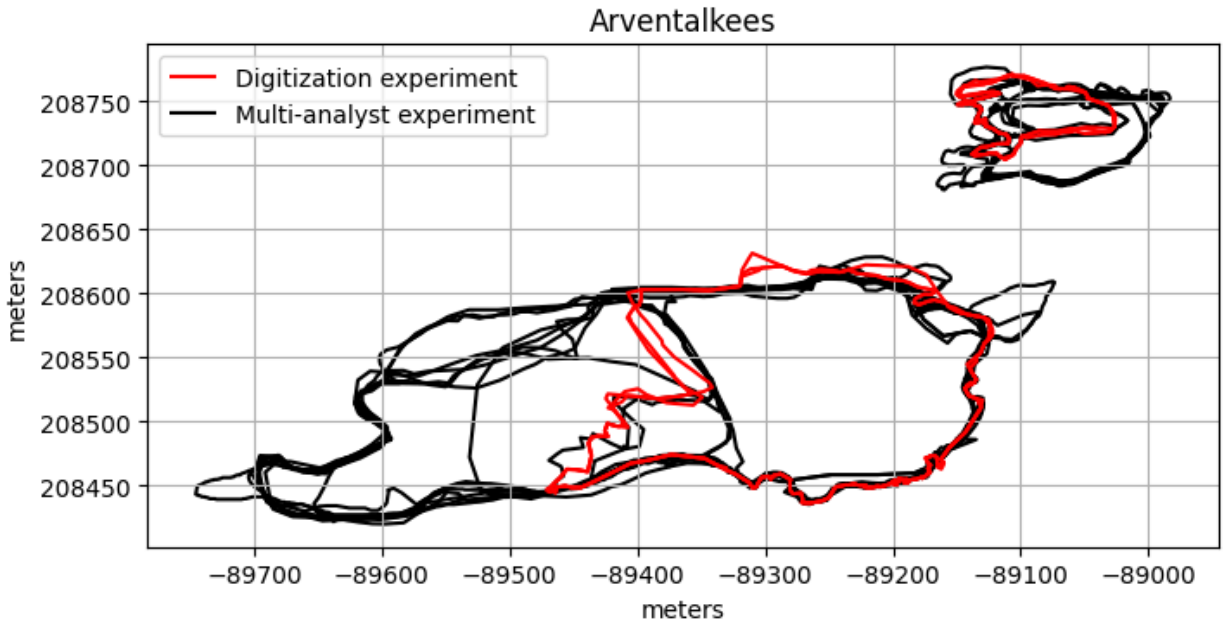
"…. Aside from inter-analyst discrepancies, there is also some amount of variability in outlines mapped by the same analyst on different days (sometimes referred to as "digitization uncertainty"). In our experience, this variability is substantially lower than the inter-analyst variability and we assume it to be covered by our general uncertainty estimates (see also Section S3 in the supplement)."

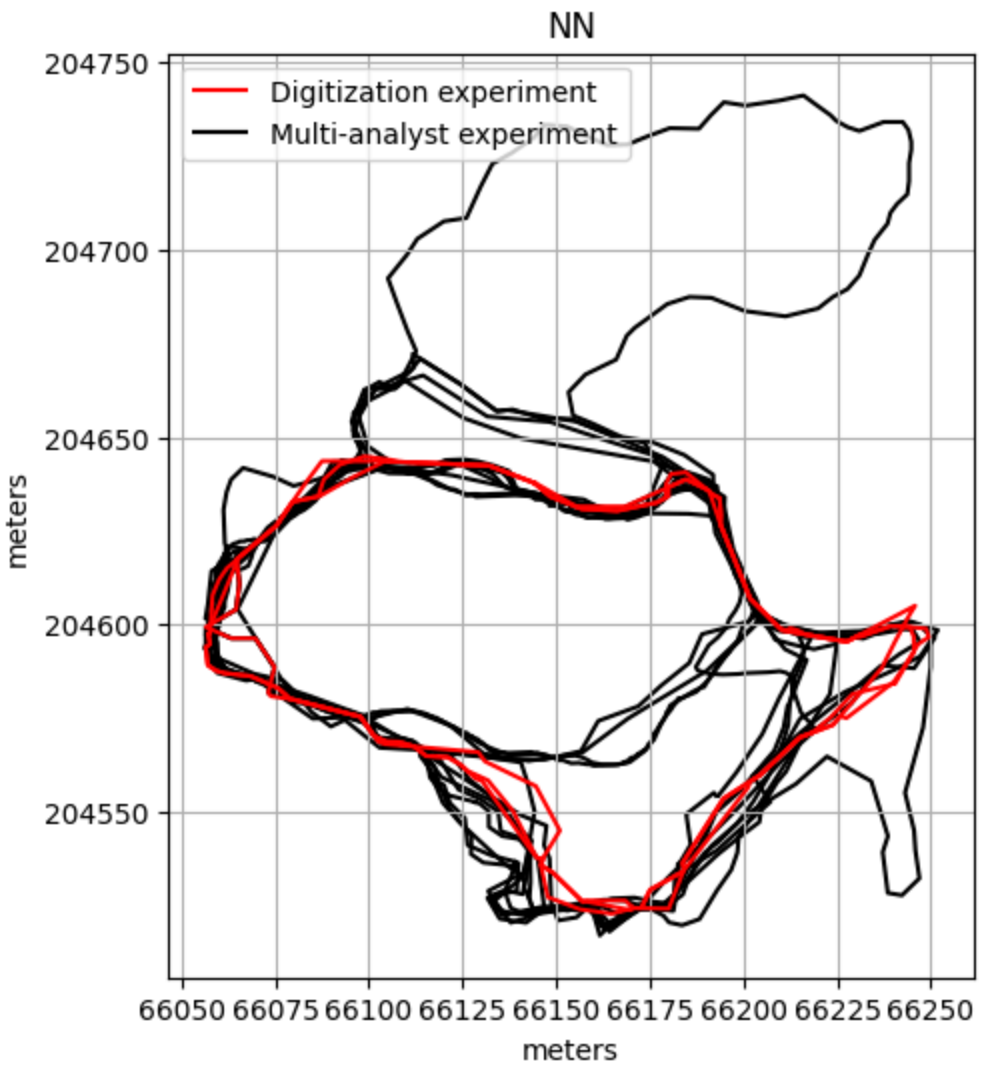
Supplement:

