Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

CryoVex 2006

Field Report

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Executive summary

This report provides an overview of the ground and airborne measurements performed north of Alert/Ellesmere Island during the ESA-funded CryoVex 2006 sea ice campaign between May 11 and 15, 2006. During the field campaign, a wide range of snow and ice measurements have been performed on two main study sites. Site 1 was a patch of rather level multiyear ice, while Site 2 was very level first year ice. Measurements comprised snow and ice thickness drilling, levelling of surface elevation, and snow pit studies. On each site, two corner reflectors were installed to support airborne radar altimeter measurements with ESAs Airborne Synthetic-Aperture Interferometric Radar Altimeter System ASIRAS. ASIRAS and a laser scanner were operated on board a Greenlandair Twin Otter. Ice thickness was also measured along coincident flight tracks by means of helicopter-borne EM thickness sounding. Thus, an extensive data set of surface elevation, snow thickness, ice thickness, and snow thickness was obtained. The report serves as background information for validation studies of ASIRAS measurements over sea ice.

1. Introduction

The CryoVex 2006 spring sea ice experiment was undertaken by investigators from AWI, FIMR, SAMS, and DNSC. The overall goals were the following.

1) High Priority Goals
Assessment of i) the influence of deep snow cover on CryoSat retrievals and ii) the validity of the overall validation concept of overlapping ground, helicopter, aircraft and satellite tracks over moving ice. To meet these objectives the following actions were required:

For objective 1-i) (snow influence)
- Identification of deep snow area overlaying ice (more than 30 cm) preferably in static/non-moving ice zone
- Installation of corner reflectors and detailed characterisation of snow/ice conditions including ice thickness for the area beneath the flight tracks.
- Acquisition of joint helicopter (HEM) and ASIRAS/Laser data over a wider area

For objective 1-ii) (validation concept)
- Install at least some of the buoys beyond the shear-zone to characterise drift and permit post-campaign simulation of validation concept
- Simulate a validation line with using helicopter and ASIRAS/Laser acquisitions compensating for drift and extending beyond shear zone

2) Lower Priority Goals
Assessing the in detail the three dimensional structure of ridges in a small area.
This objective required
- characterisation of ridge properties on ground
- over-flights with the helicopter and ASIRAS/laser.

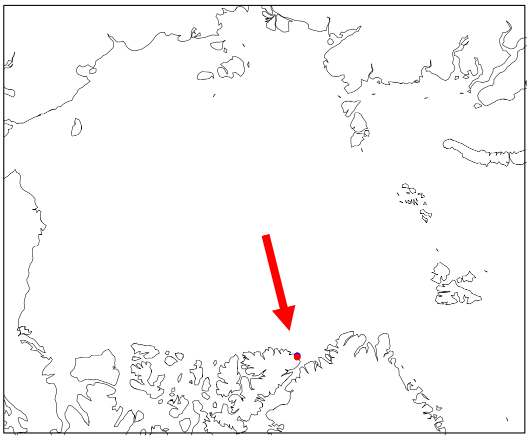

Figure 1: Map of the Arctic Ocean, showing the location of the validation sites north of Ellesmere Island as red dot.

2. Ice and weather conditions during the study period

2.1 Ice conditions observed by means of SAR imagery

The ground activities of CryoVex 2006 were performed on immobile ice north of Alert. This ice became landfast in December of 2005, and consisted of heavily ridged multiyear ice. During the freezing process divergent ice motion and shear occurred as well, and therefore small regions of first year ice formed on the resulting open water were included in the region of fast ice as well. One of these first-year ice patches was used as a validation site (site 2). The region of heavily deformed multiyear fast ice can be seen as a bright feature on the SAR image in Figure 2. The interspersed dark spots represent the first year ice.

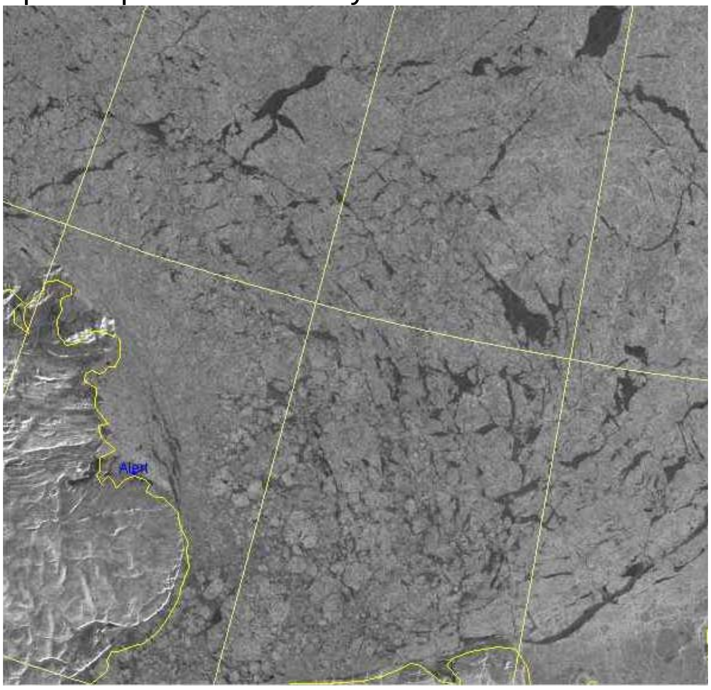

Figure 2: Envisat SAR image of the Lincoln Sea acquired on April 19, 2006, showing the region of fast ice north of Alert consisting of MY and FY (dark) ice.

2.2 Weather conditions

Weather during the field campaign was rather optimal for all operations. Most of the time clear sky condition prevailed. Data of an automatic meteorological station in the Alert is shown in the Figures below. Surface air temperature varied from -12 to -2 C. During the ASIRAS coincident flights days, 11 - 12 May 2006, air temperature was from -6 to -2 C. The wind speed was low all the time. The maximum wind speed was 4 m/s on 10 - 15 May and during the ASIRAS incident flights the wind speed was practically zero.

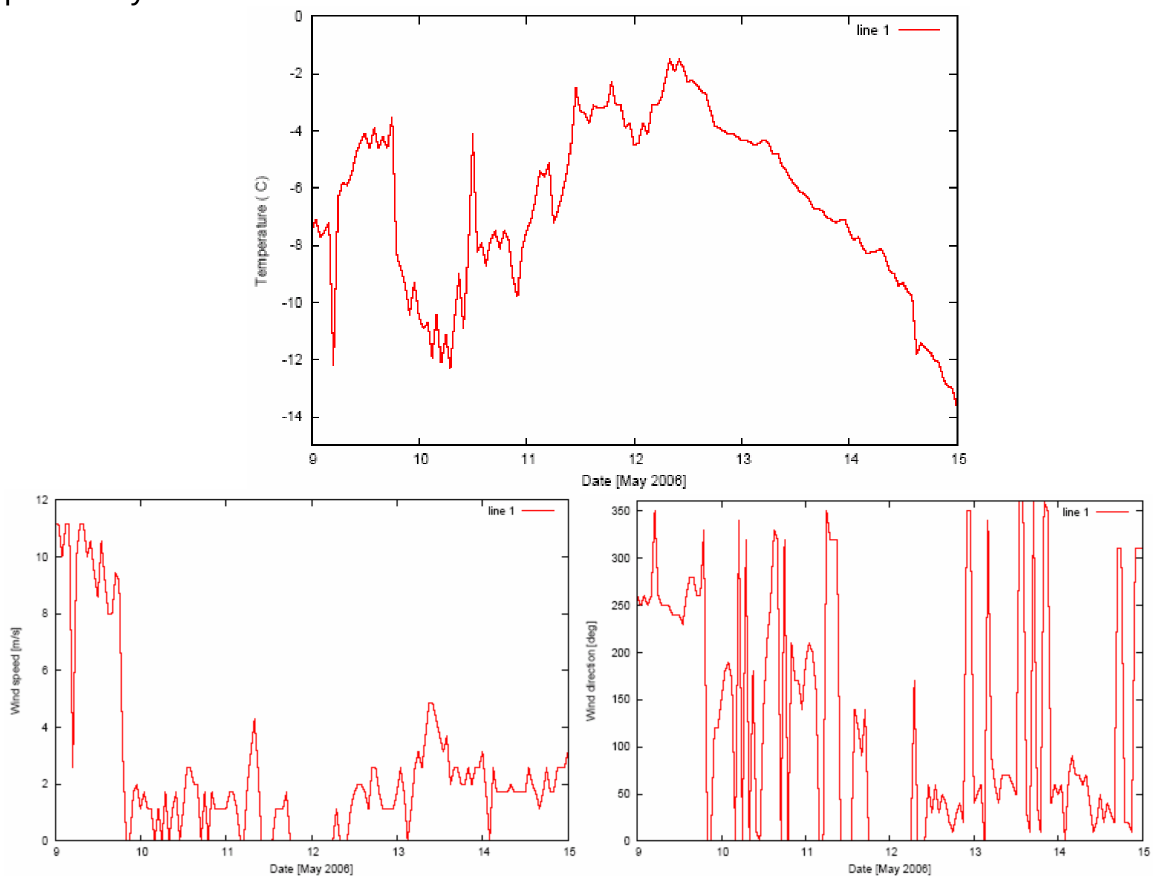

Figure: Air temperature (top),wind speed (left), and wind direction during CryoVex2006.

3. Overview of corner reflector deployments on MY and FY validation sites

Two patches of predominantly level ice were chosen as main validation sites (Fig. 3), with two corner reflectors installed on each. Both sites were on the narrow band of fast ice which has formed along the coast off Alert, composed of mostly multiyear ice floes and rubble. Site 1 was on multiyear ice (MYI), only approximately 5 km away from Alert. This site has repeatedly been visited by skidoo, despite heavy ice ridges along the route. Site 2 was approximately 10 km north of Alert, on first-year ice (FYI). This site was only reached by helicopter. Table 1 summarizes the main

characteristics of all corner reflector installation sites. Corner reflectors on each site had a spacing of approximately 120 m.
Care was taken to keep the snow cover as unaffected by the installation as possible. The aerial photos in Sections 5 and 6 demonstrate that only the minimum amount of foot prints were generated.

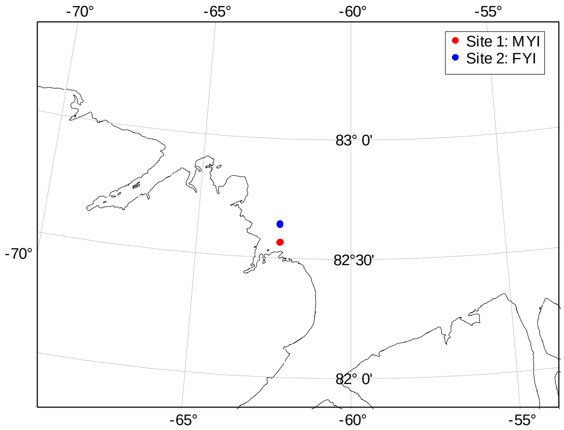

Figure 3: Map of the Lincoln Sea, showing location of validation sites on MYI and FYI.

Table 1: Main characteristics of corner reflectors. Positions were measured with a hand-held GPS. Reflector height was measured with a ruler tape from lowest tip of reflector to surface.

	Latitude (°N)	Longitude (°W)	Mean snow thickness (m)	Corner reflector height above snow surface (m)
Site 1 MYI				
Flag 1	82.56385	62.25853	0.33	
CR 1	82.56353	62.26116	0.42	1.46
CR 2	82.56271	62.26793	0.72	1.50
Flag 2	82.56198	62.27443	0.70	
Site 2 FYI				
Flag 1	82.64050	62.29175	0.39	
Flag 2	82.64001	62.29173	0.31	
CR 1	82.63943	62.29180	0.26±0.01*	1.53
CR 2	82.63823	62.29201	0.29±0.02*	1.44
Flag 3	82.63675	62.29240		

* Snow thicknesses are probably biased by impossibility of measurements through hard wind slab snow, and do probably only represent the upper soft snow thickness. See Section 5.3 for more remarks.

4. Methods

4.1 Thickness drilling

The drillings were made along the calibration line in the both sites. The drilling were made with the Kovacs ice auger. The procedure of the drilling was following

1) locate drilling points by the tape measurement
2) remove snow layer
3) measure snow thickness
4) drill by the auger drill
5) measure ice thickness by the Kovacs tape measure
6) measure ice freeboard by the ruler

Accuracy of the ice and snow thickness measurements is 1 cm. Determination of the ice freeboard was also possible to make in 1 cm accuracy in those points where the freeboard was less than 25 cm. When the freeboard was high (> 50 cm) the ruler measurements was more difficult to make and it resulted about 2-3 cm accuracy.

Figure 4: Ice thickness drilling

4.2 Ice coring

Ice cores were taken close to corner reflectors CR2 and CR4. The Kovacs Mark II coring system which retrieves a 9 cm diameter core was used. The procedure of ice coring was the following:

1) remove snow layer

2) take the ice core with the 9 cm Kovacs core drill
3) place the ice core on the canvas
4) take photo of the ice core
5) cut the core in 10 cm slices
6) measure volume of the slices
7) measure weight of the slices
8) melt the slice and measure water salinity

5. Site 1: MYI

For Site 1, an approximately 200 m x 200 m patch of level MYI was chosen. It was surrounded by large ridges and heavy rubble. However, the snow surface at the site and between the corner reflectors appeared very smooth. Figures 5 and 6 show aerial photographs of the sites.

