Fram Strait Cruise Report

3 - 26 September 2010

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Scientific Personnel

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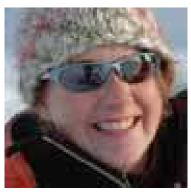
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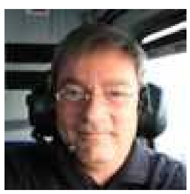
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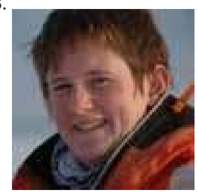
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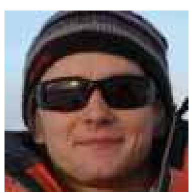
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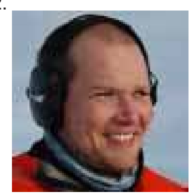
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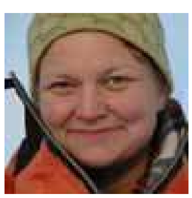
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Acknowledgements

A research cruise is a collaborative experience involving the efforts and responses of many people. I want to express my gratitude to everyone whose hard work and good will made Fram Strait 2010 a successful and enjoyable cruise.

Our engineer Kristen deserves a lot of credit for his hard and efficient work in the recovery and redeployment of the moored array as well as for fixing our numerous technical problems. We would have been in serious trouble without such an experienced engineer.

Thanks are due to Alexey Pavlov for his hard work organising the DOC, CDOM and SPM sampling and for leading the night time CTD watches so effectively. Thanks also to Ella, Hanne-Beate, Lars and Nanette for their help with the water sampling and especially for spending so many hours in front of the salinometer.

We are grateful to Justin for his tireless efforts to resolve technical problems with the EM bird, which greatly increased the amount of data that was collected using the instrument.

Thanks to Harvey and Angelika who organised and co-ordinated the sea ice program and who were patient when the ship was doing oceanographic work. Thanks also to Åre, Aleksey, Christian and Jennifer for their hard work on the ice.

Karen Heywood kindly provided two water RAS-500 samplers with which to improve our mooring at 8 W. These will help us investigate seasonal variations in tracer properties at Fram Strait.

Finally, thanks to Edmond Hansen for making the cruise possible in the first place and to the Captain, officers and crew of RV Lance for taking us where we needed to go.

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1. Introduction

1.1 Cruise outline

Since 1997 NPI has maintained an array of 4 to 6 oceanographic moorings in the East Greenland Current at Fram Strait. This array has provided a long time series of observations with which to monitor the outflow from the Arctic Ocean. The main purpose of FS2010 was to recover and redeploy the mooring array in Fram Strait. An annually repeated (since 1997) CTD section from Svalbard to the East Greenland Shelf along 78°50'N was repeated again during during FS2010 with the addition of δ^{18}O, nutrient, CDOM, DOC and SPM measurements. δ^{18}O and nutrient measurements were collected along this section in 1997, 1998, 2004, 2005, 2008, 2009. In addition to the annually repeated section at 78°50'N a second CTD and tracer section was completed across the East Greenland Current at 74-75°N. This section repeats similar CTD and tracer sections including alkalinity and nutrient or δ^{18}O and nutrient measurements in 2002 and 2008. The primary purpose of this section is to study how the freshwater composition of the East Greenland current changes downstream.

FS2010 also included a significant sea ice physics component including sea ice thickness measurements sea ice optics, snow and sea ice profiles and sea ice mechanics. Eleven sea ice stations were carried out on ice floes in the vicinity of the ship. In addition to the on-ice work a helicopter was used to fly an electromagnetic instrument which was used to estimate the sea ice thickness along the flight path. Favourable weather conditions permitted 8 flights with the instrument providing almost 7 hours of data. Two of the flights were arranged to coincide in time and space with Cryosat overpasses so as to provide validation data.

Ice conditions were extremely favourable along the 78°50'N section; wide leads and fairly open drift ice allowed the moored array to be recovered and redeployed in good time and mostly during daylight hours. The 78°50'N

CTD and tracer section was completed mostly during the nights. The sailing log in table 1.1 describes activities during the cruise, day by day, with midday positions.

1.2 Sailing log

Date	Midday position	Mooring work	CTD stations
03/09/2010	Longyearbyen (Bykaia)	-	-
04/09/2010	N 78°48' W 003°03'	F11 Recovered	001 &002
05/09/2010	N 78°61' W 003°23'	F12 Recovered F14 Recovered F17 Recovered	003 &004
06/09/2010	N 78°05' W 013°05'	F18 Recovered	005 to 009
07/09/2010	N 78°58' W 009°34'	-	010 to 016
08/09/2010	N 78°55' W 006°48'	F18 Deployed	017 to 020
09/09/2010	N 78°50' W 008°06'	F18 Deployed	017 to 020
10/09/2010	N 79°39' W 006°49'	-	024 to 030
11/09/2010	N 78°50' W 006°37'	F14 Deployed	031 &032
12/09/2010	N 78°54' W 003°37'	-	033 to 036
13/09/2010	N 78°50' W 005°08'	F13 Deployed	037 &038
14/09/2010	N 78°51' W 003°54'	F12 Deployed	039
15/09/2010	N 78°51' W 003°51'	F11 Deployed	040 &041
16/09/2010	N 78°55' E 002°00'	-	042 to 049
17/09/2010	N 78°55' E 008°14'	-	050 to 061
18/09/2010	N 78°21'	-	-

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Date	Midday position	Mooring work	CTD stations
	E 011°23’		
19/09/2010	N 77°24’ E 003°36’	-	-
20/09/2010	N 75°50’ W 014°08’	-	062 to 068
21/09/2010	N 74°40’ W 012°13’	-	069 to 079
22/09/2010	N 74°04’ W 008°46’	-	080 to 082
23/09/2010	N 70°55’ W 008°07’	-	-
24/09/2010	N 70°45’ E 004°08’	-	-
25/09/2010	N 69°30’ W 018°13’	-	-
26/09/2010	Tromsø (Dampskipskaia)	-	-

Table 1.1: Fram Strait 2010 sailing log

2. CTD Measurements

2.1 CTD sections

Three sections of synoptic hydrographic and tracer measurements were collected during FS2010 (figure 2.1). The sections cross the East Greenland Current (EGC) as it passes through Fram Strait and flows southward along the East Greenland Shelf.

Hydrographic and tracer measurements were collected at stations along each of the three sections by means of a lowered CTD package which included an 11-bottle rosette water sampler. The sampler was equipped with 10 litre bottles from which independent sub-samples were taken for oxygen isotope ratio(δ^{18}O), nitrate, nitrite, phosphate, silicate, coloured dissolved organic matter (CDOM), suspended particulate matter (SPM) and laboratory salinity measurements. Tracer samples were collected from bottles closed at depths of 5, 10, 15, 25, 50, 75, 100, 150, 200, 250 and 400 m, as well as at the bottom of each cast. Horizontal distances between stations varied from 10 km to 20 km along the sections, with stations located closer together when the depth changed rapidly.