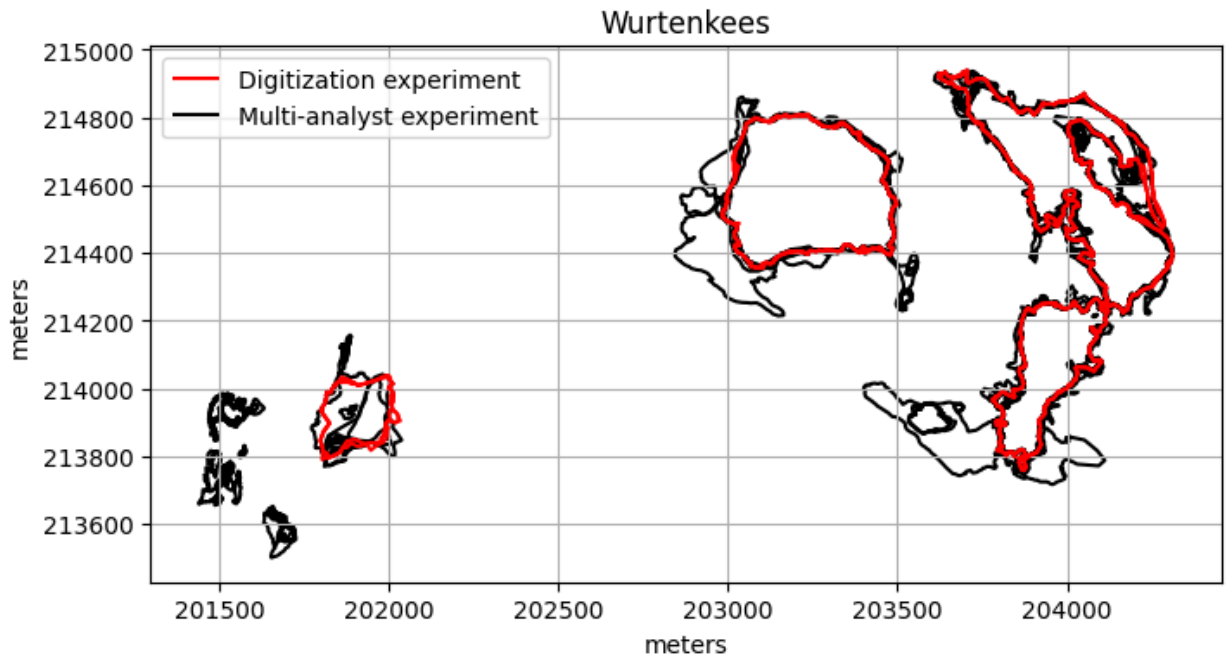
"In addition to the inter-analyst comparison, the variability in results produced by one analyst repeatedly mapping the same glacier ("digitization uncertainty") was determined for three of the RR glaciers in a smaller experiment. One analyst mapped three glaciers (NN, Arvental Kees, Wurten Kees) three times on different days. The "digitization uncertainty" was considerably lower than the uncertainty derived from the RR-comparison for all three cases (NN: 1.9%, Arvental Kees: 0.2%, Wurten Kees: 0.3%). We therefore omit a more detailed assessment of

this source of uncertainty and assume that the "digitization uncertainty" is covered by our more general uncertainty estimates."