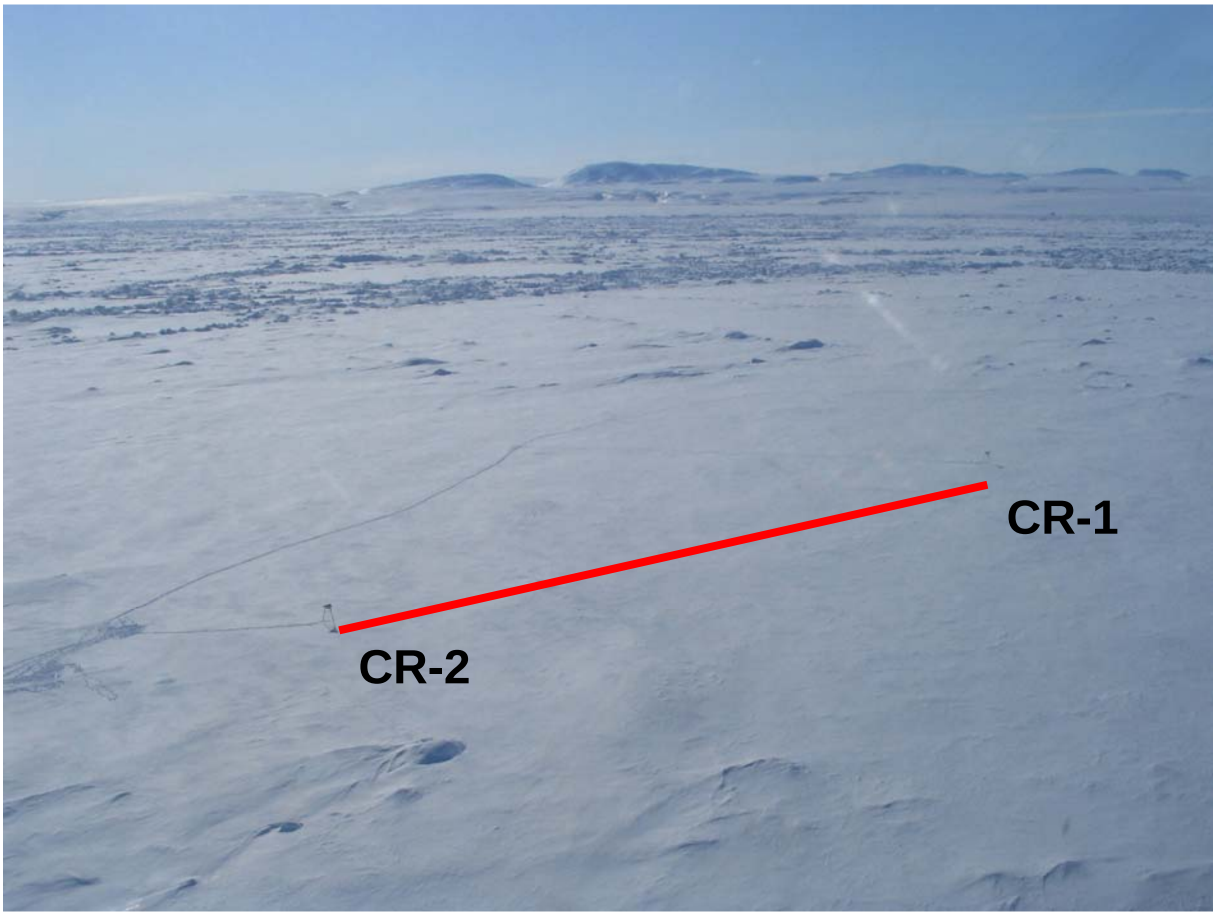

Figure 5: Aerial photo of Site 1 on MY (view towards South)I, showing the two corner reflectors just after the installation, with minimum snow disturbance by foot steps.

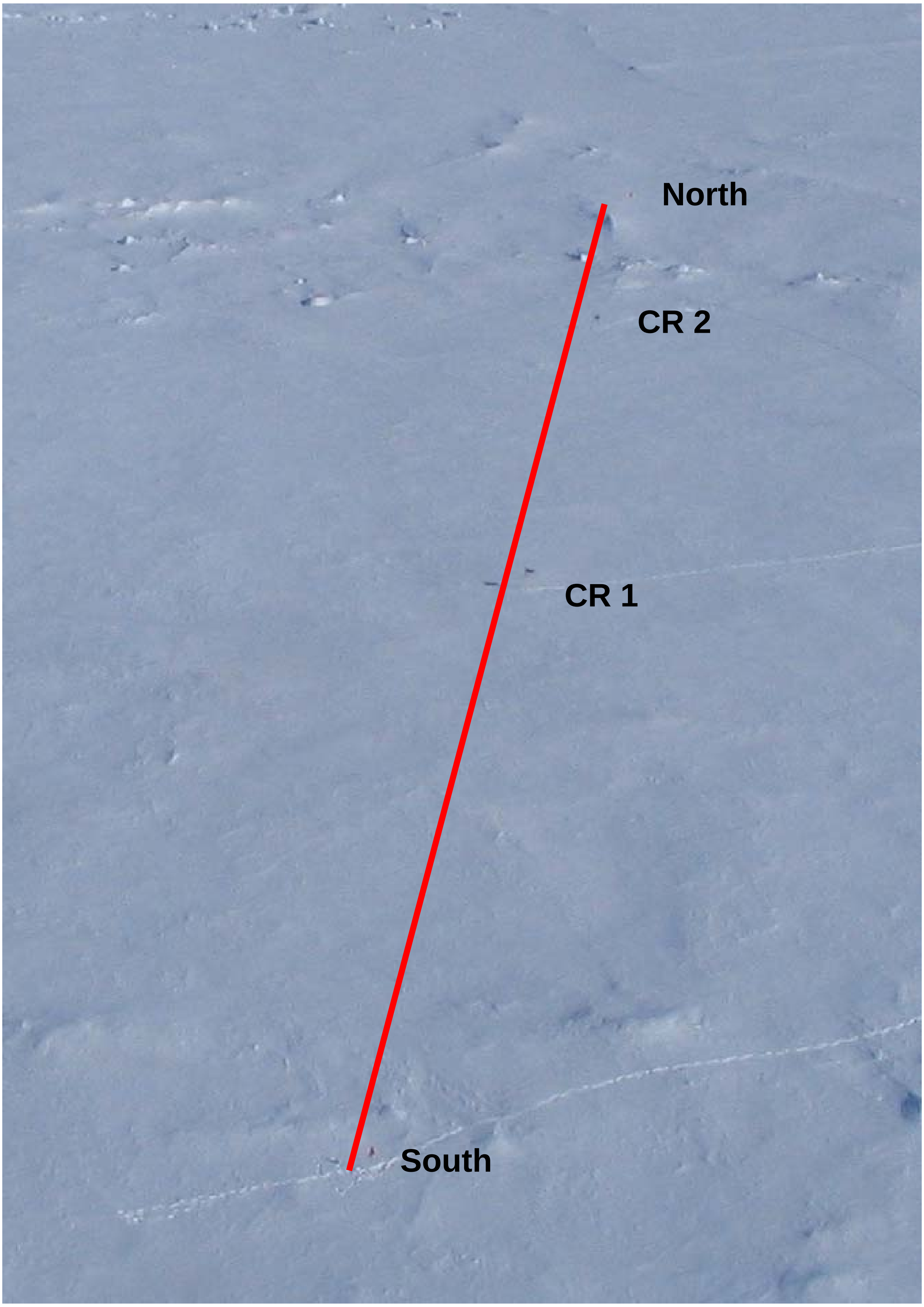

Figure 6: Aerial photo of Site 1 on MYI (view towards North), showing the two corner reflectors and flags just after the installation, with minimum snow disturbance by foot steps.

Figure 7: Photo of both corner reflectors installed on Site 1 on MYI, with the coast of Alert in the background. CR 2 is in the foreground.

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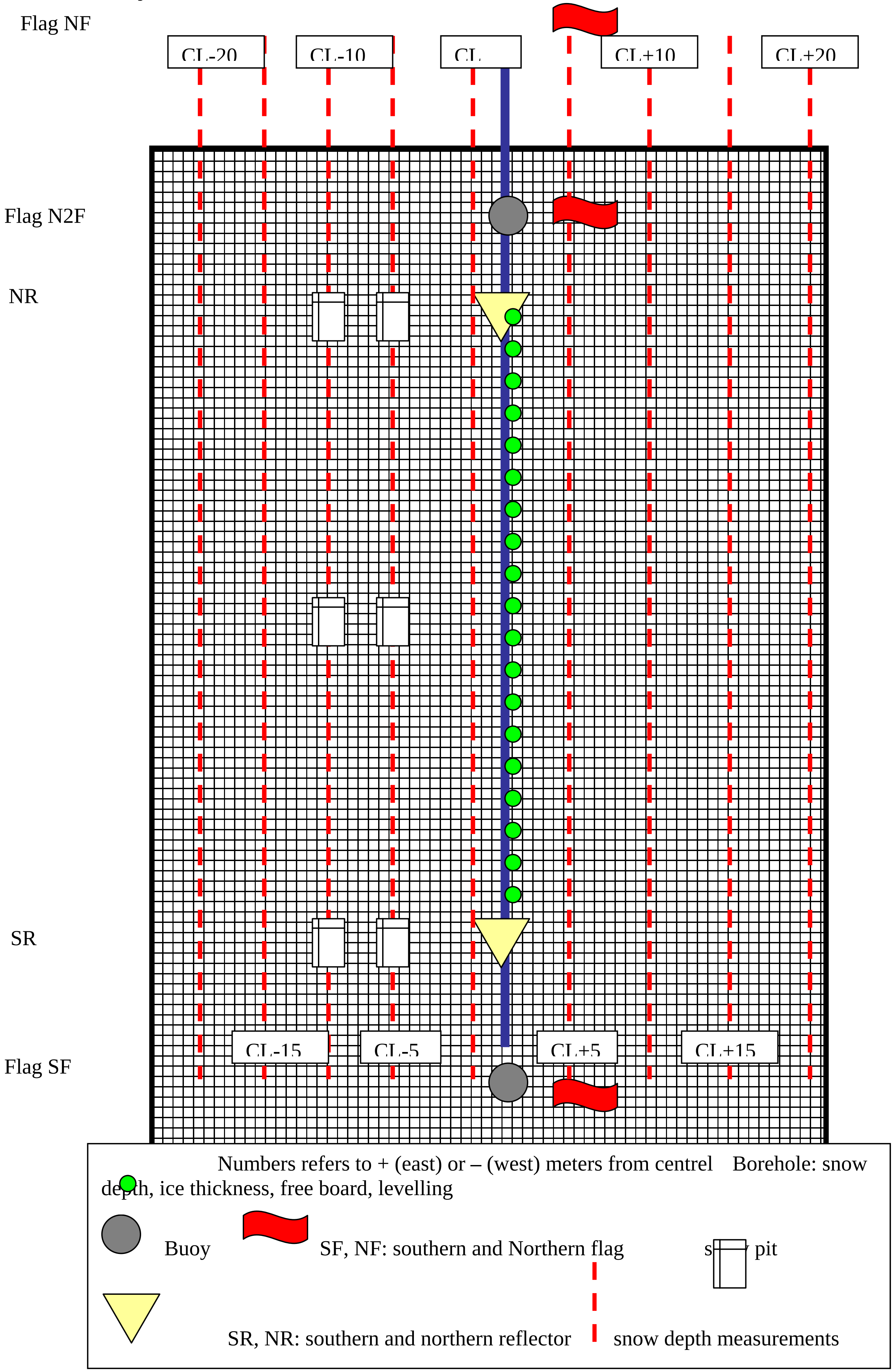
Overview of Site 1, MYI
Alert May 2006



5.1 Ice thickness profiles

In the MYI site 30 drilling's were made. The horizontal spacing was 7.5 meters both in the level and the ridged ice regions. The measurements cover a line between the corner reflectors and part of the old weathered ridge at the northern side of the validation line.

The mean level ice thickness of the MYI was 4.95 m. The minimum and maximum level ice thicknesses were 3.13 and 6.49 meters, respectively. The ridge had a solid consolidated top layer of 2.85 to 6.65 meters. Maximum measured thickness of the ridge was 15 meters. Due to the few drilling of the ridge, detailed characteristics, such as total ice volume, shape and void fraction of the ridge shape can't derived from the measurements.

Snow thickness was very variable along the validation line. In the level ice region the average snow thickness was 0.46 m. Minimum and maximum snow thickness were 0.13 and 0.9 meters, The large variability in the snow thickness is probably because of an accumulation of snow to the melt ponds due to the wind drift. The maximum snow thickness were measured in the over the ridge.

An average freeboard from top ice surface to water level was 0.39 m. The minimum freeboards were measured in the locations where the snow thickness was highest. In several points, the freeboard was below 0.1 meters and a measured minimum freeboard was 0.01 m, although the ice was more than 3 meters thick. The maximum measured freeboard was 0.71 m.

