The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2017-57-AC1, 2017

The Cryosphere Discussions
Open Access
EGU

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.

Francesco Avanzi et al.

carlo.demichele@polimi.it

Received and published: 6 June 2017

We thank Reviewer 1 for these useful comments on the manuscript. Please find below our reply to your concerns and our prospective changes in the manuscript.

Comment: "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

Printer-friendly version

Discussion paper

think this provides enough incremental advance for a publication."

Reply: The focus of this manuscript is on a comparative assessment of UAS performance vs. another high-resolution remote-sensing technique (laser scanning) and dense manual probing. This focus is motivated by two main reasons: on the one hand, existing comparisons between UAS photogrammetry and manual probing on snow use sparse dataset; on the other hand, only one example exists of a comparison with a laser scanner. We think that probing a relatively dense network of points within a small area is an essential prerequisite to further clarify the performance of UAS in capturing the spatial variability of snow depth at cm-scale. This is, in our opinion, a necessary first step before upscaling to more significant hydrological scales. This explains why we have considered such a small area and only one day. Concerning the comparison with laser scanning, we also would like to stress that we used an innovative topographic instrument called Multistation. This is an Automatic Total Station (ATS) that can make a scanning, but works differently from a Terrestrial Laser Scanner. ATS Multistation systems have been never used for a snow survey, thus this represents another point of novelty of this manuscript. From this perspective, the RMSE between MultiStation and UAS point clouds on snow is significantly smaller than what reported before (see the Discussion section) and much smaller than the RMSE between UAS and manual data. This represents a highly significant result for the snow community as it both highlights that photogrammetry on snow is highly reliable, and that manual probing may be marked by much more uncertainty than remote sensing.

Comment: "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 snow cover, 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." and "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."

Reply: "We agree with you that investigating the repeatability and transferability of our conclusions is an important point for our revision. We would like to bring to Reviewers' and Editor's attention that we are now processing the results of another field campaign (April 2017) that was realized over the same area and with both the instruments (UAS and Multistation). Compared to the 2016 campaign, we also changed the station point of the Multistation and we were, therefore, able to cover the entire area, even though this will introduce some additional spurious differences due to concurrent snowmelt. It is our intention to incorporate this new campaign in the revised manuscript and therefore discuss the repeatability of our conclusions with different snow conditions (e.g., no ice layer was detected in 2017). This could help to reply to this comment.

Comment: "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 snow cover, blurred pixels because of windy flying conditions (amongst others) are known to cause large differences in the accuracy of drone photogrammetry."

Reply: We think that an extensive study of such parameters is interesting, but may overshoot the main focus of the paper for the following reasons:

- Flights were performed around midday during both 2016 and 2017 field campaigns, which ensures a minimal shadow variation. Marked shadow variations during the flight could indeed lead to a number of mismatching. However, note that feature-based

Printer-friendly version

Discussion paper

matching algorithms such as SIFT and SURF are quite independent from minor illumination changes, like those that can occur during the flight over such a small-investigated area.

- UAS flights are usually not performed in case of strong winds, which could cause the mentioned blurred pixel effect, because this is the main factor to consider in order to carry out a safe flight.

- Thermal columns could occur in case of fixed-wind acquisitions over extended areas and at high flight height; however, this is not the case here.

- Using a multirotor UAS (and the consequently low flight height of about 60 meters) ensures that there is no cloud coverage over the investigated area. It is also important to note that in mountain areas a key factor for choosing the flight time is a good satellite sky plot, which cannot be guaranteed for the entire day over narrow valleys, surrounded by high mountains with steep faces.

- The matching over snow surfaces is challenging, especially in case of fresh snow. However, a survey over melting, old snow and the use of multiscale feature based matching algorithms (e.g. SIFT, SURF) allow to recognize a high number of tie points and to reconstruct the snow surface without introducing the high level of noise typical of bad matching. This result is confirmed by the minimal residuals between the UAS point cloud and the laser scanning.

Comment: “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 snow cover 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.”

Reply: We think this is an interesting point and we thank the Reviewer for pointing out

it. For the future campaigns, we are planning to repeat the survey considering different areas, characterized by different topography.

Comment: “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.”

Reply: See our first comment on this: while all previous studies considered different protocols for manual probing, it is our opinion that most (if not all) previous works used sparse datasets. As we show in the discussion section, the density of our grid is much higher than previous efforts. While taking more points may not represent an innovative point per se, it clarifies the impact of specific snow features (like ice layers) and therefore helps to interpret previous results.

Comment: “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.”

Reply: We agree that this is an intermediate step rather than a conclusive contribution on this topic. We will specify this in the discussion / outlook section. Unfortunately, we have at the moment no additional instrument to include in this comparison, but will promote networks with other researchers for our next steps.

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2017-57, 2017.