NuukBasic snow survey 2014
Data collection, post processing and results

Project no.: B53-04

Asiaq Report 2014-08 September 2014

Introduction

To support the studies under the Nuuk Basic monitoring program, two snow cover surveys including manual stake measurements, GPS measurements and digging snow pits were carried out in Kobbefjord March 17-19, 2014 and April 8-10, 2014, the latter being the main survey.

The surveys describe snow depths and densities at each of the three GeoBasis soil microclimate stations Soil Fen (A), Soil EmpSa (B) and Soil Emp (C), at the Heath (D) and at the Asiaq climate stations (E). At each site a snow pit study has been carried out to determine the physical properties of the snow pack. Furthermore snow depths were measured in large grids near the Heath (D) and in the South Valley (F) as well as along the paths between the stations.

This document describes the field methodology and data processing. Furthermore the results are summarized and discussed.

Snow surveys in Kobbefjord have also been carried out in 2008, 2009, 2010, 2011, 2012 and 2013, see references.

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Content

Appendices

1 Study Site

As in previous years detailed snow depth measurements were carried out at the three GeoBasic soil microclimate stations Soil Fen (A), Soil EmpSa (B) and Soil Emp (C). In March 2014 two additional sites were included for the detailed measurements; the Heath (D) and the Asiaq Climate Stations (E). Finally in April a sixth site, South Valley (F), was considered.
At sites A-E, five section nodes labeled 1-5 were established using a Leica 1200 RTK GPS. The coordinates of the nodes are listed in Table 1-1. The five nodes outline two repeatable transects (2-4, 3-5) at each site.

In order to obtain a spatial coverage of snow depth measurements, stake and RTK-GPS measurements were taken at the sites A-F across the valley. Furthermore at these locations snow pit measurements have been done. The position of the sites can be seen in Figure 1-1 and those were the sites investigated during the March survey. In Figure 1-2 the map of measurements done during the April survey is shown. Here additional travel transects throughout the South Valley and the Heath were made.

Between the survey in March and the main survey in April, no significant snow fall had occurred and no positive temperatures causing a significant melt were recorded, and we therefore expected to see little change in the measurements, except from evaporation and packing of the snow.
The weather before the snow pit surveys had been stable and the temperature had been below freezing point most of the time. In Figure 1-3 and Figure 1-4 the temperature, wind speed and precipitation measured at the climate station (D) in Kobbefjord can be seen, both for the winter period (October to May) and for the period around snow survey (March-April).

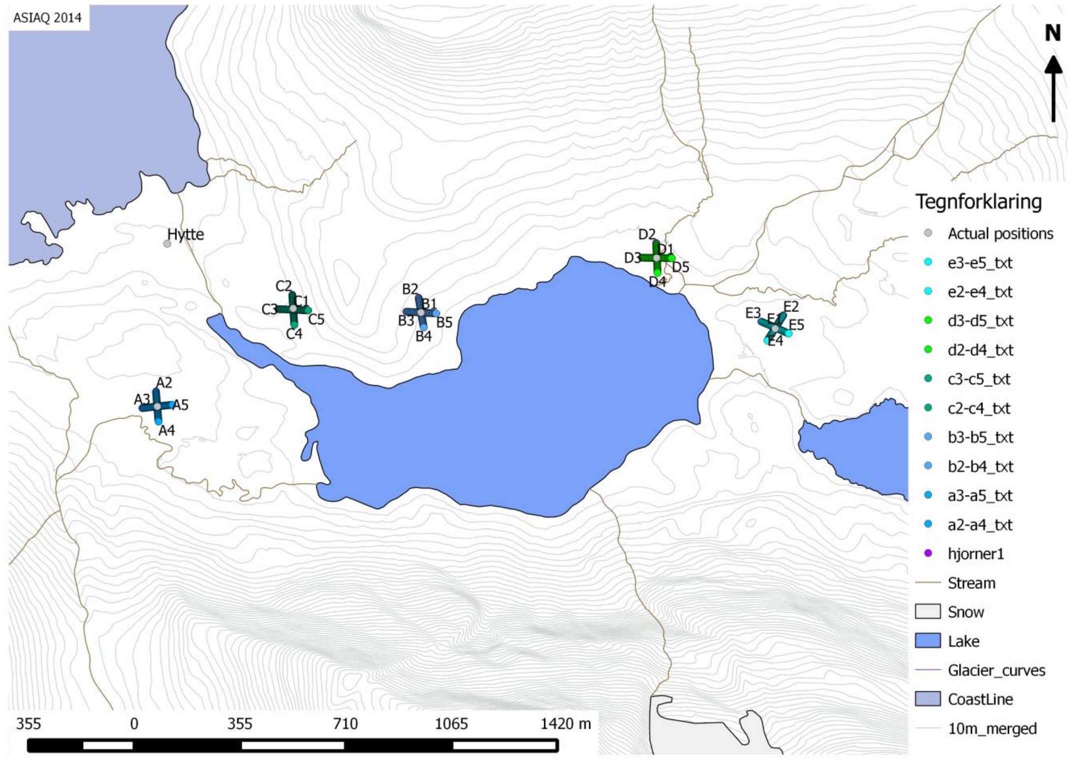


Figure 1-1 Overview map of all snow depth measurements taken in March; Soil Fen (A), Soil EmpSa (B), Soil Emp (C), Heath (D) and Climate (E). Marked by colored points are the five sites where measurements were taken along transects 1-5 (green lines), see Table 1.1.The grey points are the locations of the snow pit measurements.

