

## ***Interactive comment on “Use of an ultra-long-range terrestrial laser scanner to monitor the mass balance of very small glaciers in the Swiss Alps” by M. Fischer et al.***

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I have read the manuscript with great interest and my overall opinion is that the presented research is very interesting and the quality of the presentation is very good. Methodology is very well explained (even if needs some additional explanations) and the reliability of using very long range TLS for glaciological studies is clearly evidenced. I have a number of comments that authors may consider to use for preparing a revised version of the manuscript.

-Title: I wonder if the use of "ultra-long-range" is relatively standard, as it seems to me a bit "excessive". May be that using very long range is enough, or at least the text should inform that is a distance that has been very little used in previous research. As the

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work deal more in validating the measurements rather than explaining the dynamics of the glacier, may be better to include some reference to the validation itself or the comparison to direct glaciological method (just a suggestion).

- Introduction. In page 2 line 4 when the importance of studying small glaciers is mentioned, it can be also stated that this is the very likely evolution of many current mid-size glaciers in areas like the Alps, and it is better to properly understand the dynamics of small glaciers when they are indeed very deteriorated.

- Study site: Page 5, line 9. "...were comparatively moderate during" The use of "moderate" is rather ambiguous, I would state that area losses were less than...or similar. In some part of the manuscript, probably here, a brief description of climate characteristics of the analyzed glaciers (and main differences if exists) and mentioning how was the climate during the two analyzed years compared to long-term climate (last decades) in the Swiss Alps would help to better interpret the presented data on mass balance.

- Data and methods: Page 6 line 31: -Which is the consequence of range ambiguity? a slightly expanded explanation (or a reference) might be useful.

- Page 7. Even if supplementary material inform of the characteristics of the point clouds, I would mention here some numbers about the most usual (or minimum) density of points acquired for this study. - What is an octree filter? -Page 9, line 5: Some reference to support the used densities for ice, annual and multi-annual firn? - Page 9, line 20, again, although this is presented as supplementary material some numbers on the density of snow depth measurements may be better than just saying "...with a sufficient spatial coverage..."

- Uncertainty assessment: Page 10 lines 22-24. Even if ground is stable, small instabilities may occur between the tips of the tripod and the bare rock, of if the ensemble of the tripod, or the tripod with the TLS is not properly ensured. - Where comes from that uncertainties of volume change for ice is set to +/- 20 kg m<sup>-3</sup>? - Page 15, line 9. I do not fully understand the procedure (rerunning the mass...) used here. - I think that authors

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made their best to produce robust numbers on the uncertainty of the used methodology. They provide a very useful approach that may be replicated in future research. However, my feeling is the computation of each component of the uncertainty is based in equations and assumptions that are uncertain themselves. In this way, I think that in discussion (SECTION 6) .it should be remarked the difficulties to give exact numbers of uncertainty, that may vary spatially and also along the time, and at the end (at least in my opinion) an overall qualitative estimation that accumulated errors in the different methodological steps are much lower than observed changes in the elevation surface of the ice, is the most important, and it can be demonstrated when TLS estimations are directly compared with the changes in each ablation stake (Figure 5), or observing the annual changes in elevation surface over stable terrain (Figure 3).

References: It is cited a paper of our team that at the time of writing this paper was in TC discussion, and now is definitively published on TC., perhaps is better to change the citation: López-Moreno, J. I., Revuelto, J., Rico, I., Chueca-Cía, J., Julián, A., Serreta, A., Serrano, E., Vicente-Serrano, S. M., Azorin-Molina, C., Alonso-González, E., and García-Ruiz, J. M.: Thinning of the Monte Perdido Glacier in the Spanish Pyrenees since 1981, *The Cryosphere*, 10, 681-694, doi:10.5194/tc-10-681-2016, 2016.

Tables and figures: Table 1: i think it would be interesting to add the mean and maximum scanning distances for each glacier. Figure 1: Is it possible to provide pictures of the glaciers (1-5) just from the scanning positions? (It could ello saving Figure 2). Table 3. Probably there is space to write in the header what is each column, instead of using the symbols that needs a very long caption.

Hoping the comments will be useful,

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