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Measurement inter-comparison of bulk snow density and water equivalent of snow cover with snow core samplers

Leppänen, L., López-Moreno, J.I., Luks, B., Holko, L., Picard, G, Sanmiguel-Vallelado, A., Alonso-González, E., Finger, D.C., Arslan, A. N., Gillemot, K., Sensoy, A., Sorman A., Ertaş, M.C., Fierz, C., Fassnacht, S.R., Marty, C.

30.4.2020 **Leena Leppänen**

Introduction

- COST Action HarmoSnow ES1404 organized two field campaigns, one in Iceland in 2017 and one in Finland in 2018

- The presentation is based on research in following paper accepted for publication:

López-Moreno, J.I., Leppänen, L., Luks, B., Holko, L.,, Picard, G., Sanmiguel-Vallelado, A. , Alonso-González, E., Finger, D.C., Arslan, A.N., Gillemot, K., Sensoy, A., Sorman A., Ertaş, C. M., Fassnacht, S.R. , Fierz, C.,Marty, C. **Intercomparison of measurements of bulk snow density and water equivalent of snow cover with snow core samplers: instrumental bias and variability induced by observers**, Hydrological Processes, accepted. DOI: 10.1002/hyp.13785

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Introduction

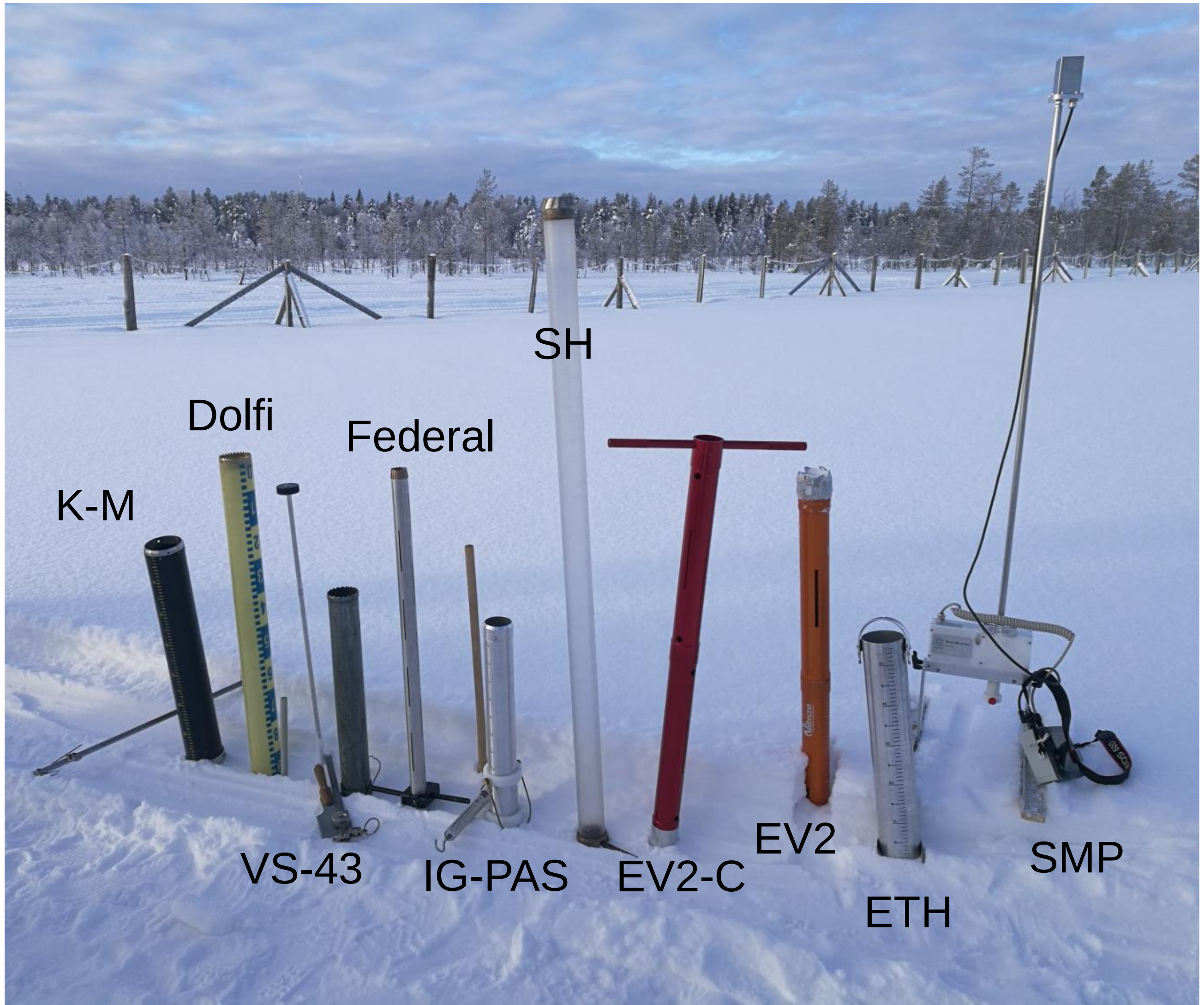
- Water equivalent of snow cover (SWE) can be manually measured by using a snow tube or snow cylinder to extract a snow core and measure the bulk density of the core by weighing it. Different snow core samplers and scales are used, but they all use the same measurement principle.
- The aim of this comparison was not to provide a definitive estimation of uncertainty for manual SWE measurements, but to illustrate the role of the different uncertainty sources.
- Collected data have enabled the distinction of the three main sources of uncertainty when measuring snow density and SWE at the local scale:
    - natural variability of snowpack at small spatial scales
    - error induced in the measurement process
    - instrumental bias when different types of snow core samplers are used at the same time and place
- Although careful measurement can partially eliminate some of the uncertainties, SWE datasets composed of data from different instruments are likely to include inhomogeneities.

