Summary of AFIN measurements on Atka Bay landfast ice in 2010

This document summarizes the field measurements 2010 of snow and ice thicknesses and freeboard on the landfast ice of the Atka Bay near the Ekström ice shelf in Antarctica. The measurements contribute to the Antarctic Fast Ice Network (AFIN).

Summary of AFIN measurements on Atka Bay landfast ice in 2010

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July 2011

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Overview

Manual measurements of ice thickness, freeboard, and snow thickness (drillings and stake measurements) were performed by the wintering team of Neumayer III along an East-West profile in Atka Bay from the end of May to December 2010. The stations were visited 6 to 9 times in this period (on average every 3 weeks). During this field campaign, the sea ice broke off in July/August before another fast-ice cover remained until the final break off early December. The measurements are intended to be repeated each year as a contribution to the Antarctic Fast Ice Network.

The Antarctic Fast Ice Network (AFIN)

AFIN was initiated as a legacy project under the International Polar Year (IPY) and is a project (#270) endorsed by the IPY's Joint Committee. AFIN set out to establish an international network of fast-ice monitoring stations around the Antarctic coastline. By now, a number of international collaborators have signed up to this project, and many have already set up fast-ice measuring sites at or near their Antarctic bases (Figure 1). AWI contributes to this international network through activities at Neumayer III starting in 2010.

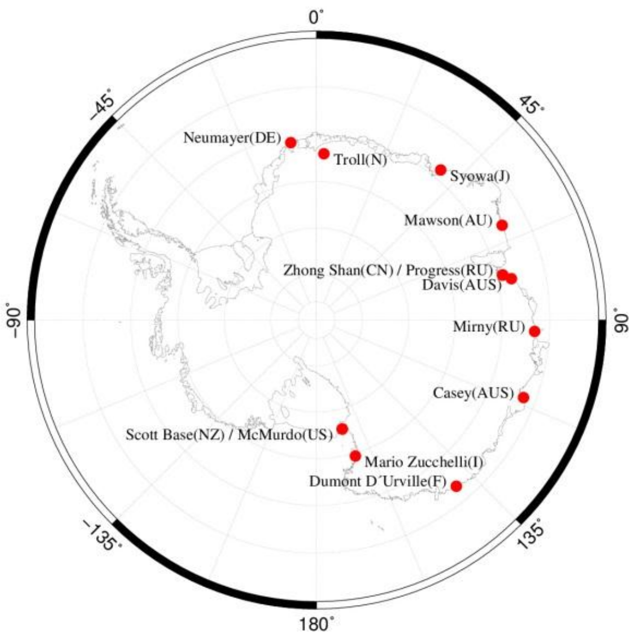

Figure 1: Antarctic Fast Ice Network

Methods

At each station (see Measuring locations and local conditions), 5 measurements were performed in order to capture small-scale spatial variability. The measurements were arranged with one in the center and four in 5 m distance in each geographic direction.

The local conditions were documented by photographs (Photo 1), and additional notes of observations were taken.

Measuring locations and local conditions – a diary

25 May

On 25 May 2010, the fast ice could be accessed by snowmobiles via the ramp at 70° 34.431' S, 8° 08.212' W for the first time this season to start the time-series measurements. But the rough sea-ice surface, deformed by dynamic ice motion near the edge of the ice shelf, was very hard to travel on at this time. The first measuring location about 1km south of the ramp could not be reached by snowmobiles, so an alternate station about 300m south-east of the ramp was chosen (ATKA00). Getting used to the procedure and the equipment took some time, so only three holes were drilled. The almost impassable conditions in this area prevented from reaching more stations further east into the Bay, so ATKA00 remained the only station drilled at this time.

Photo 1: Work on the fast ice (Holger Schmithüsen, ATKA03, 21 September 2010)

10 June

On 10 June 2010 it was possible to reach further into the Bay, with snow filling the gaps in the uneven ice-surface. ATKA00 was left out intentionally this time, because of the very time consuming drilling work in the thick ice in the vicinity of the ice shelf. After 4 km of still very rough sea-ice surface conditions, a large area of level ice favored the work on the ice so that ATKA04, ATKA08, ATKA12 and even ATKA14 at a distance of 14.5 km from the ice shelf edge could be reached. At this time it was expected to take a profile along the entire Bay the next time with the help of the acquired GPS track.