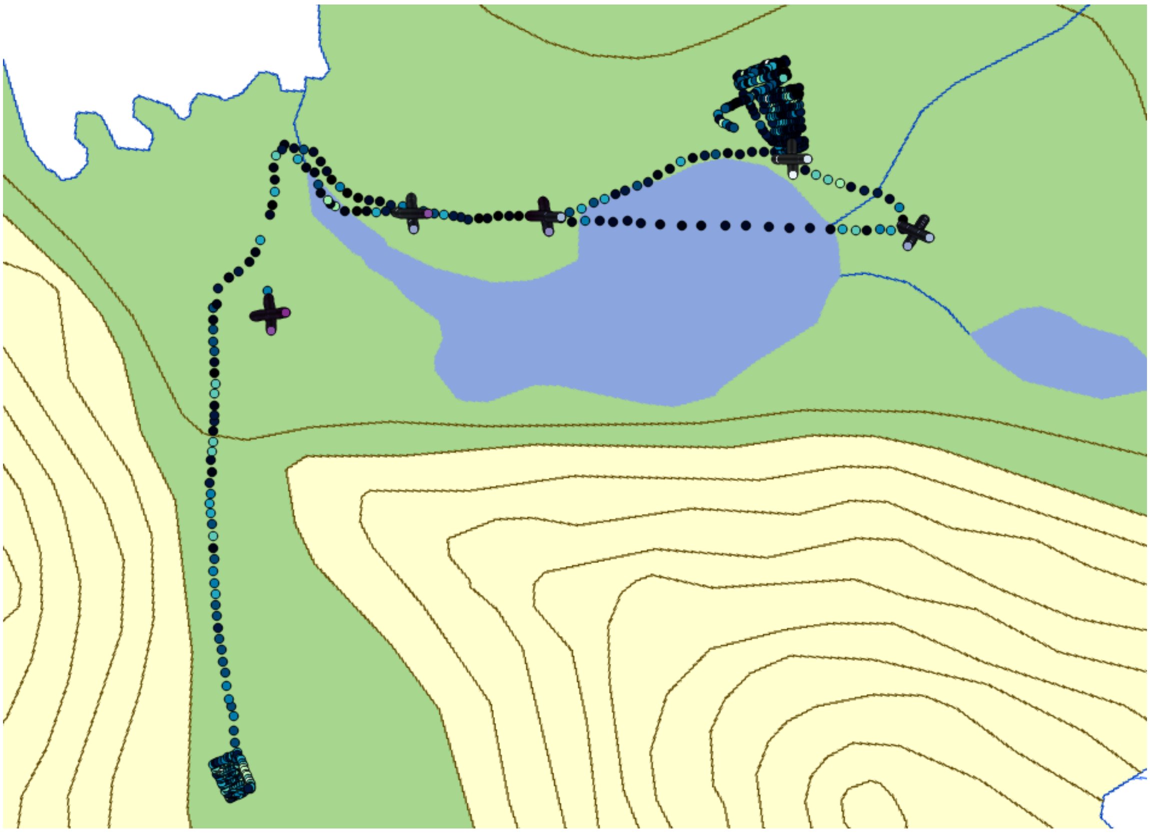


Figure 1-2 Map of April snow survey measurements. The A-E sites are visible as well as the travel transect lines along which snow depths have been measured. At the bottom of the map Site F (South Valley) can be seen.

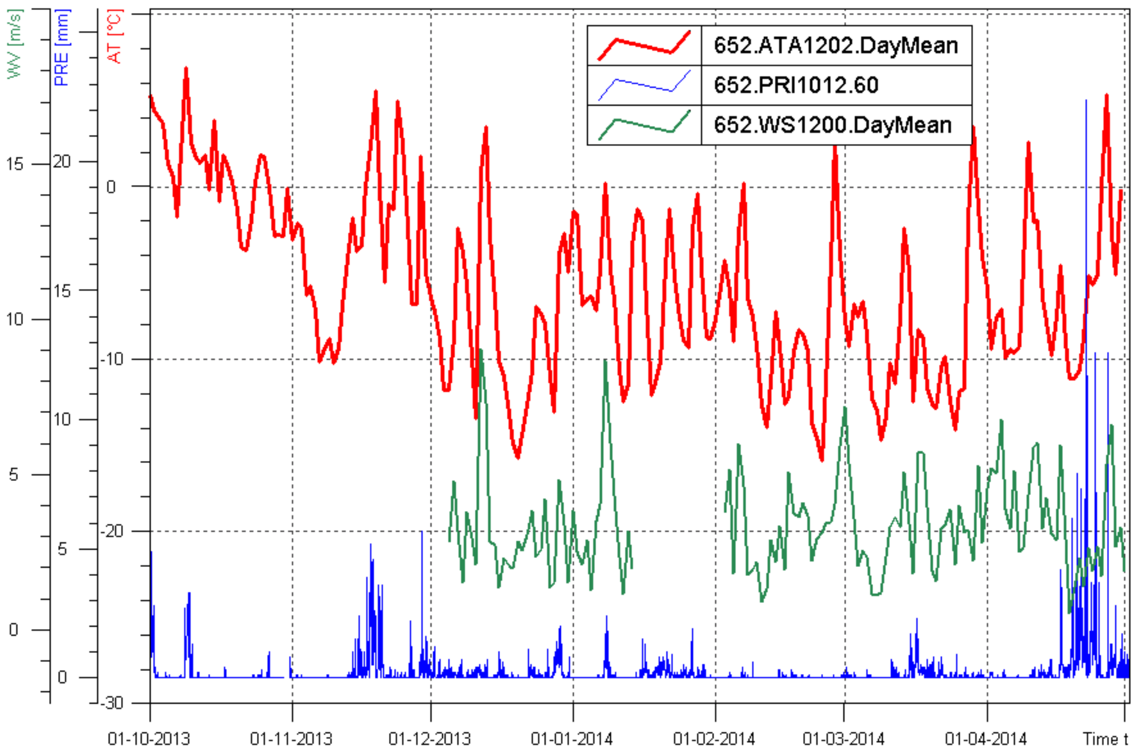


Figure 1-3 Mean daily temperatures (ATA, red), wind speed (WS, green) and precipitation (PRI, blue), October 2013 – May 2014 at st. 652, Kobbefjord 1.

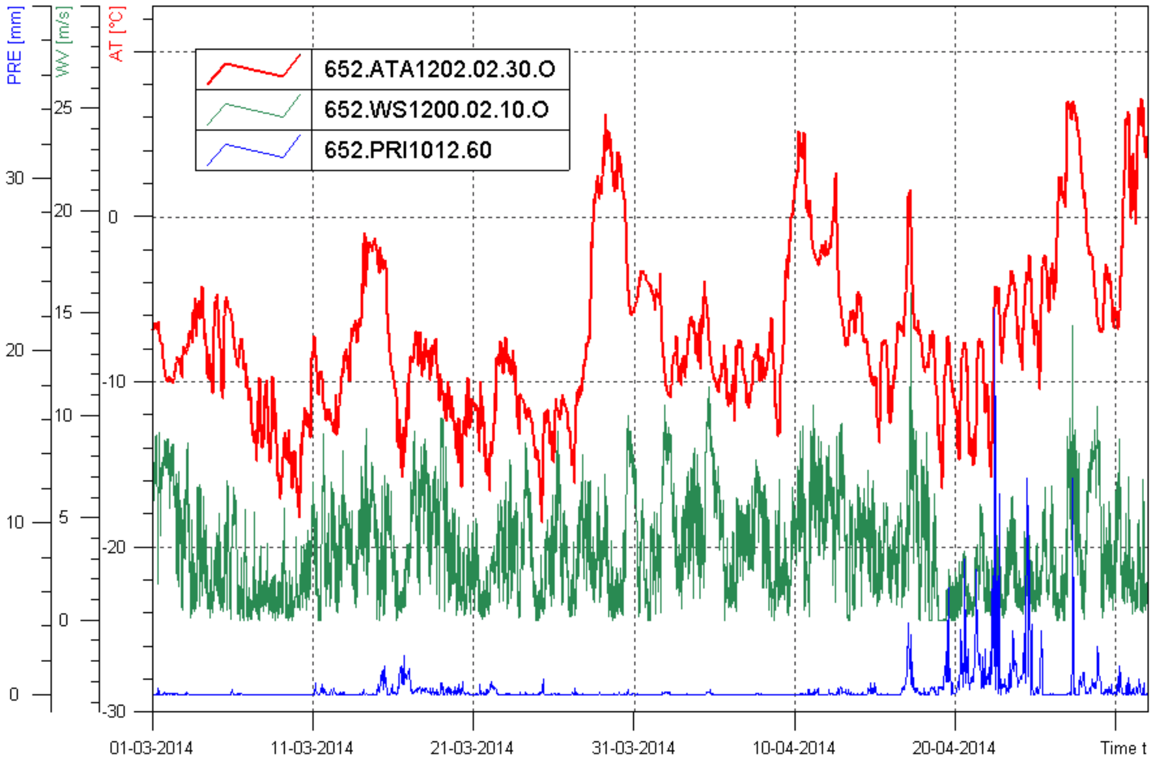


Figure 1-4 Mean 30min. temperatures (ATA, red), wind speed (WS, green) and precipitation (PRI, blue), March – April 2014 at st. 652, Kobbefjord 1.

