16 October 2018

3rd HarmoSnow field campaign

Sodankylä, Finland

20-22.2.2018

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Introduction

The 3rd HarmoSnow field campaign was organised in Sodankylä (Finland) on 20–22 February 2018. The aim of the campaign was to systematically compare the SWE samplers in dry taiga snow conditions at different field sites, and to separate the errors induced by the observers from those caused by the specific instrument design The same samplers as in the previous campaigns were purposefully used. A total of nine SWE samplers (custom EV2, Dolfi, Enel-Valtecene EV2, ETH, IG PAS, Korhonen-Melander, SnowHydro, U.S. Federal and VS-43) were used (Fig. 1 and Table 1) and 880 measurements were made. In addition, ancillary measurements using a SnowMicroPen (SMP) and snow pit measurements including stratigraphy, traditional grain size, specific surface area and density were made. The measurements were made in untouched snowpack at three fenced field sites approximately 10 x 20 m in area.

The first site, called “bog site”, had a mean snow depth of 54 cm. The ground beneath the snowpack was covered with smooth ice containing bits of grass and moss. The second site, called “forest opening”, had a mean snow depth of 73 cm. The ground under the snowpack was covered with a mix of vegetation, including lichen, moss, lingonberry, heather and small pine trees. The third site, called “antenna site”, was a forest opening (larger than the second site) with a mean snow depth of 64 cm. Vegetation was mainly moss, lingonberry and some tree branches resulting from forest cutting.

The bog and forest opening sites had similar measurement setups. Four points were measured five times with every sampler. Two additional points were measured three times with every sampler by two new observers (i.e. not experienced with that sampler). At these points, additional measurements were collected by expert observers. Snow pits were made at each site in two locations. Water equivalent of snow cover measurements were made in the snow pits with a Korhonen-Melander cylinder (the sampler used regularly by FMI observers at Sodankylä). SMP measurements were made next to measurement points 1-4 and snow pits. The antenna site had three points with five measurements by every sampler. In addition, a fourth wider measurement location was used for sampling in parallel lines (10 measurements per sampler in one line with 30–50 cm gaps). At the antenna site only one snow pit was made. SMP measurements were made as at the other sites.

Figure 1. The instruments used in the 3rd HarmoSnow field campaign (from left to right): Korhonen-Melander (made and used in Finland), Dolfi (used in Slovakia and Czech Republic; made in Czech Republic), VS-43 (used in Estonia; made in Russia), U.S. Federal (used in Turkey; made in USA), IG PAS (made and used in Poland), SnowHydro (used in Spain; made in USA), Custom EV2 (made and used in Italy), Enel-Valtecne EV2 (made and used in Italy) and ETH (made and used in Switzerland and Spain). In addition, the SnowMicroPen (made in Switzerland) is shown on the far right side.

Table 1. Participants and instruments

Name	Country	Instrument
Leena Leppänen	Finland	Korhonen-Melander sampler, snow pits
Markku Ahponen	Finland	Korhonen-Melander sampler
Ali Nadir Arslan	Finland	Korhonen-Melander sampler
Anna Kontu	Finland	Snow pits
Aleksi Rimali	Finland	Korhonen-Melander sampler, snow pits
Kairi Vint	Estonia	VS-43
Christoph Marty	Switzerland	ETH and SMP
Juan Ignacio Lopez Moreno	Spain	SnowHydro
Alba Sanmiguel-Vallelado	Spain	SnowHydro and ETH
Ladislav Holko	Slovakia	Dolfi
Arda Sorman	Turkey	U.S. Federal
Cansaran Ertas	Turkey	U.S. Federal
Andrea Soncini	Italy	Custom EV2
Roberto Azzoni	Italy	EV2