02 July

But on 02 July, new problems arose: an air temperature of -40 °C temporarily obstructed the drillings, because the motor had starting problems and the interlocking device of the auger did not work properly. The drilling of three holes at ATKA00 took 2.5 hours, and an impassable lead at ATKA04 prevented to reach the next stations (Photo 2). The ice surface on the other side of the lead looked rougher compared to previous measurements on 10 June 2010.

Photo 2: Lead through the ice (Holger Schmithüsen, ATKA04, 02 July 2010)

09 July

One week later, on 09 July, the lead was already several hundred meters wide with thin ice covering the water surface. It was decided to modify the course of the profile to ensure better accessibility. Additionally, ATKA00 was decided to be left out because of the large time consumption of drilling in this area.

19 and 20 August

On 19 and 20 August, new stations in more level-ice areas with mainly thermodynamically grown ice along the same profile were chosen (Figure 2, marked as blue in Table 1).

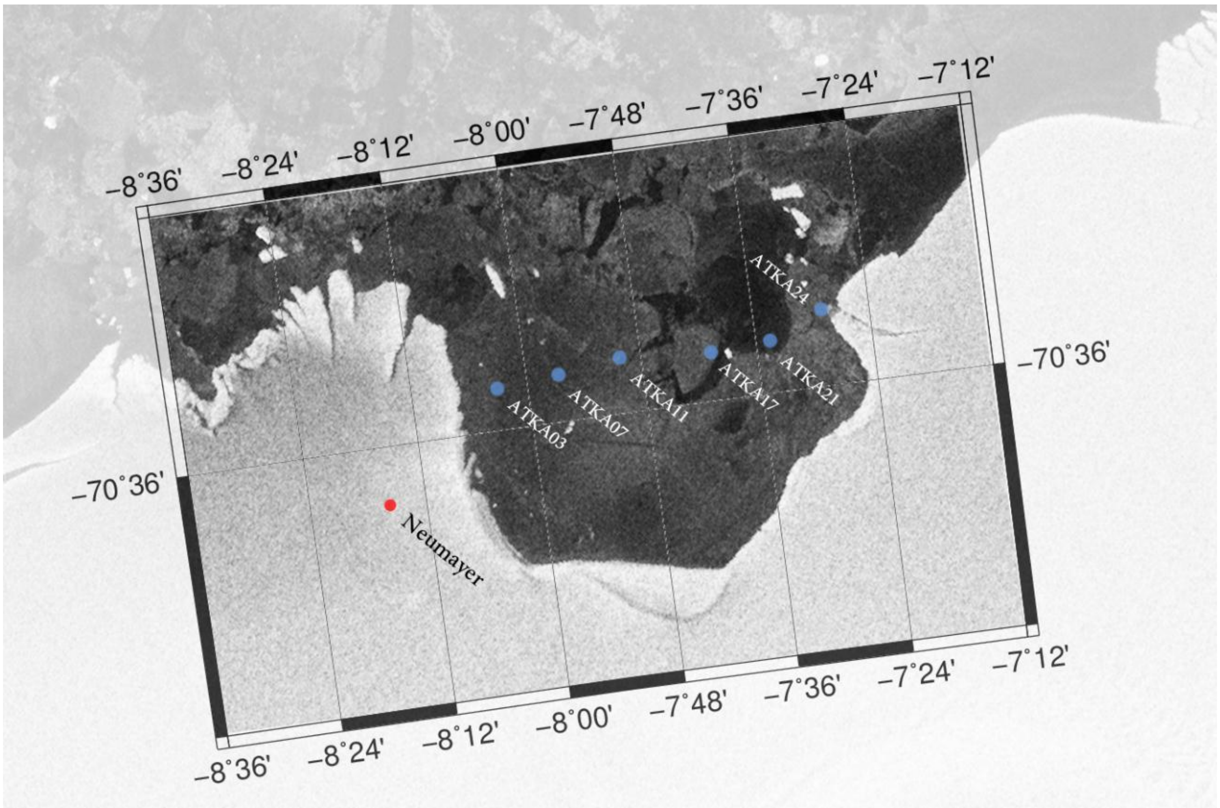

Figure 2: Map of Atka Bay (Background image: ESA Envisat ASAR imagery, 09 September 2010)

04 September

On 04 September, all stations of the new profile could be reached and measurements were successful.

21 September

Between 9 and 20 September, a small iceberg drifted past the Bay in a distance of 5-10 kilometers (Figure 3). But during the measurements on 21 September, no signs of deformation of the landfast ice were observed.

