Geosci. Instrum. Method. Data Syst. Discuss.,
doi:10.5194/gi-2015-37-AC2, 2016

Geoscientific Instrumentation Methods and Data Systems Discussions

Interactive comment on "Spatial and Temporal Variation of Bulk Snow Properties in North Boreal and Tundra Environments Based on Extensive Field Measurements" *by* H.-R. Hannula et al.

H.-R. Hannula et al.

henna-reetta.hannula@fmi.fi

Received and published: 12 April 2016

General comments:

This study presents en extensive dataset of snow depth, density and SWE in Lapland, Finland. Different type of land (open area, forest, ...) are studied. The main goal is to provide ground measurements to support remote sensing snow measurements (comparison of data, parameterization, model validation, etc). Using statistical tools, the authors analyze the spatial variability of the above properties and the "optimal" sampling frequency. The dataset is remarkable, result form a rigorous measurements protocol, and can be useful for different applications. It represents a considerable work that has to be acknowledged. The spatial variability study is interesting but the novelty

of the results should be presented more explicitly. Discussion about previous studies and results comparison are missing. There are more suitable instruments, such as the snow micro pen (Proksch et al 2015), and methods (e.g. Reuter et al. 2015) to study the snow spatial variability (but probably not available during your 2011/2012 campaign). I think it would be helpful for the reader to better express the motivation of this spatial variability study in the context of the FMI work. The paper is overall well written. It can be shortened by being more concise in some paragraph of the method and results section. The figures are suitable, except Fig 2, which is not described at all in the paper. The number of table might be reduced by merging some of them together.

Thank you for the detailed review of the paper. All comments will be now answered. Each comment is followed by the response. The revised version of the paper will be submitted after the author's response for the referee comments have been submitted. We agree that the analysis of the snow spatial variability has been left narrow and the links with previous studies are largely missing. The purpose of the scale analysis was supposed to be made in the special context of the SnowSAR-2 airborne campaign (Di Leo et al., 2015) and this has not been clearly expressed. As suggested by the Referee#1 we will expand the presentation of the data itself and we will compress the scale analysis, retaining only the most significant findings describing the collected snow dataset. The significance of these findings will be explained more elaborately, following suggestions made by the reviewer and will be better explained in the context of the FMI work.

Detailed comments:

Line 30: parametrisize → parameterize

Corrected to parameterize

Section 2: The organization could be improved for a better clarity.

I suggest

2.1 Study sites

2.1.1 Sodankylä

2.1.2 Saariselkä

2.1.3 Land cover: you can move here lines 142 to 162.

2.2 In situ measurements

Here in my view, you have to organize better and be more concise about your measurements. For instance, I don't see the reason why lines 117-129 and lines 130-138 are 2 paragraphs? It would be clearer, if it is possible, to divide into subsection such as:

2.2.1 Snow depth & SWE

2.2.2 Snow density: I will move the density paragraph here

2.2.3 Snow pit measurements

2.3 Analysis of snow spatial variability

The section 2 will be reorganized similar or close to as suggested by the referee #2 and more detailed description of the measurement methods and protocols will be added.

Line 86: Which instruments were set up for the airborne acquisition? Which data did you get from these flights? In my view we need this information to understand your motivation to perform ground measurements of density, SWE...

ESA SnowSAR instrument was set up for the airborne acquisition. The instrument is a dual-frequency (9.6 and 17.2 GHz), two-polarization (VV and VH) airborne SAR (synthetic aperture radar) system. The main focus of the aerial campaign was to test and develop an algorithm for SWE (= snow depth (cm) x snow density (g/cmˆ3)) retrieval. The data provided by SnowSAR are normalized radar cross sections (sigma nought, multi-look) of the target, provided at 2m or alternatively 10 m spatial resolution.

However, the final snow products calculated from the data will be aggregated products with resolutions up to 500m. This provides a motivation to analyse the prevailing snow properties on ground from the meter scale to up to several hundred meters: can the majority of the spatially distributed data, collected e.g. at 100 m intervals, provide an accurate reference for the aggregated SAR products? This will be better explained in the manuscript.

Line 94: Fig.1 left: you should introduce the abbreviation used for the land cover classes before, otherwise we don't understand the color scale.

The abbreviations will be explained more thoroughly and before refering to the Fig.1. This could be done in the section 2.1.3 as suggested by the referee #2.

Line 107: You should not start your paragraph with details about the airborne, but the general idea of this paragraph, i.e. line 117 "Manual sampling of SD and SWE along flight transects formed the core of the in situ data collection in support of each SnowSAR acquisition."