Results and discussion

The traditional grain size profile and snow density profiles from the bog and forest opening sites are shown in Figure 2. The stratigraphy measured in the all snow pits is presented in Figure 3. The general structure of the snowpack was quite similar at all sites, with only snow depth differing slightly. Precipitation particles and decomposed and fragmented precipitation particles were observed on top of the snowpack. The lowest densities (110–170 kg m^{-3}) were observed in the top surface layers. The smallest grain sizes (0.25–0.75 mm) were located in or below the surface layer. Typically, the middle part of the snowpack consisted of rounded grains or faceted crystals with one to four thin melt form layers. The bottom of the snowpack was formed by depth hoar. Snow density and grain size increased towards the bottom of the snowpack, with maximum values ranging from 285 to 315 kg m^{-3} and 3 to 5 mm, respectively. Generally, the snow was typical dry taiga snow with large grains, a few thin hard crust layers, and a fragile structure of faceted crystal and depth hoar layers. The SMP measurements confirmed homogeneity of the sites. The mean snow density from SMP had a relative standard deviation of less than 2% for every site.

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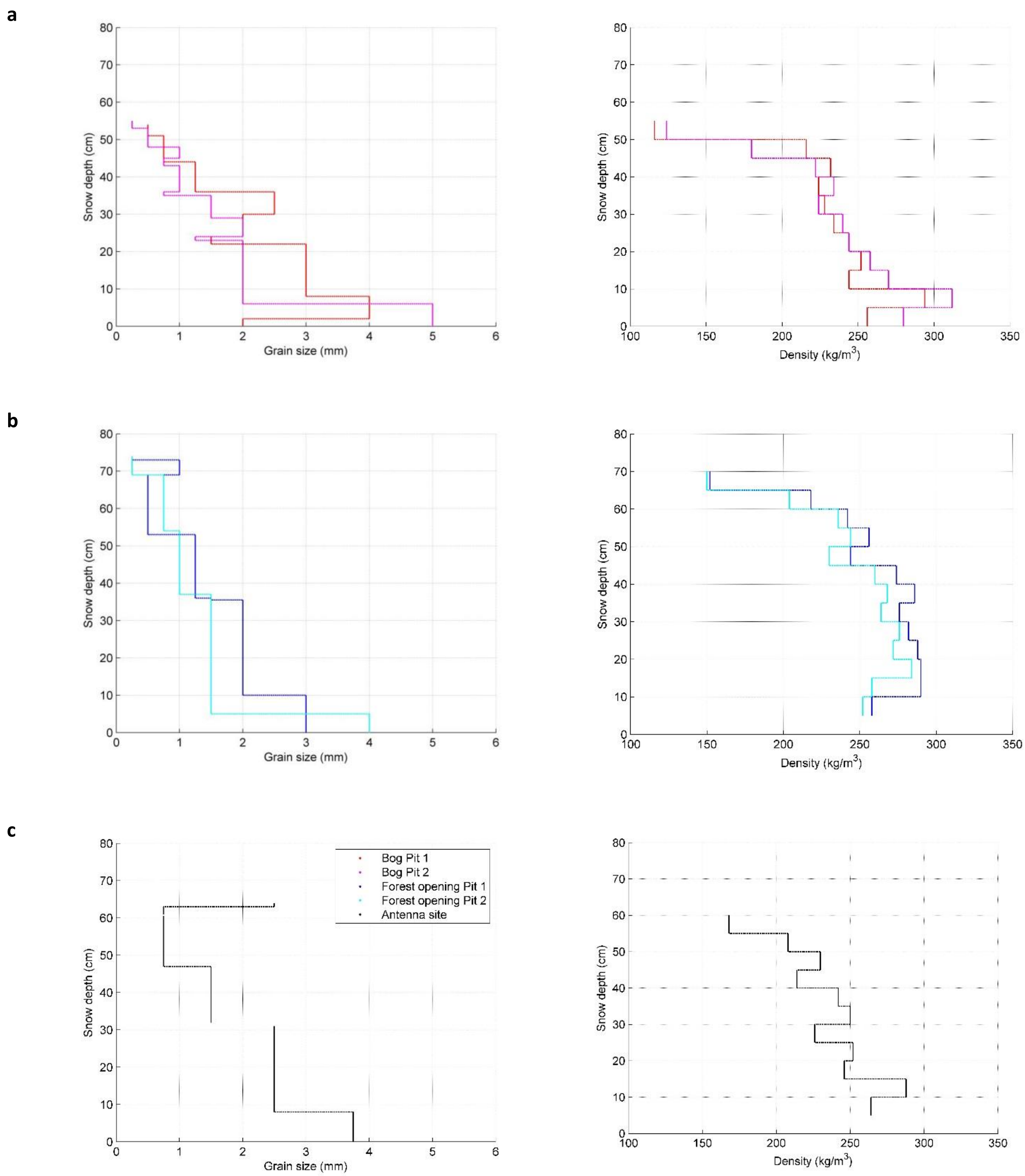

