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Interactive comment on "Measuring the snowpack depth with Unmanned Aerial System photogrammetry: comparison with manual probing and a 3D laser scanning over a sample plot" *by* Francesco Avanzi et al.

Anonymous Referee #1

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1 Summary of goals, approaches and conclusions

The goal of this manuscript is to evaluate the accuracy of drone based photogrammetry over snow. The authors compared this method with another high resolution dataset derived by terrestrial laser scanning, accompanied by a dataset of manual probing of snow depth. They conclude that drone photogrammetry is a competitive choice compared to other remote sensing techniques of snow depth.

2 Evaluation of the incremental advance provided by this manuscript

The authors cited previous papers, which addressed the accuracy of drone based pho-

togrammetry over snow. These studies provide, amongst others, comparisons of many flights during different flying conditions in different terrain, with and without Real Time Kinetic (Harder et al., 2016), a comparison with different cameras and for different illumination conditions (Buehler et al., 2016;2017), between forested and open terrain (Lendzioch et al., 2016), and different number and distribution of Ground Control Points (Gindraux et al., 2017). As the author's stated, only (Buehler et al., 2017) presented a one-day comparison with another high resolution dataset, a terrestrial laser scanner derived digital surface model (DSM). Thus, the incremental advance of this manuscript is to compare two datasets of very high spatial resolution.

However, the authors similarly present only a one-day event over snow. Furthermore, the study area extent is quite limited (100 x 100 m) and only a third was covered during the winter scan. For two reasons I do not think this provides enough incremental advance for a publication. Firstly, the authors did not include differences between accuracy dependencies during different conditions in time and, secondly, only in a quite limited way in space. The accuracy of drone photogrammetry is dependent on many influencing factors. For example, the ability to match tie-points is dependent on the contrast between the images. This ability is changing largely with time: Different albedo values, cloud cover, continuous vs. patchy snowcover, blurred pixels because of windy flying conditions (amongst others) are known to cause large differences in the accuracy of drone photogrammetry. The limited extent and the characteristics of the chosen study area limit possible conclusions of this study as well. A fine-scale comparison is interesting, but the study area is rather flat and snow depth seems to be mainly determined by the small scale summer roughness (a snow depth map is not shown). Aspect differences change the illumination, patchy snowcover change the contrast of images and thus the ability to match points (to only name a few spatially varying influences on the accuracy). With a high resolution dataset I would be interested in seeing an analysis covering different scales of roughness. Is drone photogrammetry able to build DSMs with consistent roughness on all scales, from large scale roughness (e.g. slopes, gullies), to fine scale roughness (e.g. dunes and sastrugies)? A scale depen-

dent error analysis could be presented, especially if a study area with a larger extent and more varying terrain features would be included.

This study tells me that high resolution drone photogrammetry is accurate, but only for a single snapshot in time and only for a very limited area with very special terrain and snow cover characteristics. This is not sufficient to tell other researchers how good this method is when they want to apply it in different locations and at different times. To my opinion this must be the threshold for a sufficient incremental advance given the current stage of previous publications. Thus, I suggest to reject the manuscript. I strongly encourage the authors to work on transferrable conclusions, which can be reached with including more study days and including other areas with different topographic features, e.g. shaded and sun-exposed terrain, patchy snowcover, forested environment. Given the current knowledge, I suggest to primarily focus on conditions when and where drone photogrammetry could be problematic. The large effort of manual probing on this study site is not contributing to a sufficient advance to my opinion, since this was shown by previous studies. Future study campaigns may focus on high resolution datasets, best including not only two but three data sources, which can better answer the question which technique was responsible for which error source.

References

Same as in the manuscript, except:

Gindraux, S.; Boesch, R.; Farinotti, D. Accuracy Assessment of Digital Surface Models from Unmanned Aerial Vehicles' Imagery on Glaciers. Remote Sens. 2017, 9, 186.

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