Here are visuals for your reference, the results of the single-analyst mapping on different days are in red, the multi-analyst outlines in black:




NN
Digitization experiment
Multi-analyst experiment
204750
204700
204650
204600
204550
meters
66050 66075 66100 66125 66150 66175 66200 66225 66250
meters



Whereas the issues with debris and snow cover for AGI 5 are discussed in detail, I miss a note on the impact of wrongly mapped snow in AGI 3 on area change rates. As far as I remember, the images used for it were not always optimal and due to the required consistency with previous inventories seasonal and perennial snow fields might have been included (possibly resulting in the strong area changes between 2009 and 2010 visible in Fig. 2d). As the area change rates listed in Table 4 are very high, snow fields in AGI 3 that all disappeared in 2022/23 might have an impact. As I do not know how the AGI 3 orthophotos look like, I might be wrong, but please check if this could be an explanation for the high loss rates and include a related comment in the discussion.

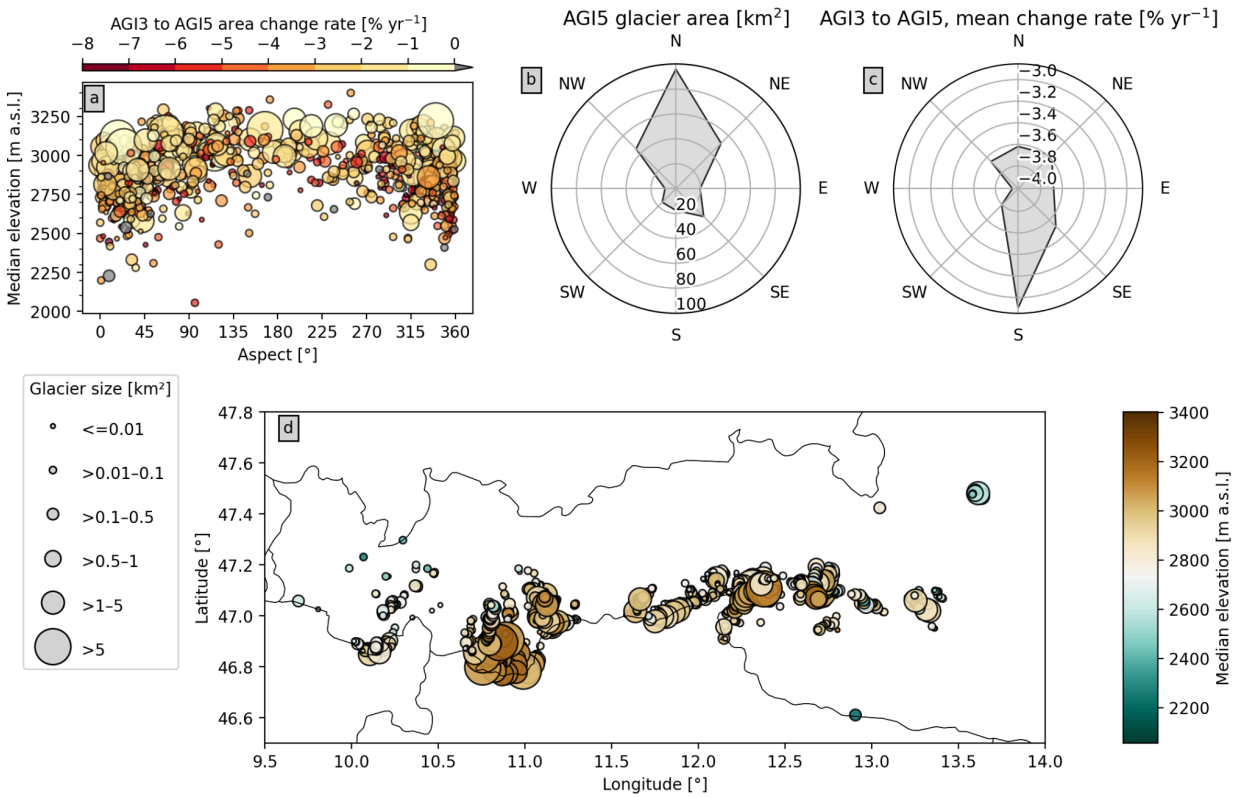
AGI3 was largely mapped from hillshades and other DEM derived information (DoDs). We discussed the issue you raised with colleagues who were involved in AGI3 and they are positive that both the Lidar data used to derive these DEMs and the orthoimagery used for mapping in a few regions were acquired during largely snow free, end of summer conditions (AGI3 is detailed in Fischer et al, 2015; https://doi.org/10.5194/tc-9-753-2015). We are confident that there were widespread, systematic issues related to snow. We cannot rule out that there were some instances of snow or poor image/data quality in the AGI3 domain (AGI5 includes an image quality flag for such cases) and have added a general note in the revised discussion to highlight this.

