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Table of Contents

1. INTRODUCTION.....	2
2. FIELD EXPERIMENTS AND DATA COLLECTION IN 2011	3
2.1 CRYOSAT CALVAL EXPERIMENTS IN WINTER 2011	3
2.2 KV SVALBARD 4-18.APRIL 2011	3
2.3 KV SVALBARD 14 – 21 SEPTEMBER 2011	6
3. NP38- RUSSIAN DRIFTING STATION 2010-2011.....	9

SUMMARY

This report gives an overview of sea ice data collected during field expeditions in the Arctic in 2011 to be used in SIDARUS based on two cruises with KV Svalbard (April and September) and data collected from the North Pole Drifting Station. The in situ data are mainly focused on obtaining freeboard and thickness data for validation of CryoSat thickness retrievals, but the data are also used for validation of sea ice classification, ridge detection and deformation obtained from SAR data. In addition, data from the CryoSat calval experiment in April-May 2011 will be available. These data, together with an overview of numerous previous experiments, are presented in D2.1.

1. Introduction

The sea ice thickness is a challenging parameter to observe and quantify from satellite data. It is therefore of high priority to collect in situ and airborne data for validation of the satellite retrievals. Sea ice thickness is an important climate parameter because it governs the heat flux and influences the radiative balance of the sea ice covered areas, with the highest sensitivity at low ice thickness. Furthermore, ice thickness is crucial for ship navigation in ice infested waters. While the sea ice area and concentration is detected daily with satellite sensors, the thickness is more difficult to retrieve from spaceborne sensors. Promising results to estimate thickness from satellites have recently been published where use of radar and laser altimeter data have been used. The freeboard data are then inverted to ice thickness, using assumption of isostatic equilibrium and climatological information about snow thickness, snow and ice density. CryoSat-2 carries a radar altimeter designed to measure average ice thickness on a large scale with high accuracy. Results suggest that the freeboard method is most useful for the upper part of the thickness spectrum, i.e. ice with thickness > 1 m, but even here much validation remains to be done since not only do snow depth and ice density vary greatly spatially and temporally, but also there is evidence that radar reflections can occur from within snow layers rather than from the snow-ice interface, affecting the validity of isostasy algorithms. Thin ice (< 0.5 m) is more difficult to derive by the freeboard method, and therefore other satellite methods can best be used to measure the thin ice. If the Arctic ice cover continues to change from mainly multiyear to more firstyear ice, observation of thin ice will become more important.

In addition to validating thickness data, it is also important to collect in situ data for validation of SAR-derived products such as ice classification, detection of ridges and deformed ice, snow-ice albedo and meltponds.

This report described data collected during Arctic field experiment in 2011, conducted mainly by NERSC and AWI.

2. Field experiments and data collection in 2011

2.1 CryoSat CalVal experiments in winter 2011

As a part of the first post-launch calibration and validation campaign for CryoSat two cruises have taken place in Spring 2011 headed by the Norwegian Polar Institute. During both campaigns valuable in situ data has been collected, including, ice thickness and freeboard as well as snow samples. This has been complemented by ice thickness measurement with an electromagnetic device (EM31). Further large scale sea ice thickness surveys have been conducted using a helicopter borne electromagnetic instrument (EM bird) underneath or close to CryoSat tracks (Angelika Renner, NPI). Supplementary high resolution SAR images dual and quadpol from Envisat and RadarSat-2 have been ordered by NERSC and met.no.

2.2 KV SVALBARD 4-18 April 2011

The first cruise took place from the 4th to the 17th April 2011 on board the icebreaker KV Svalbard in the area north of Svalbard 80-82 North and 10-25 East.