2.2 Section 1

2.2.1 Package Configuration

SBE 911+ (dual sensor) CTD system

SBE carousel water sampler with 11 Niskin bottles

SBE 11 *version 2* deck unit

RDI Workhorse Sentinel LADCP (down looking)

PAR sensor

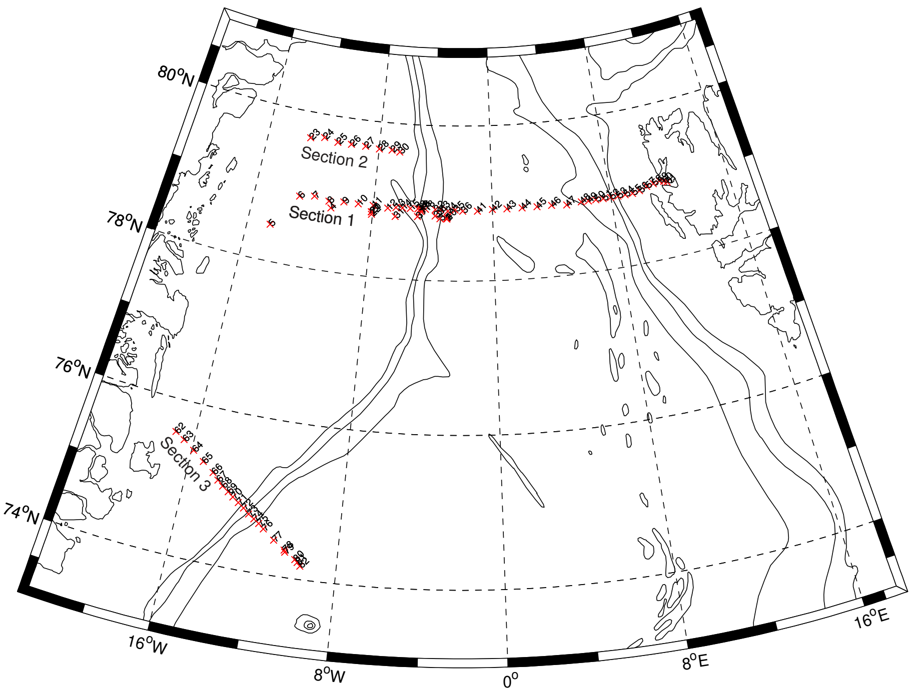

Figure 2.1: Chart showing CTD stations occupied during FS2010. Bathymetric contours are drawn at 500, 1000 and 2000 meters.

SPAR sensor

Wet Labs fluorometer

Compact rosette frame

Altimeter

Bottom alarm

2.2.2 Irregularities

Before leaving Longyearbyen the main output from the deck unit was connected to the PC mounted in the CTD room by means of a USB-serial adaptor while the modem channel was connected to the PCs single, native serial port. During the first CTD station no problems were detected, however at station 002 a malfunction occurred whereby all data from the deck unit were nonsensical and the bottom alarm sounded intermittently. After resetting the deck unit and restarting the SeaSave acquisition software the station was completed without problems. This problem reoccurred during the up-cast at stations 003 004 and was resolved in the same manner.

The manual for the deck unit warns that many USB-serial convertors are incompatible with the deck unit and lists models that have been tested by Sea-Bird. The model used was not one of those approved by Sea-Bird. After station 004 the main output of the deck unit was connected to the native serial port of the PC while the modem channel was connected via the USB-serial convertor. This seemed to resolve the problem. The Satlantic nitrate instrument was not deployed from the CTD package during section 1 as problems with the CTD were still being diagnosed.

At stations 004, 005, 006, 007 and 008 a number of the Niskin bottles attached to the rosette did not close properly. When the CTD package was brought onto deck the bottles appeared to have closed. However, water began to leak from around the lower closures of some bottles when the air valves were opened in preparation for sampling. The problem seemed to be caused by a lack of tension in the rubber bands running through the bottles. After station 008 all the bottles were replaced with bottles taken from a spare CTD rosette.

At the end of section 1 (during stations 059-061) the malfunction whereby all data from the deck unit were nonsensical and the bottom alarm sounded intermittently reoccurred. The stations at this end of the section were shallow and could be completed by repeatedly restarting the deck unit and repeating the CTD cast a number of times until a good cast was obtained. The malfunction occurred intermittently and usually during an upcast, but the cause was not identified. In an attempt to isolate the cause of the malfunction the modem cable was disconnected from the deck unit and bottles were fired using the controls on the deck unit itself. As a result some casts lack a .BL file.

The data collected along section 1 contains some bad values due to the malfunctioning CTD system. These were easily identified and removed and do not make up a significant proportion of the data. In some casts there are several hundred bad data points, but these are few when compared with the 24 Hz sampling rate of the CTD.

At the end of section 1 the CTD, rosette pylon, frame, deck unit and the cables between the deck unit and data acquisition PC were replaced with the equipment that was used during FS2008 and FS2009.

2.2.3 Calibration

The conductivity sensors used along sections 1 and 2 were calibrated immediately after the cruise using salinity samples which were analysed onboard during the cruise with a Guideline Portasal portable salinometer. The calibration procedure followed the method described in Sea-Bird Electronics Inc. application note 31, but without the benefit of post cruise calibration information for the temperature and pressure sensors. When post cruise calibration information is available for these sensors the calibration procure should be repeated. Without post-calibration information for the temperate and pressure sensors, differences between the computed bottle conductivity and CTD conductivity are minimised only by adjusting the slope of the conductivity sensors. This is inappropriate when a proportion of the difference is due to inaccuracies in the temperature and pressure data. Figures 2.2 and 2.3 show the relationship between bottle conductivity and CTD conductivity for all the deep samples collected. The bottle-CTD conductivity difference did not vary significantly either in time (station number) or with pressure. Only 50 deep salinity samples, suitable for sensor calibration were collected. Ideally sensor calibration should be based on the analysis of several hundred deep salinity samples. Few deep salinity samples were collected along sections 1 and 2 because the CTD system failed before many deep CTD stations had been completed. With more samples it would be possible to better characterise sensor drift with time.

