

# **Review of 'Reconstructed glacier area and volume changes in the European Alps since the Little Ice Age'**

by Johannes Reinthaler and Frank Paul

The manuscript presents a study of past glacier area, volume, and bed reconstruction for the European Alps, utilizing geomorphological feature identification and interpretation on high-resolution images, combined with historical topographic maps and current glacier boundaries. The results show that past glaciers have shrunk by over 50% in aerial extent, with more than 60% of their total volume lost between 1850 and 2015, which is consistent with a few previous studies in the region. Additionally, the authors estimate surface elevation of the LIA glacier extent (using an interpolation method they developed) and estimated elevation changes of the glaciers during the study period, and reported a tripling of thinning rates after 2000 compared to the overall long-term thinning rate.

In my opinion, the manuscript reconstructs and presents a crucial dataset of past glacier extents, which is vital for understanding long-term glacier behaviour in the Alps. The insights inferred from previous glacier fluctuations will also be invaluable for future glacier response modelling in the region. Considering the very high rates of glacier retreat and thinning in the Alps in the current era of climate change, understanding past rates is essential for planning mitigation strategies. Additionally, these datasets would be valuable to a range of scientific disciplines beyond glaciology, including hydrology, geohazard management, ecology, and others.

Overall, the manuscript is well-written in its different sections and concise in nature. The authors missed a few important references, as pointed out by community scientists, and they have promised to include these in the revised version. I do not have any major criticism. Below, I outline a few general comments and several minor suggestions for improvement. I recommend a minor to moderate level of revision before the manuscript's final online publication.

If any of my comments are unclear, please do not hesitate to contact me for further clarification.

## **General comments**

1. I did not find any discussion on the contrasting area/thickness/volume loss between the LIA and the current period in the western (high loss) and eastern Alps (low loss) regions. While the authors briefly touched on overall climatic conditions, there isn't a dedicated discussion on this topic, which would be valuable for understanding the influence of climatic shifts in these two contrasting (high/low loss) areas. If the authors do not plan to present a dedicated discussion, at least adding a few lines addressing climate changes in these regions, along with some basic statistics, would give readers a brief understanding of the influence of climate and its spatial variation across the European Alps, thus better establishing the connection between climate and glacier loss.

2. The authors might consider using the total uncertainty propagation technique from Mannerfelt et al. (2022). Reviewer 2 has raised concerns about the uncertainty estimation of volume changes in the current work, and I concur with these concerns. Mannerfelt et al. (2022; equation 9 in their work) used a similar dataset covering LIA outlines and varying temporal periods, which I think would provide valuable insights/guides for addressing the uncertainty issues in the current study.

## **Line-by-line comments**

L14: Here, I would have mentioned the latest year instead of 'today,' as in future years, the term 'today' will lose its relevance.

L17: I would prefer 'On average' (which sounds better I think!) instead of 'In the mean'?

L32: 'trim lines' and trimlines (in abstract; L11; also in L40, and elsewhere) needs to be consistent across the manuscript. Also, I think, as the authors have already expanded LIA in the abstract, they should not need to re-expand it. Please check with the journal's guidelines.

L39-40: I think this sentence is incomplete. Did the authors mean '...between 1350 and 1850/60, with the exact timing depending on the glacier'? Please check.

L78-80: Here, I would be happier to see 'the range of resolutions' for the very-high-resolution images those were used for interpretation/delineation.

L82-83: Which study provides the outlines from 1967-1971 for France? The authors might consider citing the reference here for the readers' quick knowledge.

L103-105: This modern DEM refer to 10 m Copernicus DEM? Right. Re-mentioning might be helpful for the readers.

L105-106: Is this 'Topo to Raster' a tool for interpolation or a known method? Not clear from the current sentence? Please clarify.

L107-108: The authors mean 'The output result..', right?

L153: Please expand SLR here, for the readers' sake.

L176-177: Here, please mention the range of the elevation changes, for further information to readers. Also, here, 'highest changes' sounds a bit awkward as the value is the most negative (lowest), so I would suggest something like 'highest mass loss/thinning'?

## **Table**

Table 1: I would suggest the authors to mention the time period of P1-P2 for clear information in the table caption.

## **Figures**

Figure 3: Are the volume change rasters (subplot d) aggregated to a specific grid size? If so, please mention it.

Figure 5: By looking at the panel b and the color contrast of elevation changes, it seems the change values are even lower than -2 m/y, if I am not wrong. The authors need to re-draw the colorbar or add extend marks.

Figure 6: Here, in panel b, the color scheme of the colorbar may not be ideal, given the range of +23 to +123 (only increasing side everywhere). A single color gradient, where the darkest shade represents the highest increase and the lighter shades represent the lowest values, might be more appropriate.

Figure S6: I would suggest the authors to label the sub-plots by citations (e.g., Sommer et al., 2020, etc.) and by the time period of the elevation change estimate. Also, same in and S10.

## References

Mannerfelt, E. S., Dehecq, A., Hugonnet, R., Hodel, E., Huss, M., Bauder, A., and Farinotti, D.: Halving of Swiss glacier volume since 1931 observed from terrestrial image photogrammetry, *The Cryosphere*, 16, 3249–3268, <https://doi.org/10.5194/tc-16-3249-2022>, 2022.