

***Interactive comment on* “The potentials of high-resolution photogrammetry for analyzing glacier retreat in the Ötztal Alps, Austria” by Joschka Geissler et al.**

Anonymous Referee #2

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This paper uses results from photogrammetry for a small glacier region in the Ötztaler Alps. Using photogrammetry to study changes in glaciers is a popular method that can give good insights. The geodetic method has been conducted on many glaciers using various sources of data and often used for reanalysis of glaciological mass balance series.

The study would benefit from improving the explanations, figures and tables. More references could have been made to existing literature on similar studies (both on elevation changes and geodetic mass balance assessments). The manuscript would have benefitted from clearer writing, it is sometimes difficult to understand what the authors

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mean.

Below I give some examples to exemplify what I mean as specific comments. Specific comments:

On the title: is ‘the potentials of high-resolution photogrammetry’ only relevant for the Ötztal Alps? The title might imply so. I would change it: e.g. increased detail of glacier retreat and mass balance using high-resolution photogrammetry in the Ötztal Alps, Austria.

Abstract: focus on the findings. The abstract needs more polishing and be clearer. The first two sentences can be deleted. In the intro you also focus on the (European) Alps.

L14: take out significant, not needed (and what does it really mean, best to avoid).

L16, sentence starting glacier retreat. . . could be changes to: Glacier retreat, extent and surface elevation changes were analyzed for the 25 glaciers in the region, including Vernagtferner. Digital surface models (DSM) were generated from (Use direct language if possible.)

Change ‘ a correction was established’ we used . . . to apply a correction Remove part ‘which reveals the potential for a combination’ & continue with the next sentence ‘Results revealed ‘ L25 Could be -> were

L32. Add European before Alps. Could add ‘hereafter referred to as the Alps’ if this is the preference of the authors. Could also add Beniston et al. 2018.

Line 47. Here it would be nice to add reference to studies on the glacier, e.g. add ‘e.g. Escher-Vetter et al, 2009.’

Line 48. Here some refs could be added on various methods, the typical method used today by many mass balance investigators are laserscanning. See also later comment. e.g. Belart et al 2020, there are many studies on glacier changes using various methods and there are no references in this section.

L54. It is difficult to assess whether this method is unique when you provide so few references, what is unique about it? Repeated aerial photos and UAC are used in many studies.

L56. Why not just write: Suitable data for photogrammetric processing were available from 2009, 2015 and 2018, covering a period of 9 years.

The last part of chapter 1 from line 63 should be rewritten, see also comment to line 54.

L75. Could also here add reference to Esche-Vetter et al 2009 or other relevant literature on the glaciological mass balance work.

L76. can add map year in parentheses after Today (map year 20xx). Do you really measure the density of the firn, e.g. going past this year's summer surface? Usually, only snow pits are used for this year's mass balance. Measuring the winter snow in spring or remaining snow in autumn.

Figure 1. Instead of (Esri et al, 2020): Image source: ESRI (2020). The frame of lower left figure is partly visible.

Decimal separator: change ',' in figures and tables to dot '.' Yields throughout.

Chap 3.1. The first paragraph sounds like introduction and could be merged there.

L97. Use -> used In general in the paper: Use past tense where you describe work done by the authors for the paper, use present tense on published work.

Change title of 3.2 to Glaciological mass balance data??

L109. First sentence already mentioned before. Remove there or here.

L110-. At the same time ->which time. Be specific so we understand what you mean.

L112. Here you mention firn pits but on line 125 only snow pits. Is it not converting to water equivalent you mean? How is glaciological mass balance interpolated from

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measurement date to fixed date? Did you use the outlines from 2015 also to reanalyze the mass balance?

Line 130/131. On mm what is the unit? Not water equivalents? What do you mean by error of the raster, you mean mass balance uncertainty in each grid cell? In this section references to work could also be added.

L136-140 Use past tense on work done for this study/where you describe the work you did. We use-> used (use past tense) is->was, are->were etc

L144. Fig.2. Full workflow (remove photogrammetric) because it involves more than that. In box instead of 'after huss et al 2013' you can rather write 'using fixed density factor

L149 (GNSS) -> using GNSS

L153 is agisoft not state of the art, maybe take-out state of the art in line 152

L148/L155: Is the ->was

LP6, last paragraph. Can mention the range of the adjustments.

L171/172. Is-> was

L173. More details of what? be specific. Of the xxx method or procedure or following. E.g. More details of the xx procedure/method can be found in xxx (year).