A single slope offset of 0.0001 and 0.0002 S/m was applied to conductivity sensors 1 and 2 respectively for all data collected during sections 1 and 2 (calibrated conductivity = slope offset × measured conductivity). These values are typical for a sensors used during Fram Strait cruises and do not indicate any type of sensor problem. Figures 2.4 and 2.5 show salinity values calculated using the uncalibrated and calibrated conductivity measurements during FS2010 in comparison to salinity measurements collected during FS2009. The slope offset applied to the conductivity data seems to align sensors 1 and 2 adequately and the data show no anomalies in comparison to the 2009 data set. Note that points with a potential temperature between -0.5 and 0.5 °C seem to exhibit a salinity 0.01 lower than points with a similar temperature in 2009. This difference is probably due to the different location of CTD stations in 2009 and 2010.

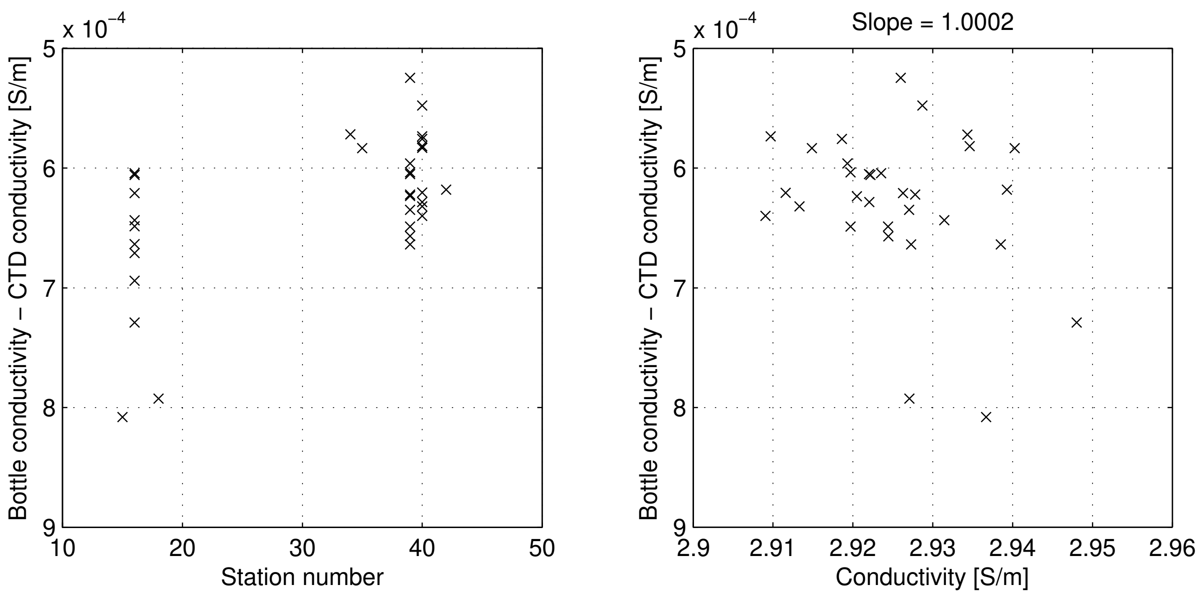

Figure 2.2: Calibration plot for the primary conductivity sensor used during sections 1 and 2. Bottle conductivity is computed following the procedure described by Sea-Bird Electronics Inc. in their application note 31

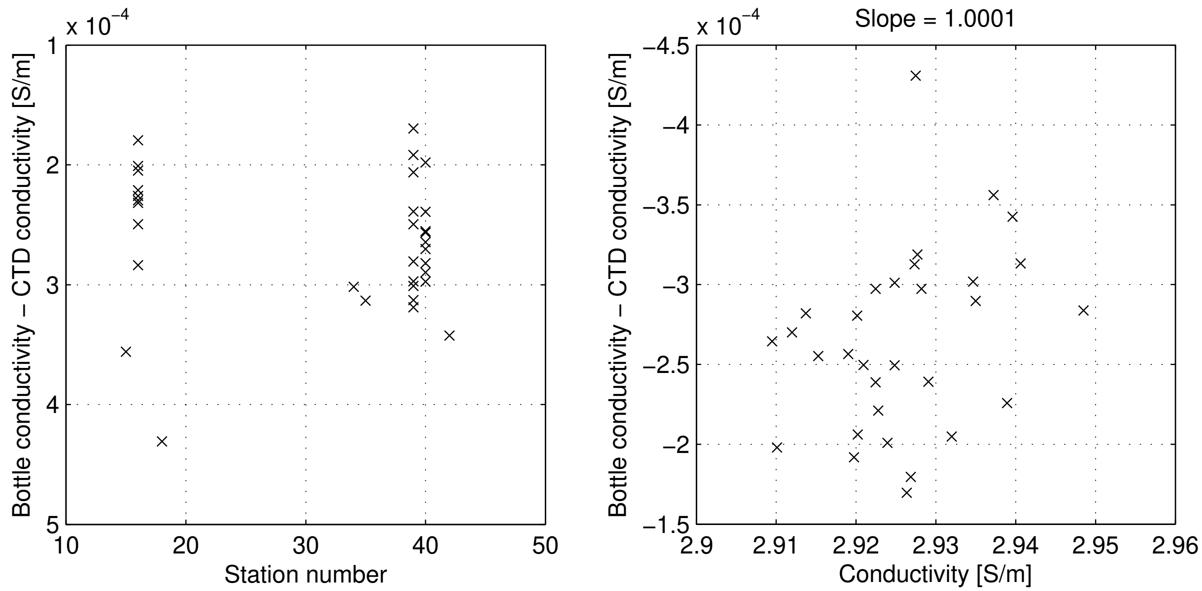

Figure 2.3: Calibration plot for the secondary conductivity sensor used during sections 1 and 2. Bottle conductivity is computed following the procedure described by Sea-Bird Electronics Inc. in their application note 31