Snow core samplers

Snow samplers used in the campaigns from left to right:

Korhonen-Melander sampler (K-M)
Dolfi
VS-43
U.S. Federal sampler
IG PAS tube
SnowHydro (SH)
Custom EV2 (EV2-C)
Enel-Valtecne EV2
ETH cylinder

Other instruments:
SnowMicroPen (SMP)



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Field campaign in Iceland: General

- March 1st 2017 on two plots located approximately 25 km south-east from Reykjavik
- Plot 1, a paved parking lot of the power plant. The ground was almost completely level and covered with a mix of grass and asphalt. Plot 2 was located approximately 190 m to the north of Plot 1, at a lava plateau, with an irregular ground surface covered by soft moss.
- The campaign focused on measurement differences attributed to different instrumentation compared with the natural variability in the snowpack

Plot 1

Plot 2

Field campaign in Iceland: Snowpack and sampling

- Snowpack was cold and dry, with an average snow depth of 48 cm (plot 1) and 53 cm (plot 2). Windblown surface features and ice layers resulting from rain-on-snow events were identified within the snowpack structure.
- The sampling strategy was to measure along a 20 m long snow trench. Depending on the duration of a single measurement, three to six measurements were taken at each spot with one instrument, with each instrument sampling at two to three spots along the trench

Results from Iceland: Variability of spots and plots

- Plot 1: Bulk snow density at each spot measured with the same device showed a variability of less than 5%, which was exceeded on only four out of 14 spots: twice with the Federal sampler, once with the K-M and once with the VS-43. Variability in repeated measurements of SWE was very similar to of the bulk snow density.
- Plot 2: Plot exhibited a larger spatial variability for snow depth between spots at the plot scale. The combination of depth and density variability leads to a coefficient of variation for SWE of 0.14 among the 12 spots.
- The results revealed a much higher variability of SWE at the plot scale, resulting from both natural variability and instrument bias, compared to repeated measurements at the same spot, resulting mostly from error induced by observers or a high variability in the snow depth.