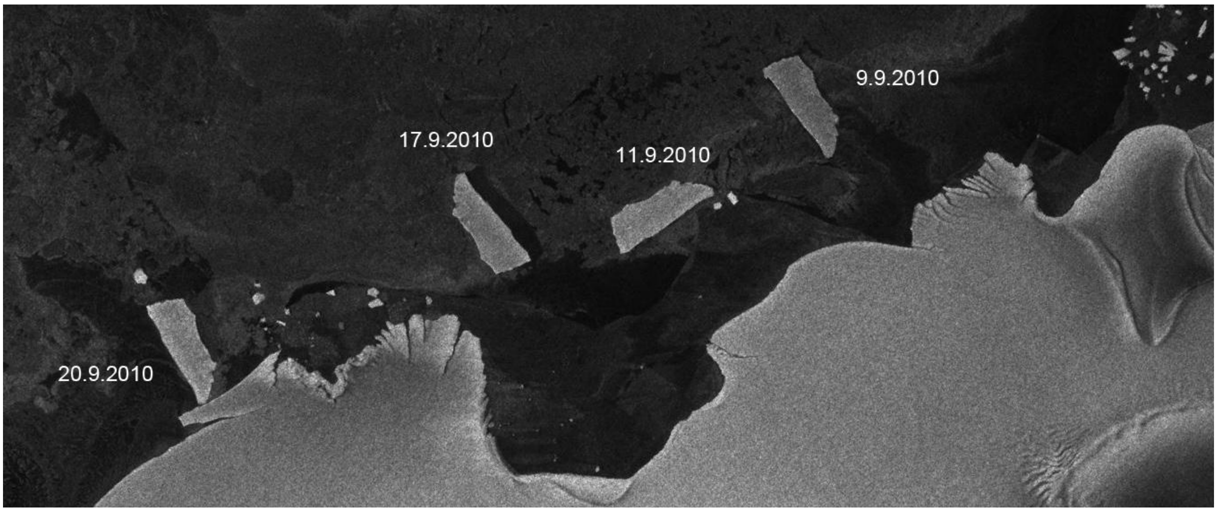

Figure 3: Iceberg near the Bay, ESA Envisat ASAR imagery, 09 - 20 September 2010

The increasing snow cover at this time, especially in the eastern part of the Bay, lead to large negative freeboard of more than 0.1 m, and the drilling of holes caused surface flooding (and consequent ice growth on the top) in an area of a few meters around the boreholes. To ensure accurate measurements, the stations were displaced accordingly at each subsequent measurement.

At ATKA24, where platelet ice had previously been observed in the boreholes, a small video camera (Oregon Scientific E-ATC3KG) was attached to a hinged pole and lowered under the ice to determine the thickness of the platelet layer under the fast ice. The poor image quality and the insufficient length of the pole only allowed for a very rough thickness estimation of *at least 1.6 m*. But during the rotation of the pole in the borehole, it was noticed that the mechanical resistance of the platelet layer against the movement was significantly higher than that of seawater and varied with depth.

16 October, 06 November and 27 November

On 16 October, 06 November and 27 November, the field measurements were carried out without further incidents.

12 December

On 12 December only ATKA03 and ATKA07 could be reached because the landfast ice in the northeastern part of the Bay had been broken off. Helicopter based observation flights confirmed that the straight-lined scarp ranged from the "Nordanleger" on the ice shelf edge north of Neumayer in a south-eastwards direction across the whole Bay (Figure 4). This marked the end of the measuring campaign in 2010!

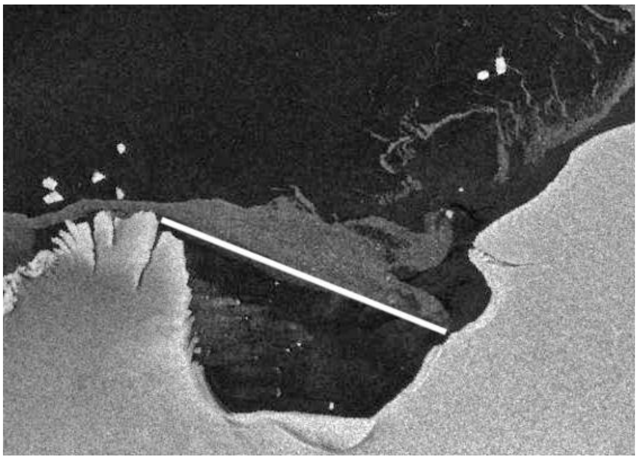

Figure 4: Scarp of the landfast ice, ESA Envisat ASAR imagery 10 December 2010

Table 1 shows the stations on the fast ice (named ATKAXX, where XX stands for the distance between the location and the western border of the Bay) and their respective coordinates. Table 2 summarizes the successful measurements of the time series in 2010.