Table 1-1 Overview of transect nodes established with RTK-GPS. Northing and Easting refers to UTM 22N WGS84, Elevation refers to geoid model gr2000g.06.

Position	Easting	Northing	Elevation (m)
A1	481228.51	7111635.94	39.76
A2	481224.30	7111686.63	42.53
A3	481178.15	7111630.46	40.32
A4	481232.97	7111585.37	40.34
A5	481278.95	7111641.62	43.02
B1	482114.69	7111951.18	39.07
B2	482106.16	7112000.56	44.62
B3	482064.65	7111953.97	46.86
B4	482123.17	7111901.25	36.42
B5	482165.00	7111947.96	33.01
C1	481685.55	7111960.15	32.96
C2	481681.89	7112010.98	30.79
C3	481634.77	7111962.49	28.44
C4	481688.98	7111909.60	33.89
C5	481735.39	7111958.23	41.28
D1	482905.90	7112134.31	26.39
D2	482903.56	7112184.42	28.94
D3	482855.70	7112135.13	25.29
D4	482908.34	7112084.12	24.33
D5	482956.20	7112133.63	27.77
E1	483302.08	7111900.61	35.18
E2	483330.18	7111941.99	33.39
E3	483256.56	7111920.69	37.23
E4	483277.22	7111857.09	33.61
E5	483348.26	7111880.81	32.88
Kobbefjordfix	481519.09	7111944.63	32.23

2 Methods

Manual stake measurements, snow pits, and density measurements were conducted as part of the snow survey. In addition the snow surface in the repeatable transects at site B and C was measured by RTK GPS in order to calculate snow depths by comparing the observations with earlier measurements of the soil surface. Station A, D and E are also measured by RTK GPS, but the results cannot yet be used in this report because of the terrain has not been measured without the snow so far.

2.1 Stake measurements

Manual stake measurements were done by field observers using a metal probe to penetrate snow from the surface to the ground and to read the depth of the snow. At Soil Fen (A), Heath (D) and Climate (E) manual stake measurements were taken every 2 m along both transects (2-4, 3-5). At Soil Emp (C) and Soil EmpSa (B), manual stake measurements were taken every 10 m to compare with RTK GPS snow surface measurements.

During the 2013 snow survey it was observed that the RTK GPS are producing a better result than the manual stake measurements, since the uncertainties arising from ice layers in the snow pack not being penetrated by the manual stake are avoided. Of course there is still an uncertainty within the elevation model of at least the uncertainty of the instrument. Therefore it was decided to use only RTK GPS measurements whenever possible. However, the soil surface was only measured at site B and C, therefore the manual stake measurements was carried out at site A, D and E. At site B and C the stake measurements were only used to check the RTK GPS measurements.
The soil surface at the remaining three stations is planned to be measured in fall 2014.

For a more detailed overlook of the snow depths of the entire area, snow depths have been measured along the travel transect between stations and in two larger grids in the area, one near the site D and one in the South Valley near site F (see Figure 1-2) . Due to time limitations this was only done for the main survey in April.

2.2 RTK GPS measurements of snow and terrain surface

During the snow survey in 2014 the snow pack was without thick ice layers but it contained also hard, compacted snow mostly at the bottom of the snow pack. The thickness of hard compacted snow was up to 22 cm and mostly laid on soil surface, but the thickness of this layer was ranging from 1 to 22 cm between the sites.

During summer 2012 the soil surface along the repeatable transects B and C was measured by RTK GPS. Based on the measurements two-dimensional terrain elevation models along the transects were extracted. During the snow survey the snow surface was measured by RTK GPS and the snow depth was calculated by projecting the measured snow surface onto the terrain model.

At all stations (A, B, C, D and E) the snow surface was measured every 2m at the repeatable transects (2-4, 3-5). For each transect a mean snow depth and the corresponding standard deviation was calculated. The results are presented in Section 3.1.

2.3 GPS and spatial precision

In order to achieve a precise geographical reference, the section nodes at all repeatable transects (A-E) were established with a Leica 1200 RTK GPS. The GPS rover receives corrections from a GPS base station placed on the reference point Kobbefjordfix, which consists of a bolt anchored in rock (Table 1-1). Using the RTK GPS rover and base station allow the horizontal and vertical position to be determined within 3 and 5 cm, respectively.
However the DEM itself also has uncertainties arising from the instrument mentioned above, but also from the human influence when doing the terrain survey along with the extrapolation of the measured points within the terrain model calculation.

2.4 Snow pits

To document the properties of the snow pack, snow pits were analyzed at A1, B1, C1, D1 and E1, see Appendix 1. This includes density measurements taken with a rip cutter every 10 cm, temperature profiling and a description of snow grain size, grain shape and hardness throughout the profile.
This was done in March and April for the five sites, and in April an additional snow pit study at site F (South Valley) was conducted.
In the previous years the density and temperature of the pits have been weighted by the depths, a so-called depth weighting, where the individual parameters for each site have been put relative to the mean value for the given parameter. That is, if the mean density for the five snow pits was 290kg/m^3 and the mean depth was 65cm, then the depth weighed density for A1, for instance, would be

$$\rho w(A1) = \frac{\text{depth(A1)} * \rho\text{(A1)}}{\text{mean depth}}$$

However, this year the raw data are presented instead as the previously described procedure did not contribute to more accurate results and to a better understanding or interpretation of the data.

2.5 Density measurements with tube

In March density measurements were carried out with a snow density tubing instrument for site A, B, D and E. Three samples were taken at each corner 2, 3, 4 and 5. Then a mean density and depth was calculated and compared with the snow pit density found at the center of the site; that is at point 1.

2.6 Used software

In the following different programs have been used to obtain the visual output of the measurements:
General calculations and visualization: *Microsoft Excel*
Map of area (seen in Figure 1-2): *QGIS*
Weather leading up to survey (seen in Figures 1-3 and 1-4): *WISKI graphs*
Box plot figures of snow depth (seen in Figures 3-1 and 3-2): *Origin7 (32bit)*
Snow pit studies (seen in Appendix 3): *PC-Pilot (64bit)*

3 Results

3.1 Snow depth: Stake and RTK GPS measurement

Snow depth measurements are available in Appendix 1 and 2. Box plots describing the snow depths at the repeatable transects (Figure 3-1) are also shown.

3.1.1 Soil Fen (A)

Manual stake measurements of the snow depth at Soil Fen (A) were carried out on March 18 along the two 100 meter transects (n=104). The snow depth ranged from 55 cm to 124 cm with a mean value of 72.2 cm and a standard deviation of 9.2 cm, Figure 3-1.

In April the snow depth ranged from 37 cm to 119 cm with a mean value of 66.5 cm and a standard deviation of 9.8 cm (n=104), Figure 3-2.

3.1.2 Soil EmpSa (B)

The snow depth at Soil EmpSa (B) was measured along the two 100 meter transects on March 18 both by RTK GPS measurements every 2 meters and by manual stake every 10 meters. The measured snow surface was compared with RTK-GPS measurements of the soil surface carried out in summer 2012.