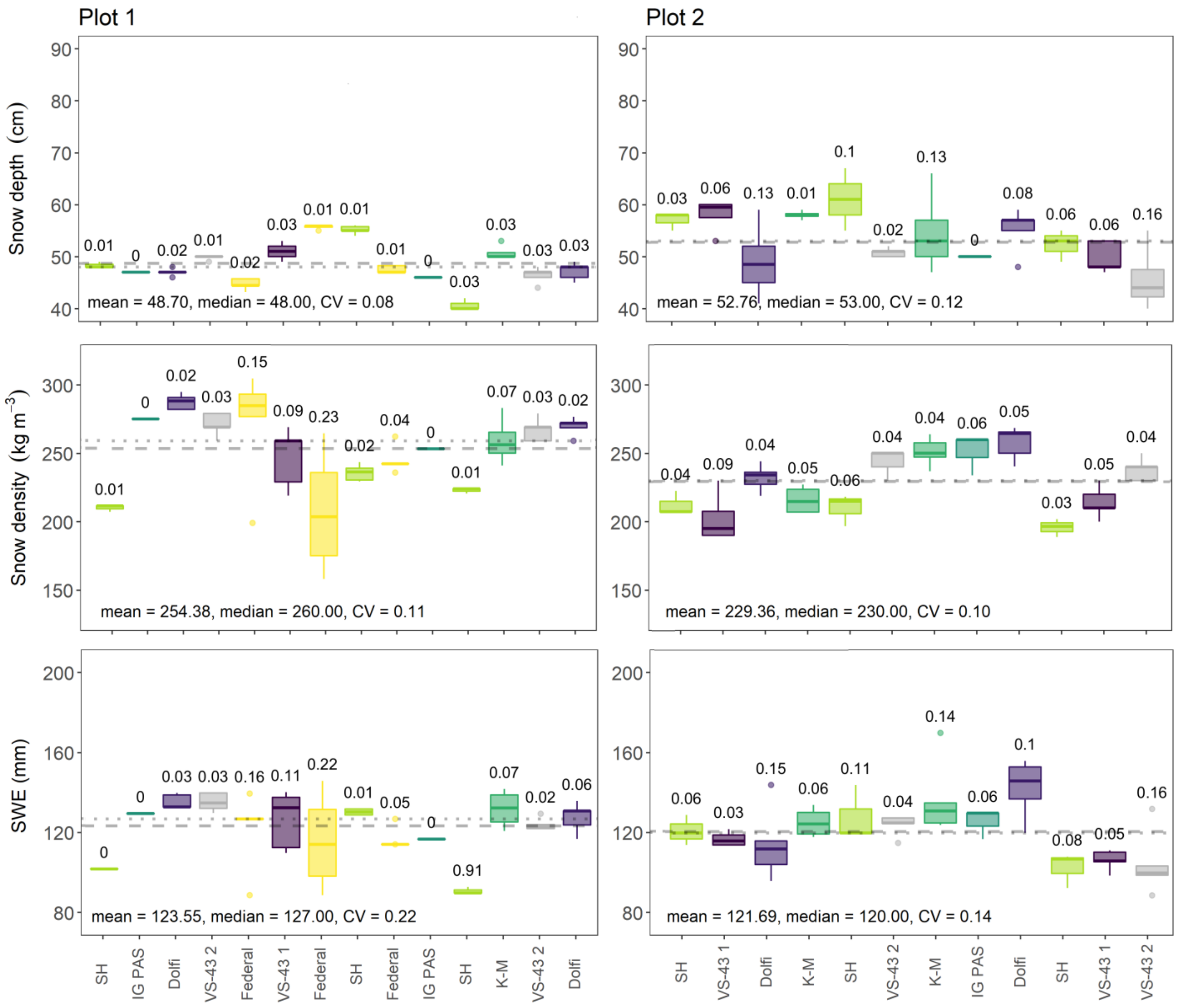

Image: Lopez-Moreno et al., accepted

Results from Iceland: Uncertainty from snow depth

- When snow is measured on a homogeneous surface like at Plot 1 (smooth parking lot and lawn) the snow depth measurement has minimal impact on uncertainty of SWE estimation. The opposite occurred at Plot 2, where snow depth was largest source of uncertainty in SWE estimation.
- Snow depth measurement may be an important source of uncertainty in SWE estimation for various environments, when ground is covered by shrubs or unfrozen bog areas and snowpack is shallow

Field campaign in Finland: General

- The second field campaign was conducted from the 20th to 22nd of February 2018 at Sodankylä
- Three sites: Bog, Forest, Antenna (larger forest opening)
- The aim of this campaign was to systematically distinguish the instrument based error from both the observer induced error and the natural variability of the snowpack.

Bog

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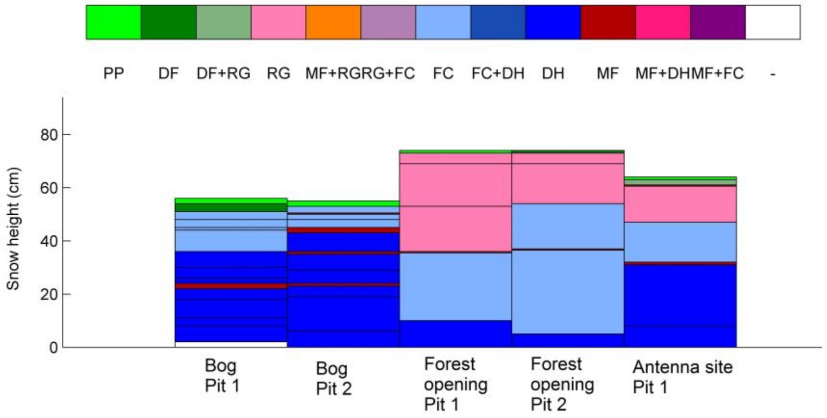
Field campaign in Finland: Snowpack and sampling