L176. Remove additionally. L 177. Remove as well.

L177. The details in this gradual change are unclear to me and firn density can be higher than 550. Suggest to rewrite it.

L186. Write out standard deviation SD first time mentioned.

L188.L192. Do you mean you use a fixed correlation based on finding in one year? But this will differ from year to year. Why not use meteorological data to estimate mass balance? This is a common approach. You could compare this to model estimates.

L240. Add in meter (m) after differences. I miss scale bar and glacier outlines. Add name Hintereisferner. There are several glaciers on the map.

L231. In general, glaciers have thinned and reduced in size.

Fig. 5. Outlines not velar/easy to read. Lacks scale bar and legend. Add name(s).

Fig 6. Readability of the figure could be improved to be clearer and sharper. Avoid grey background. Use black font. Replace ; with . in figure text.

Fig 7. Maybe it would be better to just show surface elevation changes or changes before and after correction.

L 288 add (geodetic) after photogrammetric.

Regarding this comparison, has a proper reanalysis of the data been carried out (ref. Zemp et al., 2013) for instructions. Have the outlines of 2015 been used in the mass balance calculations? This could be discussed.

L291: is-> was

L300. Is this tested against the procedure in Zemp et al (2013)? Should be referred to in this paragraph (the reference is in the paper but not referred to or used here).

317 do not only. . . ., something is missing. Do you mean to connect the next sentence? Then rephrase.

318. is there a difference between photogrammetric and geodetic since, why not use geodetic?

Fig 9 it is not unproblematic to compare it that directly for shorter time periods due to submergence/emergence and density issues.

Figure 10. instead of a-e why not use a shortening of the glacier names?

L353. I suggest to also add the full period, could be good to have results for full period, better for density conversion as well.

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Figure 11. here – could show the results spatially on a map, easier to see. I miss the names on location figure 1 or in the other figures.

L374/375. The potential for using photogrammetry such as this has been shown in multiple studies for a long time, and the authors should cite such studies. This is not novel. Would rewrite

L383. The dead ice body is not indicated in figure 4. Should be marked with a letter or number to help the reader.

L387-388. See comment to line 374/375- This is already stated. Again, it is not new to use photogrammetry to study glacier changes. I miss also a comparison with lidar studies, pros and cons using aerial photogrammetry versus lidar. Could be a good addition.

L403. Could use for the full period.

L409. Again, this applies only for that year and not the two other years. Here you should justify it by comparing met data and mass balance conditions for the three mapping years/dates. You mention it, but you are not using it. It must be meteorological data you could check and refer to.

L420. I am not sure it is representative for more than that year and that glacier. See comment above.

L433. What do you mean with great importance for future studies?

L452. Do you find that this is a proper reanalysis according to Zemp et al 2013 or should this be conducted, this is unclear to me. Here you can refer to 'reanalysis' and how others have used such data, there are several papers in the cryosphere (and other journals) on this topic. just search 'reanalysis'.

Data availability: The geodetic mass balance data is not available in a table in the paper. I suggest having a table in the paper that lists all the 25 glaciers with surface

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elevation change, area of the mapping years and geodetic mass balance for the full period (9 yrs), and perhaps subperiods (e.g. in supplement). Adding a table in the paper gives users the chance to use the data further. Table could be accompanied with a figure in the paper showing the changes and glacier outlines. The tabular data could be submitted to WGMS, they store such data. In data availability thus add 'Geodetic mass balance data will be submitted to WGMS.'

References.

BELART, J., MAGNÚSSON, E., BERTHIER, E., PÁLSSON, F., AÁŘALGEIRSDÓTTIR, G., & JÓHANNESSON, T. (2019). The geodetic mass balance of Eyjafjallajökull ice cap for 1945–2014: Processing guidelines and relation to climate. *Journal of Glaciology*, 65(251), 395-409. doi:10.1017/jog.2019.16

Beniston, M and others (2018). The European mountain cryosphere: a review of its current state, trends, and future challenges, *The Cryosphere*, 12, 759–794, <https://doi.org/10.5194/tc-12-759-2018>, 2018.

Escher-Vetter, H., Kuhn, M., & Weber, M. (2009). Four decades of winter mass balance of Vernagferner and Hintereisferner, Austria: Methodology and results. *Annals of Glaciology*, 50(50), 87-95. doi:10.3189/172756409787769672

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