For the March survey:
The snow depths found by the RTK GPS method (n=104) ranged from 20 cm to 140 cm with a mean value of 65.1 cm and a standard deviation of 26.6 cm.
The snow depth measured by stake measurements (n=22) ranged from 33 cm to 90 cm with a mean value of 58.4 cm and a standard deviation of 14.6 cm (Figure 3-1).

For the April survey:
The snow depths found by the RTK GPS method (n=104) ranged from 19.8 cm to 139.6 cm with a mean value of 63.9 cm and a standard deviation of 25.4 cm.
The snow depth measured by stake measurements (n=22) ranged from 19 cm to 86 cm with a mean value of 55.0 cm and a standard deviation of 16.2 cm (Figure 3-2).

Results from the two methods are compared as box plots in Figure 4-4 and 4-5.

3.1.3 Soil Emp (C)

The snow depth at Soil Emp (C) was measured along the two 100 meter transects on March 17 both by RTK GPS measurements every 2 meters and by manual stake every 10 meters. The measured snow surface was compared with RTK GPS measurements of the soil surface carried out in summer 2012.

For the March survey:
The snow depths found by the RTK GPS method (n=105) ranged from 38 cm to 123 cm with a mean value of 69.2 cm and a standard deviation of 19.8 cm.
The snow depth measured by stake measurements (n=22) ranged from 40 cm to 103 cm with a mean

value of 62.0 cm and a standard deviation of 16.4 cm (Figure 3-1).

For the April survey:
The snow depths found by the RTK GPS method (n=103) ranged from 28 cm to 109.3 cm with a mean value of 61.6 cm and a standard deviation of 18.0 cm.
The snow depth measured by stake measurements (n=22) ranged from 40 cm to 102 cm with a mean value of 55.0 cm and a standard deviation of 16.2 cm (Figure 3-2).

Results from the two methods are compared as box plots in Figure 4-4 and 4-5.

3.1.4 Heath (D)

Manual stake measurements of the snow depth at Heath (D) were carried out on March 18 along the two 100 meter transects (n=102) every 2 m. The snow depth ranged from 30 cm to 112 cm with a mean value of 55.3 cm and a standard deviation of 13.2 cm, Figure 3-1.

In April the snow depth ranged from 23 cm to 115 cm with a mean value of 51.8 cm and a standard deviation of 14.4 cm (n=102), Figure 3-2.

3.1.5 Climate Stations (E)

Manual stake measurements of the snow depth at Climate stations (E) were carried out on March 18 along the two 100 meter transects (n=102). The snow depth ranged from 0 cm to 90 cm with a mean value of 48.3 cm and a standard deviation of 20.1 cm, Figure 3-1.

In April the snow depth ranged from 0 cm to 95 cm with a mean value of 48.6 cm and a standard deviation of 23.3 cm (n=102), Figure 3-2.

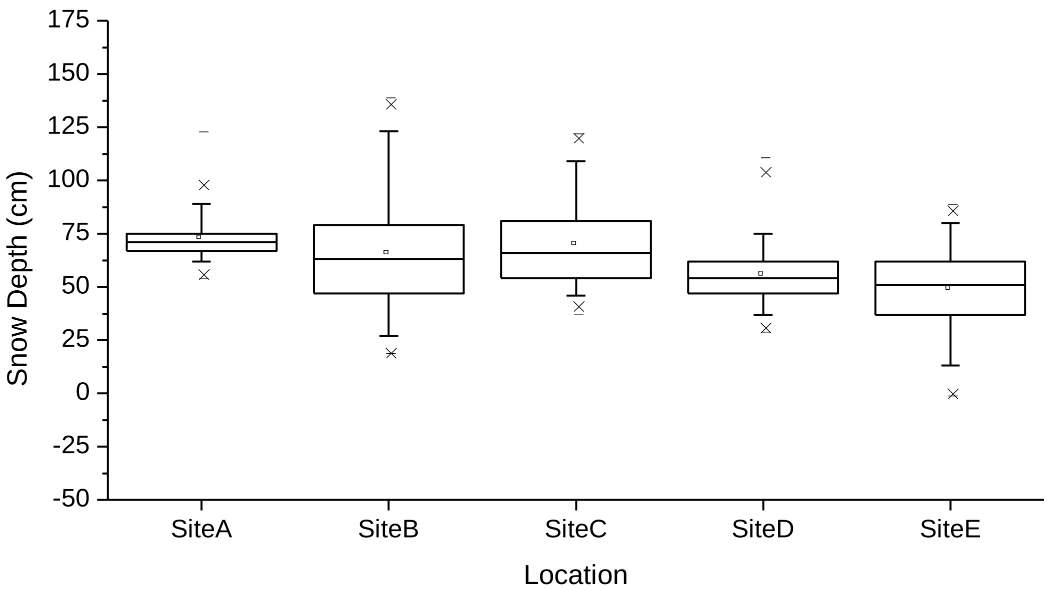
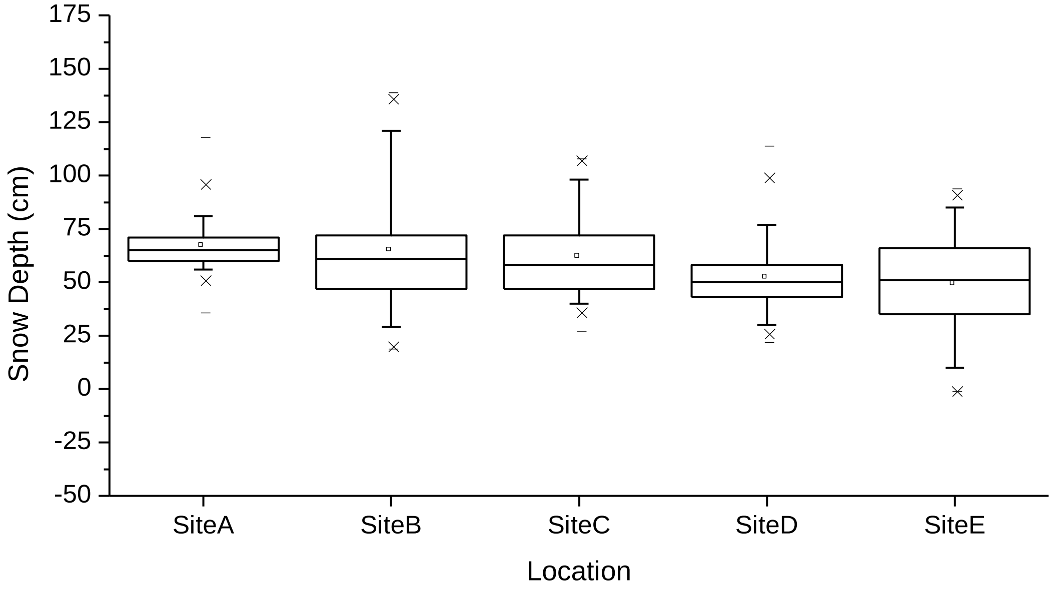


Figure 3-1 Snow depths measured at repeatable transects March 17-19, 2014 using a stake (GPS for B and C). Boxes extend to the 25th and 75th percentiles with the means shown as squares and medians denoted as horizontal

lines through the boxes. Whiskers extend to the 5th and 95th percentiles. The 1st and 99th percentiles are marked



with an "x". The minimum and maximum are denoted with a "-" mark.