The start of the paragraph will be reorganized as the referee #2 suggests so that the general idea can be understood before going into the details of the flight plan.

Line107-113: I wander if we really need the detailed planning of the airborne acquisitions. I will rather just say that ground measurements were performed during the day of the airborne flights to allow comparison (or the day after, if no strong changes, as mentioned line 114).

The description of the detailed airborne acquisitions can be shortened as it is not the actual focus of this paper. However, generally understanding the motivation and protocol of the in situ measurement collection is seen as an important background.

Line 124: the description of the tool used for snow depth measurements is missing here. Since you also used the MagnaProbe, you should give a name for this method (latter on, line 199, you define it as conventional method).

The description of the snow stake measurements will be added. Conventional method refers to these snow stake measurements which were made less frequently than the Magnaprobe measurements. This will be explained more elaborately in the text, and a description of the tools for all the snow measurements and their approximate scales will be added (as also suggested by the referee #1).

Line 127: Is there a reference paper on the MagnaProbe? If yes, please site.

There is not a reference paper for the Magnaprobe, but the web-page of the manufacturer will be cited: http://www.snowhydro.com/products/column2.html.

125: the description of the tool used for the SWE measurements is missing.

SWE coring tubes manufactured and calibrated by the FMI were used. The description of the tool will be added.

Line 132: "The main objective..." either this sentence is redundant with line 117, either it should be moved in the beginning of the paragraph.

The sentence will be moved to the place where the general idea behind the in situ measurement collection is described (to the beginning of the whole section).

Line 135: "Additionally, the manual snow measurement...": you have to be more specific, what measurements did you do? Stratigraphy, Ramsonde, temperature profile, etc, with which tools?

Here, specifically the snow pit measurements executed on a weekly basis at FMI-ARC are meant. We will add a description what measurements and which tools these snow pit measurements include, as now, only a publication describing the whole measurement procedure is cited.

Line 163-176: I will move this density section above, as suggested in the plan above.

See the answer for the comment about the section 2.

Line 163: Give the equation to retrieve density from depth and SWE, also it is trivial.

The equation will be added.

Line 171: From your computation of density, is that right that you compute the SWE from snow depth values in a 10 m radius location? Please clarify in the text. Did you study the error that you do by using 1 density value for all the SWE estimations over a 10 m radius area?

One density value was averaged within one land cover group, but the snow depth measurements at each point consisted of 3 independent snow stake measurements within a 10 m radius. In case of the Magnaprobe measurements, only one independent measurement at each GPS point was done, and thus, they represent even smaller area. A description of all the measurements and the used datasets and their approximate scales will be added for a clarification. The error introduced by the density averaging was not discussed, but this kind of analysis will be added by comparing the effect of averaging within land cover types, where several density measurement points are available.

Line 172: "For some data points no density..." either you explained why, either this sentence is not useful since we don't get anything from it.

The sentence will be replaced with an explanation about why it was not possible to determine SWE for all the data points where snow depth was measured.

Line 177-179: should be move in the "snow pit" paragraph.

Lines will be moved to the snow pit paragraph as suggested by the referee #2.

Line 189: Explanations and references are clearly missing about the autocorrelation method.

Discussion and references for the autocorrelation method will be added.

Line 199: The information of the snow depth measurements should be moved to the

data collection section.

The snow depth info will be moved to the data collection section as suggested.

Line 205-214: it might be helpful to give references for all the statistical tests that you are using.

The references for the statistical tests will be added. These were originally left out as they were considered as general knowledge.

Line 216: delete comma after “investigated”.

Comma will be deleted.

Throughout the results section: You should give number instead of only use qualitative words like “low values”, “higher than”. It will give more “dynamic ton” to your writings. I also think that you can be more concise and only mentioned the results that lead to interesting interpretation. The section could be rename “Results and Interpretation” since you already interprets your results for some of them.

This will be corrected in the revised version. Either the results and discussion will be clearly separated or then these two sections will be combined as suggested by the referee #2.

Line 238: it would be nicer to start by an introductive sentence about Figure 3. Explain what is the red line and blue box. Give to the reader a big picture / overview of your SD values, before to go in the details.

A general explanation of how the data is described in Figure 3 will be added in the beginning of the section to help the reader.

Line 240: “generally lower than”, “than” is missing

‘Than’ will be added.

Line 265: I think you can insert a paragraph break before “Regarding. . .”

Paragraph break will be added.

Lines 291-293: Give values instead of colors.

Colors will be replaced with actual values.

Line 300: “Temperature profiles reflect the fact that air temperature was the same at all pits measured on the same day; the differences in the snow surface temperatures can be explained by the differing measurement times.” How can you distinguish the air temperature from the snow surface temperature in Fig 6?