- The snowpack was dry and rather soft consisting mostly of faceted crystals and depth hoar with grain size larger than 1 mm, showing very homogeneous characteristics on all three plots.
- All three plots are flat and the snow depth measured with probes or SWE samplers did not vary by more than 11 % at any of the three plots. Average snow depths were 53.2 cm (Bog), 71.1 cm (Forest) and 62.7 cm (Antenna).
- The ground was frozen, facilitating the identification of the contact point between snow and soil. Low vegetation (5-15 cm on average), was present at the Forest and Antenna plots, whereas there was only isolated grass on a mostly icy ground at the Bog plot.
- The sampling strategy was to divide a plot (ca. 10x20 m) into four subplots, where each of the samplers collected five replicates.



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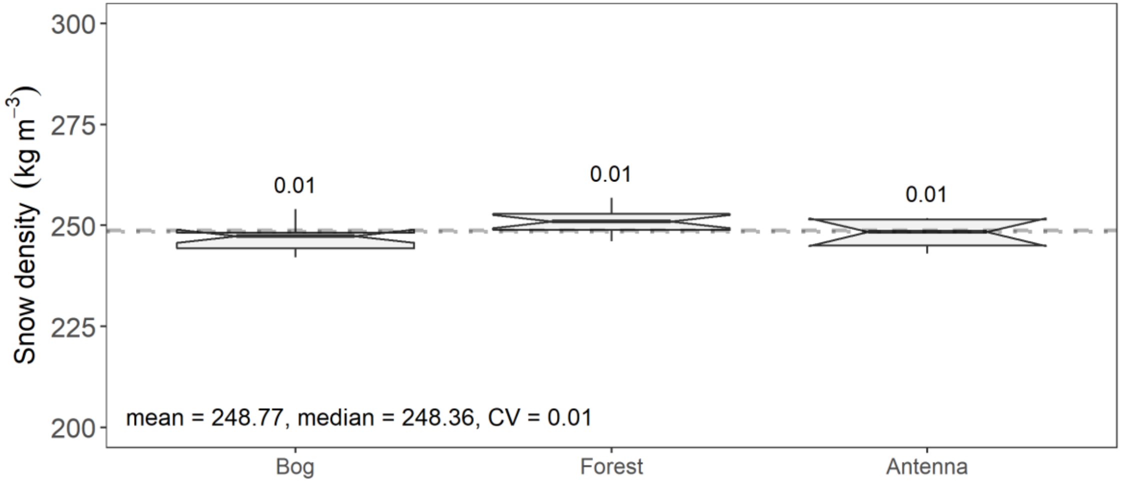
Field campaign in Finland: SnowMicroPen

- A total of 99 SMP measurements, more than 26 on each plot, were taken in undisturbed snow after all SWE measurements were completed on each subplot.
- Homogeneity of snow was confirmed by 99 SMP measurements with a very low spatial variability in snow penetration resistance and density (CV lower than 1% at each study plot).
- The relative uncertainty among repeated, objective penetration resistance measurements is low and thus a good measure for the spatial variability of the snowpack is obtained