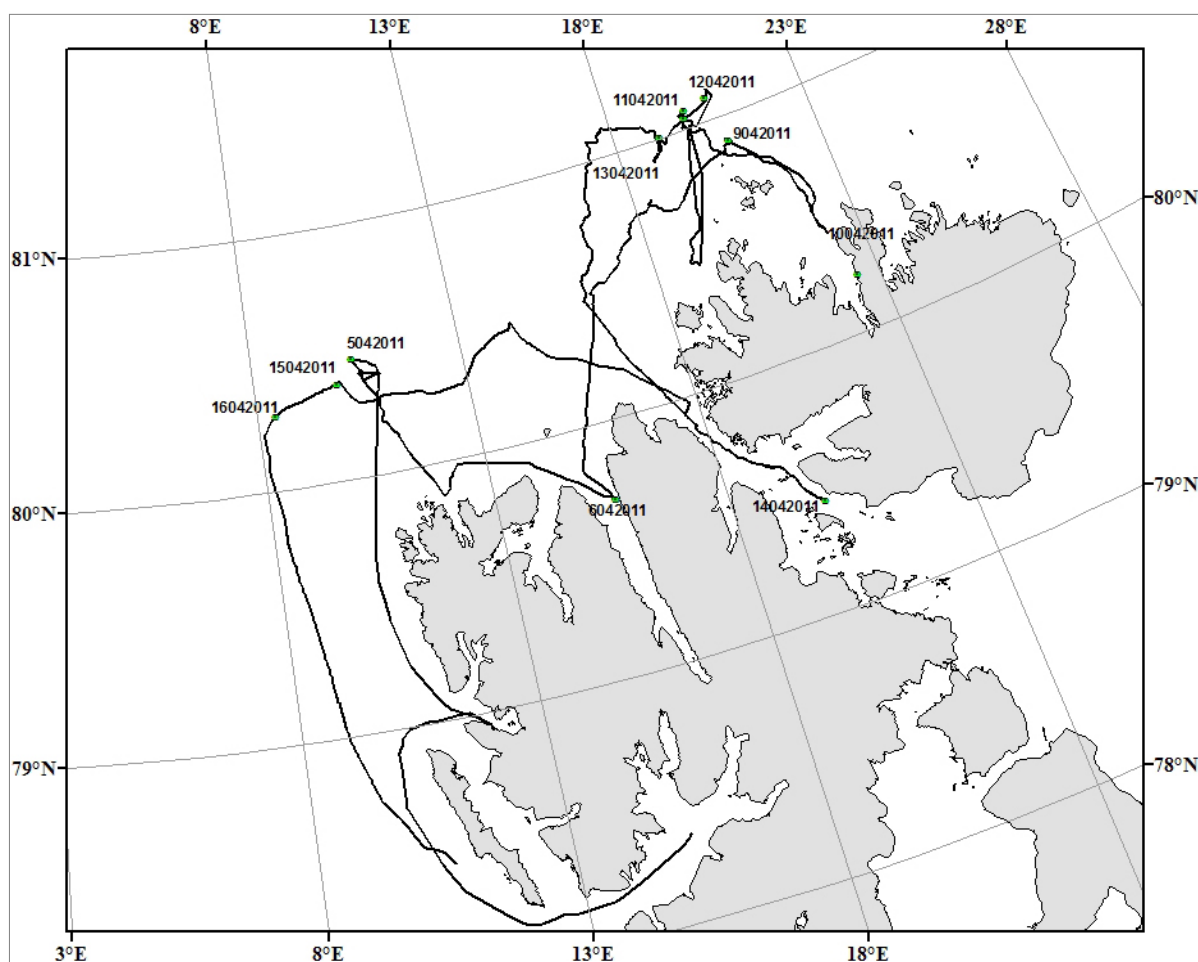


Figure 1: Ship track and positions of ice station for KV Svalbard Cruise for CalVal 2011. (M. Babiker)

Some of the stations where the measurements were taken were on stable fast ice in the fjords around Svalbard while others along the first year ice edge further north. An overview about the ship track and the stations is given in Figure 1.

The collected in-situ data includes thickness drillings and freeboard measurements as well as up to five ice cores for different parameters such as salinity, temperature, density or archival storage. On ice floes with a sufficient snow amount and safe working conditions the snow has been analysed in more detail. An overview about the collected data is given in table 1.

Table 1: Overview of fieldwork and collected data during KV Svalbard Cruise in April 2011. The positions of the ice stations are shown in Figure 1.