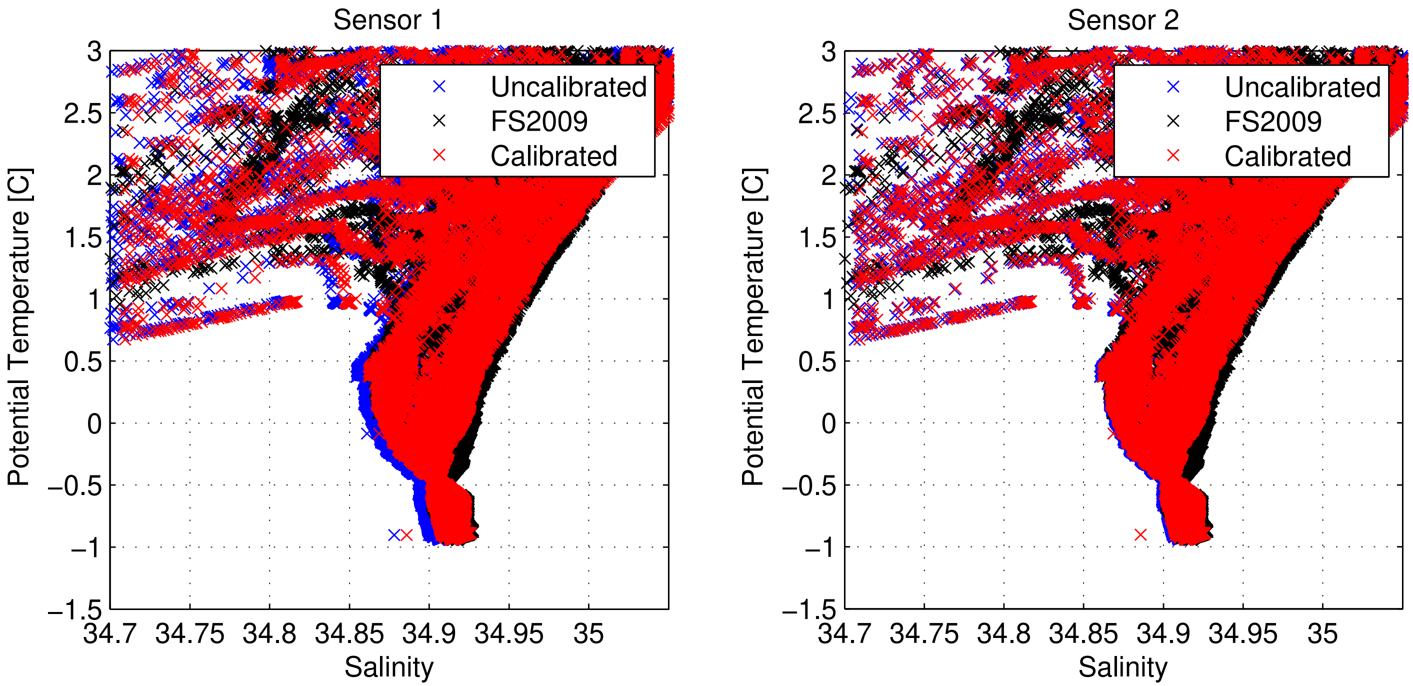

Figure 2.4: Calibration assessment plot for conductivity sensors used during sections 1 and 2.

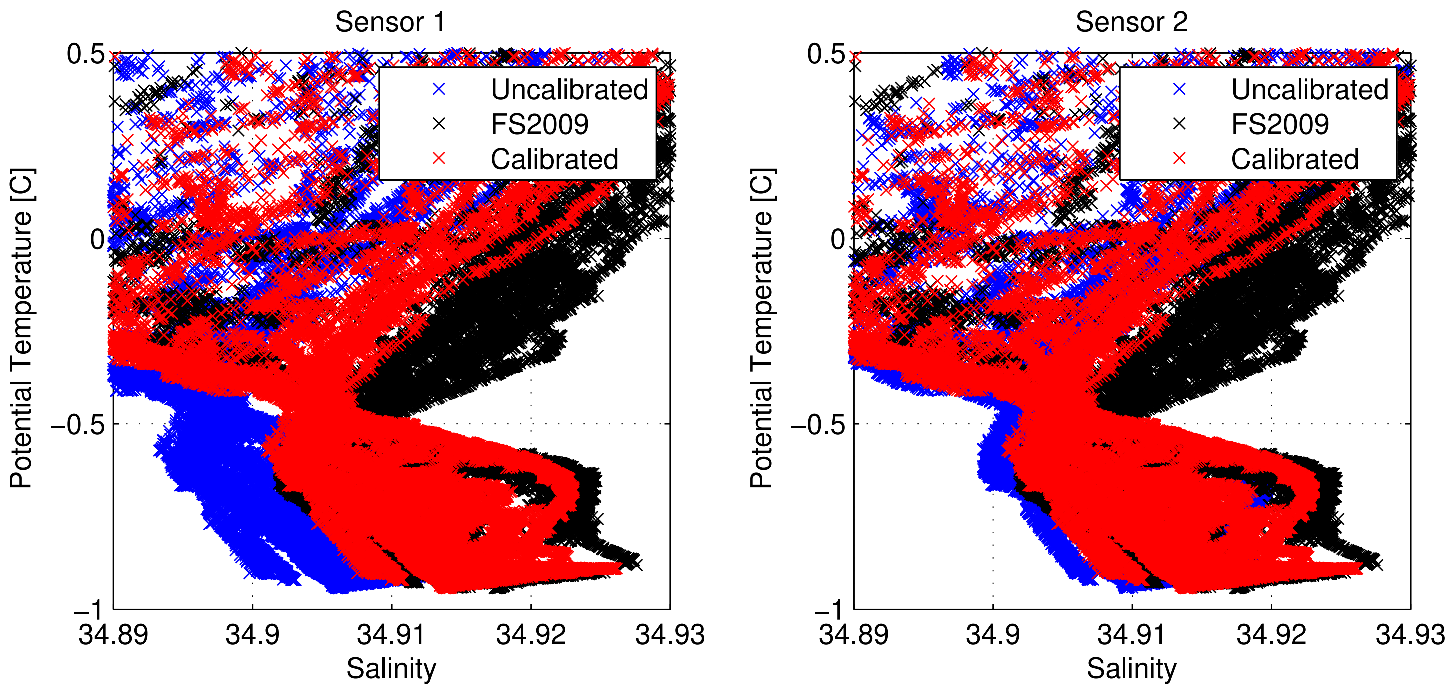

Figure 2.5: Large scale calibration assessment plot for conductivity sensors used during sections 1 and 2.

2.2.4 Section Plots

Figure 2.6 shows the salinity, potential temperature and potential density along section 1.

2.2.5 Station Positions

The positions of CTD station along section 1 are listed in table 2.1.

Station	Latitude	Longitude	Date	Time UTC	Depth
001	78.8000	-3.0667	04/09/10	21:37:01	2433
002	78.8000	-3.0333	04/09/10	23:18:53	2448
003	78.8000	-3.5000	05/09/10	17:22:16	268
004	78.8167	-10.8000	05/09/10	22:03:41	268
005	78.4667	-14.5167	06/09/10	00:20:15	217
006	78.9000	-12.9933	06/09/10	21:21:34	176
007	78.9333	-11.9983	07/09/10	04:56:40	304
008	78.9000	-10.9950	07/09/10	07:36:57	246
009	78.9167	-10.0000	07/09/10	09:18:31	219
010	78.9167	-9.0167	07/09/10	11:14:56	284
011	78.9167	-8.0167	07/09/10	12:56:02	173
012	78.9000	-7.0167	07/09/10	14:43:43	248
013	78.9167	-6.4833	07/09/10	16:12:22	293
014	78.9167	-6.0333	07/09/10	17:32:40	361
015	78.9167	-5.5167	07/09/10	19:11:36	753
016	78.9167	-4.7500	07/09/10	21:41:05	1384
017	78.8833	-4.7833	08/09/10	00:13:05	1305
018	78.9167	-4.5000	08/09/10	01:15:14	1564
019	78.9167	-4.8333	08/09/10	03:16:36	1317
020	78.8333	-8.0667	08/09/10	21:35:10	172
021	78.8333	-8.1000	09/09/10	11:38:59	229
022	78.8000	-8.0667	09/09/10	12:54:52	229
031	78.8000	-6.4833	11/09/10	17:13:27	265
032	78.9167	-3.8333	12/09/10	04:26:48	1945
033	78.9167	-3.4650	12/09/10	08:13:44	2224
034	78.9000	-3.0017	12/09/10	11:48:50	2224
035	78.9167	-2.5000	12/09/10	15:09:26	2535
036	78.9000	-2.0000	12/09/10	18:12:35	2602
037	78.8167	-5.0000	13/09/10	06:52:16	1004