Table 1: Stations and their coordinates

Station	Latitude (WGS84)	Longitude (WGS84)
ATKA00	70° 34.502′ S	8° 07.730′ W
ATKA03	70° 34.568′ S	8° 03.055′ W
ATKA04	70° 34.431′ S	8° 01.013′ W
ATKA07	70° 34.375′ S	7° 56.727′ W
ATKA08	70° 34.431′ S	7° 54.479′ W
ATKA11	70° 34.121′ S	7° 50.187′ W
ATKA12	70° 34.456′ S	7° 48.214′ W
ATKA14	70° 34.431′ S	7° 44.556′ W
ATKA17	70° 34.349′ S	7° 40.873′ W
ATKA21	70° 34.189′ S	7° 34.632′ W
ATKA24	70° 33.392′ S	7° 28.947′ W

Table 2: Summary of successful measurements

Station	25.05	10.06	02.07.	19.08.	04.09.	21.09.	16.10.	06.11.	27.11.	12.12.
ATKA00	x	skip	x							
ATKA03				x	x	x	x	x	x	x
ATKA04	lead	x	lead							
ATKA07				x	x	x	x	x	x	x
ATKA08		x								
ATKA11				x	x	x	x	x	x	lead
ATKA12		x								
ATKA14		x								
ATKA17		lead		x	x	x	x	x	x	
ATKA21				x	x	x	x	x	x	
ATKA24				x	x	x	x	x	x	

Results and Discussion

Figure 5 shows the resulting profiles along the Atka Bay, and the time series of each station are plotted in Figure 6. The colored circles in each graph indicate the local variability of the 5 drillings at each station (see Materials and Methods). The solid black line at z = 0 m specifies the water surface. Lines are drawn through the averaged values of snow and ice thicknesses and freeboard, with snow cover filled in gray and ice thickness in blue.