Station_ID	EM31	Thickn.Drills	A-Core	S-Core	T-Core	D-Core	B-Core	Snow Pit	Snow Salinity	Idronaut
KVS05042011	x	x						x		
KVS06042011		x								
KVS07042011	x	x	x	x	x		x	x	x	x
KVS09042011	x	x	x	x	x		x	x	x	
KVS10042011			x							
KVS11042011	x	x	x	x	x	x	x	x	x	
KVS11042011	x	x								
KVS12042011	x	x	x	x	x	x	x	x	x	
KVS13042011	x	x	x			x		x	x	
KVS14042011		x								
KVS15042011	x	x	x	x	x	x	x	x	x	x
KVS16042011						x				

During the time the cruise seven large scale ice thickness surveys using an airborne electromagnetic device the EM bird have been carried out. A summary of the airborne EM-surveys are presented in Table 2. Two of the surveys were flown underneath a CryoSat track and one in co-location with a high resolution RadarSat-2 SAR image. An example of the EM bird data is given in Figure 2.

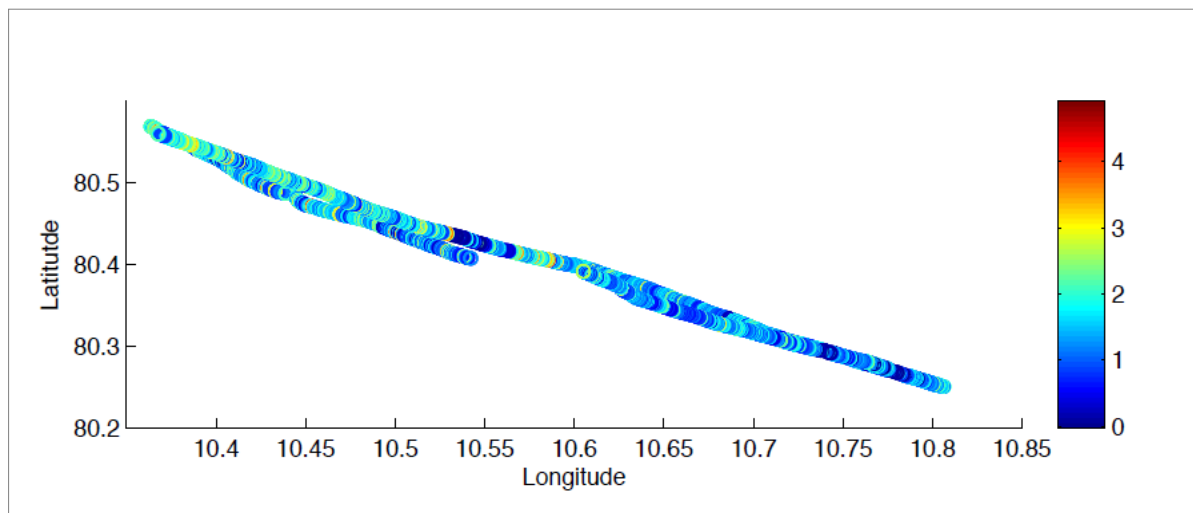


Figure 2: Flight track with snow and ice thickness from the flight on the 6.5.2011 underneath a CryoSat track (Ref. A. Renner, NPI) .

Table 2. Airborne EM-surveys conducted by AWI in the Svalbard area in April 2011 as part of the CryoSat calval campaign

Date	Time start	Time end	Go Pro	GPS base	Start Lat	Start Lon	Comments
04/04/2011	07:56 GMT	08:08 GMT	N	N	Bykaia LYB	Bykaia LYB	test flight for LN-OPW, no data collected
06/04/2011	08:00 GMT	08:53 GMT	N	?	N 80.399	E 10.602	regular flight
06/04/2011	10:04 GMT	11:17 GMT	N	?	N 80.404	E 10.549	Cryosat-2 flight
09/04/2011	08:53 GMT	10:17 GMT	Y	Y	N 80.885	E 20.875	Cryosat-2 flight
11/04/2011	12:30 GMT	13:25 GMT	Y	Y	N 81.089	E 20.078	SVP deployment; attempted RS2 flight: connection problems => no data
12/04/2011	07:27 GMT	07:56 GMT	Y	Y	N 80.478	E 19.087	test flight for WLAN connection
12/04/2011	15:43 GMT	17:23 GMT	Y	Y	N 81.109	E 20.544	RS2 flight