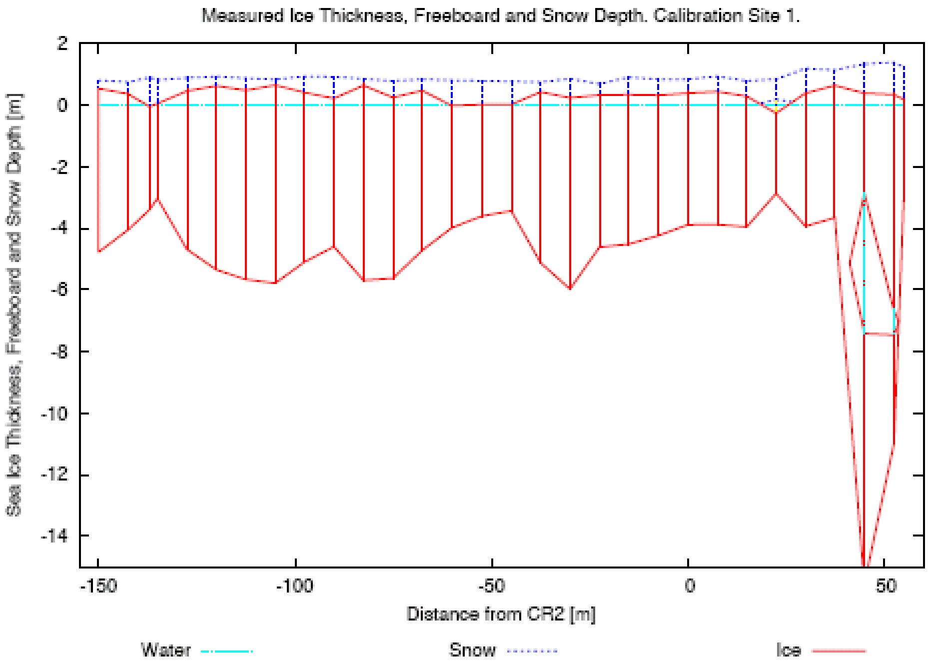


Figure 8: Ice and snow thickness and freeboard along the validation in the MYI site

5.2 Ice core salinity and density

The ice core was taken close to the corner reflector 2. A total thickness of the core was 4.96 meters. The whole core was managed to drill without distribution of sea-water oozing to the drill hole. Average salinity and density were 1.39 PSU and 890.8 kg/m^3, respectively.

Figure 9: Photo of ice core drilled at site 1.

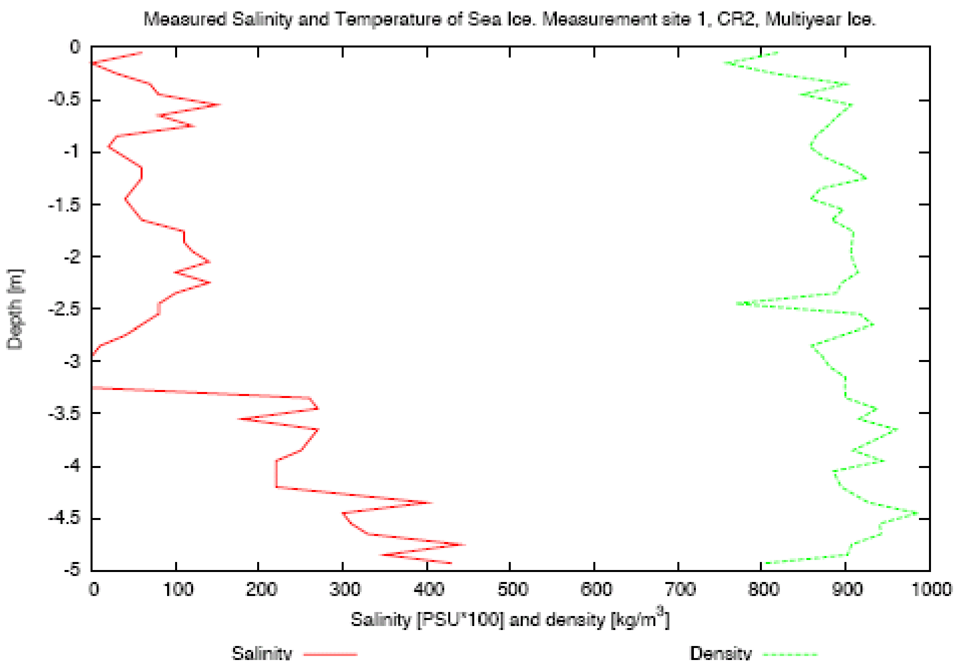


Figure 10: Salinity and density profile of the MYI.

5.3 Snow thickness

Snow thickness was measured by means of a snow stake connected to a data logger for easy data recording (Snow-Magnaprobe, M.Sturm, CRREL, USA). On site 1, nine lines with a spacing of approximately 7 m were measured, with a point-spacing of approximately 5 m along the lines. The mean snow thickness along each line was 0.28 +/-0.19 m. However, it should be noted that this number is much smaller than the 0.46 m measured at the drill holes (Section 5.1). The difference is due to the presence of extremely hard windblown snow at depths of 10 to 20 cm below the snow surface (Section 5.4), which could not be penetrated by the snow stake. Therefore, the snow thickness measurements performed on the grid between the Corner Reflectors rather represents the thickness of new, soft snow above the hard wind slab layer.

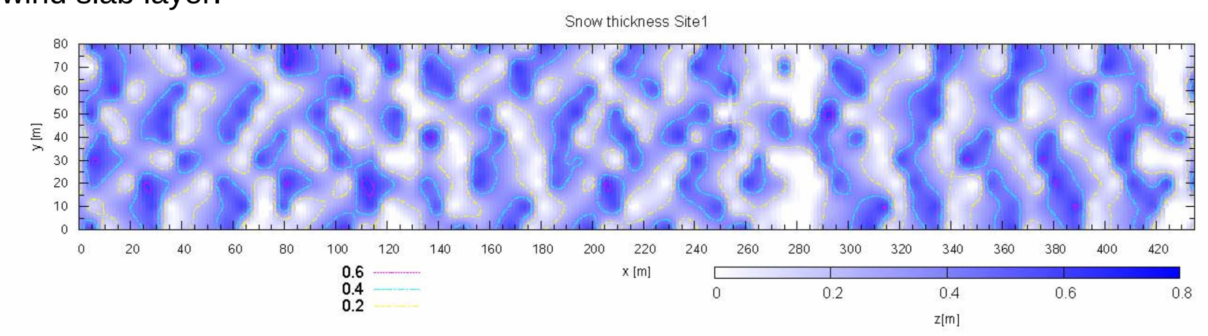


Figure 11: Snow thickness map of site 1, measured with the Magnaprobe. Corner reflectors are at Y=40 m on each side of the grid. Note uncertainty of snow thickness measurement due to presence of hard windblown snow.

5.4 Snow pit studies

Six snow pits were dug on site 1, on May 13. Snow temperature, salinity, density, and texture and stratigraphy were measured. The snow at site 1 was partially extremely dense and hard, so that the snow thickness stake could not penetrate to the snow/ice-interface, thus biasing the snow thickness measurements (Section 5.3). Underneath the hard layer, there was a layer of large depth hoar crystals (Figure 12). Figures 13-15 summarize the measurements at all six snow pits. Pits were identified by the proximity to a corner reflector, and by their distance to the center line, which was 5 or 10 m away. Please note that the salinity of all samples was 0, as expected for multiyear ice with high freeboard.

Figure 12: Depth hoar sample from site 1, snow pit SR10; Diameter of snow tube is 6 cm.

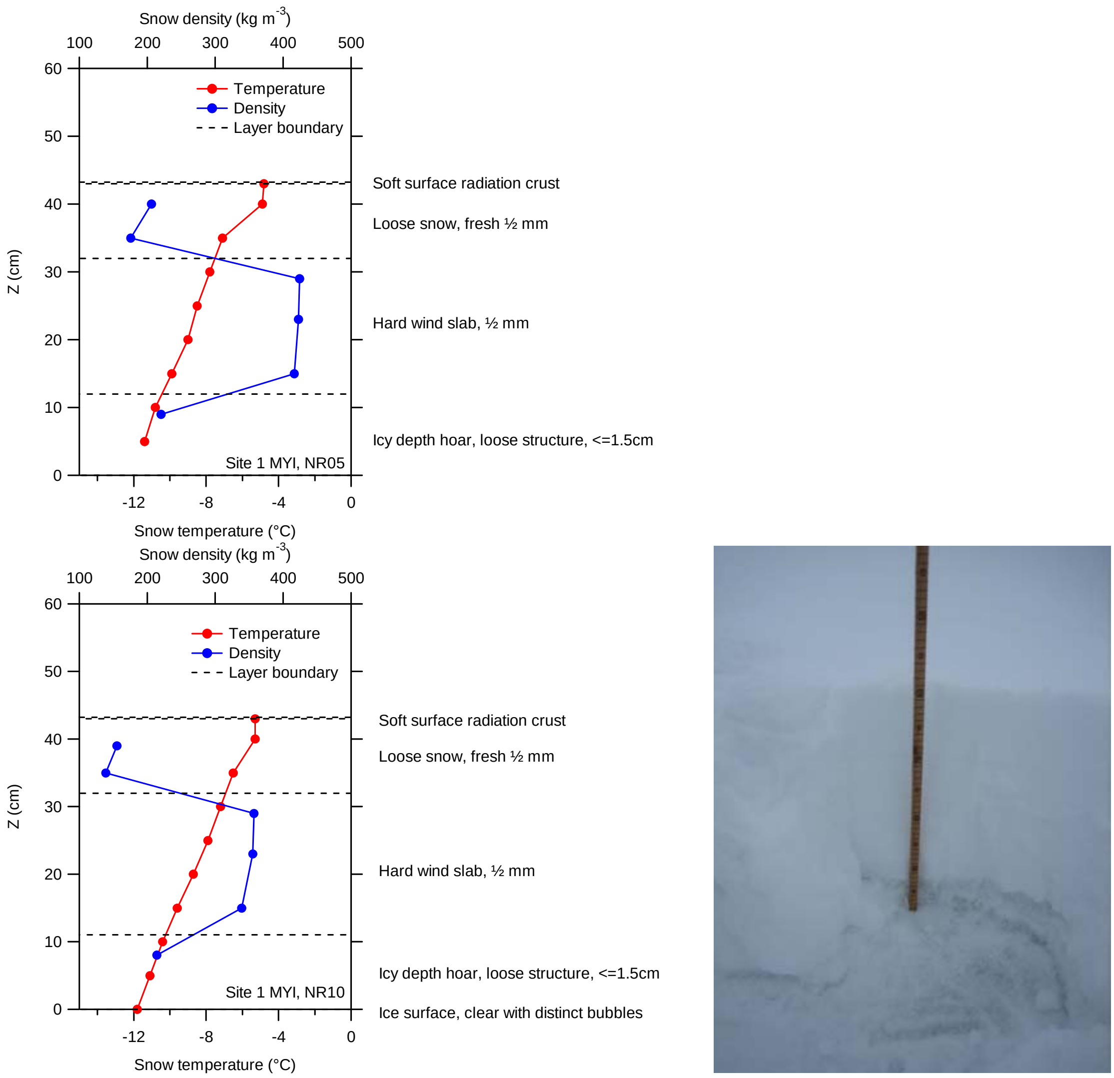


Figure 13: Snow pit data of site 1, pits NR5 (top) and NR10 (bottom)

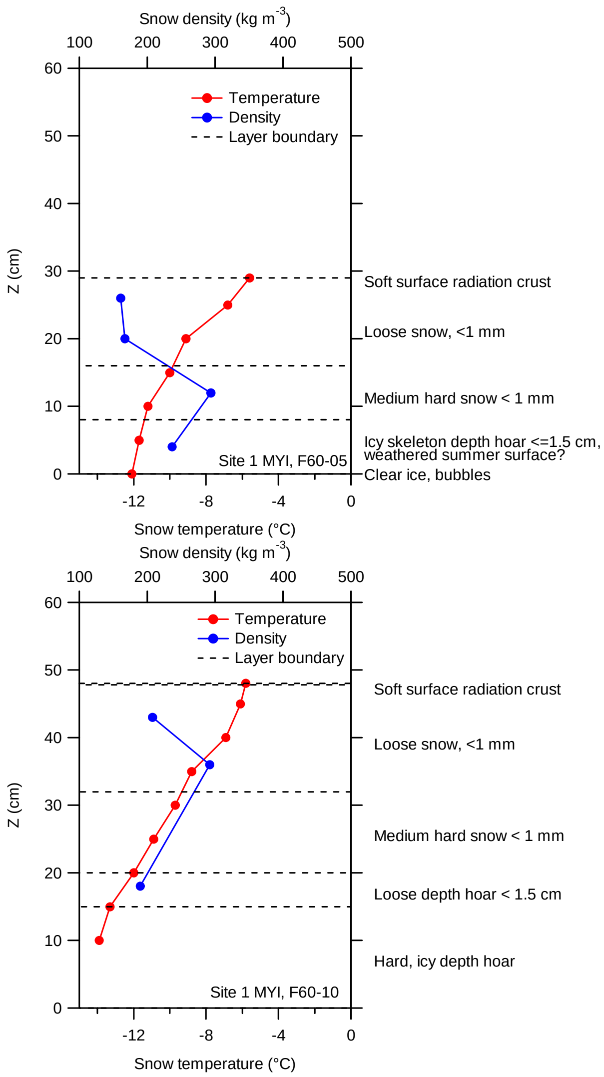


Figure 14: Snow pit data of site 1, pits F60_5 (top) and F60_10 (bottom), at 60 m of thickness profile.