Figure 2. Grain size and snow density profiles measured in snow pits at a) bog, b) forest opening and c) antenna sites.

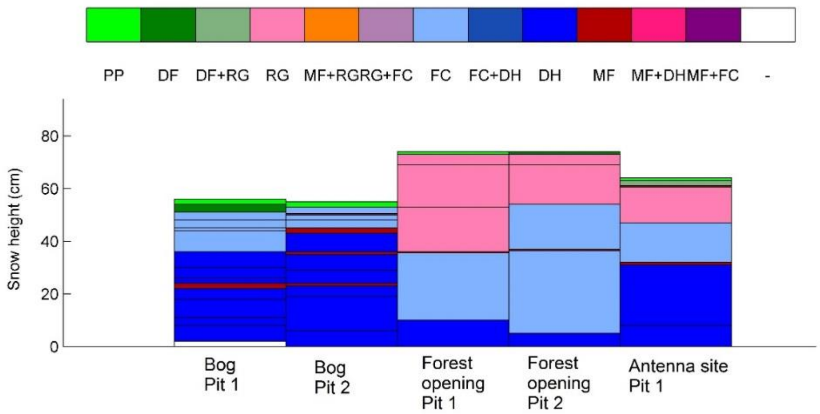

Figure 3. Stratigraphy measured in snow pits.

Mean SWE values were: 113 mm w.e. at the bog site, 156 mm w.e. at the forest opening site, and 134 mm w.e. at the antenna site (Table 2). Snow depth varied from 48 to 63 cm with a mean of 53 cm at the bog site, from 63 to 83 cm with a mean of 73 cm at the forest opening site, and from 55 to 72 cm with a mean of 63 cm at the antenna site. Snow density varied from 81 to 291 kg m^{-3} with a mean of 210 kg m^{-3} at the bog site, from 144 to 329 kg m^{-3} with a mean of 216 kg m^{-3} at the forest opening site, and from 151 to 248 kg m^{-3} with a mean of 210 kg m^{-3} at the antenna site.

The results reveal that, under very homogeneous snow conditions, density estimations from the various samplers differed from the site mean by less than 10% in the majority of cases (Fig. 4 and Table 2). Of all samplers tested, U.S. Federal, EV2 and custom EV2 tubes resulted in the largest differences from the site mean. These snow tubes are extracted directly from the snow without digging a snow pit, and they have a smaller diameter than the other samplers tested. Repeated measurements carried out close to each other of each sampler from each measurement location gave very similar values for the majority of samplers, with differences usually less than 5%. U.S. Federal, EV2 and custom EV2 tubes, as well as the IG PAS cylinder, provided the least consistent measurements, with differences close to 10% in some of the measurement points. Measurements made by new and experienced observers for each sampler are presented for the bog site and forest opening site in Figure 4. Generally, the variability was approximately the same for both observer groups. However, it was larger for new observers for the U.S. Federal tube as well as for the ETH and IG PAS cylinders. This comparison is based on all measurements at the site, and the number of measurements was different for experienced and new observers, which may have affected the result. Variability among the replications of each sampler and variability among the samplers were both less than 10% (Fig. 5). However, the uncertainty introduced by using different samplers was higher than the uncertainty caused by observer error.