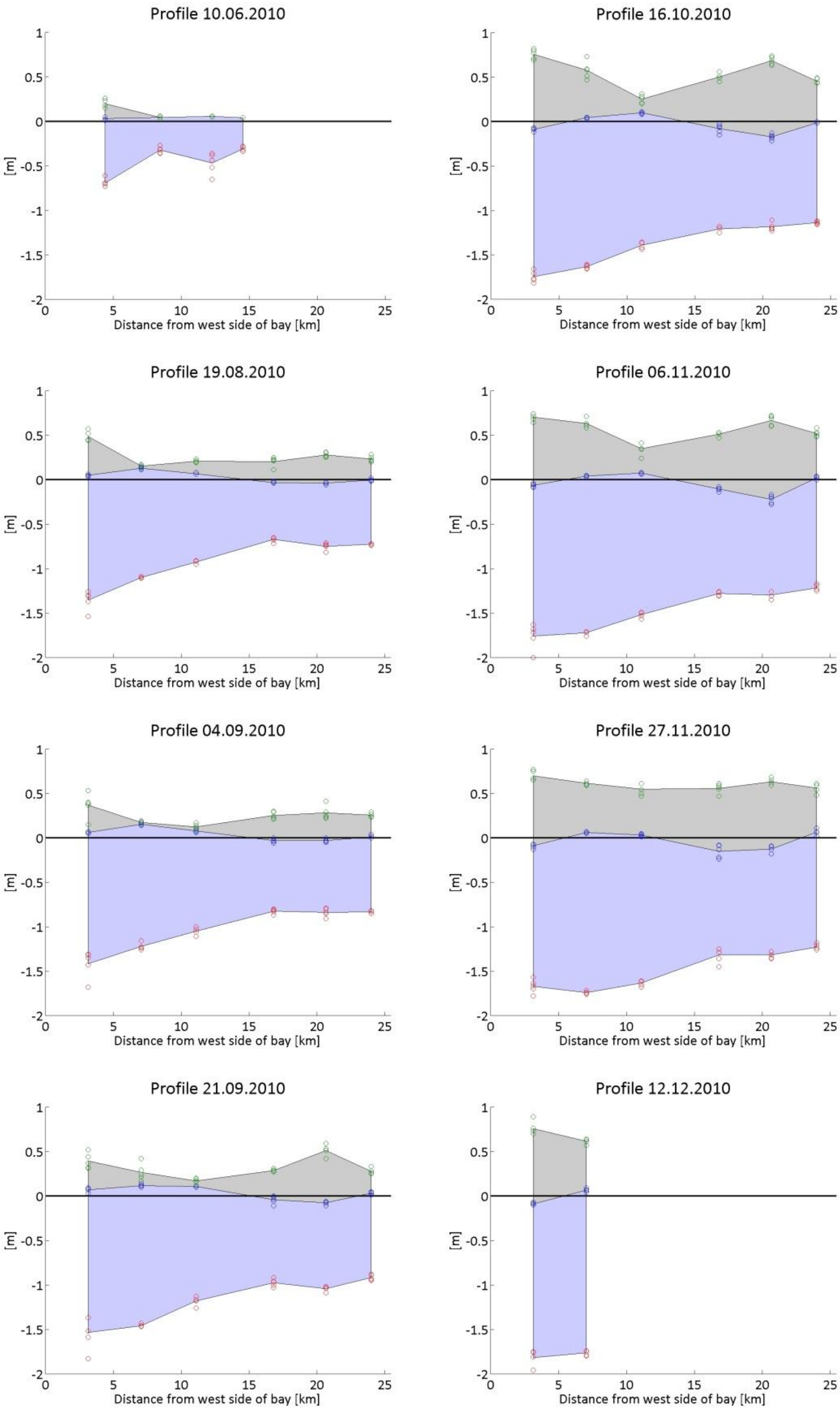

Figure 5: Profiles along the Bay

The results show that the ice in the western part of Atka Bay is generally about 0.5 m thicker than in the East. A possible explanation of this observation can be given by the water-current patterns in the Atka Bay and below the Ekström ice shelf: relatively warm water masses enter the Bay in the East, are cooled down by interaction with the ice shelf, and leave the Bay in the West. This cold water may, on the one hand, support early ice growth in the West, whereas the freezing of sea water in the eastern part is delayed. On the other hand, the cold water may lead to an increased freezing rate in the West as opposed to the East. Another explanation could probably be given by the wind conditions, which push the growing sea ice towards the western side of the Bay and which also influence the redistribution of the snow cover (see below).

The time series imply that in September snow is accumulating at a faster rate until mid-October. From then on until the ice breaks off in December, it either stays constant or contributes to a negative freeboard. Snow cover is generally lower in the center (ATKA11), because the snow is drifted away in westward direction by strong easterly winds over the Bay. Additionally, snow is accumulated in the lee of the eastern ice shelf.