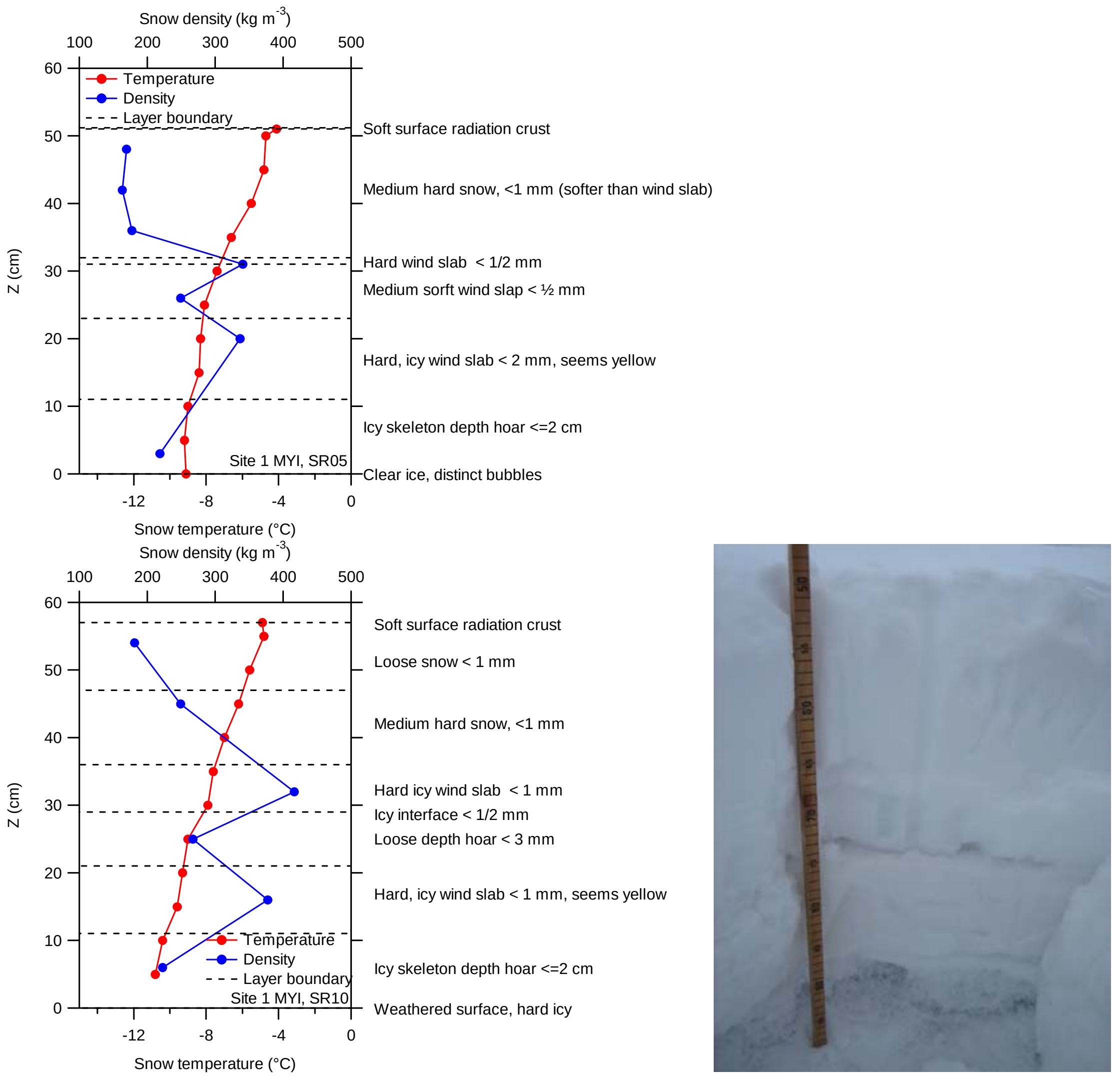


Figure 15: Snow pit data of site 1, pits SR5 (top) and SR10 (bottom).

5.5 ASIRAS flights

ASIRAS flights were performed over both validation sites on May 10. The sites were overflown several times, at different altitudes. Figure 16 shows a map of all flight tracks and derived surface elevations.

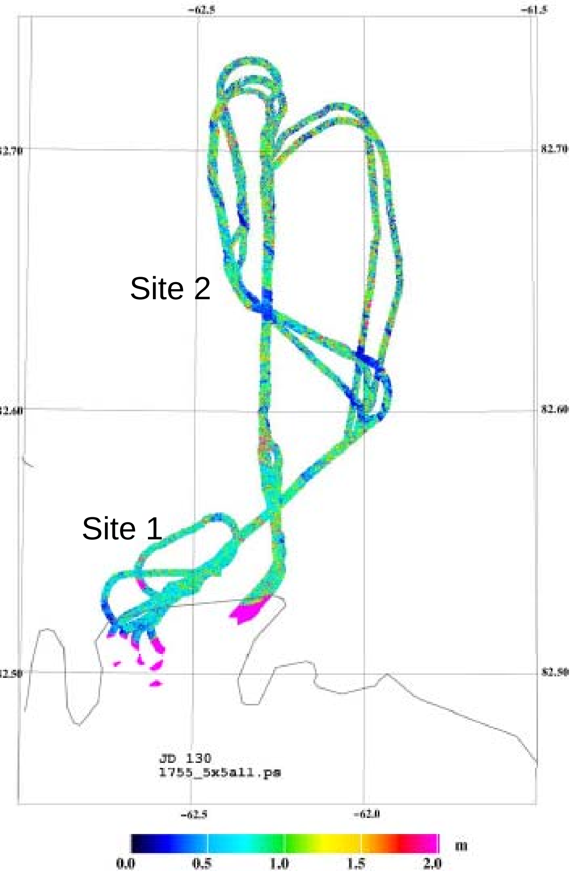


Figure 16: ASIRAS flight tracks of all validation site overflights on May 10

5.6 HEM flight lines

Site 1 was overflown with the HEM bird on May 11 and May 15. Figure 17 shows the tracks of all overflights. Two profiles were laid 50 m to the east and west of the main line. Note that the profiles were also extended to the northeast and southwest, and thus provide short but accurate coincident profiles with the ASIRAS overflights.

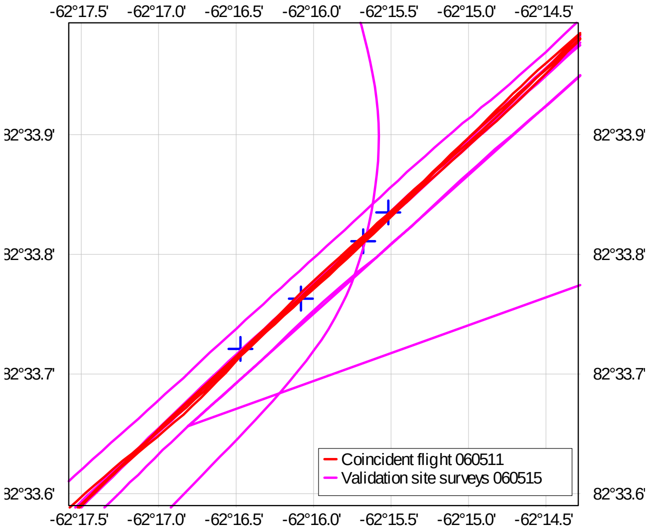


Figure 17: Map of HEM flight tracks over site 1.

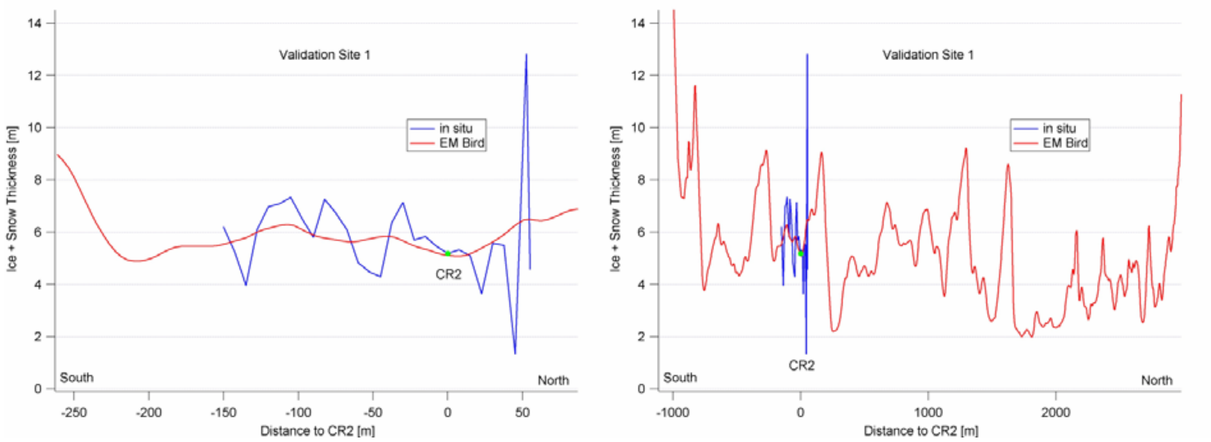


Figure 18: Comparison of HEM ice thickness profile over site 1 with drill-hole ("in-situ") data (cf. Fig. 8).

6. Site 2: FYI

For Site 2, an approximately 200 m x 200 m very smooth patch of level FYI was chosen. It was surrounded by large ridges and heavy rubble of MYI origin. The FYI has formed in a shear zone between MYI floes. Figures 19 and 20 show aerial photographs of the sites.

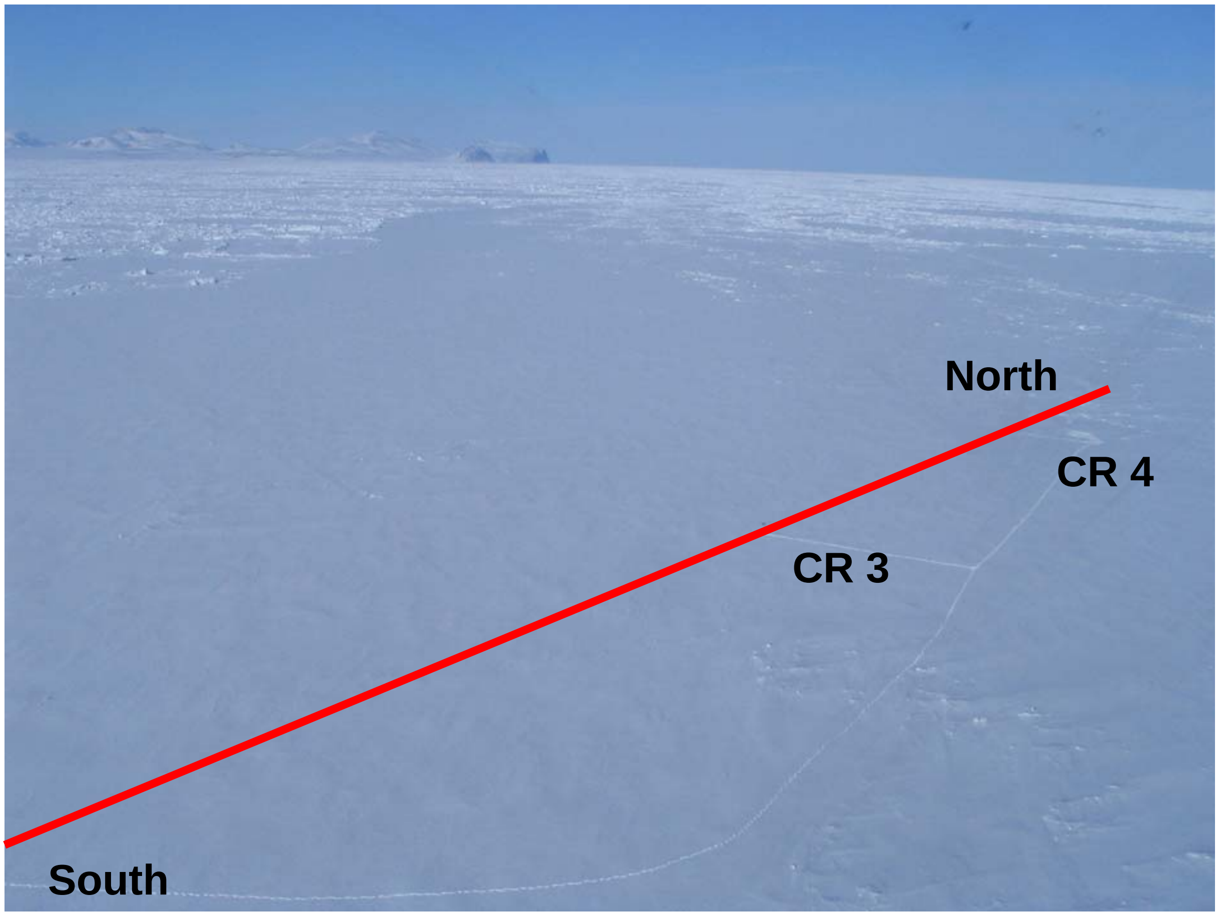


Figure 19: Aerial photo of Site 2 on FYI (view towards Northwest), showing the two corner reflectors and flags just after the installation, with minimum snow disturbance by foot steps.