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Station	Latitude	Longitude	Date	Time UTC	Depth
038	78.9167	-5.0000	13/09/10	20:07:08	1195
039	78.8333	-3.8333	14/09/10	10:41:24	2001
040	78.8167	-3.0167	15/09/10	10:43:01	2467
041	78.9000	-1.0000	15/09/10	18:51:30	2609
042	78.9167	-0.0000	16/09/10	00:07:35	2488
043	78.9167	0.9833	16/09/10	04:21:27	2490
044	78.9167	2.0000	16/09/10	08:40:30	2470
045	78.9167	3.0000	16/09/10	12:04:11	2318
046	78.9167	3.9833	16/09/10	14:55:33	2453
047	78.9000	5.0000	16/09/10	17:58:54	2569
048	78.9167	6.0000	16/09/10	21:07:48	2289
049	78.9167	6.4833	16/09/10	23:22:35	1737
050	78.9167	6.9833	17/09/10	05:40:08	1307
051	78.9167	7.4833	17/09/10	07:27:32	1162
052	78.9167	7.9833	17/09/10	08:58:42	1027
053	78.9167	8.4833	17/09/10	10:29:52	433
054	78.9167	8.9833	17/09/10	11:45:50	216
055	78.9167	9.4833	17/09/10	12:46:39	198
056	78.9333	9.9833	17/09/10	17:50:20	218
057	78.9667	10.5167	17/09/10	17:04:36	201
058	78.9833	10.9833	17/09/10	17:56:20	139
059	79.0000	11.4167	17/09/10	18:46:48	315
060	78.9833	11.7000	17/09/10	19:28:14	307
061	78.9667	11.9167	17/09/10	20:08:02	296

Table 2.1: Positions of CTD stations along section 1.

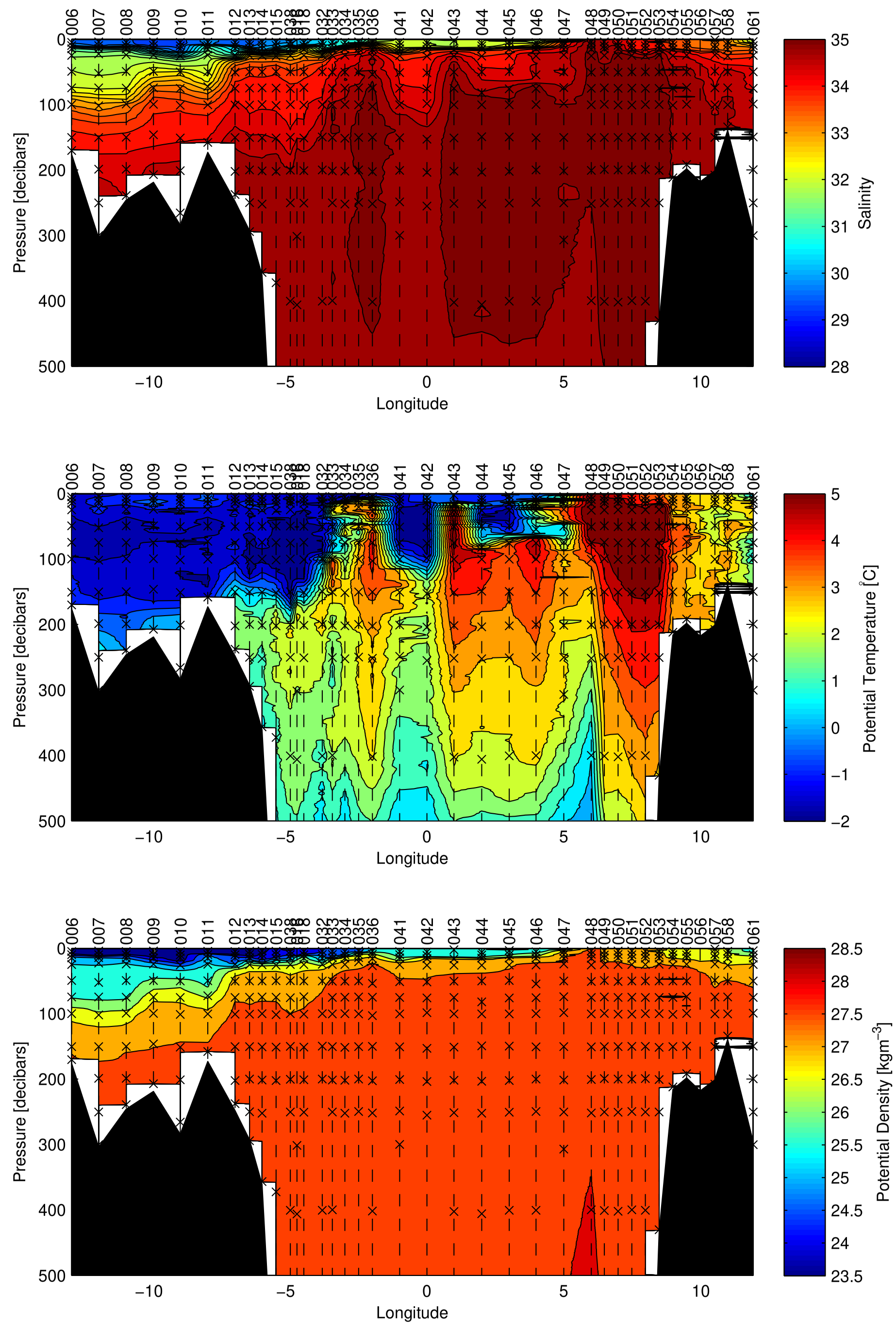

Figure 2.6: Salinity (top panel), potential temperature (middle panel) and potential density (σ_0)(bottom panel) fields measured along section 1. Numbers above panels indicate station numbers. Bottle firing locations are shown by black crosses.