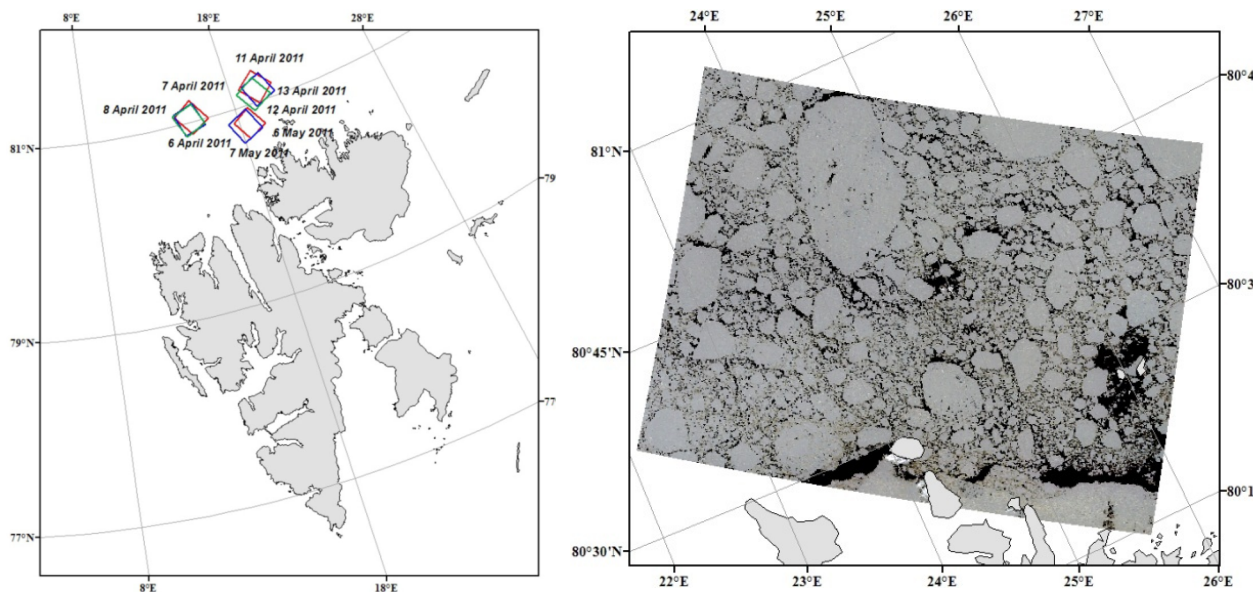


Figure 3: Left: Location of available QuadPol high resolution RadarSat-2 SAR and SPOT images in the area north of Svalbard in the period from 2-18 April 2011. Right: Example of SPOT image (M.Babiker).

More airborne data which has been collected during this year is described in D.2.1. High resolution satellite images were ordered supplementary and are available through an agreement between the Norwegian Space Centre and Kongsberg Satellite Services. In particular 6 fine Quadpol images with a size of 25x25 km are available during this period. The SAR images have a resolution of 5.4x8m and are available in HH, HV, VV, VH.

2.3 KV Svalbard 14 – 21 September 2011

The Nansen Center organised a cruise with KV Svalbard in the Fram Strait in September 2011 with support from several projects (ACOBAR, SIDSARUS and WIFAR), where one of the objectives was to collect sea ice data for validation of satellite data and to support oceanographical and wave data in the marginal ice zone.

Ice thickness and freeboard measurements were conducted in the strongly deformed ice along the ice edge in the Fram Strait. The positions of the stations are shown in Fig. 4 and the measurements are listed in Table 3. . Next to the drillings some ice cores have been taken.