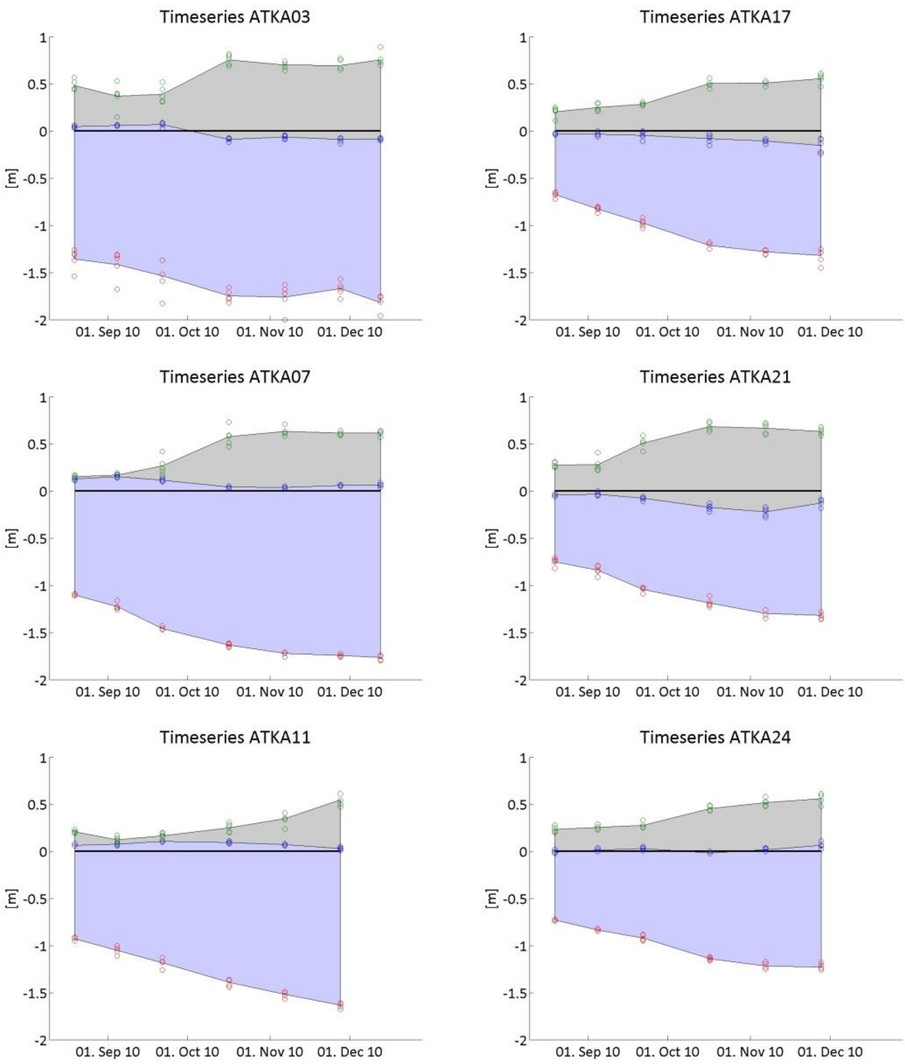

Figure 6: Time series of the stations

The local variability (colored circles) is highest in the vicinity of the western ice shelf (ATKA03, ATKA00- not shown here), which supports the idea of sea ice floes being pushed towards the western part of the Bay.