2.3 Section 2

2.3.1 Package Configuration

SBE 911+ (dual sensor) CTD system

SBE carousel water sampler with 11 Niskin bottles

SBE 11 *version 2* deck unit

RDI Workhorse Sentinel LADCP (down looking)

PAR sensor

SPAR sensor

Wet Labs fluorometer

Compact rosette frame

Satlantic nitrate instrument

Altimeter

Bottom alarm

2.3.2 Irregularities

Before section 2 the configuration file used with the SeaSave data acquisition application was erroneously modified so as to cause the deck unit to average every 24 data scans. This error was not detected until the end of the section. The sampling rate after the averaging was approximately 1 Hz and at times the package descended with a velocity greater than 1 ms^{-1} (for example when the ship rolled). As a result some data gaps occur when the data is binned into 1 m deep bins.

2.3.3 Calibration

The same conductivity, sensor and pressure sensors were used along section 1 and section 2. See section 2.2.3 for calibration information.

2.3.4 Section Plots

Figure 2.7 shows the salinity, potential temperature and potential density along section 2.

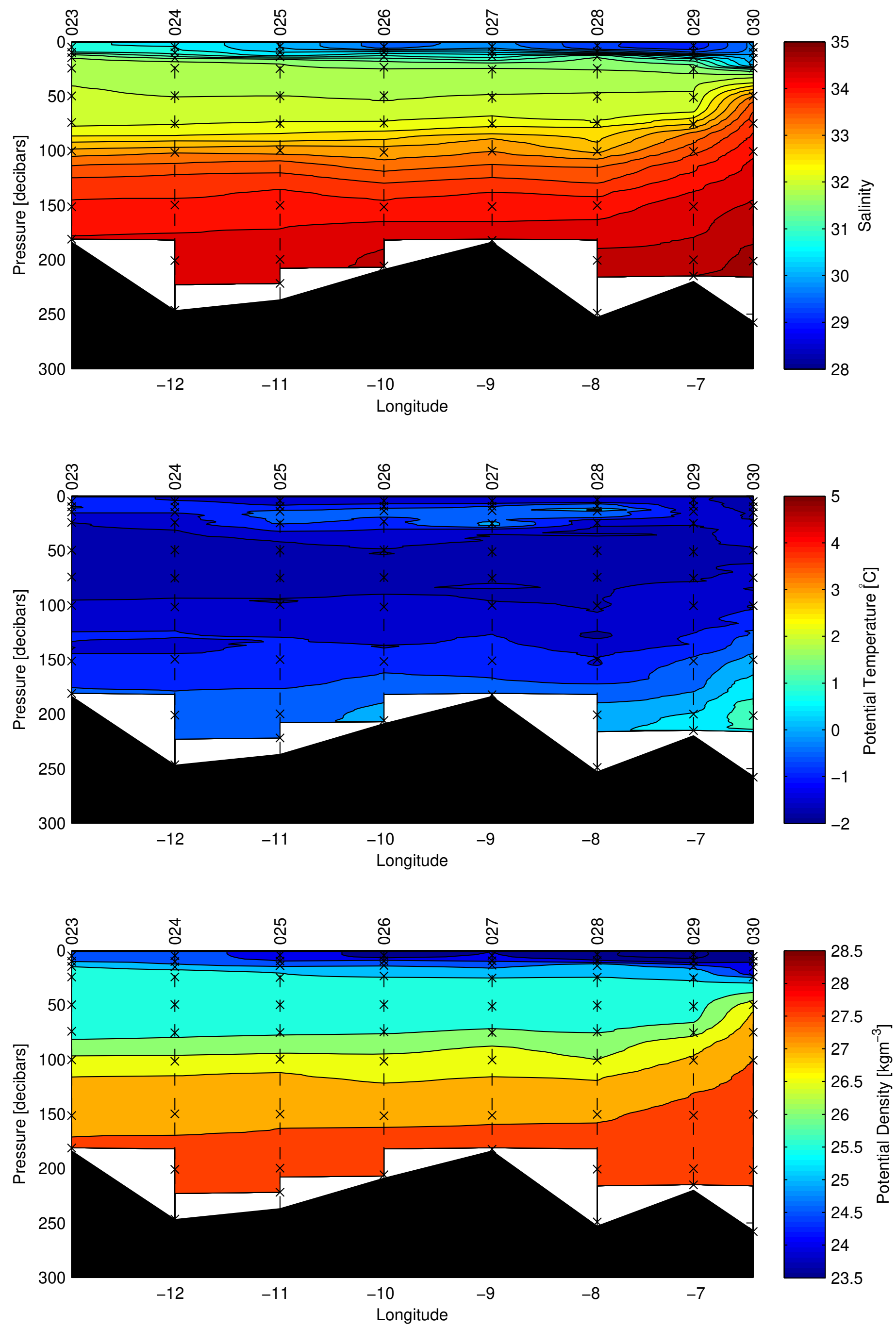

Figure 2.7: Salinity (top panel), potential temperature (middle panel) and potential density (σ_0)(bottom panel) fields measured along section 2. Numbers above panels indicate station numbers. Bottle firing locations are shown by black crosses.

2.3.5 Station Positions

The positions of CTD station along section 2 are listed in table 2.2.

Station	Latitude	Longitude	Date	Time UTC	Depth
023	79.6667	-12.9833	09/09/10	23:17:44	184
024	79.7000	-12.0000	10/09/10	00:41:15	247
025	79.6667	-11.0000	10/09/10	02:05:27	237
026	79.6667	-10.0117	10/09/10	03:27:55	209
027	79.6667	-8.9833	10/09/10	04:55:53	184
028	79.6500	-7.9833	10/09/10	06:18:33	253
029	79.6500	-7.0667	10/09/10	08:12:11	220
030	79.6333	-6.5000	10/09/10	15:25:15	257

Table 2.2: Positions of CTD stations along section 2.

2.4 Section 3

2.4.1 Package Configuration

SBE 911+ (single sensor) CTD system

SBE carousel water sampler with 11 Niskin bottles

SBE 11 *version 1* deck unit

RDI Workhorse Sentinel LADCP (down looking)

Compact rosette frame

Altimeter

Bottom alarm

2.4.2 Irregualrites

Along section 3 the CTD system malfunction experienced during section 1 occasionally reoccurred. This suggests that the cause was not related to the CTD, rosette pylon or deck unit (which were replaced at the end of section 1). All connections were inspected and appeared normal. Due to the intermittent nature of the malfunction the cause was not be identified during section 3.