We note that there were initial mapping limitations related to snow cover during the first data acquisitions for **AGI2**. The first AGI2 surveys had substantial cloud and snow cover in the imagery in some regions of Austria. Additional surveys were carried out at later dates for the affected regions to obtain imagery during better conditions. These later surveys formed the

basis for the final AGI2 outline mapping. This is also the cause of the relatively large acquisition date range for AGI2.

Text added to revised discussion (section 4.1.4):
"The imagery and source data used for mapping of the AGI was largely acquired during favorable, mostly snow-free conditions. However, it cannot be ruled out that off-glacier seasonal snow was erroneously included in glacier outlines in some instances across the AGI time series. If these snow patches then disappear and are not included in the subsequent inventory, derived loss rates are overestimated. Due to the mostly good quality of imagery in AGI5 and based on the available information on source data of older AGI, we do not consider this to be a systematic issue in the dataset but acknowledge that the effect may be present in individual cases."

Specific comments
Comments to figures and tables
What is currently missing, but in my view also very interesting, are scatter plots showing:
- Mean aspect vs. median elevation (e.g. using differently sized and coloured circles for the size class)
- A map showing glaciers >0.1 or 0.5 km2 as filled circles that are colour-coded by median elevation (with the precipitation colour table)
- A rose diagram showing area change rates vs. aspect sector
These are all helpful suggestions, thank you. Reviewer N. Kirchner advised to reduce the number of figures in the manuscript, so we suggest adding the multi-panel figure below to a revised supplement and adding a reference to it in the main text. (I am unsure what "precipitation colour table" means; if this is important, please clarify.)



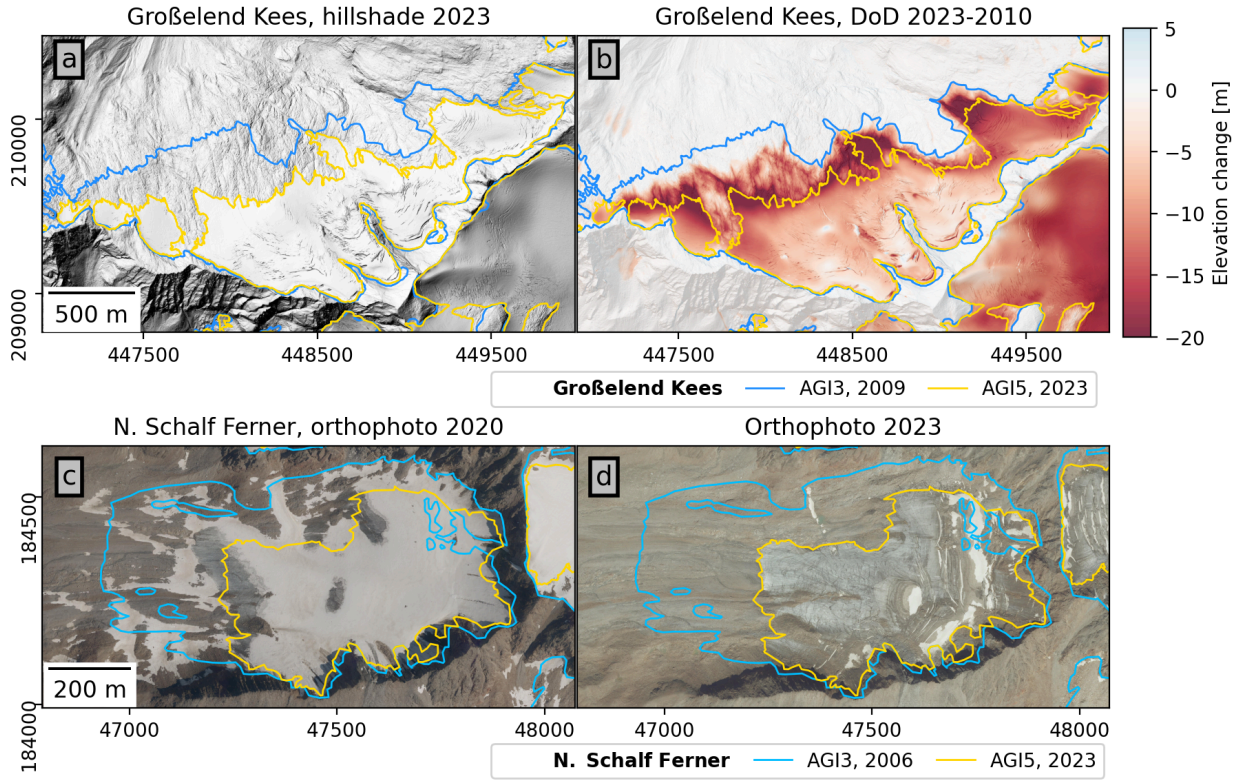
[Caption] a: AGI5 median glacier elevation against mean aspect. Marker color indicates AGI3 to AGI5 area change rates, marker size indicates AGI5 glacier size. b: Polar plot of AGI5 glacier area in 45° aspect bins. c: Polar plot of mean change rates per aspect bin. d: Markers scaled to AGI5 glacier size and centered on the glaciers' centroid coordinates. Colors indicate median glacier elevation.