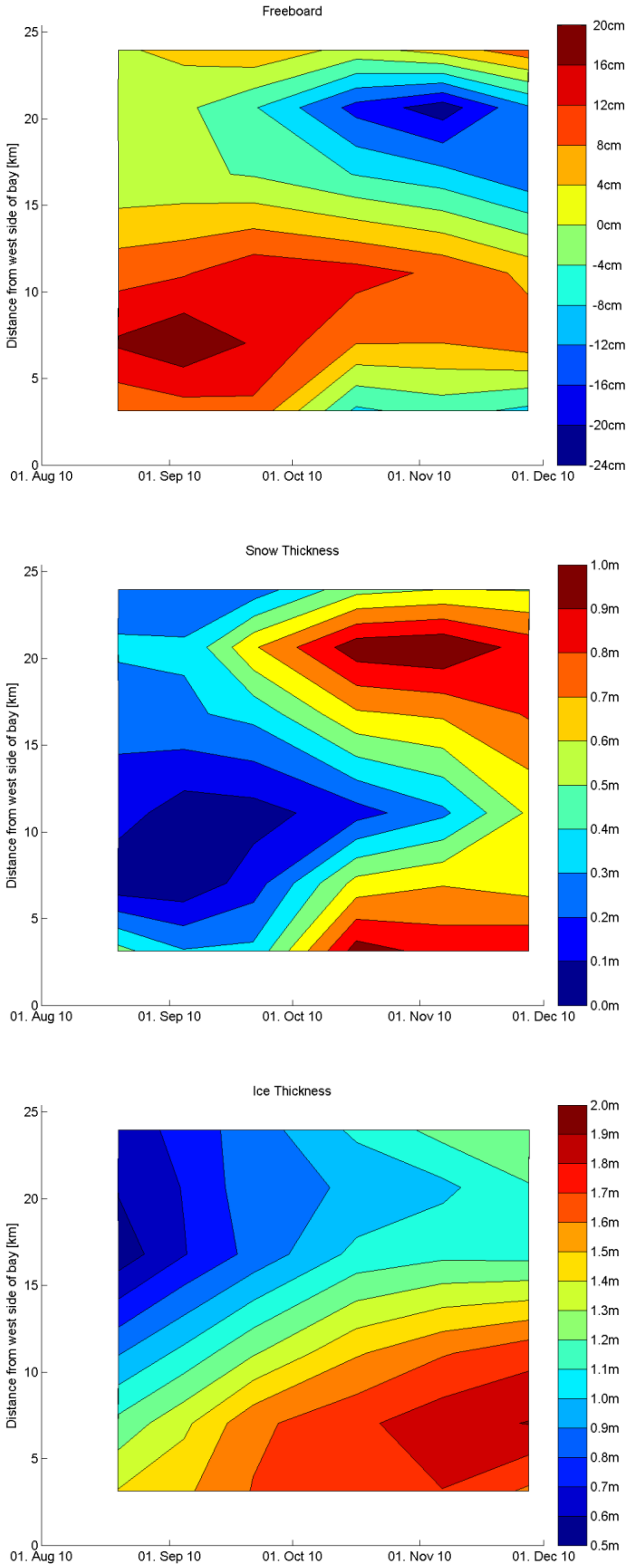

Figure 7: Contour plots of snow and ice thicknesses and freeboard

Platelet ice

During many drillings, platelet ice was observed floating upwards to the water surface of the boreholes and corresponding notes where taken.

Some efforts were made to determine the thickness of the platelet-ice layer, but methods need to be improved in the next season. Options include a specialized video camera, a rotating pole or a plummet.

Satellite images

Through the cooperation with Angelika Humbert (University of Hamburg), we have received more than 30 satellite scenes from TerraSar-X. These scenes are a mixture of strip (sm), scan (sc), and spotlight (sp) mode. They cover the time between 13 November 2010 and 15 February 2011, meaning most of the scenes were only recorded after the observational program had to be stopped. These scenes were particularly recorded to support logistical operations around Neumayer III.

In addition, ENVISAT wide-swath mode images are routinely archived (script by Lars Kindermann, AWI, PALAOA observatory) from www.polarview.aq. For this field season, we have 193 images (processed jpg images) between 01 June and 31 December 2010.

Outlook

Updated profile

As already mentioned above, the fast ice in the northeastern part of the Bay broke off in mid-December 2010. To make a longer period of measurements more likely in the next season, the course of the profile will be shifted further south. The new profile was chosen on June 6th, the first day of the 2011 measuring campaign.