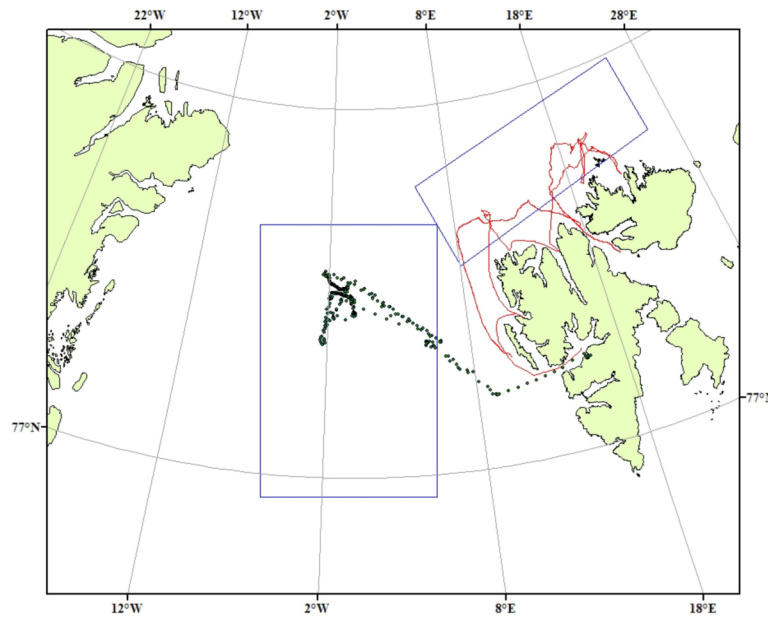


Figure 4. Map of the tracks by KV Svalbard during the April cruise (red lines) and the September cruise (black dots)

Table 3. Ice stations obtained by KV Svalbard in September 2011 with measurements

Date	Longitude	Latitude	# Drillings	EM- 31	Salinity Core	Density Core
16.09	79 46.913	02 16.747	5	x	x	x
17.09	79 34.280	00 35.782	4	x	x	-
18.09	78 30.106	01 37.407	3	x	x	x
19.09	79 27.117	00 25.655	3	x	x	-
19.09	79 25.909	00 20.494	3	x	x	-

The drilling of holes in the ice floes were used to measure coincident thickness and freeboard. The data are plotted in Fig. 5.

Based on the in-situ data the relationship between sea ice freeboard and thickness has been calculated to $I_{\text{thickness}} = 1.11 + I_{\text{freeboard}} * 6.366$.

Additionally to the drillings in the ice the snow-ice thickness has been measured using an electromagnetic device the EM31. The in-situ measurements and the EM31 measurement have been found to be in good agreement. An example from 19.9.2011 (2) with calculated freeboard based on the above derived relationship is shown in Figure 6.

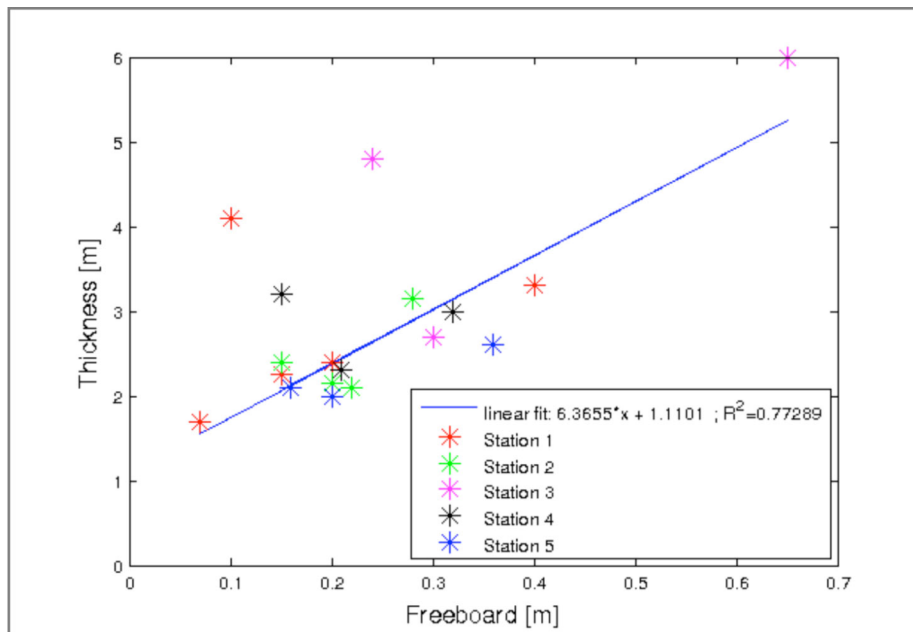


Figure 5. In situ measurements of thickness and freeboard of firstyear floes with ridges.