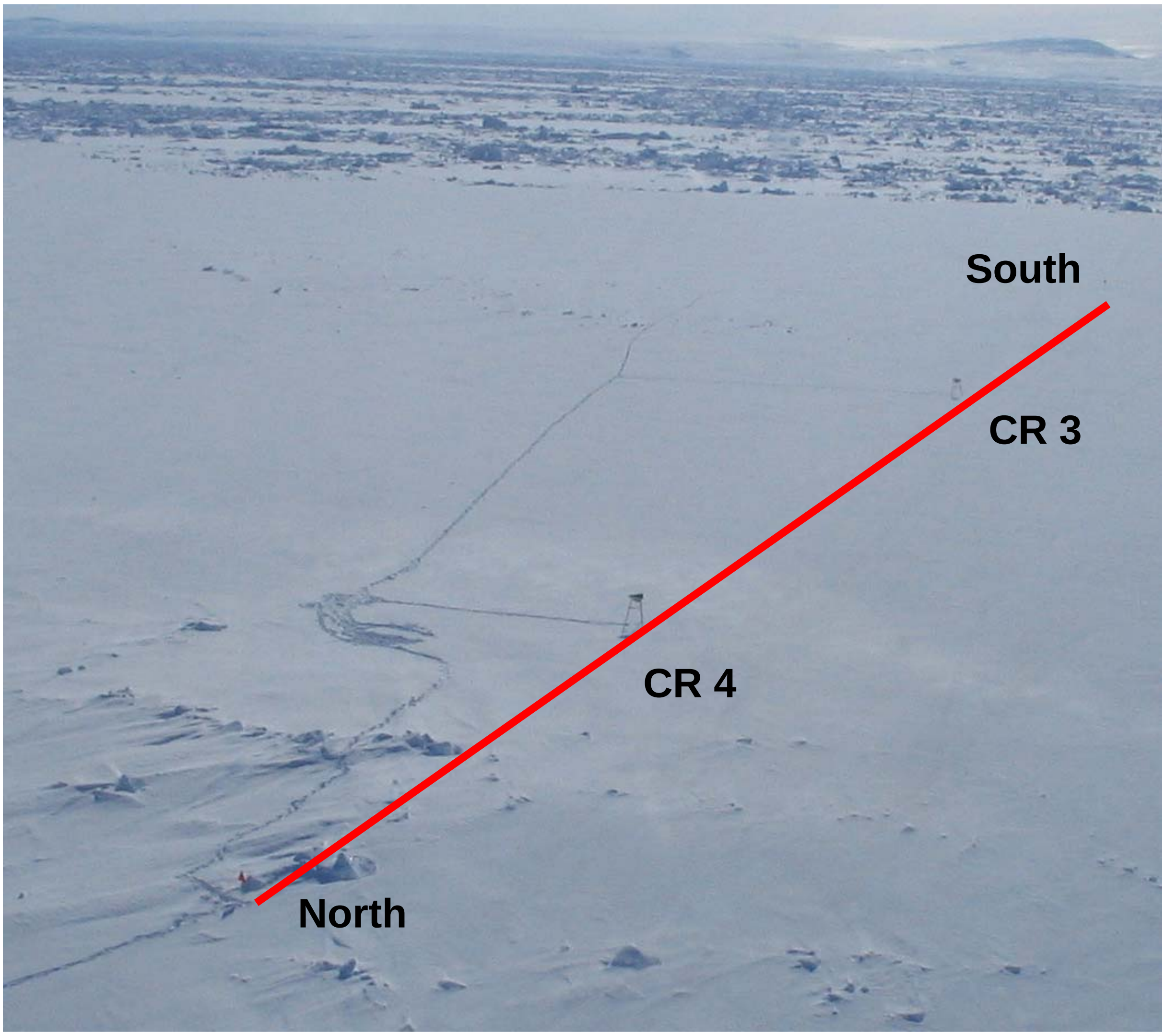
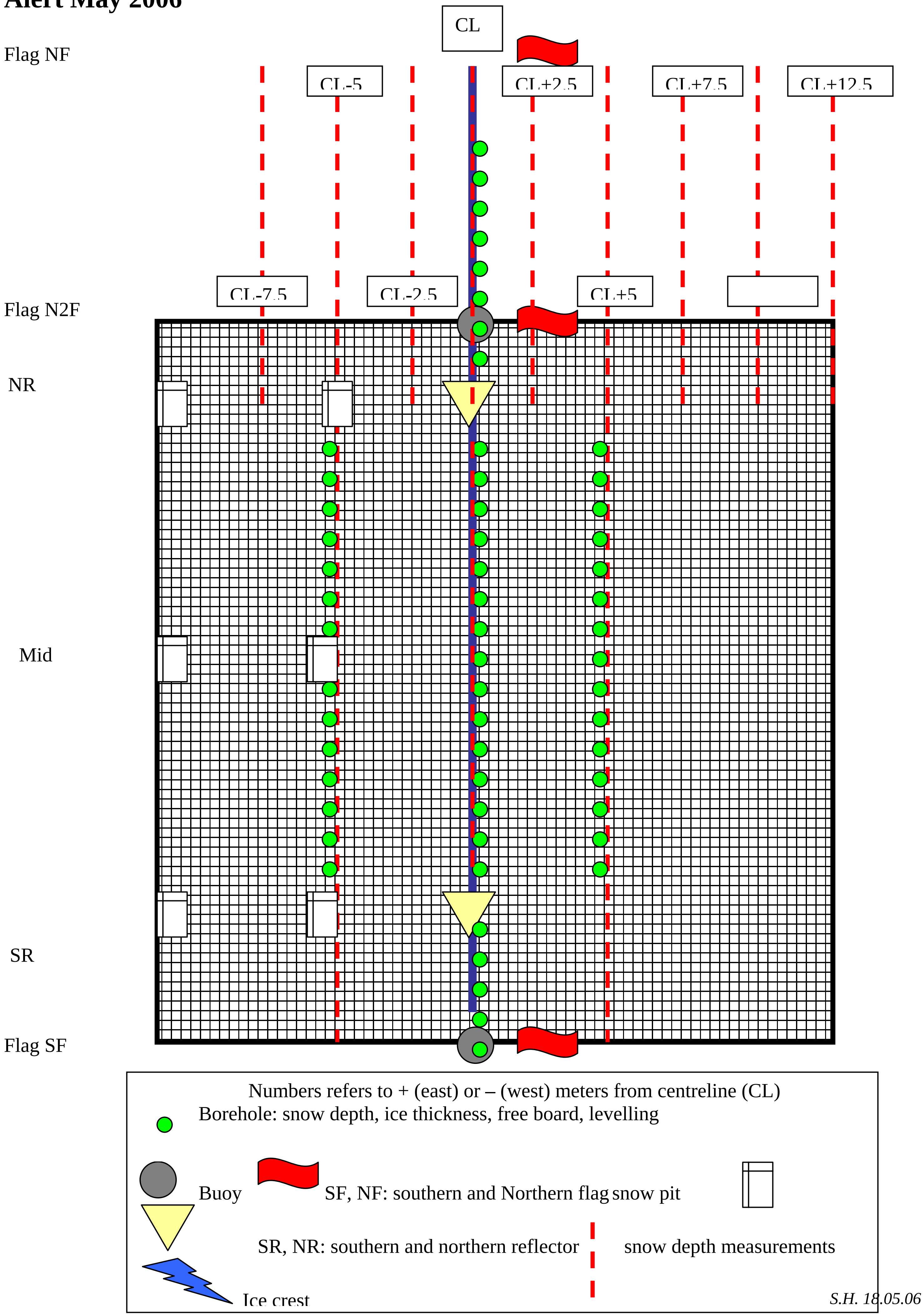


Figure 20: Aerial photo of Site 2 on FYI (view towards South), showing the two corner reflectors and flags just after the installation, with minimum snow disturbance by foot steps.


Figure 21: Photo of corner reflectors installed on site 2 on FYI, with the coast of Ellesmere Island to the West in the background.

Overview of Site 2, FYI
Alert May 2006



6.1 Ice thickness profiles

In the FYI site 57 drilling's were made. The horizontal spacing was 7.5 meters in the level ice region and 2.5 meters in the ridged region. The measurements cover a line between the corner reflectors and part of the new ridge at the northern side of the validation line.

The mean level ice thickness of the FYI was 1.34 m. The minimum and maximum level ice thicknesses were 1.18 and 1.49 meters, respectively. The ridge was rather small, the maximum measured thickness was only 3.3 meters. The parent ice thickness where the ridge was initially formed was 0.22 meters.

Snow thickness was rather constant over the level ice. An average snow thickness was 0.26 m. Minimum and maximum snow thickness were 0.2 and 0.35 meters. In the ridged ice region, the snow was much thicker and variable due to the accumulation of the drifting snow. The maximum measured snow thickness was 0.88 meters.

An average freeboard was in the level ice region was 0.07 m. The minimum and maximum values were 0.01 and 0.12 meters. In the ridge, a maximum freeboard was 0.47 meters and, as expected negative freeboards were measured between the ridge and level ice.

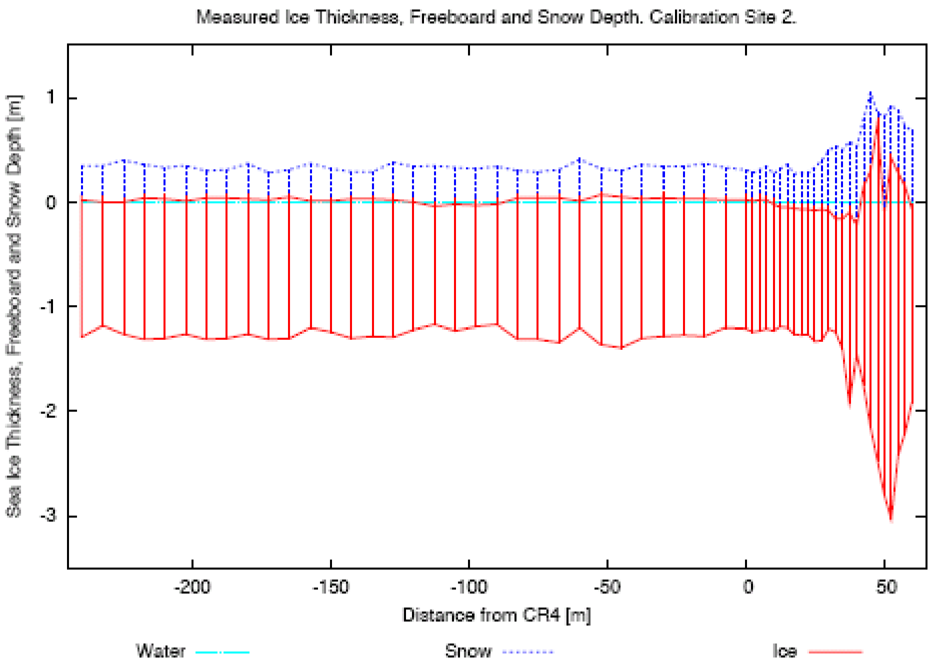


Figure 22: Ice and snow thickness and freeboard along the validation in the FYI site

6.2 Ice core salinity and density

Three ice cores were taken close to the corner reflector 4. Thicknesses of the cores were 1.34, 1.26, 1.28 meters. Every core was managed to drill without distribution of sea-water oozing to the drill hole. Average salinity and density were 1.39 PSU and 890.8 kg/m^3, respectively.

Figure 23: Photo of ice core drilled at site 2.

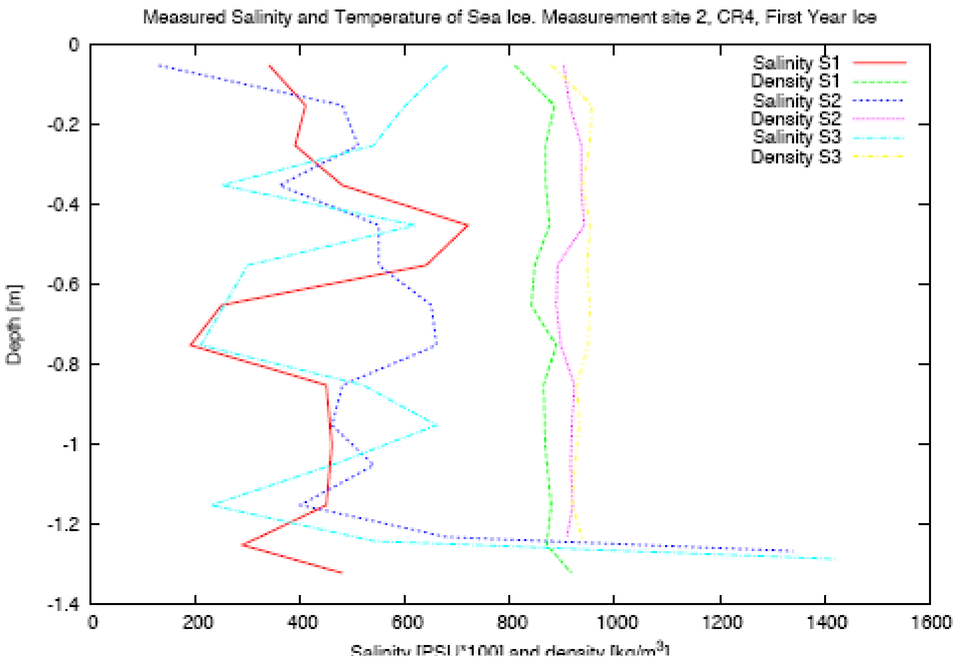


Figure 24: Salinity and density profile of the FYI

6.3 Snow thickness

In addition to the snow thickness measurements along the drill-hole profile, a region north of the northern reflector was extensively mapped by snow thickness measurements and surface elevation levelling for comparison with the laser scanner and ASIRAS profiles. Measurements have been performed with a point spacing of 2.5 m between individual points, along nine 100 m long lines. Figure 25 shows the results of those measurements. Freeboard was obtained by subtracting snow depth from surface elevation. Note that the snow was rather soft throughout, and therefore the accuracy of the measurements is very good, in contrast to the measurements on site 1 (see above). Over the levelling site, the mean snow thickness was 0.30 +/- 0.18 m.