2.4.3 Calibration

The conductivity sensor used along section 3 was calibrated in the same manner as the sensors used along sections 1 and 2. See section2.2.3 . Figure 2.8 shows the relationship between bottle conductivity and CTD conductivity for all the deep samples collected along section 3. The bottle-CTD conductivity differences were small and did not vary significantly either in time (station number) or with measured conductivity. Only a limited number of deep salinity samples, suitable for sensor calibration were collected due to the short length of section 3. Ideally sensor calibration should be based on the analysis of several hundred deep salinity samples. Few deep salinity samples were collected because the sensor was only used after the previous sensor failed and because the cruise ended after section 3. With more samples it would be possible to better characterise any sensor drift with time.

No slope offset was applied to the conductivity sensor used on section 3 because the magnitude of difference between the CTD-measured conductivity values and salinometer-measured conductivity values was small relative to the precision of the salinometer. These sensor was unusually stable and accurate compared with typical sensors used during Fram Strait cruises

2.4.4 Section Plots

Figure 2.9 shows the salinity, potential temperature and potential density along section 3.

2.4.5 Station Positions

The positions of CTD station along section 3 are listed in table 2.3.

Station	Latitude	Longitude	Date	Time UTC	Depth
062	75.5786	-17.0181	20/09/10	14:50:12	323
063	75.5028	-16.5022	20/09/10	16:39:02	177
064	75.3974	-15.8980	20/09/10	18:16:36	126
065	75.2857	-15.2874	20/09/10	19:50:54	158
066	75.1732	-14.6878	20/09/10	21:19:40	203
067	75.0913	-14.3632	20/09/10	22:22:30	182
068	75.0283	-14.0745	20/09/10	23:18:05	182
069	74.9715	-13.7475	21/09/10	00:20:29	192

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Station	Latitude	Longitude	Date	Time UTC	Depth
070	74.9175	-13.4635	21/09/10	01:18:27	217
071	74.8592	-13.1463	21/09/10	02:20:55	505
072	74.8012	-12.8492	21/09/10	03:41:02	1303
073	74.7368	-12.5440	21/09/10	06:20:45	1923
074	74.6881	-12.2560	21/09/10	08:46:45	2294
075	74.6408	-11.9783	21/09/10	11:31:36	2637
076	74.5815	-11.7148	21/09/10	14:17:45	2875
077	74.4586	-11.1358	21/09/10	17:38:18	3037
078	74.3524	-10.5671	21/09/10	21:01:30	3024
079	74.3272	-10.5230	21/09/10	23:37:39	3025
080	74.2507	-10.0018	22/09/10	00:50:46	3087
081	74.2170	-9.8705	22/09/10	03:42:42	3101
082	74.1733	-9.7218	22/09/10	06:56:40	3115

Table 2.3: Positions of CTD stations along section 3.

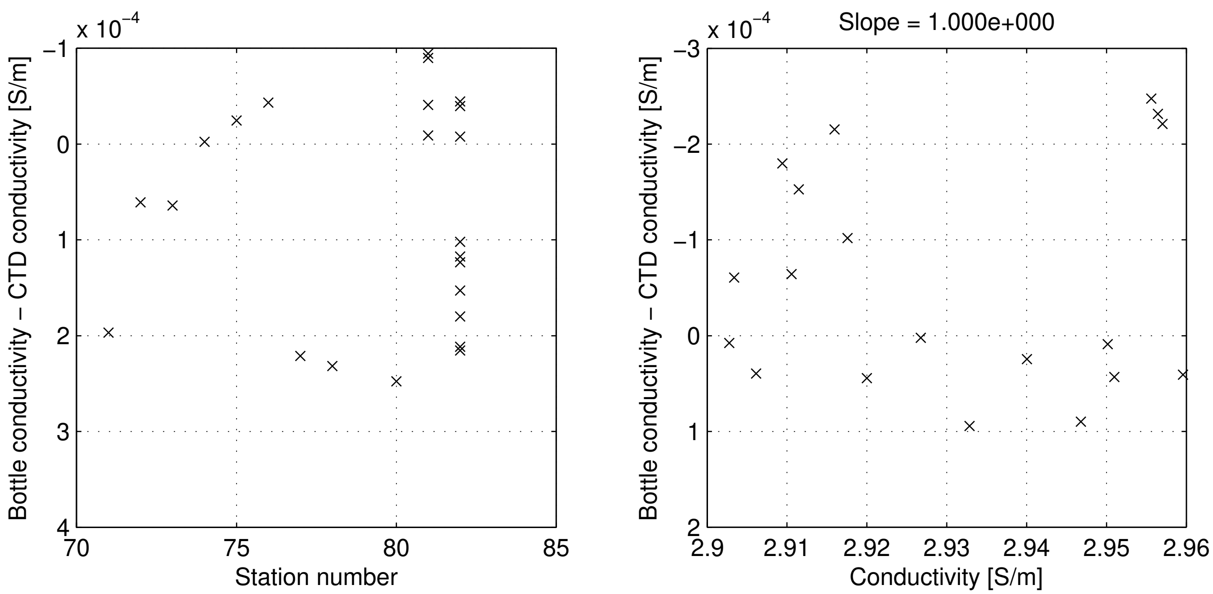


Figure 2.8: Calibration plot for the single conductivity sensor used during section 3. Bottle conductivity is computed following the procedure described by Sea-Bird Electronics Inc. in their application note 31