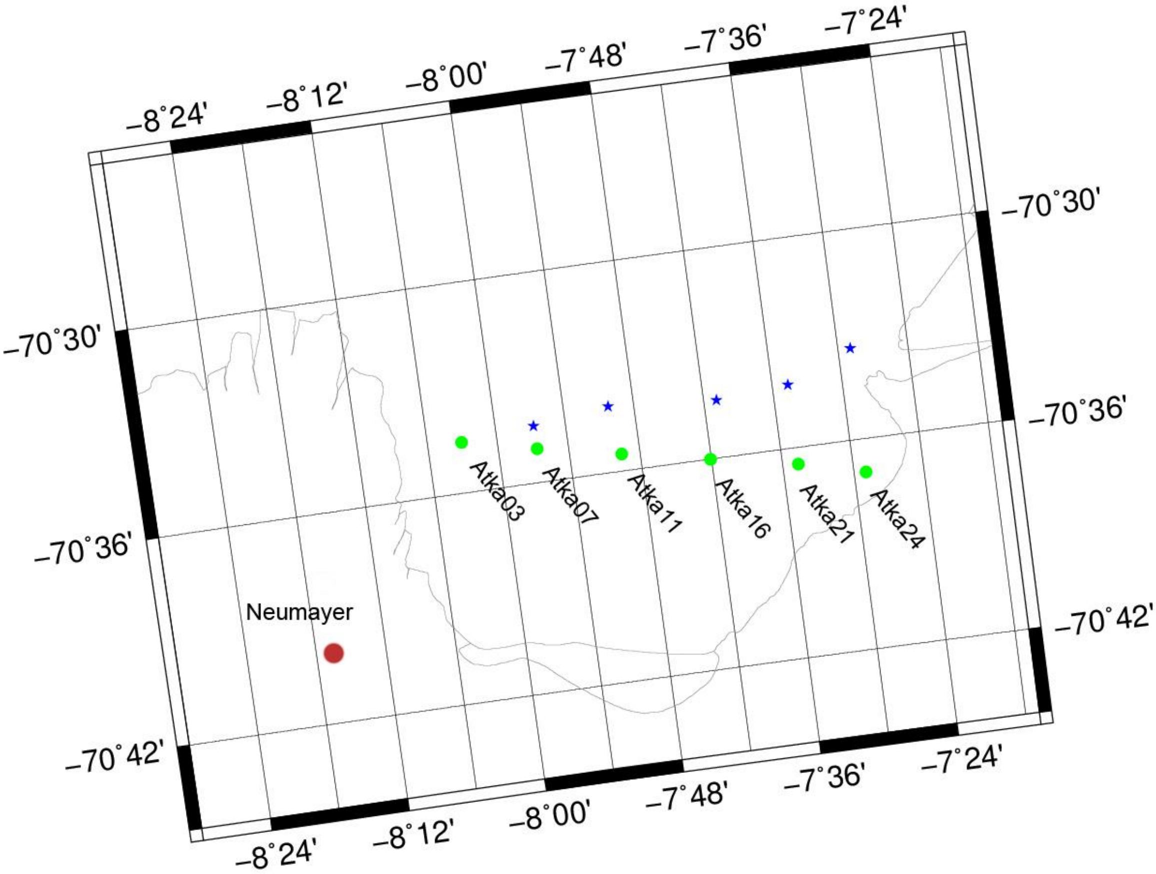

Figure 8: Map of 2010 (blue star) and 2011 (green circle) measuring locations

Table 3: Coordinates of measuring locations in 2011

Station	Latitude (WGS84)	Longitude (WGS84)
ATKA03	70° 34.560’ S	8° 03.055’ W
ATKA07	70° 35.040’ S	7° 56.728’ W
ATKA11	70° 35.520’ S	7° 49.586’ W
ATKA16	70° 36.000’ S	7° 42.073’ W
ATKA21	70° 36.480’ S	7° 34.632’ W
ATKA24	70° 36.960’ S	7° 28.945’ W

Automatic Weather Station (AWS)

Complementing the sea-ice measurements, an automatic weather station (AWS) will be deployed on the sea ice near ATKA03 in July 2011. Aim of the AWS is to monitor atmospheric conditions on the sea ice. This will support data analysis and enable additional studies, as e.g. forcing of numerical models or comparison of meteorological conditions with the measurements on the ice shelf by the BSRN station.

The weather station will be based on a Campbell Scientific data logger and mounted on a 3m-high tripod, which is anchored into the ice. Power supply will be through batteries, buffered by a solar panel. The power supply should last at least 2 weeks without any charging, aiming for a continuous operation, when all components work as planned. Data storage will be local.

Table 4: Sensors aboard the AWS

Sensor	Measured Parameter
SR50A Sonic Ranging Sensor	snow thickness
CNR4 Net Radiometer	long- and short-wave radiation
05106-5 Wind Monitor Marine	wind velocity and direction
61302V-5A Barometric Pressure Sensor	air pressure
HMP155A Temperature & Relative Humidity Probe	temperature, relative humidity

Sea ice mass balance

In addition, the manual thickness measurements will be extended through an autonomous ice mass-balance station in July 2011 in order to receive time series of ice thickness and physical properties in high temporal resolution. The concept of the designated mass-balance station is based on a thermistor string with 194 sensors in 2 cm spacing. The data is stored on a local memory card and can also be transferred via Iridium.

EM31

For the 2011 field campaign, ice-thickness measurements are planned to be performed using an EM31-system, mounted on a sled and pulled with a snow mobile along profiles. Such measurements could almost replace the drillings, while only some (3 to 5) calibration drillings would be necessary. Beside measurements of ice (plus snow) thickness, it might be possible deriving thickness and extent of the platelet ice layer under the sea ice.

Data Archive

All data will be archived and published through the PANGEA data publishing system (www.pangea.de) after each field season. From this archive, they will receive a unique digital object identifier (doi). We are currently working on the 2010 data, as described in this report

Acknowledgments

We are most grateful to **the wintering team 2009/2010 at Neumayer III**, and in particular **Holger Schmithüsen, Olaf Wetegrove, Tanja Fromm and Armin Ganter** who spent lots of hours of hard field work in the relentless cold of the Antarctic in order to gather the results shown in this report.

We thank **Angelika Humbert** (University of Hamburg) for providing us high resolution-, geo-referenced TerraSAR-X satellite images courtesy of Deutsches Zentrum für Luft- und Raumfahrt. This helped a lot for planning of the measurements and the operations on the ice. We highly acknowledge **Gert König-Langlo**, **Bernd Loose**, **Lars Kindermann** and **other colleagues at AWI** for their great support in getting the project started and providing us with a lot of practical help and information. The initiative and work of **Petra Heil**, as the coordinator of the AFIN, was most essential for establishing this program at Neumayer III and on the ice of Atka Bay.

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