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# *Interactive comment on* "Snow depth estimation by time-lapse photography: Finnish and Italian case studies" *by* Marco Bongio et al.

**Marco Bongio et al.**

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We would like to thank the Reviewer for the time and valuable comments to our work. Below we will report our replies to each of your comments following this format:

Reviewer'1 comment

Authors reply

Reviewer #1 says "The authors describe in the manuscript an automatic procedure aimed to estimate the snow depth from stake positioned in front of a camera. They considered three different sites and two different approaches in order to estimate the efficiency of their tool. Results are promising but I suggest to fix some issues in order to improve the readability of the paper."



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Authors reply: Many thanks for your kind comment.

Reviewer #1 says: “1) too long introduction - authors are focusing the attention on snow depth and they should refer strictly on SD and secondly on the relative impact on other parameters - authors describe methods for estimating SD using about 40 lines but the considered methods required less 10 lines. Are satellite and airborne approaches useful in this manuscript? You considered only ultrasonic tools and visual inspection of camera pictures...”

Authors reply: In the revised version of the manuscript, we have condensed the introduction, we focused on snow depth, and time-lapse photography.

Reviewer #1 says: “2) case studies - You should highlight better that in Sodankyla you considered camera detection (automatic and manned) versus ultrasonic estimations and that the snow pit observations confirm or not the ultrasonic “ground-thruth”.

Authors reply: Yes. Sodankyla case study is the only one in which we can compare time-lapse photography (FMIPROT) retrievals versus ultrasonic measurements, so, first we tried to check if ultrasonic measurements and manned ones are comparable in an overlapping period of observation, defined as “calibration”. This fact allows to use the ultrasonic measurements as “the ground truth” to compare, in a different time period, ultrasonic sensor and FMIPROT retrievals.

Reviewer #1 says: “What is the distance between camera and the 3 stakes? - What is the Camera height? - What is the distance between the ultrasonic device and the camera? - How many pictures you have acquired and how many can be used? - How many ultrasonic values you have in the same period?”

Authors reply: The camera features are: - Distance between camera and stakes: from the left to the right respectively: 10, 20.2 and 4.16 m. The camera height is 2.08 m above the ground with a vertical angle of 18° (pitch) and horizontal one of -2° (roll). - The ultrasonic sensor is at the SO003 station, 222 m far from the Peatland site.





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The available dataset related to this site is:

- Campbell (Ultrasonic Sensor): from 03/11/2011 to 27/03/2019; n° of measurements: 383963; temporal resolution:10 minutes; - Manual Measurements: from 03/11/2011 to 28/04/2015; n° of measurements: 105; temporal resolution:Weekly; - Visual Estimations: from 07/11/2015 to 01/05/2019; n° of measurements: 129; temporal resolution:Daily; - Camera Images: from 06/11/2015 to 28/04/2019; n° of measurements: 11604; temporal resolution:30 Minutes;

Ultrasonic measurements had a resolution of 10 minutes and didn't present noise, so probably were published after a correction procedure. We used 11604 images and selected the period from 06/11/2015 to 28/04/2019 from 9.00 AM to 3.00 PM because: - Before 9.00 AM and after 3 PM images were in most of the cases totally black; - The relative position between camera and stake was the same;

We have added this info in the revised version of the manuscript.

Reviewer #1 says: "- Gressoney photo – manual inspection - What is the distance between camera and stake? - What is the Camera height? - How many pictures you have acquired and how many can be used?"

Authors reply: The features of this camera-stake configuration are: - Camera's height: 2 m; - Distance between camera and stake: 10 m; - Type of camera: Siap Micros without protection.

Related to the images: AINEVA operator gave us images at hourly resolution from :2014-2019, generally from 6.00 AM to 8 PM. However, we decided to use only images from 01/11/2014 to 31/12/2017 and 1/11/2018 to 01/05/2019, at 8.00 am and 2.00 PM because in this period we have these 2 mandatory conditions: 1) AINEVA operators gave us an excel file in which they reported the snow depth visual estimated. With this information we could compare our results; 2) The relative position between camera and stake wasn't changed; Within this period, we had and we used for our estimations





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1058 images. We have added this info in the revised version of the manuscript.