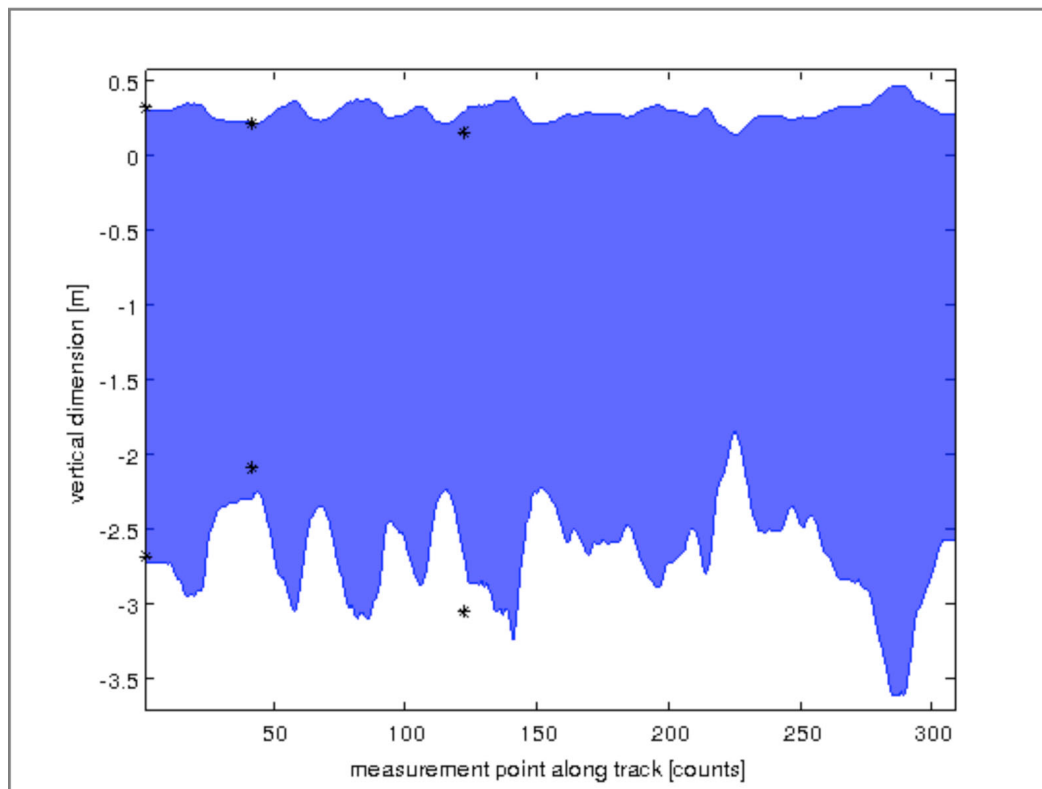


Figure 6: Ice thickness as measured using the electromagnetic device EM31 on the 19.9.2010. The asterixes are in situ measurements. The freeboard has been calculated based on the above derived relationship.

3. NP38- Russian drifting Station 2010-2011

The Russian Arctic and Antarctic research Institute AARI has been conducting measurements in the Arctic with help of an drifting ice station since 1954. Since then one to three such stations were operating simultaneously every year measuring the snow and ice conditions as well as a large number of atmospheric parameters. After a break from 1991 to 2003 the program has been revived and is again providing important valuable and rare data of ice thickness in the Arctic. The drifting station in the season 2010-2011, named NP38 started their journey on the 14th October 2010 and ended 20th September 2011. The drift of the station is shown in figure 6.