Table 2:
I think this is important information, but it does not much contribute to the science. I would move the table into the supplement.
OK, moved to supplement.

Figure. 2:
All panels: Please use more different colours for the outlines of AGI 3 and 5. At this scale the dotted lines are hard to distinguish from the solid ones. For panels e) to h), please use thicker lines, they are barely visible. Panel a): Instead of using AGI 3 and AGI 5 please write to which year the outlines refer to. I assume for individual glaciers this is possible. Should the lines in the lower four panels (Schalf Ferner) have different years than the upper four, please repeat the legend on panel e), maybe in the lower left. Legend: As the two EPSGs are difficult to translate, please add for both glaciers' approximate longitude/latitude coordinates.

- changed the colors and linewidths of the outlines to improve visibility. Note: We used this tool to check color blind suitability of the lines and they are distinguishable from the background and each other in all of the options in the simulator https://www.color-blindness.com/coblis-color-blindness-simulator/

- Added outline years to the legends
- Added centroid Lat/Lon coordinates for both example glaciers in the caption.
- We reduced the number of panels following general advice by NK to reduce the amount of space taken up by figures. The extra panels showed additional examples of older hillshades and orthophotos which are not really needed here.



[CAPTION]: a: Großelend Kees (centroid coordinates: Lon. 13.315°, Lat. 47.025°; Ankogel-Hochalmspitz Group, region 2) as seen in a hillshade generated from a 2023 DEM (September 2023; Province of Carinthia, CC BY 4.0) b) Großelend Kees elevation change 2023-2010 overlayed on the hillshade (DoD: DEM of Differences). c, d: Multitemporal orthophotos of Nördlicher Schalf Ferner (centroid coordinates: Lon. 10.956°, Lat. 46.796°; Ötztal Alps, region 11; orthophotos: 28. July 2020, 19. August 2023; Province of Tyrol; CC BY 4.0 AT). a, b: EPSG: 31258; c, d: EPSG: 31287. Grid in meters. For additional information on data sources see Table S1 in the supplement.

Table 3:

Also very important, but maybe not for the science part. I suggest moving this table also to the supplemental material.

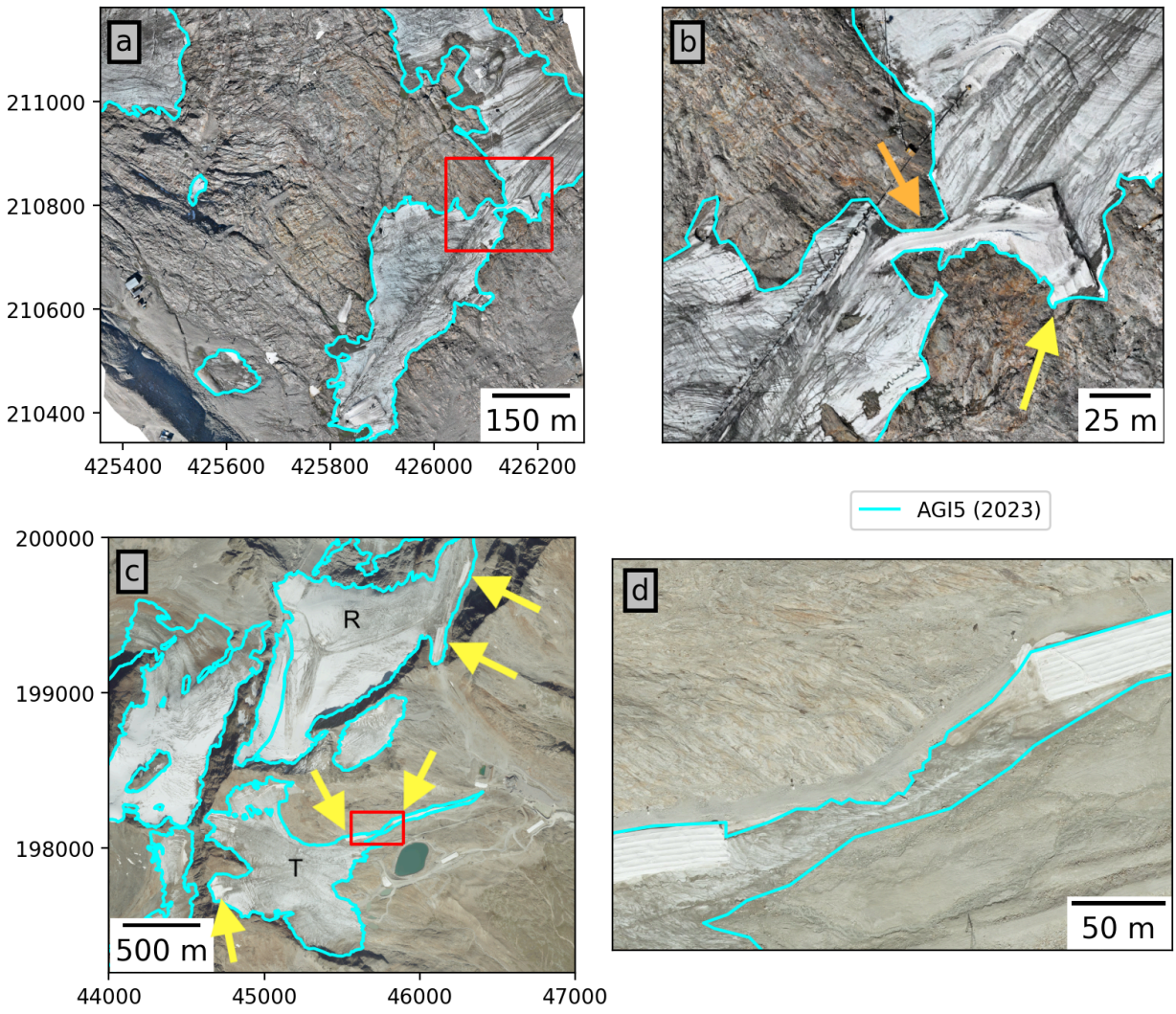
We would prefer to keep this table in the main manuscript because we frequently refer to it in the results and discussion sections where we present content related to the different categories of image quality, debris cover scores, etc, which are detailed in the table. We believe it is helpful for the readers to have the table readily accessible to understand the categories.