Figure 3-2 As Figure 3-1 but for the April survey

3.2 Snow pits

Six snow pits were analyzed during the 2014 snow survey, Table 3-1. Density, temperature, hardness, grain type and grain size measured in the snow pits are given in Appendix 3.

During the snow survey campaign from March 17-19, 2014, snow pits were dug at five sites: in A1, B1, C1, D1 and E1. The mean depth of the five snow pits analyzed during this period was 61.2cm with a standard deviation of 4.8cm. The mean temperature of the snow pack was -5.2°C with a std.dev. of 1.4°C. The mean density and snow water equivalence (SWE) were 274.0kg/m^3 and 16.7cm with a std.dev. of 19.5kg/m^3 and 1.0cm, respectively.

During the April survey the sites A1, B1, C1, D1, E1 and F1 were analyzed, resulting in a mean depth of 70.2cm and a standard deviation of 19.5cm. The mean temperature of the snow pack was -5.0°C with a std.dev. of 0.7°C. The mean density and snow water equivalence (SWE) were 311.0kg/m^3 and 22.1cm with a std.dev. of 18.0kg/m^3 and 7.0cm, respectively.

Table 3-1 Total depth, mean temperature of snow pack, mean density of snow pack and total snow water equivalence (SWE) for 2014 snow pits.

Site	Date	Depth	Temperature	Density	SWE
		[cm]	[°C]	[kg/m^3]	[cm]
A1	18-03-14	68	-4.5	249.7	16.98
A1	08-04-14	68	-4.7	283.3	19.26
B1 - Soil EmpSa	18-03-14	61	-4.6	302.8	18.47
B1 - Soil EmpSa	09-04-14	81	-4.0	329.3	26.67
C1 - Soil Emp	17-03-14	53	-7.8	290.1	15.37
C1 - Soil Emp	09-04-14	55	-5.4	301.6	16.59
D1 - Heath	18-03-14	61	-5.5	263.1	16.05
D1 - Heath	08-04-14	39	-5.0	297.0*	11.58
E1 - Climate	18-03-14	63	-3.6	264.2	16.64
E1 - Climate	08-04-14	78	-4.8	330.0	25.74
F1 – South Valley	09-04-14	100	-6.3	324.8	32.48
Mean		66	-5.1	294.2	19.6
Std. dev.		15	1.1	26.2	5.8

*** density measurement beneath top 20cm not possible**

3.3 Density measurements with tube

During the March survey we did a density measurement experiment at three of the sites, that is A, B and D. Here we compared samples of the density measured during the snow pit study, using the rip cutter, with samples taken at the corners of the transect lines using a density tube (hollow pipe with a drill head at one end). The data can be seen in Appendix 4.

**Table 3-2 Mean depths and density for the density measurement done at the corners of the transect lines.
The density is compared to the density measured at the
snow pits and a difference is calculated.**

Site ID	Depth [cm]	Density [kg/m^3]	Δ depth [cm]	Δ density [kg/m^3]
	mean	mean	X1-Xn	X1-Xn
A2	83.5	257.1	-16	-7
A4	63.0	191.9	5	58
A3	64.7	183.6	3	66
A5	58.3	267.9	10	-18
B2	53.3	270.0	8	33
B4	68.0	245.0	-7	58
B3	54.3	255.0	7	48
D2	32.3	222.1	31	42
D4	47.7	252.8	15	11
D3	45.7	270.8	17	-7
D5	65.0	291.3	-2	-27

4 Discussion

4.1 Comparison of snow depths with previous years

A comparison of average snow depth for the sites A-C can be seen in Table 4-1.

Table 4-1 Comparison of snow depths at sites A-C (repeatable transects measured by stake), 2009-2014.

Snow survey dates	Soil Fen (A) Mean depth [m]	Soil EmpSa (B) Mean depth [m]	Soil Emp (C) Mean depth [m]	Heath (D) Mean depth [m]	Climate St. (E) Mean depth [m]
April 15-16, 2009	0.91	0.90	1.02	-	-
April 15-16, 2010	0.25	0.19	0.17	-	-
April 7-9, 2011	0.87	0.92	0.91	-	-
April 17-18, 2012	0.96	0.74	0.92	-	-
March 20-22, 2013	0.42	0.35	0.32	-	-
March 17-19, 2014	0.72	0.65*	0.69*	0.55	0.48

* measured by GPS

The snow depth varies considerably from year to year and date of maximum snow depth is also strongly variable from year to year as seen in Figure 4.1. In 2014 the snow survey campaign was carried out in mid-March and again in the beginning of April, and almost no snow had fallen between the two surveys. In the end of April there was a large snowfall again followed by a melt period. All snow was gone by June 1st, which is quite late compared to the other years. Only the winter 2010/2011 had a snow cover persisting longer than this year.

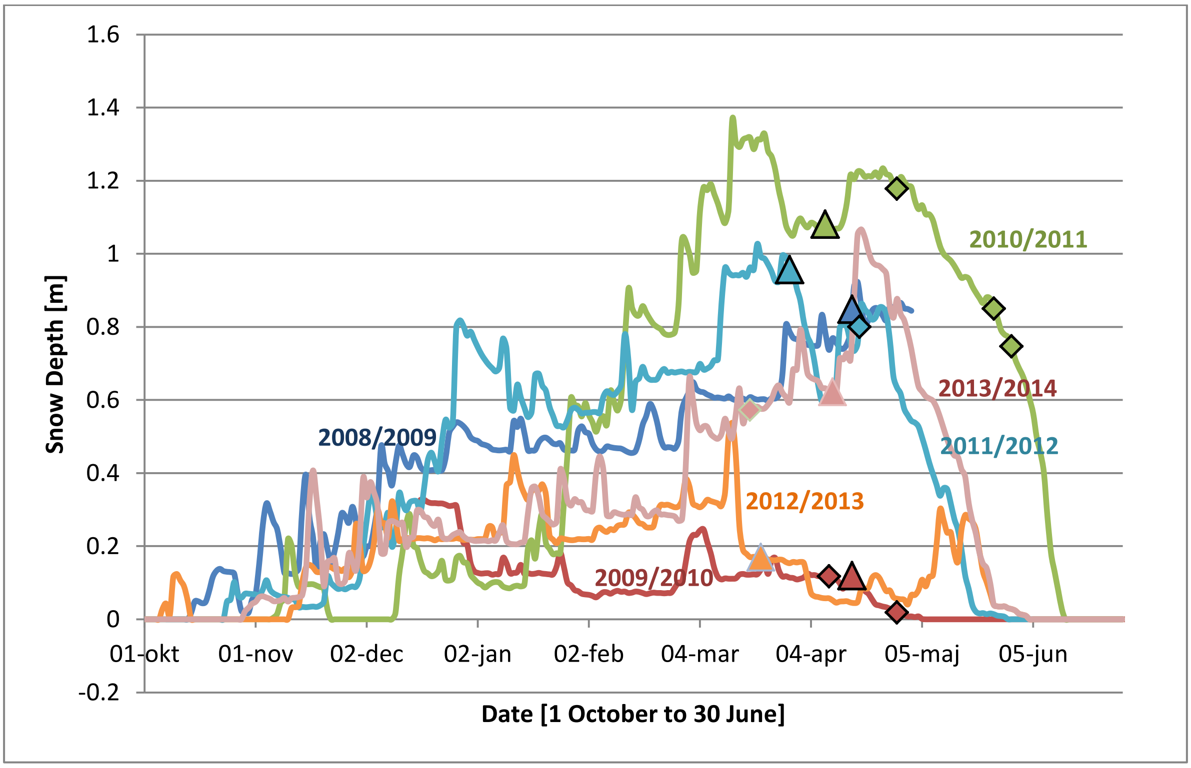


Figure 4.1 Snow depth measured at the ClimateBasic' climate masts and time of snow surveys, 2009-2014. Triangles represent the main survey for the year and the small diamonds represent additional snow surveys.