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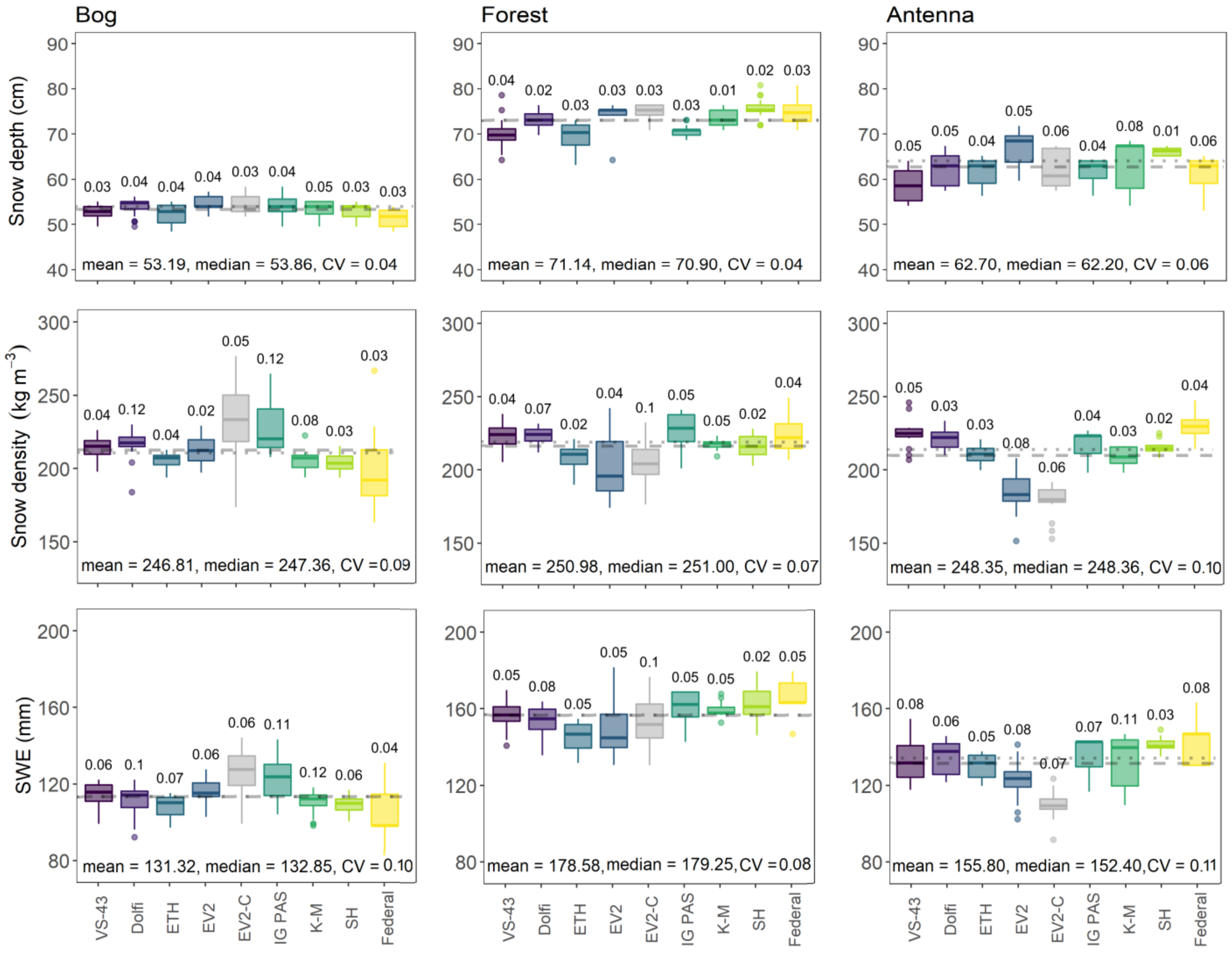
Results from Finland: Variability of repetitions and samplers

- Variability between the repeated measurements was much higher than that observed for the SMP but still relatively low (compared to results from Iceland, for example)
- More significant were the observed differences between the bulk snow densities measured by the different snow core samplers than repetitions of one sampler
- This implies that the differences between estimates from each SWE sampler or the variability between replicates for each device are primarily due to either instrumental errors or errors induced by the observer.