Figure 3: The legend for the outlines is missing. Regarding panel d, I think including the elongated ski run is a bit of a far stretch. When zooming in, it looks as if it is not connected to the glacier. But even if it is, I think it can be safely cut away as there is no active ice included here.

- Added legend.
- Added arrows to indicate coverings following comments by NK.
- Changed zoom level to show a close up of the connection between the coverings.

We are aware that it is debatable whether this “should” be considered part of the glacier. Our aim was to have a consistent approach to dealing with the coverings in the mapping process and we concluded that including all coverings still visibly connected to the rest of the glacier was the most practicable option as it avoids forcing the analysts to make case-by-case judgement calls. There are many instances of ice that is not “active” in the AGI; the covered sections are only a small fraction of this. As detailed in the manuscript, we include all ice that can be mapped and do not attempt to determine activity levels. This applies regardless of the coverings. The example of Tiefenbach Ferner is an extreme case of coverings affecting the shape of the outline, which we think is worth showing. The revised figure is below. We have also expanded and rephrased the text a bit to provide further context for the figure:

“.... The resorts apply white reflective coverings to locally reduce melt and preserve particular patches of ice and snow relevant to resort operations (e.g., for snow storage or to maintain lift tracks). Such patches of covered ice and snow were included in the outline mapping if they were connected to a remaining uncovered feature. Covered patches not connected to uncovered ice were not included. Examples are shown in Fig.3. Fig. 3 a and b show coverings and snow management used to locally reduce ablation in the vicinity of ski resort infrastructure on Wurtenkees (skiresort "Mölltaler Glacier", Carinthia). In Fig. 3 c and d, coverings near the glacier margins of Tiefenbach and Rettenbach Ferner (Tyrol) are highlighted. A narrow band of ice still connects the main sector of Tiefenbach Ferner with the elongated, covered remnant of the tongue (Fig.3 d).”



[CAPTION]: a: Wurtenkees in the Goldberg Group with the Mölltaler Gletscher ski resort (Carinthia). The red box marks the subset shown in b. b: Zoomed in view of Wurtenkees; reflective coverings (yellow arrow) are applied to reduce ice melt in this sector in the vicinity of resort infrastructure. The orange arrow indicates a narrow connection between two sections of the glacier which is maintained through snow management measures. c: The ski resort of Sölden (Tyrol) operates infrastructure and ski runs on glacierized terrain in the central Ötztal Alps, mainly on Tiefenbach Ferner (T) and Rettenbach Ferner (R). Yellow arrows indicate coverings near the glacier margins. The red box marks the subset shown in d. d: Close-up view of reflective coverings on the terminus of Tiefenbach Ferner and a narrow band of connecting ice between the two coverings. Blue lines indicate AGI5 outlines in all panels. Background image a, b: 2023 UAV orthophoto, courtesy of Geosphere Austria. c, d: 2023 orthophoto mosaic, Province of Tyrol (CC BY 4.0 AT).

