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

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Manually collected snow data can be considered as ground truth for many applications, such as climatological or hydrological studies. 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. However, there are various sources of uncertainty that have not been quantified in detail. To increase the understanding of these errors, different manual SWE measurement devices used across Europe were evaluated within the framework of the COST Action ES1404 HarmoSnow. Two field campaigns were organized in different environments to quantify uncertainties when measuring snow depth, snow bulk density and SWE with core samplers. The 1st field campaign in 2017 in Iceland focused on measurement differences attributed to different instrumentation compared with the natural variability in the snowpack, and the 2nd field campaign in 2018 in Finland focused on device comparison and on the separation of the different sources of variability. To our knowledge, such a comparison has not previously been conducted in terms of the number of device and different environments.

During the 1st campaign, repeated measurements were taken along two 20 m long snow trenches to distinguish snow variability measured at the plot and at the point scale. 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. Snow Micro Pen sampling showed that the snowpack was very homogeneous for the 2nd campaign, which allowed for the disregarding of the natural variability of the snowpack properties and the focus to be on separating between instrumental bias and error induced by observers. Results confirmed that instrumental bias exceeded both the natural variability and the error induced by observers, even when observers performed measurements with snow core samplers they were not formally trained on. Under such measurement conditions, the uncertainty in bulk snow density estimation is about 5% for an individual instrument and is close to 10% among different instruments. The results showed that the devices provided slightly different uncertainties since they were designed for different snow conditions. 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.