The Cryosphere Discuss., 8, C1205–C1208, 2014
www.the-cryosphere-discuss.net/8/C1205/2014/

The Cryosphere
Discussions
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Interactive comment on "Spatially continuous mapping of snow depth in high alpine catchments using digital photogrammetry" *by* Y. Bühler et al.

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Received and published: 10 July 2014

Dear Mat

Thank you for your valuable comments!

We have absolutely no intention to criticize ALS. Instead we see photogrammetry as an upcoming, cost-efficient and faste alternative, which might be considered if cost or acquisition speed are critical boundary conditions. This is the key motivation for our paper. We will make sure to amend the manuscript to avoid a misinterpretation of our intentions.

The cost saving is mainly coming from reduced flight time covering large areas (> 100km2). We will adapt the conclusions section to make these point more clear. Ap-

plying digital photogrammetry enables a much higher flight level over ground and flight speeds than ALS with a reasonable point density. Due to doubled detector elements, the new sensor generation ADS100 for example enables the acquisition of 0.20 m ortho-imagery from approx. 3000 m above ground resulting in a swath width of approx. 4 km (Leica Geosystems 2014). This enables a fast coverage of large areas. It is true that both sensors, ALS and digital imagery, can be used on the same platform simultaneously but the flight planning has to be optimized for one sensor system. Generally ALS needs lower flight heights above ground and slower flight speeds than the digital imagery sensor. Therefore the cost savings gained with photogrammetry rise with the size of the area to cover. We did not find illumination caused limitations in our photogrammetry dataset even though it is in high alpine terrain. Due to the high radiometric resolution of 12bit enough matching points were found even in cast shadow areas and no saturation was observed. Unfortunately we have no winter ALS data available for our investigation area.

We do not state in our paper that photogrammetry is better than ALS and do not understand how you come to this conclusion. ALS is a very valuable and well-investigated and highly accurate method for surface model generation as well as for snow depth mapping. This has been investigated and published in different studies cited in our paper (Deems et al. 2013, Mevold and Skaugen, 2013). But because both technologies, ALS and digital photogrammetry, can be applied for similar investigations it, is in our opinion, important to discuss their relative advantages and disadvantages.

Costs are of course not a main finding of this study but can be an important argument in favor of photogrammetry. Comparable costs for data acquisition with ALS and digital photogrammetry are difficult to estimate because they can vary a lot between different service providers and are also dependent on the location mainly because the prices vary significantly dependent on the service provider and the size and location of the area of interest. However we asked for quotations from different service providers to cover the test site of our investigation (145 km2) with ALS and with digital photogram-

metry. We will integrate those numbers into the revised manuscript. Until now we can provide the following estimates listed in the attached table 1.

We do not have an area where we have the coverage of more than one reference data set. Therefore the proposed cross section does, in our opinion, not bring significant additional value. It would make sense in the comparison with the TLS data. But we give a pixel-by-pixel comparison of the snow depth values from TLS and ADS in Figure 9c, giving a more complete picture of the deviations than a transect.

In our opinion we discuss the limitations of photogrammetry in detail throughout the paper and in particular in the conclusion section including: a) Weather dependency b) Forests and scrubs c) Steep slopes (> 50°) d) Image orientation in snow covered terrain e) Data processing limits f) Problems comparing reference point measurements to the photogrammetric snow depth data

However, we will adapt the conclusions section of the revised manuscript to give the challenges more weight.

References

Deems, J., Painter, T., and Finnegan, D.: Lidar measurement of snow depth: a review, J. Glaciol., 59, 467–479, 2013.

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Interactive comment on The Cryosphere Discuss., 8, 3297, 2014.

	Data acquisition	Relative difference	Data processing	Relative difference	Total	Relative difference
ALS	25 – 40	40 - 52%	25 – 40	28 – 35%	50 – 80	25 – 40%
Photogrammetry	12 – 24		18 – 36		30 – 60	

Table 1. Cost estimation ranges in 1000 CHF derived from quotations to acquire a final DSM with approx. 2m spatial resolution over the test sites Davos and Wannengrat (145 km^2) with ALS and digital photogrammetry.

Fig. 1.