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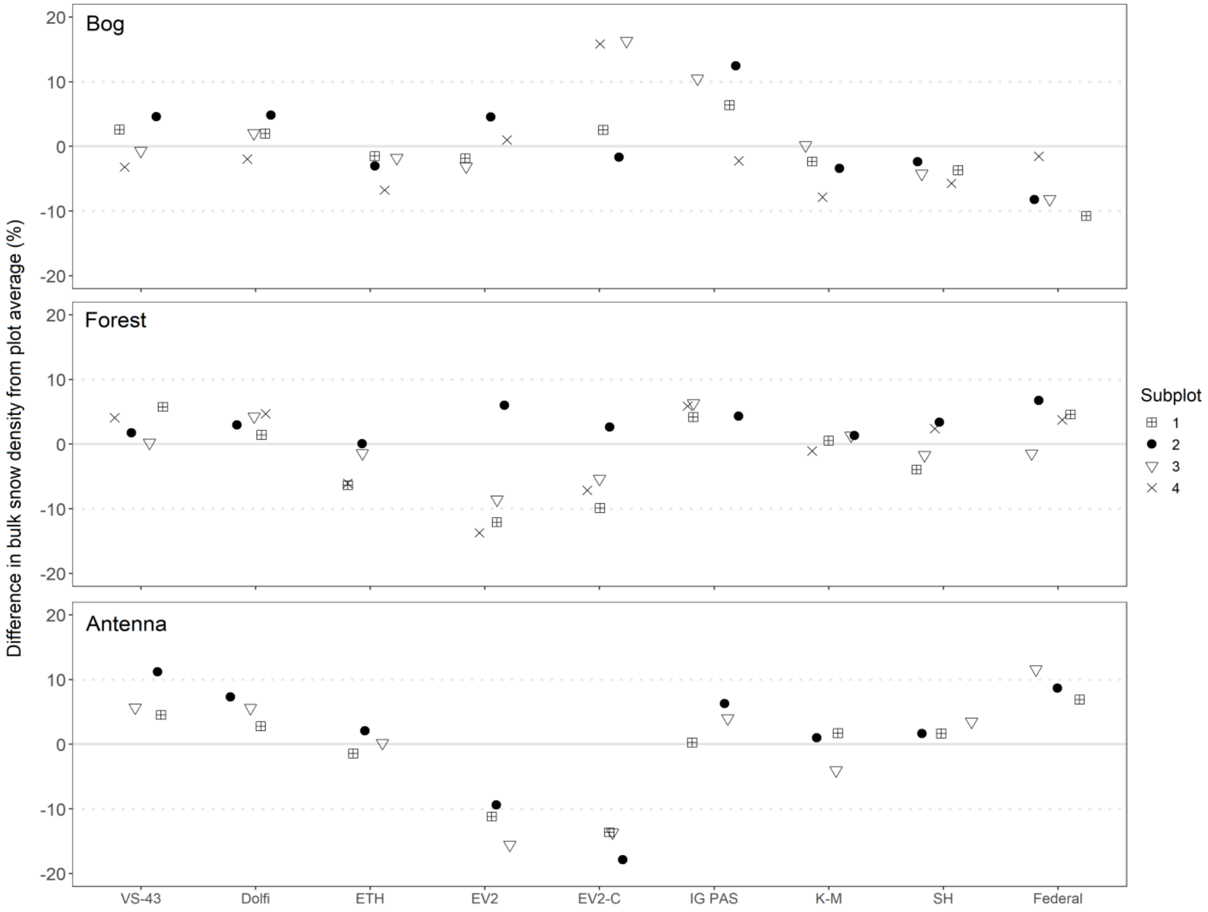
Results from Finland: Sampler properties

- Results show that K-M and SH tend to provide similar data, as do VS-43 and Dolfi, while bulk snow density measurements with the Federal were significantly different than all other samplers on all three plots. The instruments that yield the highest variability between replicates were EV2 (in particular the customized model EV2-C), Federal, and IG PAS.
- The entire snowpack is sampled at once with EV2 and Federal, i.e. no digging is needed; SWE may have been underestimated due to the loss of snow from the bottom of the tube after its removal from the snowpack, due typically lacking soil plug originating from frozen soil and ice on top of the ground.
- Resolution of the scale used with IG PAS was low (50 g), which contributed substantially to the relatively high variability for the bulk snow density observations. The length of the IG PAS, which is only 50 cm, also caused problems with snow depth exceeding it.
- Three of them (K-M, Dolfi and ETH) have a relatively high diameter (10, 8 and 9.45 cm, respectively) compared to the others, which could be beneficial for the very soft and low-density snowpack we experienced over the Sodankylä campaign
- The shorter snow core samplers (ETH, IG-PAS, VS-43) were in general not long enough (55, 50 and 60 cm, respectively) to sample the whole snow column at once and measurements needed to be split into two steps, which increases the probability of errors.
- In summary, for the snow conditions found in this study, snow core samplers of length ≥ 70 cm and having a diameter ≥ 8 cm resulted in the best balance between accuracy and time required to perform the measurements.



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Conclusions

- We would like to note that the devices used in the intercomparison are routinely used in national monitoring networks or research in Europe and elsewhere.
- To our knowledge, such a comparison in terms of number of device and environments has not been conducted before. The results showed that the devices provided slightly different uncertainties since they were designed for different snow conditions.
- The uncertainty in snow density estimation is about 5% for an individual instrument and is close to 10% among the different instruments.
- Since this is not always possible to conduct the field intercomparison of the instruments, one can assume that the uncertainty of density measurements conducted by various devices in non-ideal snow conditions is approximately within 10-15%. Thus, for the estimation of SWE this uncertainty has to be added to the uncertainty of snow depth measurements.