Reviewer #1 says: "- Careser dam photo – manual inspection - What is the distance between camera and stake? - What is the Camera height? - How many pictures you have acquired and how many can be used?"

Authors reply: The features of this camera-stake configuration are: - Camera's height: 3 m; - Distance between camera and stake: 6 m; - Type of camera: Axis 214 PTZ with semispherical pet protection. We have added this info in the revised version of the manuscript.

About images: the Civil Protection Agency of Trentino gave us images from 01/01/2014 from 31/12/2018, 4 images per day at 5:15,8:15,11:15 AM and 2:15 PM. As in the previous case, we decided to remove the first (at 5:15) because in most of the cases were totally black, and we selected the period from 01-01-2016 to 01-06-2018, in which the relative position between camera and stake was the same. We used 1714 images.

Reviewer #1 says: "- Authors should discuss how many valid observations they have obtained compared an ultrasonic device before extrapolating time-series."

Authors reply: In order to validate the reliability of the ultrasonic snow depth sensor, we compared manual measurements with the ultrasonic data. These two datasets have following features: - Ultrasonic measurements: available for the period 03/11/2011 to 27/03/2019 every ten minutes (383963 observations). In the graph we plotted these measurements at hourly resolution; - Manual measurements: available for the period 03/11/2011 to 28/04/2015, with a daily resolution. During this period the manual measurements were not conducted every day. There was a lack of data in comparison with the ultrasonic measurements. These snow depth time series (105 manual observations) were measured by rulers by FMI researchers, generally in the morning; So, the comparison between the manual measurements and the ultrasonic measurements was done for 105 observations which were measured at the same hour/day/month/year.





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In the revised version of the manuscript, we have discussed this issue.

Reviewer #1 says: “You showed for Sodankyla time-series in Fig.7 and 8 without showing correlation plots between ultrasonic, manned and automatic estimations. I see several strong understimations while the snow depth is very high. How many? Why?”

Authors reply: Unfortunately, we cannot compare all these three methods because manual measurements are not available when the camera was installed. High underestimations occurred simply because when the algorithm fails and cannot identify correctly the snow depth level, it gives zero as value. This happened in some cases (obstruction of the camera’s view, poor visibility conditions. . .) now reported in the “discussion” section of the revised manuscript.

The correlation plot, in the Gressoney case study helped us to define the method to correct the data, trying to minimize FMIPROT estimation errors. In the Sodankyla case study, we tried to correct measurements with another approach that is those reported in the figure S4 in the supplement document, defining an ensemble of simulations with different parameters. In this way we showed two different solutions to make our results more affordable.

Reviewer #1 says “You showed for Gressoney time-series in Fig.9 showing the correlation plots between manned and automatic estimations. What do you mean with “simulated?”

Authors reply: We mean “retrieved” by FMIPROT. We have fixed it in the revised version of the manuscript.

Reviewer #1 says: “You defined two different correction factors, are they site-specific or operator-specific?”

Authors reply: Operator specific. We have fixed it in the revised version of the manuscript.

Reviewer #1 says: “You showed for Careser dam time-series in Fig.14 without showing

the correlation plots between manned and automatic estimations. - How much the distance between the camera and the stack affects the determination?

Authors reply: We have not investigated how much the distance between camera and stake could affect our measurements. For sure, increasing the distance will increase the possibility that some obstructions or some shadows appear on the snowpack and so the algorithm could detect those as snow levels. Furthermore, if the stake 1 were positioned at a greater distance than the stake 2, in the former case, within a single pixel we could observe 2 black markers, while in the latter case only one. Therefore, in the first case, the algorithm is unable to distinguish between the two markers, reflecting in a poor retrieval of the snow depth.

Reviewer #1 says: “They are discussing about an optimal geometry (4.5): could you give distances or heights? Can you suggest a final setup and discuss much effort require this kind of facility compared to an ultrasonic device?”

Authors reply: It’s difficult to say how it is the optimal geometric configuration, because it depends strongly on the camera’s parameter, type of objective, lenses. Of course, a rough suggestion can be given as: a stake 2 m long, a camera-stake distance of 4-5 m, and a camera height of 1.5 m. We clarified this in the revised version of the manuscript.

Reviewer #1 says: “Minor issues: - Numbers...10*10ËĘ-2m or 0.01m - several font bugs”

Authors reply: Fixed

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