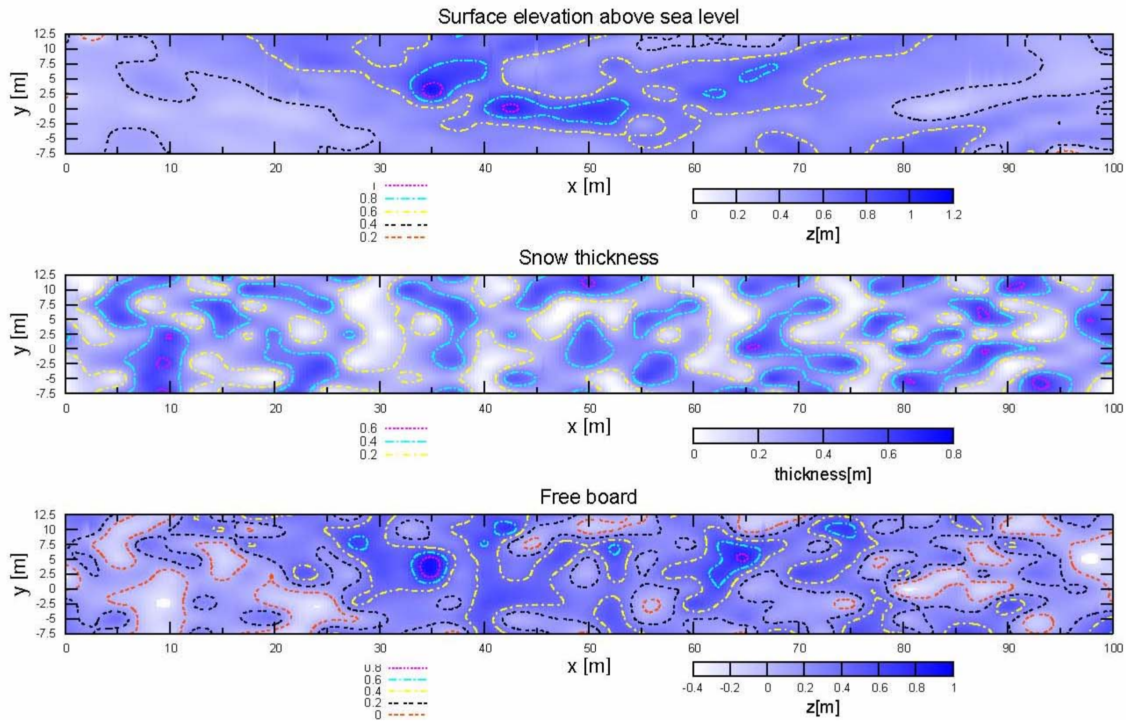


Figure 25: Results of measurements of snow thickness and surface elevation of a region north of the northern corner reflector on site 2.

6.4 Snow pit studies

Six snow pits were dug on site 2 on May 14. Snow temperature, salinity, density, and texture and stratigraphy were measured. Figures 26-28 summarize the measurements at all six snow pits. Pits were identified by the proximity to a corner reflector, and by their distance to the center line, which was 5 or 10 m away. Please note that the salinity of many samples was higher than 0, in agreement with the young age of the underlying ice.

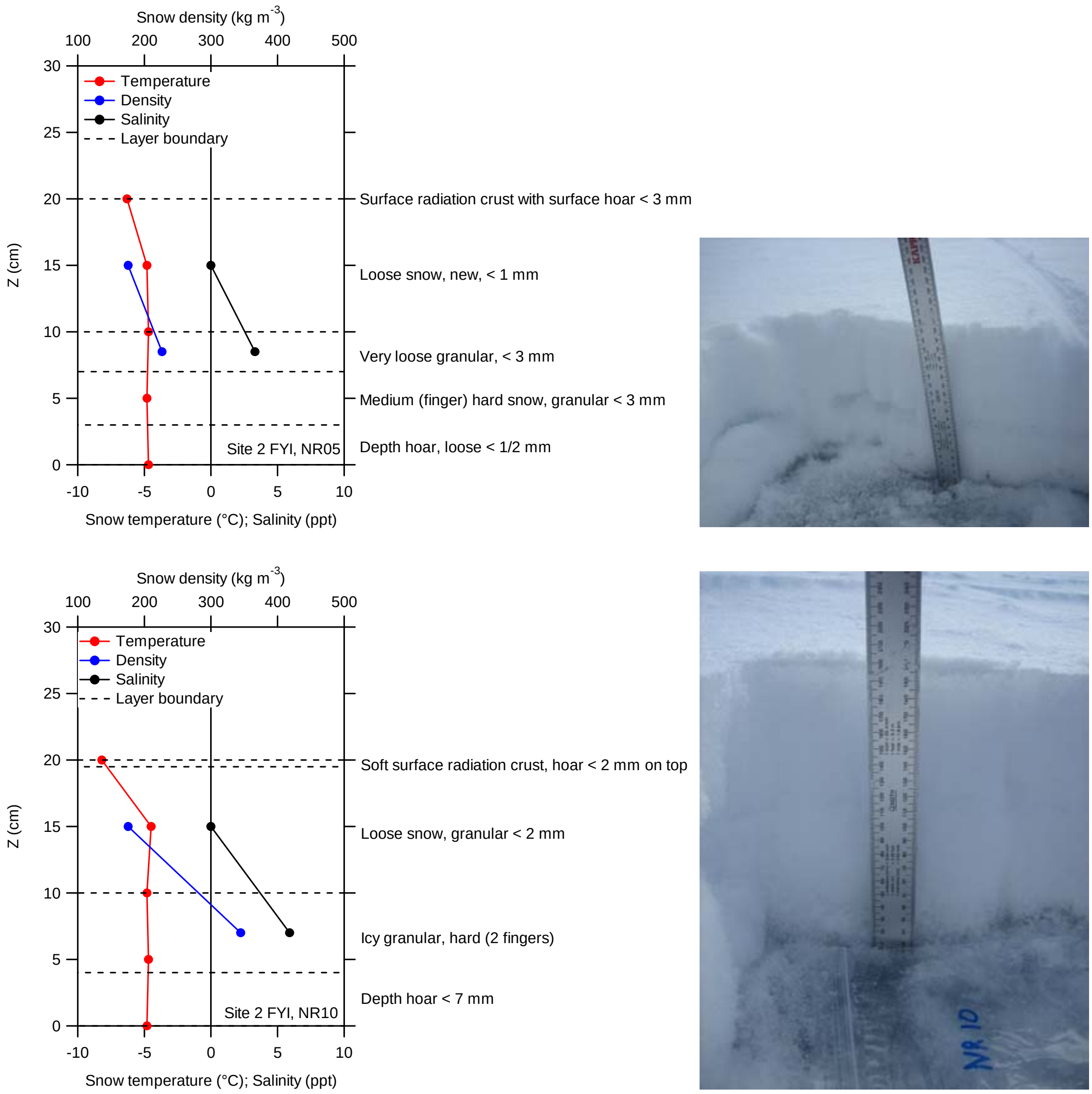


Figure 26: Snow pit data of site 2, pits NR5 (top) and NR10 (bottom).

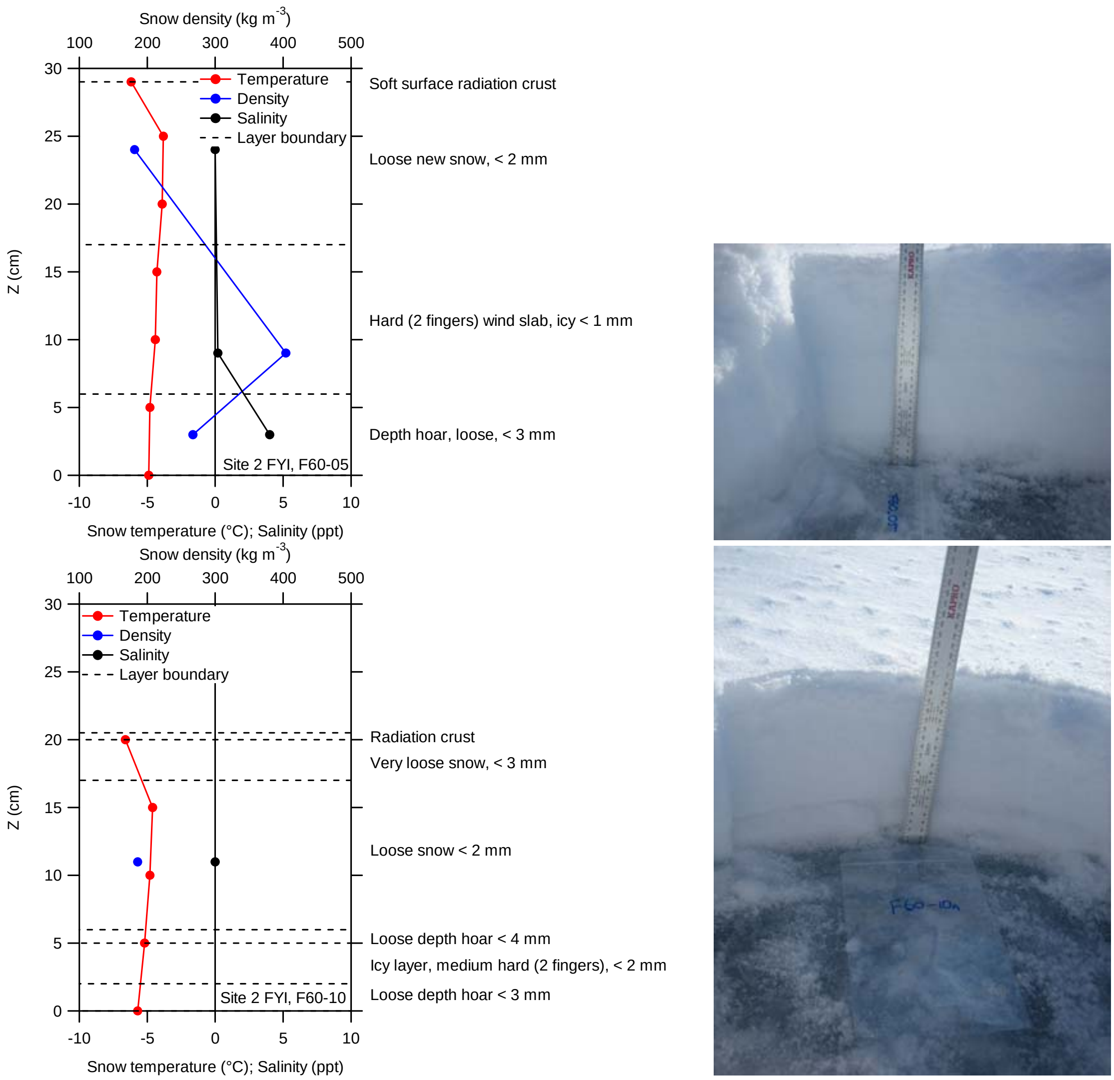


Figure 27: Snow pit data of site 2, pits F60_5 (top) and F60_10 (bottom), at 60 m of thickness profile.