Table 2. Measurement results at the three sites. *Mean SWE* and *Mean HS* are the mean of the SWE and snow depth measurements at a single point with a single instrument. *RSD* is the relative standard deviation of the values. For the Antenna site Point 4 was the measurement when sampling was done in parallel lines in respective order.

		Bog				Forest opening				Antenna			
Instruments	Point	Mean SWE (mm w.e)	RSD SWE (%)	Mean HS (cm)	RSD HS (%)	Mean SWE (mm w.e)	RSD SWE (%)	Mean HS (cm)	RSD HS (%)	Mean SWE (mm w.e)	RSD SWE (%)	Mean HS (cm)	RSD HS (%)
Korhonen-Melander	1	112.6	1.1	54.2	0.7	157.2	1.8	72.2	0.6	143.2	1.4	67.0	0.0
VS-43	1	117.4	0.9	53.8	1.6	159.4	1.4	69.6	1.6	123.4	1.9	56.2	2.8
U.S. Federal	1	101.3	7.2	53.4	0.9	166.7	4.4	73.6	2.3	130.8	0.0	58.3	4.6
SnowHydro	1	112.3	3.5	54.8	0.7	153.2	3.4	73.6	2.0	141.0	1.6	66.0	1.1
IG PAS	1	122.2	5.8	54.0	0.0	161.2	7.2	71.4	1.5	124.8	5.7	59.2	2.5
ETH	1	114.4	1.1	54.6	0.9	141.0	4.6	69.6	5.2	122.2	2.6	59.0	2.0
EV2	1	118.2	3.9	56.6	0.8	143.6	4.9	75.4	0.7	115.4	8.0	61.8	2.6
Dolfi	1	112.8	3.9	55.0	0.0	144.4	5.3	71.6	1.5	129.6	6.0	60.6	4.8
Custom EV2	1	119.5	5.8	54.8	1.4	146.4	7.0	75.0	1.3	106.8	8.2	58.8	1.4
Korhonen-Melander	2	113.0	1.0	55.0	0.0	158.4	0.9	72.2	1.5	141.8	2.9	66.8	1.9
VS-43	2	120.6	0.7	54.2	1.4	154.4	3.8	70.2	7.1	145.4	5.2	62.2	3.1
U.S. Federal	2	104.6	8.6	53.6	0.9	171.6	4.8	74.2	2.4	147.1	0.0	64.4	0.8
SnowHydro	2	111.3	2.8	53.6	1.8	166.6	2.5	74.4	2.0	141.0	1.6	66.0	1.1
IG PAS	2	137.8	5.1	57.6	0.8	158.6	6.9	70.2	0.6	143.0	0.0	64.0	0.0
ETH	2	112.2	1.6	54.4	0.9	153	0.9	70.6	2.1	135.6	1.0	63.2	1.3
EV2	2	121.0	4.7	54.4	1.6	171.8	5.1	74.8	1.1	128.7	6.4	67.6	0.7
Dolfi	2	118.4	2.7	55.8	0.7	153.2	3.4	72.0	2.2	141.2	1.3	65.8	1.2
Custom EV2	2	119.2	15.5	57.0	1.2	168.1	3.5	75.6	1.2	115.3	7.7	66.8	0.6
Korhonen-Melander	3	114.2	2.0	53.6	0.9	164.6	1.8	75.0	1.6	114.6	4.5	56.8	3.2
VS-43	3	112.2	1.6	53.1	1.3	152.8	3.6	70.4	1.6	130.2	6.2	58.6	3.9
U.S. Federal	3	98.1	16.6	50.2	0.8	163.4	0.0	76.6	2.2	155.3	5.3	66.2	1.2
SnowHydro	3	110.0	1.5	54.0	0.0	159.7	2.8	75.0	0.0	143.2	3.9	65.8	1.7
IG PAS	3	127.4	8.5	54.2	0.7	161.2	4.4	70.0	1.0	137.8	5.2	63.0	1.6
ETH	3	107.8	2.0	51.6	0.9	151.6	2.6	71.0	2.4	132.2	4.1	62.8	4.5
EV2	3	109.7	4.5	53.2	2.4	143.7	6.2	72.8	6.0	123.8	9.3	69.8	1.1
Dolfi	3	114.8	0.9	54.1	0.3	157.2	3.8	73.6	1.5	134.4	7.4	61.4	4.4
Custom EV2	3	131.6	3.2	53.2	0.7	154.6	6.0	75.4	1.2	110.3	2.7	60.8	1.8
Korhonen-Melander	4	99.6	1.3	50.8	0.7	159.0	0.9	74.2	1.1	128.0	6.4	64.6	3.3
VS-43	4	103.8	4.2	50.4	0.9	160.6	7.7	71.2	4.8	139.5	4.1	63.8	5.3
U.S. Federal	4	104.6	13.9	50.0	1.4	166.7	8.2	74.2	5.1	138.9	0.0	63.8	0.5
SnowHydro	4	103.1	1.6	51.4	1.7	172.6	3.7	77.8	1.9	139.9	2.3	65.2	1.2
IG PAS	4	104.0	0.0	50.0	0.0	163.8	4.3	71.4	1.3	162.5	4.2	69.5	1.0
ETH	4	98.8	1.6	49.8	0.8	140.0	2.1	68.8	1.9	145.1	3.6	66.3	2.6
EV2	4	116.1	5.4	54.0	1.3	139.4	4.2	74.6	0.7	125.4	3.7	65.4	2.1
Dolfi	4	100.0	5.2	51.0	1.2	159.2	2.4	75.4	1.0	137.3	1.3	65.0	1.4
Custom EV2	4	100.0	5.8	51.0	1.3	159.2	2.8	75.4	1.2	139.2	3.2	64.5	1.2