The first clause of the sentence will be removed and only the snow surface temperatures will be mentioned, as the variance of air temperatures cannot be seen from the referred Fig 6.

Line 305-311: All this paragraph should be move to the method section when you explain the autocorrelation analysis.

We will move these lines to the method section, excluding the last line which is already explaining the results.

Line 323: What is the mean coefficient of variation?

Coefficient of variation is the standard deviation divided by the mean. This was calculated for each of the 8 land cover groups for each measurement day. The results of each land cover group were averaged to represent the whole measurement campaign period, and the mean coefficient of variation is referring to these averaged values of coefficient of variation. A more elaborate explanation will be added to the method section.

Line 323: I will write “coefficient of variation” instead of using the abbreviation “CV”. A page latter, I would guess that readers would have already forgot this definition.

Abbreviation “CV” will be removed and ‘coefficient of variation’ will be used instead.

Line 328 and Table 5: you have to explain the analysis you did in the method section and define all the term “Df”, “t-statistic”, ”p”, etc. What does it mean and represent?

An explanation for each statistical test will be added and the terms will be defined. Originally this was left out as the tests were kept as ‘basic’ knowledge. However, adding the background information helps to understand the results and what they represent. Nonetheless, all the terms should be properly defined.

Table 5: The term “snow depth” does not appear here and neither in the legend! Please give also the unit.

The term “snow depth” and the unit (cm) will be added.

Line 351: “land cover specific density values”: what do you mean? This appellation appears here but was not define before.

The averaged density value (averaged from all of the available density measurements within each land cover group during the same measurement day) is meant. The definition will be added to the data and methods section handling the calculation of the density values and a consistent terminology will then be used throughout the paper to refer to these density values. See the answer to comment for Line 163.

Line 390: What do you mean by ”true variance”?

The ”true variance” is referring to the natural pattern of snow depth variance at the time of the measurements. However, our only knowledge of this variance is the collected in situ dataset described in this paper, which itself already includes some errors of estimation, and as such, does not describe the “true variance”. As also noted by the referee #1 this concept have been used without rigorous definition, so we will add definitions for different concepts already in the introduction, mostly following the suggested terminology by Blöschl (1999).

Discussion section: In overall, I found very few comparison / discussion of your results with previous studies. In particular, you should point out more clearly what are the new

results from your work concerning spatial variability and sampling frequency.

We agree that links with previous studies are largely missing and we will correct this in the revised version of the paper. In the revised version we will also concentrate on the description of the dataset and the success of the measurement campaign’s sampling strategy to catch the apparent variance in the snow properties during the campaign. As such, the results, which are based on exceptionally large manual survey, largely verify the results of previous studies, and can be used when planning similar kind of campaigns in the same kind of environments. The dataset is interesting for deeper analysis for various applications in the future.

Table 6: The column should be aligned.

The column will be aligned.

Table 3 and 4: Can you merge these two tables together? Ideally 1 or 2 large tables regrouping all the small ones would be even better and make the information easy to find.

Tables 3 and 4, and 2 will be merged to create one new table. This indeed, helps to find and interpret the results when they are next to the explanations of the land cover abbreviations.

Table 3: Please add the unit.

The unit (m) will be added.

Fig 2: This figure is not commented in the paper, so either there is something interesting about it and you should describe it, either you delete it.

The Fig.2 was added to show the weather conditions during and between the measurement days (temperature change, precipitation event, major winds). This was done to justify the use of density information from the previous or the subsequent measurement day in case there was no density information for a specific land cover group during the

measurement day in concern. However, this will be just explained in the text and the Fig. 2 will be removed as it does not add anything interesting to the paper.

References:

Proksch, M., Löwe, H., & Schneebeli, M. (2015). Density, specific surface area, and correlation length of snow measured by high – resolution penetrometry. Journal of Geophysical Research: Earth Surface, 120(2), 346-362.

Reuter, B., Richter, B., & Schweizer, J. (2015). Snow instability patterns at the scale of a small basin. Journal of Geophysical Research: Earth Surface.

References added by the authors:

Blöschl, G. (1999). Scaling issues in snow hydrology. Hydrological Processes, 13, 2149-2175.

Di Leo D., Coccia, A., and Meta, A. (2015). Technical Assistance for the Development and Deployment of an X-and Ku-band MiniSAR Airborne System (SnowSAR). ESTEC No. 4000106761-CCN1. (https://earth.esa.int/web/guest/campaigns).

Interactive comment on Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-37, 2016.