

Interactive comment on “Uncertainty analysis for evaluating the accuracy of snow depth measurements” by J.-E. Lee et al.

Anonymous Referee #2

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This study estimates errors in snow depth measurements by comparing manual, ultrasonic and laser sensors over a winter season. This is an important topic since errors in snow depth measurements remain large and poorly understood. The measurement system seems to have been carefully prepared for a proper comparison between the different sensors. The data set is quite short, but seems comprehensive and was carefully quality-controlled. The uncertainty analysis appears to be sound, based on classical statistical methods. However, the interpretation of the results is quite disappointing and the authors do not reach very substantial conclusions (see the main comments below). The text and figures must be improved (see specific comments). The text should be shorter and more concise.

Main comments

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- A comparison between different sensors is used to estimate the measurement uncertainties. However, the errors are not related to the sensor specifications nor to the climatic conditions (snowfall, strong wind, and so on. . .). Then, the discussion remains quite vague and the numerous results obtained in this study are not very useful for other studies. For instance, Section 5.1 concludes that the snow depth is higher on the west than on the east of the study site, but this result is not discussed in relation with the site characteristics nor with the wind conditions during the snowfall events. At the beginning of the paper, Section 3 mentions that the prevailing wind direction is west to east and that the surface of the site has a slight slope east to west (P4164), but this information is not used to interpret the results of the error analysis. The analysis of the measurement errors of each sensor should be expanded (Section 5.2.1). The second paragraph of the section is not clear (P4170-4171). Different kinds of errors are expected for laser or sonic sensors; they have different resolutions, beam angles, sensitivities to climatic conditions (wind, humidity. . .) and so on. . . These points should be discussed.

- In relation with the previous comments, there is often confusion between measurement errors and spatial variability. For instance, Section 5.1 concludes that ‘the uncertainty for manual snow depth measurements should be lower bound of the range of 1.33 to 1.81cm’. This uncertainty appears quite large considering a resolution of 0.5 m. In fact, part of this variability may reflect actual spatial variability of the snow depth. Lines 3-5, P4166: mention that the spatial variations of manual snow depth measurements may also be due to measurement errors. The text mentions that the negative BEs of snow depth sensors on bases 20 and 11A may result from ‘the spatial distribution of snow depth’ (Section 5.2.1). However, Figure 8a shows that the manual observations give the largest snow depths on bases 20 and 11A. Please clarify.

- The measurement time step is set to 1 minute, which is quite short (P4167). As the depth variations should be measured over a time interval long enough to detect true depth changes, the time step should be defined in relation with sensor resolution (and

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accuracy).

Specific comments

- The abstract is not clear and should be rewritten - Explain better Equation (7) - P4164: what does 'well-exposed' mean? - P4165: give the beam angle and size of the target on the ground for each sensor, FEL resolution is missing, the resolution of the laser sensor is probably less than 1 mm (0.1 mm?). - P4168: automatic measurements above snow free ground can be used to estimate the random errors (Figure 7 is useless: change the Y-scale or remove the figure). This estimation should be compared to the errors derived from Figure 12b, even if the snow signal may be different from the bare ground signal. - Section 4.2 is too long. Only give the percentages of outliers in each data set. What are the causes of the numerous FEL errors at the end of the study period (Figure 5a)? - P4168: justify the choice of the average snow depth of stakes 1 to 4 on base 12A as a reference. It must be noted that this base has the highest random errors (P4169). - P4170: the text mentions that snowfalls may perturb the ultrasonic measurements. However, it is not clear if the data during snowfall events were removed from the analysis. - Equations 1-3: only introduce the variables that are used in the results (MAE?) - Tables 2 and 3: the unities of BE and 'uncertainty' are missing - Figure 1: mention the color of each automatic sensor. - Figure 5 is not very useful and could be removed. - Figures 9 and 11: the text is too small. - Figure 12A: clarify the differences between diamonds and circles.

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