

Dear Etienne,

Thank you for your answer and your comments on our revised manuscript.

You can find our detailed point by point answer below. We also uploaded a tracked-changed version of our manuscript.

Our main changes focus on:

- Missing temporal correction has high influence on geodetic mass balance
- Error contribution of horizontal shift of DOM 2009
- Discussing that presented methods need further testing on new datasets

Please do not hesitate if you have any further questions.

Looking forward to your final decision.

Best regards,

Joschka Geissler and Co-Authors

L11: this is not useful for the TC reader. Funders/Projects should only be named in the acknowledgment section.

Following your comment, we only name the project in the acknowledgments.

L 21: debris cover

We defined the following spelling convention and double-checked consistent writing:

...debris cover...

...debris-covered areas...

L 25: this not only retreat but also mass loss. Maybe a more generic term? wastage?

We prefer remaining consistent with the manuscript, in which we refer to glacier retreat and mass loss. We thus added "and mass loss" and did not use a new, generic term.

L66: If you read the conclusion of Huss, 2013 (not only the abstract) you will see that 5 years is recommended in fact. Maybe "three to five" years?

Thank you for pointing this out. We have incorporated your comment. L452 was adapted accordingly to be consistent.

L158: As TOM is not a usual acronym in glaciology I really recommend to remove it from the entire text.

We now use the more generic term orthophoto. Checked the manuscript and figures for consistency.

Figure 3: Authors should provide the exact dates of survey in the legend of this figure. This is key for the easy understanding of the figure.

We now provide the exact dates of survey in the legend and the caption. Changed L215 for consistency.

Table 2: Unclear to me why this is late August here when it is 30 sept for all other years (2009 and 2018). Can authors clarify this? The title of this column should be improved it does not correspond to "Acquisition date photogrammetric data". 30 sept is the end of the glaciological year.

Thank you for your valuable comment. Here, you found two mistakes that were corrected as follows:

- Header was renamed from “Acquisition date photo. Data” (wrong!!) to “Correction periods”
- Row 2 must be 30.09. 2015 (typo!). Also changed the corresponding number of days. We double-checked our calculations (used the right period here).
- We changed some explanations to clarify the method.

Figure 4: change to 2500 m (no dot)

We changed this. Thank you for finding this typo.

L 258: clarify that it was not corrected (right?)

Even though we were unsure what you mean by “corrected”, we did take into account this comment. A) We clarified that error assessment was conducted using uncorrected DSM differences and B) extended our discussion regarding the remaining error depending to the aspect. L436pp (See also comment below)

Figure 6: This indicates that for North (or north-west) oriented glacier, the error would be almost 1 m so 0.15 m/yr given the 6 years time interval. Is this fully included in the error bar? Did the authors verify the same plot for the other periods of interest. If similar biases are found for the 2015-2018 period, the error could be almost 0.3 m/yr for the annual rate of change. Far from negligible.

Thank you for your feedback on our error assessment. We discussed your feedback and decided to add the results of the period 08/2015-09/2018 to the figure 6 for the sake of completeness although errors are much smaller for this period and no relation to the aspect can be found. We revised some sentences in the methods and results and, more importantly, improved our discussion.

In general, the accuracy assessment conducted (following Rolstadt 2009) relies on the determination of range and sill – values within the semivariograms (see sect. 4.3 for more information on this method and the assumptions made). Since semivariograms have a sill for all our datasets, we assumed that the prerequisites for this method were fulfilled.

However, you are right that for a north-facing (or northwest-facing) glacier the error related to the aspect can get quite high:

Following your example, for the period 09/2009-08/2015, the error of the DSM difference would – for a N-facing glacier – be **0.13 m ice a⁻¹**. Given the mean surface change of all glaciers within that period (-0.5 m ice a⁻¹) this would be 26%. We agree, that this error is not negligible.

For the same period, for a (hypothetic) north-facing glacier of 2.6 km² surface area (mean surface area of all glaciers), the confidence interval would lie at **0.1 m ice a⁻¹**. Thus, the possible error would be larger than our error bars due to the relation of the error to aspect. This fact was already discussed in earlier versions of our manuscripts (L430 in the last version published) and is now discussed with even more detail within our discussion (L436pp). This problem could have been addressed with a complete coregistration of all DSMs. The error was not fully captured by our methodology possibly due to inaccurate assumptions. However, it does not affect the methodologies presented in the manuscript. For the Vernagtferner (on which the focus of our work is), having orientations between E and SW, this error is negligible.

We have taken special care to ensure that the reader is always able to assess the errors involved. Additionally, we checked all geodetic glacier mass balances and other numeric results presented in the manuscript, if the confidence interval covers the potential errors caused by the relation to the aspect. We highlighted those glaciers in table 4, where our confidence intervals underestimate potential errors due to the relation to the aspect.

For your information, for the period 09/2009 – 09/2018, the horizontal shift of the DSM 2009 also results in an error related to the aspect. However, these errors are smaller (max median vertical error 0.098 m a⁻¹) and all errors for this period lie within our error bars.