4.2 Comparison of snow depth methods

At site B and C snow depths at the repeatable transects were observed by manual stake measurements and by RTK GPS measurement of the snow surface, which was compared with a terrain model of the soil surface, section 0 and **Fejl! Henvisningskilde ikke fundet.** (see Appendix 5 and 6). Subtracting the two values yields the snow depth. Generally snow depth measurements by manual stakes are lower than GPS RTK snow depth measurements. The main deviation is 1-3 cm between the two methods.

Measurements with RTK GPS rover and base station is expected to give results with a horizontal precision of +/-3 cm and vertical precision of +/-5 cm. However if this was the main error source the difference between results from the two methods should be centered on zero, i.e. the interval [-1:1] should have the highest frequency in the frequency plot, Figure 4-. Since this is not the case it points to a systematic error/difference between the methods. It can be seen that it is more common that the RTK GPS method is producing snow depths higher than the stake.

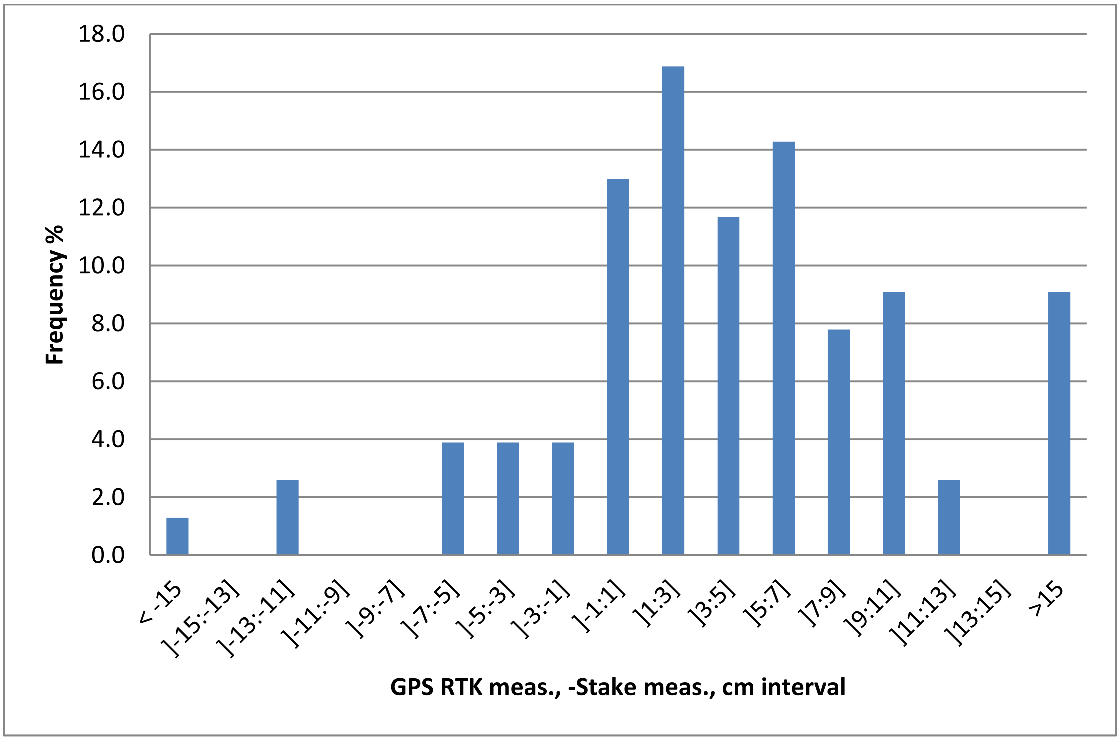


Figure 4-2 Histogram showing the relative frequency for intervals of differences between the snow depth measured by the RTK GPS and the snow depth measured by the stake. When positive the stake is lower than the GPS. Data are from March and April.

Besides the uncertainties of the RTK GPS method, uncertainties in the stake measurements must also be considered. In fact, the ground surface characteristics vary along the transects consists of bare rock/top of stones, hard soil surface or the top of any continuous layer of mosses/loose soil. When carrying out manual stake measurements the stake is rammed through the snow layer until a hard surface is met, which is assumed to be ground surface. However, not always is it surface but rather a hard ice layer, resulting in too low snow depths. This is what is seen in the histogram, Figure 4-.

At some points large differences (> 15 cm) between stake and GPS measurements can be observed. These mainly occurred at site B (can be seen in the data in excel file) which has a more uneven ground surface with more stones than site C. It is thus assumed that the stake was slightly out of line/ not vertical, and had just missed a stone that was included in the terrain model, resulting in too high values (is seldom happening as seen in Figure 4-).

An example of ground and snow surface along one transect is shown in Figure 4-. Similar graphs for the other transects can be found in Appendix 7 and 8.