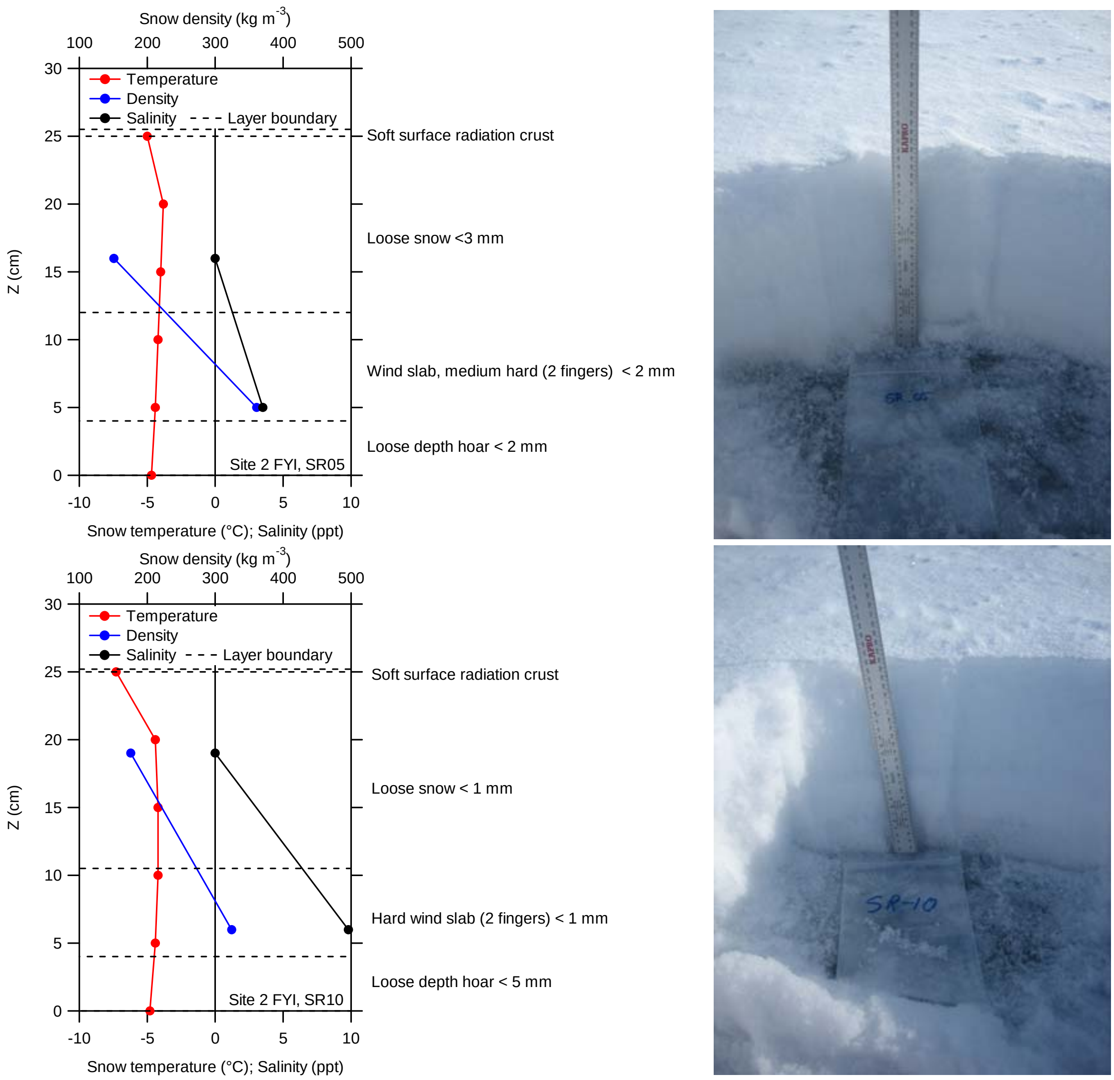


Figure 28: Snow pit data of site 2, pits SR5 (top) and SR10 (bottom).

6.5 Levelling

On May 16, the surface elevation of the region north of the main validation line on site 2 was surveyed, including a pressure ridge. This data can later be compared with the laser scanner DEM. Figure 29 shows a contour plot of the surface elevation of the surveyed region.

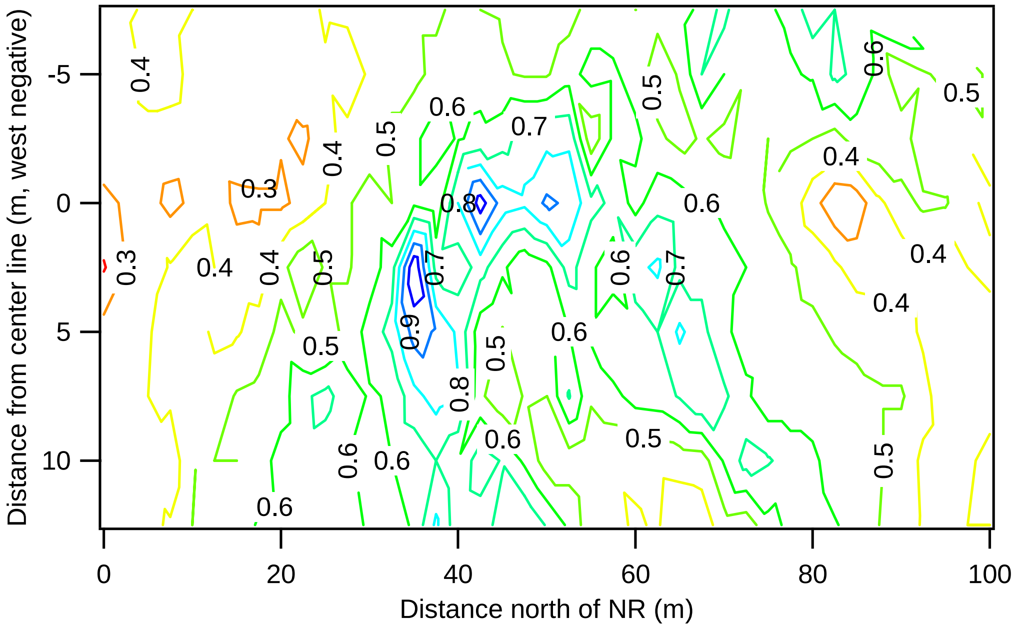


Figure 29: Contour plot of surface elevation of region north of northern reflector on site 2.

6.6 ASIRAS flights

Site 2 was overflown on May 10, together with site 1. A map of the flight tracks is shown in Figure 16.

6.7 HEM flight lines

Site 2 was overflown with the HEM bird on May 12 and May 15. Figure 30 shows the tracks of all overflights. Two profiles were laid 50 m to the east and west of the main line. Note that the profiles were also extended to the north and south, and thus provide short but accurate coincident profiles with the ASIRAS overflights.

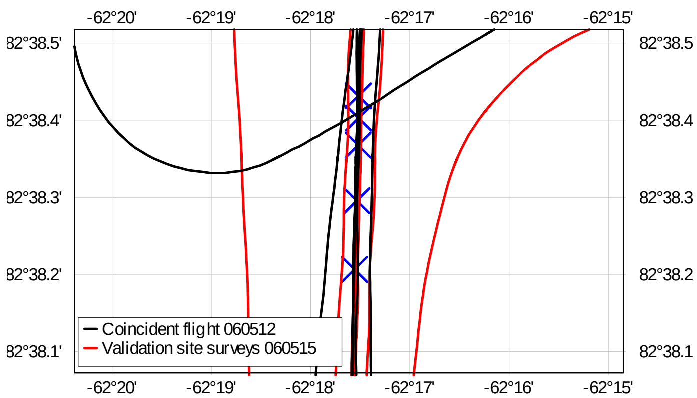


Figure 30: Map of HEM flight tracks over site 2.

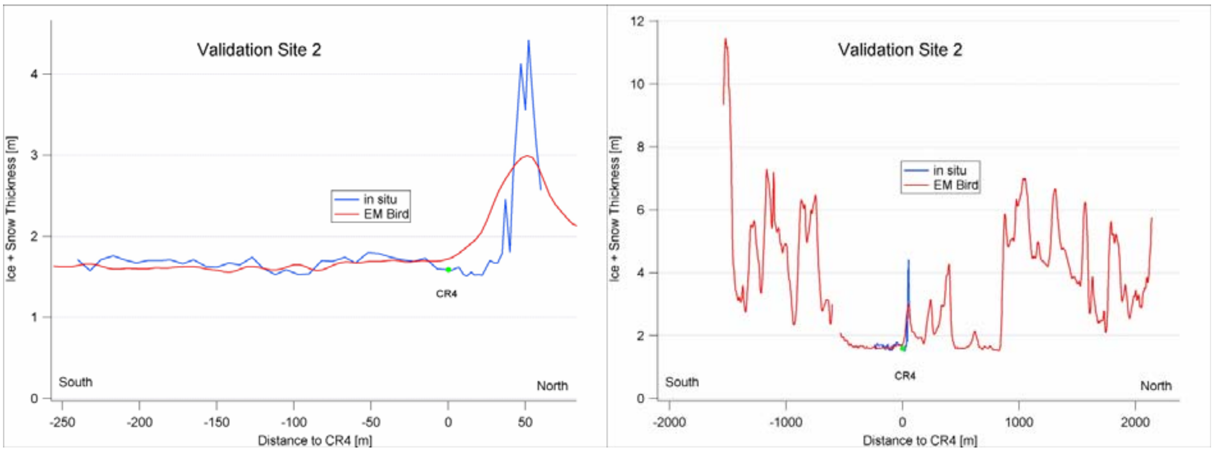


Figure 31: Comparison of HEM ice thickness profile over site 2 with drill-hole ("in-situ") data (cf. Fig. 22).

7. Coincident flights

7.1 Buoy trajectories and snow thickness under coincident flight track

CryoVex 2006 offered the opportunity to prove the CryoSat Cal/Val concept with respect to the reconstruction of ice drift for the coincident sampling of the same ice. A line of 5 GPS buoys was deployed north of Alert, and ice drift data was obtained in near-real-time (Section 9). By means of the buoy drift data, ice drift was predicted for the next hours, and the helicopter and Twin Otter were given different way points to account for the drift (Section 9).
At the buoy deployment sites, snow thickness was also measured along a 200 m profile centred at the buoys. Table 2 lists the positions and mean snow thicknesses on the buoy deployment floes. The data is also important for independent ice thickness retrievals from both the laser scanner and the EM bird.

Table 2: Snow thicknesses measured at buoy deployment sites.

Buoy ID	Latitude	Longitude	Mean Zs (cm)	StdDev (cm)
5	N83 00.325'	W062 12.416'	28.5	16.9
7	N83 17.648'	W062 17.289'	29.5	17.5
8	N83 36.138	W062 12.159'	32.3	16.2
9	N83 51.577'	W062 08.883'	38.8	17.3
10	N84 5.900'	W62 14.997'	32.6	14.9

7.2 ASIRAS flights

Coincident flights of ASIRAS and the HEM bird were performed on May 11 and May 12. For the Twin Otter, the coincident flight was only a small part of a much larger survey. On May 11, ASIRAS flights were performed up to approximately 85.5°N (Figure 32). On May 12, the coincident flight was continued for a long survey in to

Station Nord, with the Twin Otter leaving Alert for the remainder of the campaign (see DNSC field report).

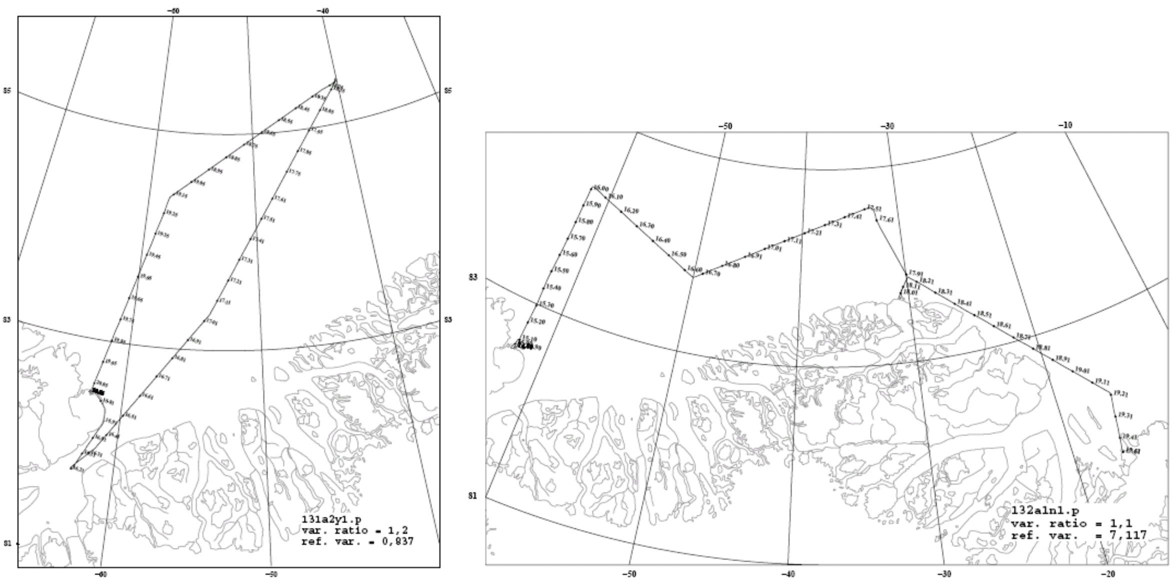


Figure 32: ASIRAS flight tracks on May 11 and 12, performed as part of the coincident flights with the HEM bird.

7.3 HEM flights

Coincident flights of ASIRAS and HEM were performed on May 11 and 12. Unfortunately, both HEM flights had to be aborted due to bad weather at approximately 83°N. On May 11, the coincident profile was laid from the northern end of Nares Strait to the northeast. On May 12, the flight track was adjusted to the predicted ice drift, with a heading of approximately 0°.

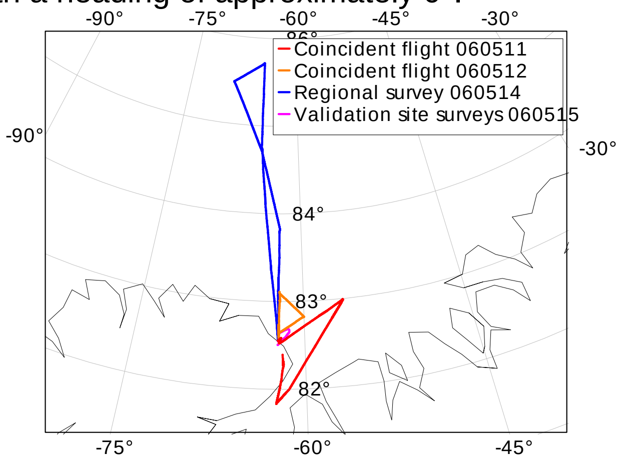


Figure 33: Map of all HEM flight tracks. Coincident flights were performed on May 11 and 12.

