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The Cryosphere Discussions

Interactive comment on "Mapping snow depth in open alpine terrain from stereo satellite imagery" *by* R. Marti et al.

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The paper entitled "Mapping snow depth in open alpine terrain from stereo satellite imagery" by R. Marti et al. investigates the potential of very high spatial resolution (VHR) optical satellite imagery for snow depth (HS) mapping in an alpine catchment. This investigation is to my knowledge the first attempt using such data for this purpose and is therefore a significant contribution for many different potential applications.

The achieved precisions of the snow depth values compared to manual probe and UAV measurements are approximately 0.5 m. This is slightly better than the 0.7 m spatial resolution of the input imagery and therefore in line with other investigations applying digital photogrammetry from airplanes (Bühler et al. 2015, Nolan et al. 2015) and UAVs (Bühler et al. 2016, Harder et al. 2016, Vander Jagt 2015). In my opinion this

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Discussion paper

contribution should be published after taking into account the following comments:

1. During the process of generation the snow depth maps and its evaluation, systematic offsets between the summer and winter DSMs as well as the reference datasets are eliminated. These x,y and z-offsets are crucial for the final product as they influence the error by 100% or more. The calculation of these offsets and their elimination is described in the text. However, it is very hard to follow and to understand. I propose that you generate an overview in a table or a figure where you list the different offsets, their amount and how they were eliminated. What information is necessary to eliminate them?

2. I do not understand the comparably low precision (SD 0.6 m) of the UAV reference data set even though the correlation and the NMAD are better than for the Pleiades HS values. Recent studies report accuracies of approximately 0.1 m (Bühler et al. 2016, Harder et al. 2016, Vander Jagt 2015). Was the problem saturation of the imagery? Even though the RTK signal was lost the relative accuracies within the DSM should be much better. Please explain this issue in more detail and relate your results to the recent studies mentioned here.

3. Compared to the manual reference data you achieve an underestimation of the HS values of approximately 0.15 m (median). Is there an explanation for this? Could it come from uprising summer vegetation such as bushes that are pressed down to the bottom by the snowpack as reported in Bühler et al. (2016)?

4. You state that the major benefit of the Pléiades sensor is its 12-bit radiometric resolution compared to 11 bits of other comparable satellite sensors. I doubt this statement. I do not think that there is a significant benefit of 12-bit data compared to 11-bit data (while there should be one compared to 8-bit sensors!). Are really all 4096 digital numbers used? In my experience also 11-bit data never uses the whole dynamic range. Could you show some histograms of the input imagery? I would guess that you get very similar results using 11 bit data. With 11/12 bit data you should get good results

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in shadowed areas but you have to mask them out. Can you explain why you do so?

5. There should be a table listing all available and planned satellite sensors that could potentially be applied for HS mapping including their temporal, spectral, radiometric and spatial resolution.

6. In my opinion there should be a discussion of potential important applications. For what applications the identified precision of 0.5 m is sufficient? What are the applications where you need better precision for example generated from UAV or laser scanning data?

Technical corrections:

P1L1: there is passive microwave; you describe this later in the paper.

P1L2: optical stereo satellites

P1L12: please give the calculated precision vs. the UAV data here

P1L14: I think it is very dangerous to propose the application of remote sensing data without any field data! You need at least some reference measurements to be sure your values are OK. I really suggest deleting this statement!

P1L23: From my experience it is more wind, snow avalanches and terrain features that generate the high spatial variability of alpine snow depth distribution.

P2L27: The main advantage of near-nadir looking instruments against TLS is that you have no holes caused by terrain features such as ridges or bumps and that you can cover the entire area spatially continuous.

P3L29: UAS?

P5L6: It would be nice if some more details on the UAS campaign could be given here. How many images were acquired? What camera did you use? . . ..

P5L16: approximately 501?

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P6L13: Why did you choose these spatial resolutions? Please justify.

P6L15: Gaussian distribution?

P6L17: What are the drawbacks of this method? The winter and summer surface is not similar due to the snow cover. Why is this approach still working? Or did you only use snow free areas to do the SD calculations? Why did you use the 4 m DEMs? This is not clear to me.

P6L27: Can you give some more details on the classification? What happens if snow is in shadow areas?

P7L11: I think it is a bit dangerous to sent negative snow depth to no data as you might change the statistics significantly. There might also be many false values, which are slightly positive. These values might differ out more or less. Can you discuss this point and give some indications?

P7L26: What do you mean by bad stereo orientation? I do also not completely understand you approach with the trend surfaces. These points need a better description.

P8L9: How do you get to the error value of 0.15 m for probe measurements? Please justify. I would assume it is much less, something around 0.05 m.

P8L24: (Fig. 9) P10L15: Where and why do you get these data gaps in the point clouds?

P10L18: 527.103 what entity is this? Also pts.m2 throughout the document.

P10L19: SD and NAMD are pretty bad compared to the other results. Can you explain why? The NMAD Satellite/Probe is 0.45 m and the NMAD UAV/Probe is 0.35 m. Are they both shifted in the opposite direction? Or how can you get to a NMAD of 0.78 m?

P12L17: Why?

P14L15: Discuss your results in the context of the results published by Harder et

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al.(2016), Bühler et al. (2016) and Vander Jagt et al. (2015).

P16L1: Please explain CV

P16L18: Please mention the result of the Satellite / UAS HS comparison

P16L28: This statement is dangerous! You need at least had probe measurements in the file to get an idea about the achieved accuracies.

P16L29: What is the outreach of these results compared to HS measurements with LiDAR, airplanes and UAV? What are potential applications?

P27 Fig. 5: Please indicate the outline of the UAV extent in the Pleiades extent.

P28 Fig. 6: The chosen bins are too wide. If you change to a continuous color scale ranging over more than one color, you can make much more details visible. Please adapt the color scale.

P31 Fig. 9: Please change the color scale as in Fig. 6. Also the error bins are too wide in my opinion. You only see the very large errors of more than one meter like this. Could you set the profile from one end to the other, like this you do not display the big errors in the northeast because you stop just before that.

P32 Fig. 10: How do you get errors compared to the probe measurements for the summer DSM? I do not really understand the figure caption, please clarify.

P36 Tab4: Why is there only one cos value for all snow depth classes? What does the star mean? The same for the slope classes and the aspect classes.

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