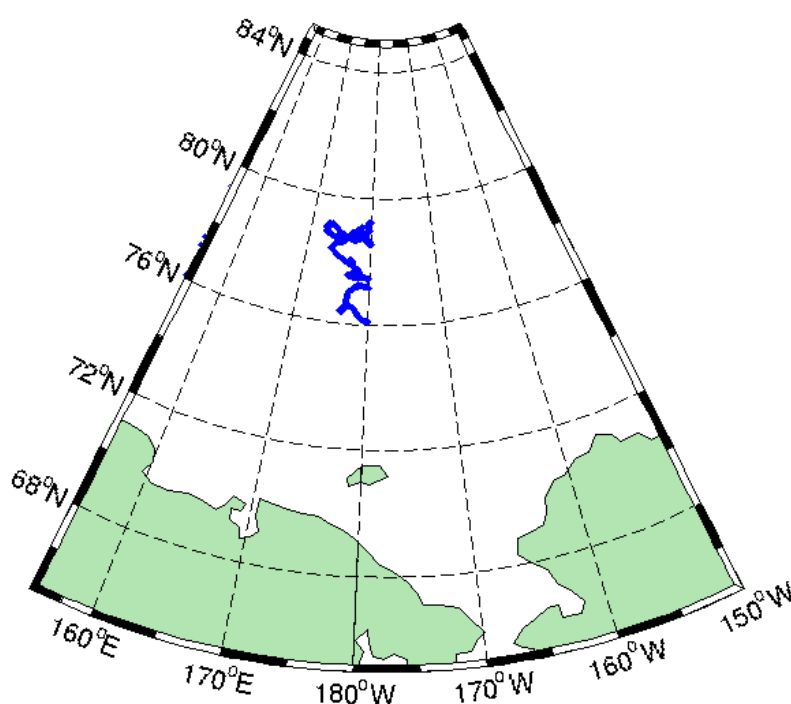


Figure 6: Northward drift of the Russian North Pole Station NP38 between October 2010 and September 2011. The total drifted distance was 3025 km.

Around the station ice thickness, freeboard and snow depth have been measured at several different locations. The distance between the positions was approximately 100m. Examples of measurements obtained in October 2010 as well as every 2 weeks between July and September 2011 are presented in Fig. 7. Based on this data the relationship between freeboard and thickness is found to be $I_{\text{thickness}} = 0.3.9063 * I_{\text{freeboard}} + 0.6525$.

There are more sea ice data available from the recent North Pole Drifting Stations, and these will be presented in later reports.

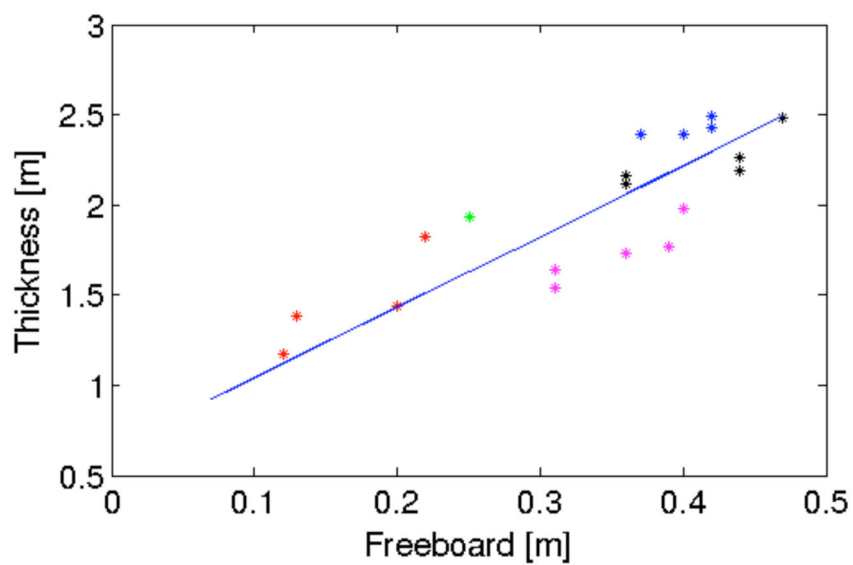


Figure 7: Freeboard and Ice thickness measurements during the drift of the Russian North Pole Station NP38. Different colours indicate the different measurement locations around the station. The linear relationship between freeboard and thickness is found to be $I_{\text{thickness}} = 0.3.9063 * I_{\text{freeboard}} + 0.6525$.

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