Figure 4: Panels a/b: Please think about the colours used for the two pie charts. They jump around but are still difficult to separate (e.g. the light blue and green). Please also consider colourblind people (no red and green in the same chart).

Panel c: Please use numbers instead of exponents for the km 2 scale (e.g. 1 instead of 100 or 10 instead of 101). I also suggest reducing the size of the filled circles a bit to better see the lines. Please also move the x-axis annotation to the bottom of the plot and show minor tick marks on both sides (please add 100 m tick marks on the y-axis). For the colours of the largest glaciers, I would use more saturated colours that change gradually rather than Random.

- Changed the colors in the pie charts.
- Reduced circle size in panel c.
- Adjusted colors of the largest glaciers to change gradually (panel c)
- Added minor tick marks at 100 m spacing (panel c)
- We would prefer to keep the legend on top of the plot to use space efficiently. We will change it if you feel strongly about this but we see no obvious benefit to moving it to the bottom of the plot.
- Similarly, we would prefer to keep the exponential notation but will change it if you feel strongly about this. Using the same tick values as on the current scale would require four decimals in “normal” notation. We assume all tick marks should have the same number of decimals, so we end up with ticks from 0.0001 to 10.0000. This seems more cumbersome than exponential notation.

Figure 5

Panels a: Please add minor tick marks to the x-axis and stretch it a bit in the x-direction. Panel b: I find it rather difficult to obtain the area change value from the colour table. I suggest using discrete values and maybe a dichromatic or spectral/rainbow colour table that is suitable for colourblind view.

- Added minor ticks to panel a
- Adjusted size of panel a to slightly stretch it in the x direction
- Changed colors in panel b to a discrete colorscale using a sequential red-orange-yellow colormap.

Figure 6

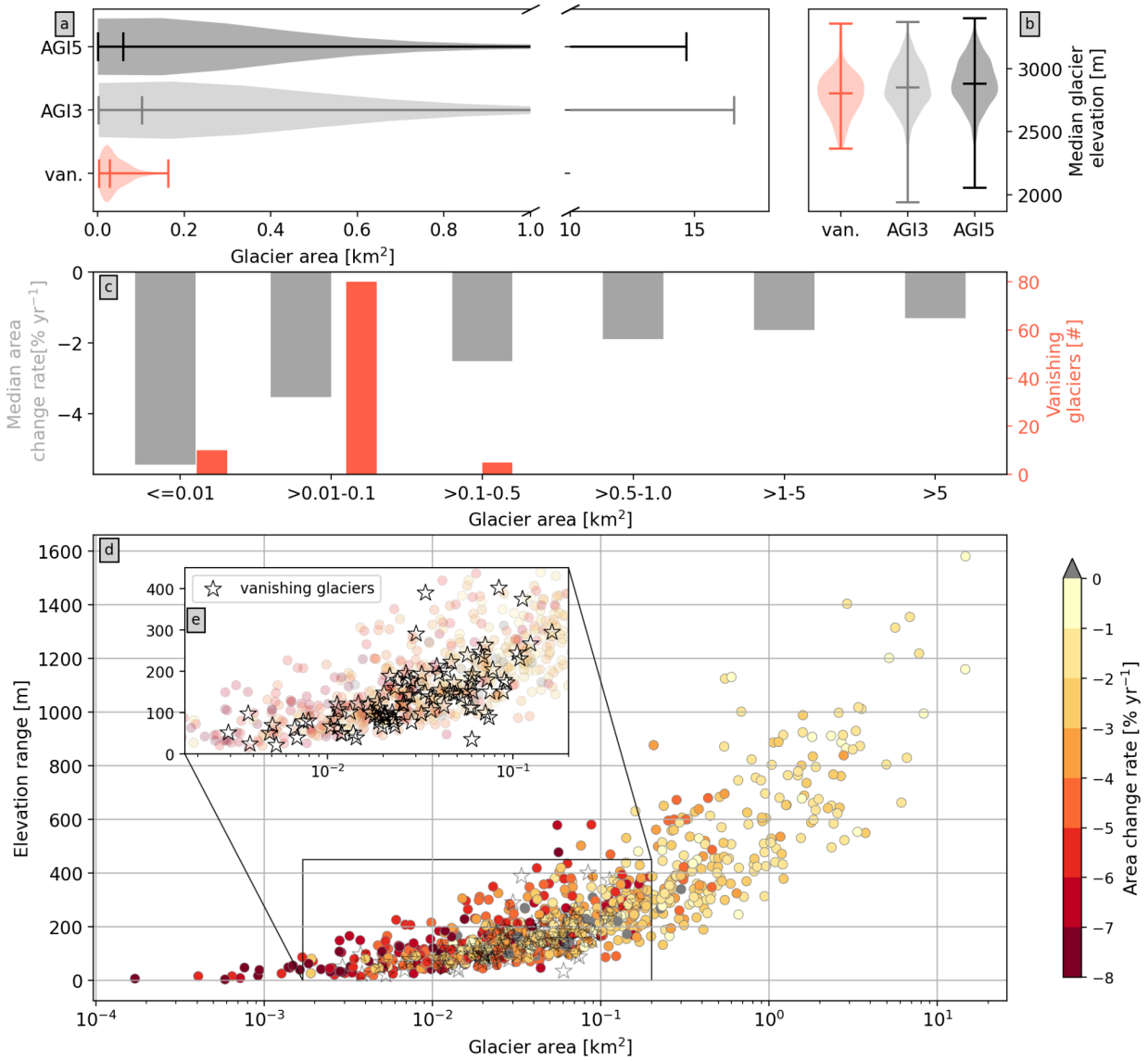
Panel c: I suggest changing the 0.01 to 0.1 size class to two size classes 0.01 to 0.05 and 0.05 to 0.1 km2. Please also provide the values (of the area change rates) in the plot or a separate table. Try to avoid on overlap with the bars for the vanished glaciers. Panel d: As for Fig. 4c, please use normal numbers instead of the exponential form for the area in km2. As the distribution against median elevation is already shown in Fig. 4c and I think there is not much to learn from it (there is no dependence with glacier size), I suggest using a more interesting parameter for the y-axis, for example elevation range. Moreover, it is quite difficult to derive area change values from the monochromatic colour table. Hence, I suggest using here relative area change for the y-axis (size for the x-axis) and elevation range for the y-axis of Fig. 4c.