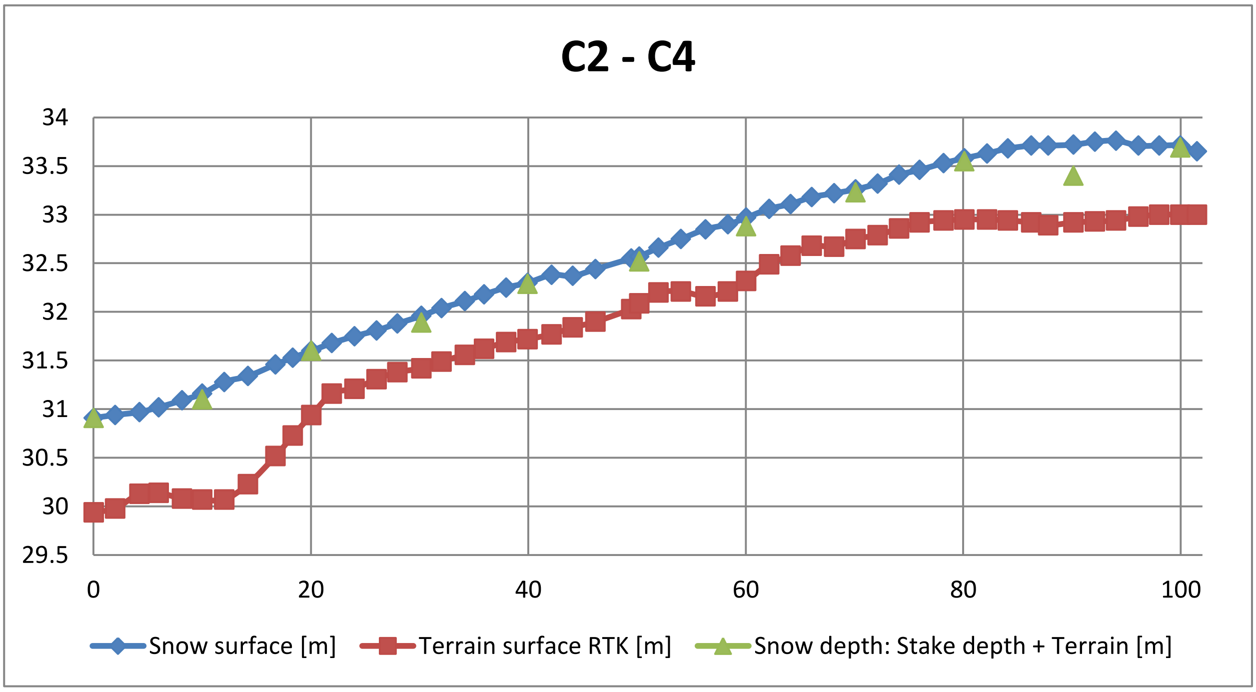


Figure 4-3 Transect line at site C, C2-C4, the red line is the ground surface, the blue line is snow surface measured with RTK GPS and the green line is snow surface found from stake measurements.

The RTK GPS method is found to be easy and precise, where the ground surface is well defined and stable. The method is not affected by ice layers in the snow pack, which can lead to erroneous results for the manual stake measurements. At site A the ground is fen, thus the height of the bottom of the snow pack will vary from year to year depending on the amount of water within the top layer of the ground as winter sets in and the amount of melt water deployed during the snow season. Here is has been noticed that an ice layer of more than 20cm every year resides at the bottom (probably melt water from the snowpack above as well as run off melt water from the surrounding area) which is included in the snow depth measured by GPS but not when measuring with a stake.
Therefore if we want information on a possible layer of ice at the bottom, we need to do both a stake and a GPS measurement, as the GPS measures through both ice and snow, and a stake only penetrates through the snow layer.

If it is assumed that the ice layer at the bottom, which was evident in every snow pit study, causes the positive difference (lower than 15cm) between the measuring methods, the mean thickness of the ice layer then ranges from 3.2-6.6cm, which is consistent with the snow pit observations.

The box plot figures in Figure 4-4 and 4-5 show the snow depths measured by stake and GPS for site B and C in March and April, respectively. Observations are consistent as effectively no snow has fallen; however, the variance of the measurements has decreased suggesting that the snow has packed together smoothing out the irregularities. This is especially seen at site B for the GPS measurement. Also the minimum snow depths are larger and the maximum snow depths are smaller in April than in March, indicating that a lot of wind driven snow drift had occurred.

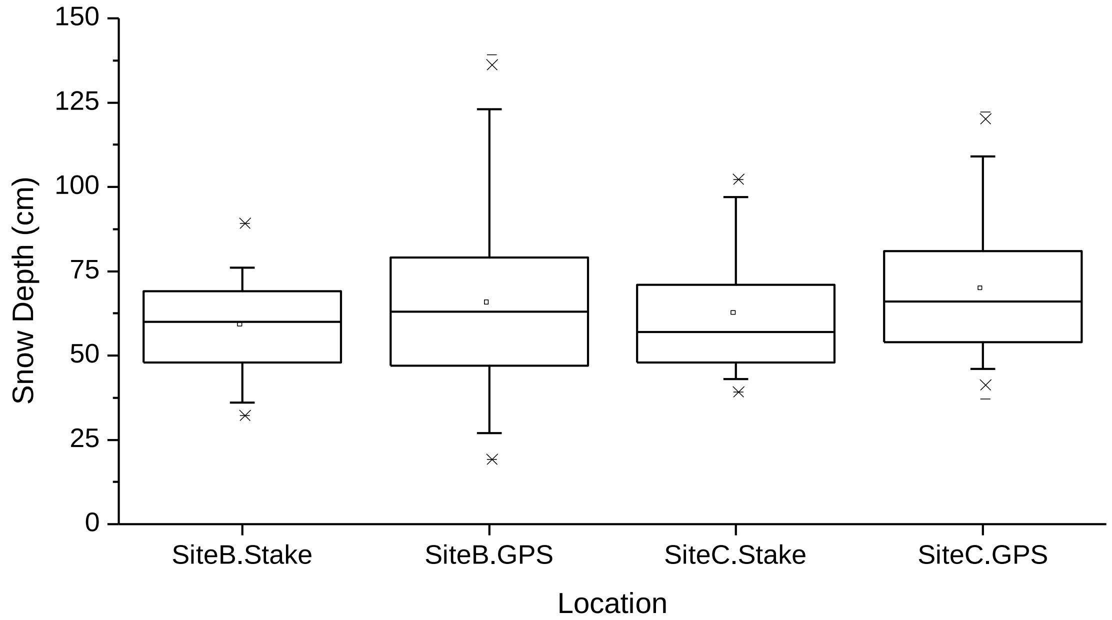


Figure 4-4Snow depths measured at repeatable transects B and C in March 17-19, 2014. Comparison of manual stake measurements (.Stake) and measurements of snow surface with RTK-GPS (.GPS). Boxes extend to the 25th and 75th percentiles with the means shown as squares and medians denoted as horizontal lines through the boxes. Whiskers extend to the 5th and 95th percentiles. The 1st and 99th percentiles are marked with an "x". The minimum and maximum are denoted with a "-" mark.

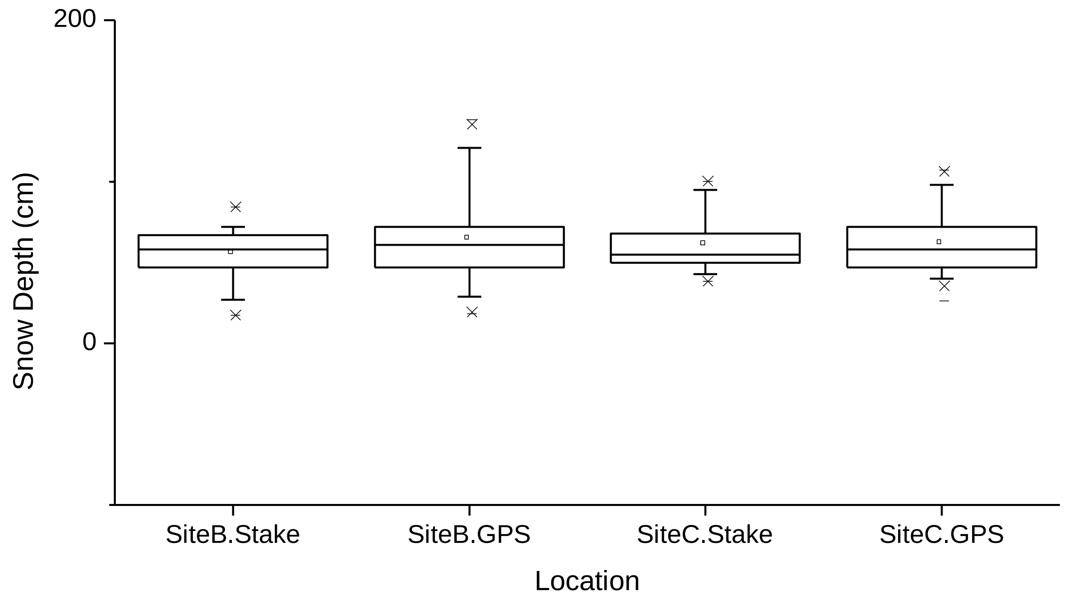


Figure 4-5 As Figure 4-4, but from the April survey.