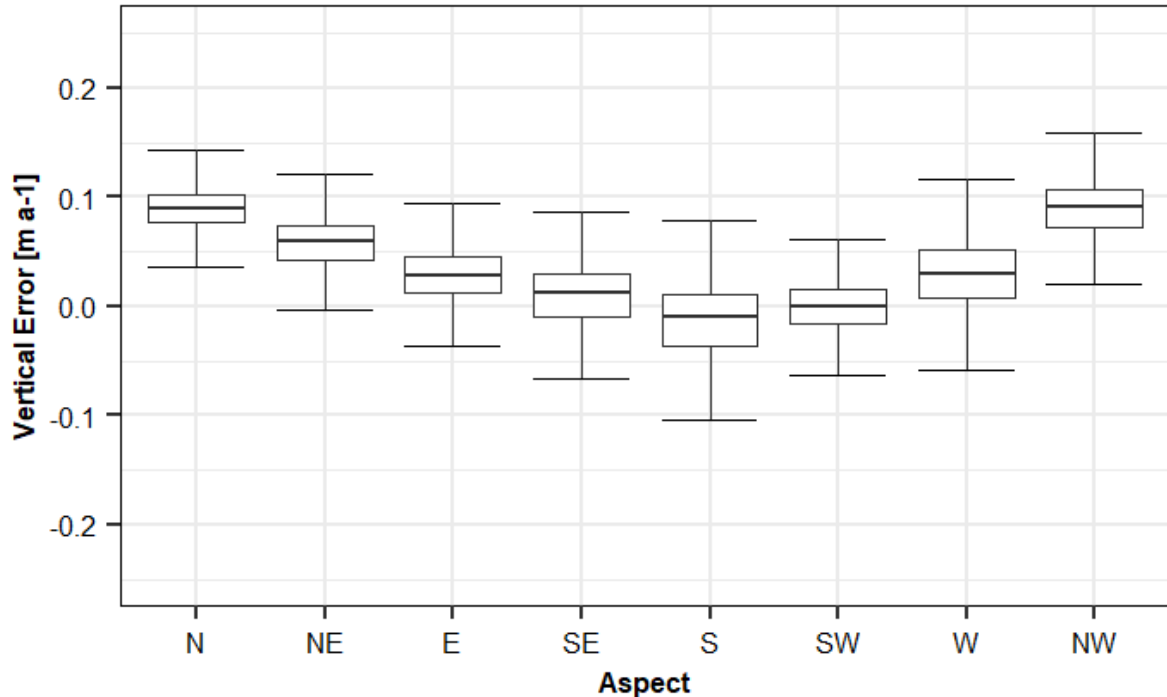


Figure 1: Relation of the vertical error to the aspect for the period 09/2009-09/2018

Figure 7: Authors should change the X-axis so that all values are shown (some curves are cut)
 We changed the figure accordingly.

L345: This seems a very large difference to me (but not impossible). Can authors double check?
 There was an error involved in the computation of the debris cover and dead ice body volume change that was corrected (L345+L432) Thank you for your attentive reading.

Table 3: Title of the table need improvement
 We improved the title of table 3.

L380: and also the quadrupling is partly due to the lack of seasonal corrections. This must be noted.
 L 390: The illustration of my statement above. The quadruple is now a doubling "only" (in agreement with the glaciological data). This really needs to be discussed as some readers may jump to an erroneous conclusion. This is also the issue when comparing too short time period, like only 3 years here. Authors need to tell that the magnitude of the acceleration in mass loss is not very well constrained due to this.

We agree, that the quadrupling is influenced by the missing temporal correction. This fact has already been noted in the latest version of our manuscript (L381 L397 of the last manuscript):

It must be noted that there was no correction applied for the acquisition times. Accordingly, the mass balances do not refer to glaciological data. (...) If a time correction is assumed to have a similar influence on the annual mass balances of other glaciers as it had for the Vernagtferner (...)

We have addressed your comments as follows:

- We have merged Sect. 5.3 so that both of our statements above will be read by the reader without an interruption of a figure and a table.
- We have included this issue into the discussion L469
- Improved this section in the manuscript L390pp

Please note, that we improved the terminology of the geodetic mass balances and ensured consistency within this revision: We always refer to temporally uncorrected geodetic mass balances with year and month, e.g. 09/2009-08/2015. This is also the case for the legend in Figure 11 where we show the months of the underlying

time periods. For corrected periods, we only provide the years (e.g. 2015-2018). We now refer to “temporally corrected geodetic mass balances” as “annual geodetic mass balances” since they were recalculated to an annual basis and the prefix “annual” is more commonly used within literature. -> L235

Table 4: This table could be moved to an appendix. It is not necessary for the core article. Two decimals seems sufficient given the errors bars.

- This table was removed from the appendix and moved to the core article following the feedback of referee #2 (06.04.2021). We agree with him, that opening an appendix section only for this figure is not needed.
- Changed to two decimals.

L414: What about glaciers in Italy and France? Maybe more diversity in the references?

We added a references that provides a good overview on glacier mass balances of 239 glaciers throughout the alps.

Davaze, L., Rabatel, A., Dufour, A., Hugonnet, R. and Arnaud, Y.: Region-Wide Annual Glacier Surface Mass Balance for the European Alps From 2000 to 2016, *Front. Earth Sci.*, 8, 149, <https://doi.org/10.3389/feart.2020.00149>, 2020.

authors develop the correction method using a single observation period. So the transferability to another period remain to be tested and fully demonstrated. I would recommend writing the need for further tests in the discussion and proposing to repeat this evaluation of short-term elevation changes in the future.

The fact that the method is robust still need to be demonstrated (e.g., using new surveys as proposed above). Right now its application to new periods or other glaciers is not fully validated.

Thank you for your comment. We use one observation (“correction”) period (in 2018) and apply the derived correction to three different periods (September 2009, September 2015, September 2018). Fig. 8 proves that the results are good, also for the retrospective corrections. Thus, in our discussion, we want to underline the possibility of the retrospective correction (with different limitations that are mentioned). However, you are right that further testing of the robustness of this method is needed, using different surveys on different glaciers and periods...

We have made the following changes in this regard:

- We avoid the word robust in this context
- We underline that new surveys are needed to test and evaluate our method. L487

Glaciologic/Glaciological

Following your advice, we now write “glaciological” instead of “glaciologic”. Checked manuscript for consistency.