The revised plot is below. Changes made:

- Moved bars in panel c to avoid overlap
- Added table of area change rates to the supplement and a reference to it in the caption of this figure. The table contains both the suggested split size class and the 0.01-0.1

value as in the figure. We would prefer to keep the size bins as they are in the figure to match the size bins we used elsewhere in the manuscript.

- For d, we changed the y axis to show elevation range and included an inset axis to highlight the vanishing glaciers and improve visibility. We adjusted the color scale for better readability (as in Fig. 5) and feel that three interesting parameters (elevation range, area, area change rate) can be included in the plot in this manner. We would prefer to keep median elevation in Fig. 4c and hope this is an acceptable compromise.
- As in Fig. 4 (see previous comment), we would prefer to keep the exponential notation on the x axis but will change it if you see a significant benefit to “normal” notation.



[CAPTION] a: Violin plots for glacier area in AGI5, AGI3, and the AGI3 area of the vanishing glaciers. b: Median glacier elevation in AGI5, AGI3, and the vanishing glaciers (AGI3 elevation). c: Median area change rates for glaciers grouped by size categories (left axis) and number of

vanishing glaciers per size category (right axis). Vanishing glaciers are grouped by size bins using their AGI3 area. These values are provided in tabular form in the supplement (Table S4.) d: Glacier elevation range (maximum - minimum elevation) plotted against glacier area (log-scale) for all AGI5 glaciers. Colors indicate area change rates. Black stars show AGI3 area and elevation of the vanishing glaciers. e: Subset of d; scale and marker transparency adjusted to highlight the vanishing glaciers.

Fig. 7
The light blue circles are hard to see against the grey background of the hillshade. You might either use a much brighter (white/yellow) or darker colour.
Changed marker colors and combined with content of previous Fig. 8 following suggestions by NK.

Fig. 8
Panel a: Please add minor tick marks on both axes.
Added minor ticks. This was moved to the supplement in response to advice by NK to reduce the number of figures.

Table 5
I suggest adding a further decimal to the area change rates in %.
Changed as suggested.

Figure 9
As we read from left to right, I would arrange 0, 1, 2, etc. in the first row and 8 to 14 in the second row. If individual analysts should be identifiable in the plot, I would not only use coloured circles but also other symbols in the plot. The x-axis legend is missing below all plots (what is shown, what is the unit)? As all glaciers have different sizes, wouldn't it be better to show relative differences?

- Removed tick marks from x-axis to avoid confusion. These are standard violin plots showing rotated kernel density functions. We have added box plots on top of the violins as additional context.
- Rearranged the legend to show the numbers row-wise.
- We would prefer to keep absolute areas in this figure to explicitly show how interpretations vary for the different selected glaciers. They vary in size and in terms of debris cover and fragmentation. Relative metrics are provided in Table 5 (note that they break down for Madlein Ferner where most analysts determined an area of zero). We believe having both absolute and relative values better contextualizes the figures in the supplement for readers interested in the details of the RR experiment.

Supplemental Material
I suggest showing Figures S1 to S7 at full page width. I suggest adding a column to Table S1 showing the size of the glacier. Please make Fig. S11 readable for (red-green) colourblind people.

- Enlarged the figures to slightly more than text width
- Added a column to the table as suggested
- Changed colors in previous Fig S11. Numbering has changed in the revised supplement, this is now Fig S2.