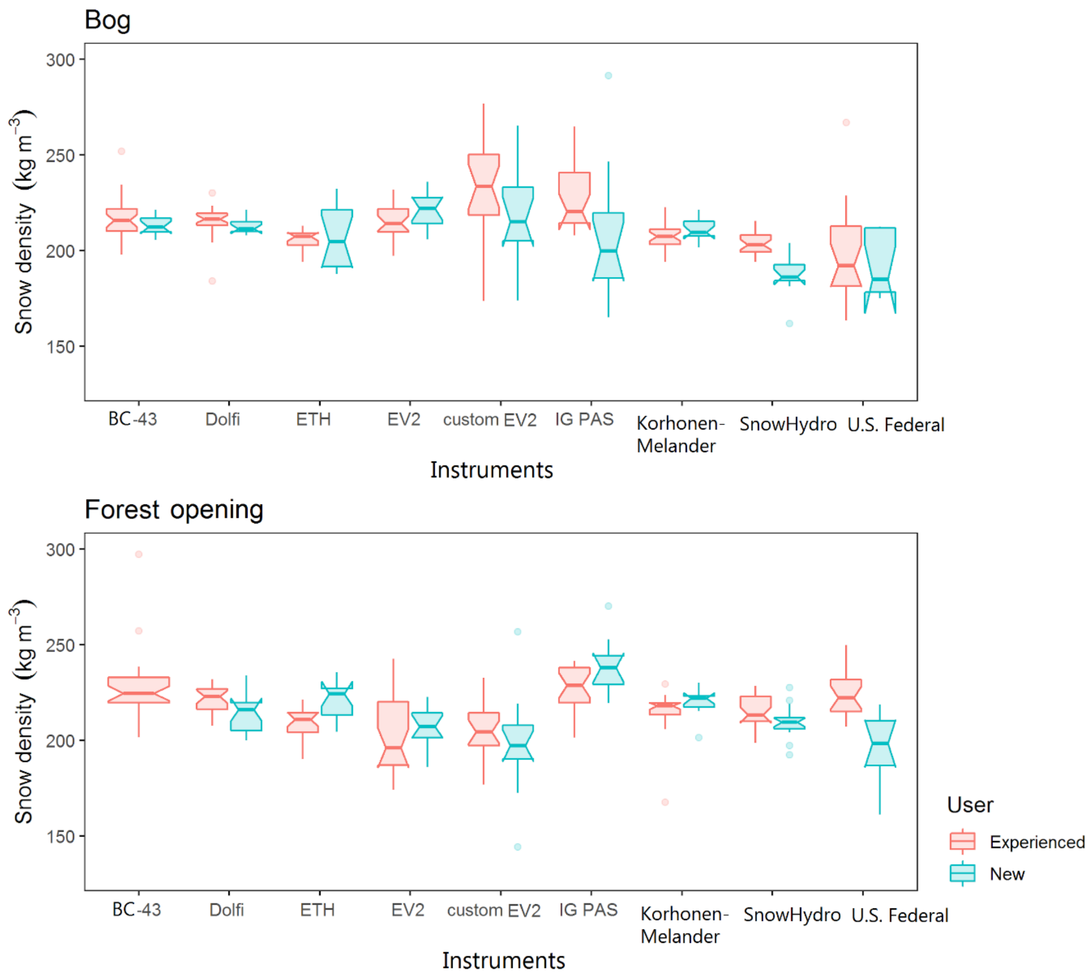

Figure 4. Boxplot of snow density measured with each sampler by experienced and new observers at the bog site and at the forest opening site. The variability was less than 10 % for both experienced and new observers.