8. SAR imagery

Part of the preparation for the campaign was to determine general ice conditions and spatial extent of fast ice in Lincoln Sea. A series of EnviSat ASAR wide swath mode images were used for this task. First ASAR-images for campaign were acquired in November 2005 and the data acquisition will go on through summer and fall 2006. An ASAR image of sea ice in Lincoln Sea is presented in figure 34. Areas of open water and level ice can be seen as dark areas indicating low backscattering. A slightly brighter area indicating a rubble field can be seen near CFS Alert.

To visualize temporal changes in sea ice three ASAR images acquired on different dates were combined as color channels of an RGB image. In resulting image areas of constant scattering such as land, fast ice and polnyas appear as different shades of gray. Areas where there have been temporal changes in scattering such as opening or closing cracks or moving areas of open water appear in bright colors.

RGB-ASAR -images were created with BEAM toolbox. An example of an RGB-ASAR image from Lincoln Sea area from March and April 2006 is presented as figure ERI2. Crack between fast and drift ice can be seen. Furthermore can be seen that the fast ice zone is only few kilometers wide. Ice velocities further at the sea can be estimated to be less than 5 cm/s. This image was used in planning the location of two calibration sites, however the final choosing of measurement lines and floes to serve as calibration sites was made on the site from a helicopter.

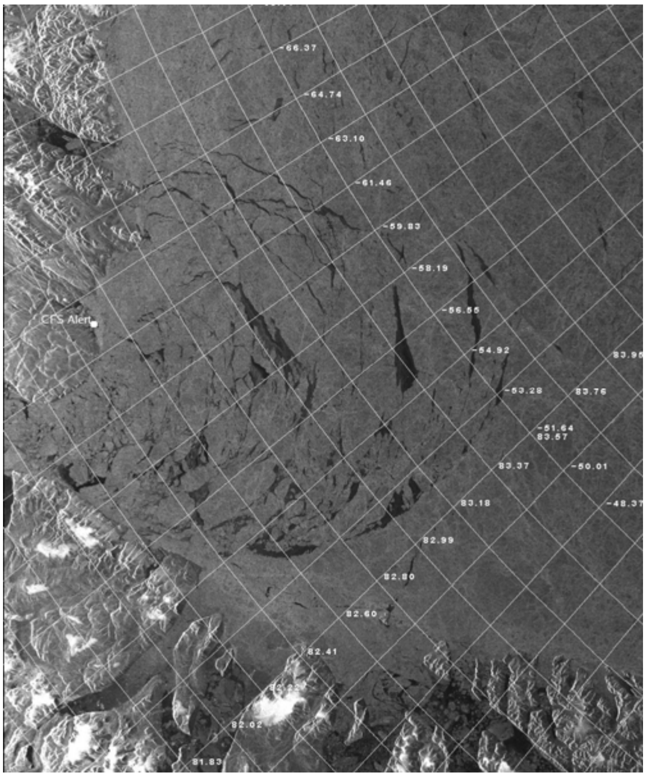


Figure 34: EnviSat ASAR WSM-image from Lincoln Sea area acquired November 9:th 2005.

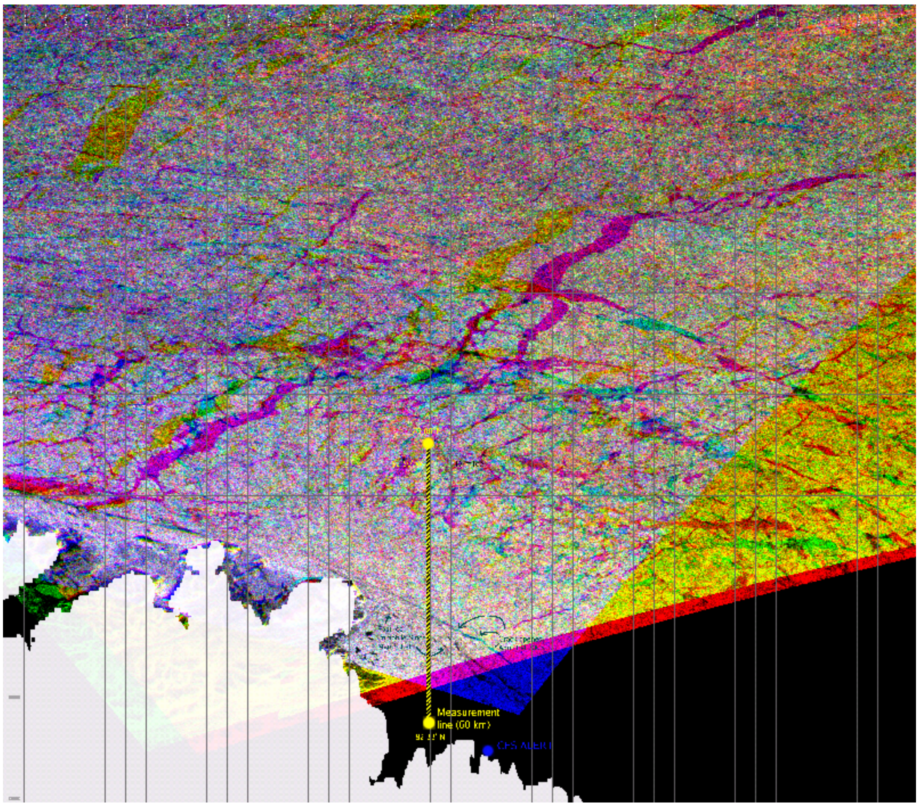


Figure 35: Three ASAR-images from spring 2006 combined as an RGB-image to visualize ice movement and a suggested measurement line. (Channels: R=May 11:th G=May 30:th B=April 2:nd).

9. Buoy deployments

In order to obtain accurate validation of the returns from the ASIRAS system, which was flown on the Twin-Otter, it is necessary that all field measurements are obtained over the same sea ice and ideally at the same time. Due to the different speeds of the twin otter, helicopter and field crew it is impossible to perform measurements at the same time, and therefore it is very important to track the movement of the ice at a high temporal and spatial resolution until all measurements are performed.

Deriving ice dynamics from satellite observations is now at such a stage of development that daily estimation of fields of motion over most of the polar region in winter is now routinely made. We took advantage of this technology to obtain drift vectors before and during the field campaign (see remote sensing chapter). However the infrequent number of daily satellites passes meant that the high frequency motion within the ice field was missed. The only way to obtain information on the drift of the sea ice at the resolution we demanded was with drifting buoys.

Furthermore the buoys must be small enough that significant numbers of them could be easy deployed from a helicopter during a single flight campaign.

This was achieved through the development of a compact ice buoy (CIB) by the Scottish Association for Marine Science. The CIBs took advantage of the “text messaging” service provided across the Iridium satellite phone network which enabled their GPS location to be bundled in to a text message and emailed back to the office. In order for everyone to have access everyone to access the buoy data in real time the positions were automatically posted on a number of web-pages. The first is a table of the most recent 20 fixes from the CIBs. As we are sampling every 20 minutes this mean that the data base will be just over 6 hours in length. Each row has a time stamped GPS position for the buoys. The table is refreshed every 20 minutes . This means that in the worst case scenario the latest data will about 20 minutes old

The web page for most recent 20 fixes are available for Buoy 3, Buoy 4, Buoy 5, Buoy 6 is:

http://www.dinkyd.co.uk/CryoSat/recentA.php

The web page for most recent 20 fixes are available for Buoy 7, Buoy 8, Buoy 9, Buoy 10 is:

http://www.dinkyd.co.uk/CryoSat/recentB.php

Daily information on the drift of the buoys will be in the form of a zipped file. This file is update at 00:55 British Summer Time. The file name is as follows: cryo01_060421.zip where cryo is short for cryosat; 01 is the buoy number; 06 is the year; 04 in the month; 21 is the day. There will be a new file produced each day for each buoy. All daily files will stay on this site.

Daily files can be obtained at:

http://www.dinkyd.co.uk/CryoSat/web_data/

The Iridium satellite system also enables two-way communication which gives the user dynamic control of sampling strategies and extensive diagnostic capability. This enabled us to change the sampling rate at anytime should the ice drift change at anytime. A total of 10 CIBs were built for the campaign: 2 test buoys and 8 for deployment during the field experiment.

Deployment sites

The deployment of the buoys was performed after the deployment of Radar Reflectors; May 9 2006. All buoys were deployed on one dedicated helicopter mission. Due to unexpected heavy fog at around 84 N it was not possible to deploy the buoys as far north as we would have liked. The positions of the buoys can be seen in the figure below. Buoy 3 and 6 were deployed at either end of Site 1 in order to observe any rotational information on the floe. It turned out the buoys 3 and 6 (Site 1: MYI) and buoy 4 (Site 2: FYI) were within the fast ice zone and all other buoys were within drifting pack.

At each deployment site a 100 m transect of snow depth measurements were performed at a spacing of 5 m and one or two drill holes were performed in order obtain freeboard and ice thickness measurements.

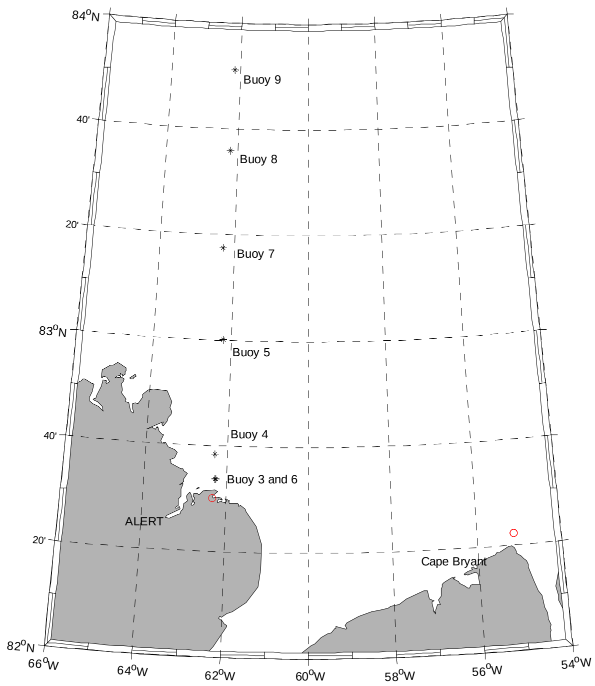


Figure 36. Deployment positions of each CIB

Processing of data to obtain drift vectors

In order to predict the ice movement during the coincident twin otter and helicopter flights software was written to prediction where the buoys would be in 20 minute intervals during the flights. This script applied a centred median-filter, length 3 hours, over the latest 6-hour dataset that was obtained from the web site mentioned previously. This was applied to smooth out any high frequency noise in the data. A linear regression was then applied to the last 3 hours of data from the median filter dataset. The resultant was a prediction of the drift of the ice in 20 minute intervals. The results were then given to each pilot before takeoff. An example of the output from the script can be seen in the figures below.

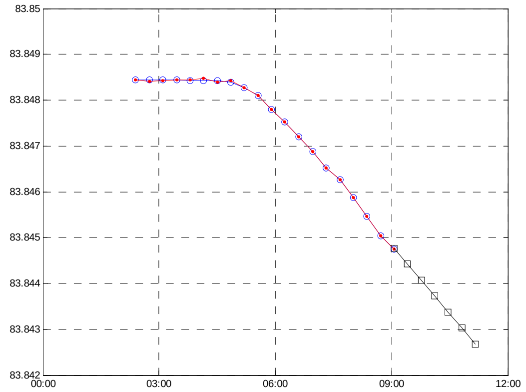


Figure 37 Latitudinal drift track for buoy 9 which was the furthest buoy from Alert. Red line and dots are original buoy positions, blue circles positions after a median filter was applied. Black square predicted ice position.

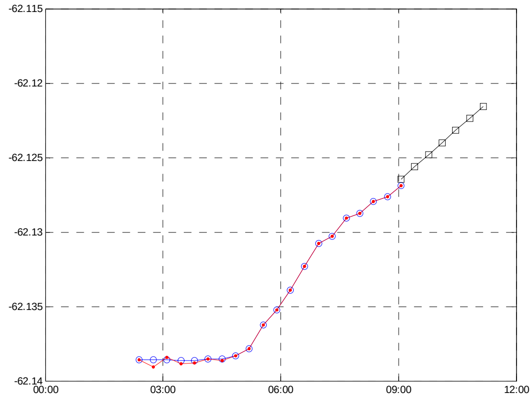


Figure 38 Longitudinal drift track for buoy 9 which was the furthest buoy from Alert. Red line and dots are original buoy positions, blue circles positions after a median filter was applied. Black square predicted ice position.

An example of the look-up table produced for predicted buoy locations is shown below. A complete listing of the predicted positions for all buoys was then given to each pilot. Unfortunately there was a slight delay to the twin-otter's departure and thus there may have been some drift errors as the predictions are naturally less reliable the older they become. Further analysis comparing the actual drift track to the predicted drift track will enable a greater understanding of the errors associated with this method.

Hour	Minutes	Latitude (Degrees)	Latitude (Digital minutes)	Longitude (Degrees)	Longitude (Digital minutes)
9	3	83	50.685	-62	7.6134
9	24	83	50.702	-62	7.6566
9	45	83	50.728	-62	7.6776
10	6	83	50.752	-62	7.7262
10	27	83	50.776	-62	7.7448
10	48	83	50.791	-62	7.8162
11	9	83	50.812	-62	7.8456

Table Example of the predicted position of ice drift in the vicinity of buoy 9. A table similar to this was produced for each buoy and given to the pilots.