4.3 Travel transect depths

During the April survey the snow depths for a large area near site F (South Valley) and site D (Heath) have been measured by stake and handheld GPS. In addition, the travel transect lines from site F to the hut and from site B to site E and to the hut have been surveyed and can be seen in Appendix 9.

The highest snow depths are found at the heath where the stake wasn't long enough to measure the actual depth, which is more than 2 meters deep. At other places the snow didn't cover the ground. In Table 4-2 the mean snow depths and standard deviations are seen for the areas measured (a map of the areas are seen in Figure 1-2 and 1-3), and in Figure 4-6 the box plots for the travel transects are seen.

On average the South Valley receives more snow than the remaining area. This is due to the fact that moist air masses always come directly from the ocean side, that is when the wind comes from West/Northwest, and thus reach the South Valley before the remaining area. Furthermore, the South Valley area is more confined and the snow may not move that far around, as well as the snow from the mountain ridge on the west side is blown down in the valley.

Table 4-2 Mean snow depths and standard deviations for all measurements done in April. The unit is [cm].

Site	**Grid F**	**Grid D**	**F to hut**	**B to E to hut**	**A**	**B**	**C**	**D**	**E**	**Mean**
Mean	85.1	59.3	72.2	55.2	66.5	64.2	61.9	60.5	51.8	64.1
Std.dev.	26.9	39.8	28.9	31.9	9.8	19.0	16.1	16.1	14.4	22.5
Remarks	Stake	Stake	Stake	Stake	Stake	GPS	GPS	Stake	Stake	Both

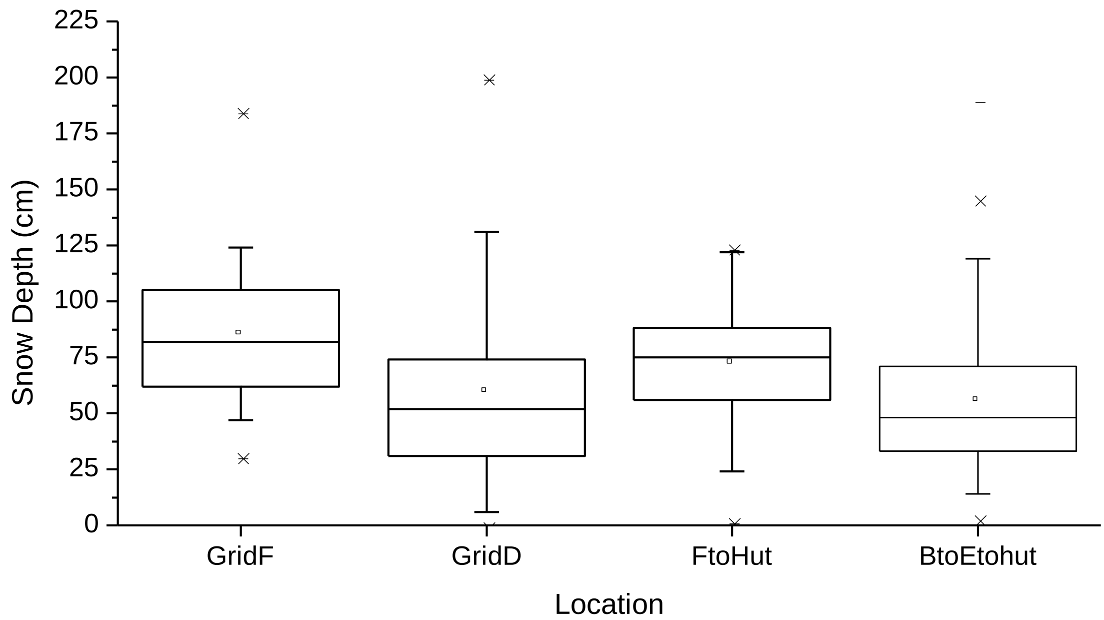


Figure 4-6 As Figure 4-4, but from the travel transect lines measured during the April survey.

4.4 Comparison of snow density methods

Two methods of density measuring were tested during the March survey; a tubing method and a rib cutter method.

In Table 3-2 the mean densities and depths of the tubing sites are seen, as well as the differences between the snow pit sites and tubing site parameters. Since the tubing densities were taken at the transect corners of the site and the rib cutter densities were taken at the center of the site, there of course will be some differences in the densities due to the varying depths, since a deeper core causes a higher mean density due to compression of the snow above.

However, it is noticed that there is no clear trend regarding the Δ densities and the Δ depths. It was anticipated that for a larger depth (when comparing corners and center, i.e. A2 and A1), there would simultaneously be a higher mean density. This is not the case, for instance with B4 and B1. Here the density at B4 is 19% lower with an 11% higher depth. This could of course occur if there has been very recently a snow fall, which would have added a lot of light snow and the remaining snow pack didn't have time to adapt to the added snow mass. However, that would require an unrealistic snow fall of a few meters, or a very uneven snow fall, which is also unrealistic given the small distances between the sites (50m). In addition the climate stations and the visual impression gave no reason to think that any snow had fallen in the days before the survey. Therefore it is assumes that too many uncertainties are connected to the tubing method; for instance by getting the tube pressed through the ice layers, by keeping all snow in the tube while lifting it up from the hole ~~and~~ while weighting the tube, and by making sure the tube is completely empty before a new tube is filled. It is at the same time difficult to find out whether or not the entire snow column is collected in the tube as the snow is being compressed during the collection and therefore it is not possible to determine if there is, for instance, 60cm of snow (measured by the stake) since it may only fill out 52cm inside the tube. So even though the method is extremely easy and quick compared to digging a snow pit, it is difficult to get a reliable result.

5 Conclusion

This report presents snow depths and densities in Kobbefjord measured in March and April 2014 using different methods.
The measurements were concentrated at Soil Fen (A), Soil EmpSa (B), Soil Emp (C), Heath (D), Climate station (E) and South Valley (F). Five snow pits were analyzed to calculate densities and to describe the snow properties. All data including stake, GPS RTK measurements and snow pits are available as appendices.

Snow depths for the surveyed area ranged from 0 to above 200cm, with a mean depth of 66.1cm, a mean density of 294.2kg/m^3, a mean temperature of -5.1°C and a mean snow water equivalent of 19.6cm.

The GPS measurements taken at B and C is considered to be the best method to obtain snow depths as the hard ice layers can be difficult for the stake to penetrate through causing too low snow depth values. This is avoided when considering height above ground measured by GPS. However, for specific soil surfaces (e.g., fen) the stake method or a combination of the two methods is recommended to obtain a value for the, at times very substantial, ice layer at the bottom (more than 20cm).
Snow densities measured in snow pits yielded the most accurate results while the tubing instrument is, due to larger uncertainties, not recommended. The difference between the densities measured at the corners and the center ranged from -27 to 66kg/m^3, corresponding to an error of +/-10-35%.

6 References

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