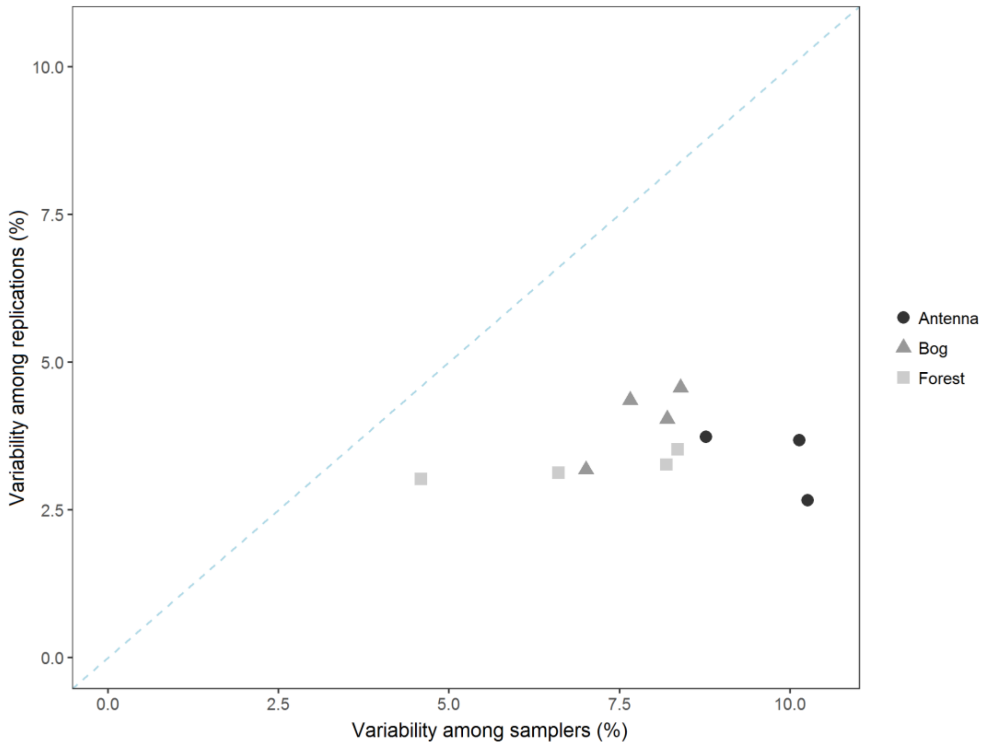

Figure 5. Average variability in snow density among SWE samplers (x-axis) and among repeated measurements carried out close to each other of a given sampler (y-axis) at the three field sites.