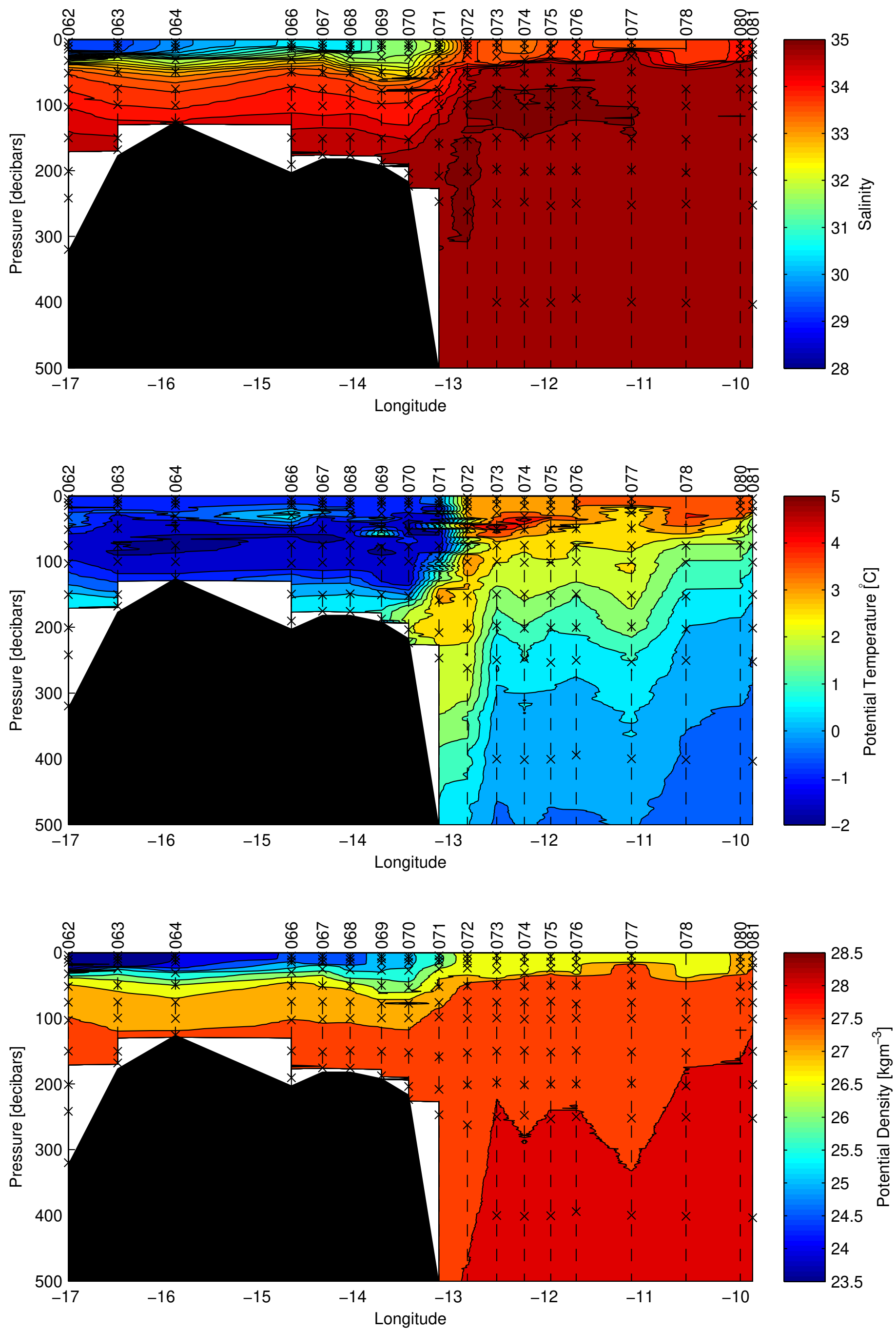


Figure 2.9: Salinity (top panel), potential temperature (middle panel) and potential density (σ_0)(bottom panel) fields measured along section 3. Numbers above panels indicate station numbers. Bottle firing locations are shown by black crosses.

3. Tracer Measurements

3.1 Sampling locations

Samples for laboratory salinity and $\delta^{18}O$ measurement were collected along all sections. Sampling was at standard depths of 5, 15, 25, 50, 75, 100, 150, 200, 250, 400 m and at the bottom of the cast. Samples for coloured dissolved organic matter (CDOM), total organic carbon (TOC) and suspended particulate matter (SPM) were collected at selected stations along sections 2 and 3 at the same standard depths as $\delta^{18}O$ samples. Additional tracer samples were opportunistically collected below 400 m when Niskin bottles were closed in deep water. This was possible (for example) at calibration stations. At other stations all 11 Niskin bottles were required for the surface tracer sampling program. Figure 3.1 shows the position of stations at which tracer samples were collected during Fram Strait 2010. The tracer samples collected at each station are also summarised in table 3.1.

Station	Salinity	$\delta^{18}O$	Nutrients	CDOM	TOC
001	×	×	×	×	×
002	×	×	×	×	×
003	✓	×	×	×	×
004	✓	×	×	×	×
005	✓	×	×	×	×
006	✓	✓	✓	✓	✓
007	✓	✓	✓	✓	✓
008	✓	✓	✓	✓	✓
009	✓	✓	✓	✓	✓
010	✓	✓	✓	✓	✓
011	✓	✓	✓	✓	✓
012	✓	✓	✓	✓	✓
013	✓	✓	✓	×	×

Continued on next page

Station	Salinity	$\delta^{18}O$	Nutrients	CDOM	TOC
014	✓	✓	✓	✓	✓
015	✓	✓	✓	×	×
016	✓	✓	×	×	×
017	✓	✓	✓	✓	✓
018	✓	✓	✓	×	×
019	✓	×	×	×	×
020	✓	×	×	×	×
021	✓	×	×	×	×
022	✓	×	×	×	×
023	✓	✓	×	×	×
024	✓	✓	×	×	×
025	✓	✓	×	×	×
026	✓	✓	×	×	×
027	✓	✓	×	×	×
028	✓	✓	✓	×	×
029	✓	✓	✓	×	×
030	✓	✓	×	×	×
031	✓	×	×	×	×
032	✓	✓	✓	✓	×
033	✓	✓	✓	✓	×
034	✓	✓	✓	✓	×
035	✓	✓	✓	×	×
036	✓	✓	✓	✓	×
037	✓	×	×	×	×
038	✓	✓	✓	×	×
039	✓	×	×	×	×
040	✓	×	×	×	×
041	✓	✓	✓	✓	×
042	✓	✓	✓	✓	×
043	✓	✓	✓	×	×
044	✓	✓	✓	✓	×
045	✓	✓	✓	×	×
046	✓	✓	✓	✓	×
047	✓	✓	✓	×	×
048	✓	✓	✓	✓	×
049	✓	✓	✓	×	×
050	✓	✓	✓	✓	✓
051	✓	✓	✓	×	×

Continued on next page

Station	Salinity	$\delta^{18}O$	Nutrients	CDOM	TOC
052	✓	✓	✓	✓	×
053	✓	✓	×	×	×
054	✓	✓	✓	✓	×
055	✓	✓	×	×	×
056	✓	✓	×	✓	×
057	✓	✓	×	×	×
058	✓	×	×	✓	×
059	✓	×	×	×	×
060	×	×	×	×	×
061	✓	×	×	✓	×
062	✓	✓	×	✓	×
063	✓	✓	✓	×	×
064	✓	✓	✓	✓	×
065	✓	✓	✓	×	×
066	✓	✓	✓	✓	×
067	✓	✓	✓	×	×
068	✓	✓	✓	✓	×
069	✓	✓	✓	×	×
070	✓	✓	✓	✓	×
071	✓	✓	✓	×	×
072	✓	✓	✓	✓	×
073	✓	✓	✓	×	×
074	✓	✓	✓	✓	×
075	✓	✓	✓	×	×
076	✓	✓	✓	✓	×
077	✓	✓	✓	×	×
078	✓	✓	✓	✓	×
079	✓	✓	✓	✓	×
080	✓	✓	✓	×	×
081	✓	×	×	×	×
082	✓	×	×	×	×

Table 3.1: List of tracer samples collected at each station.

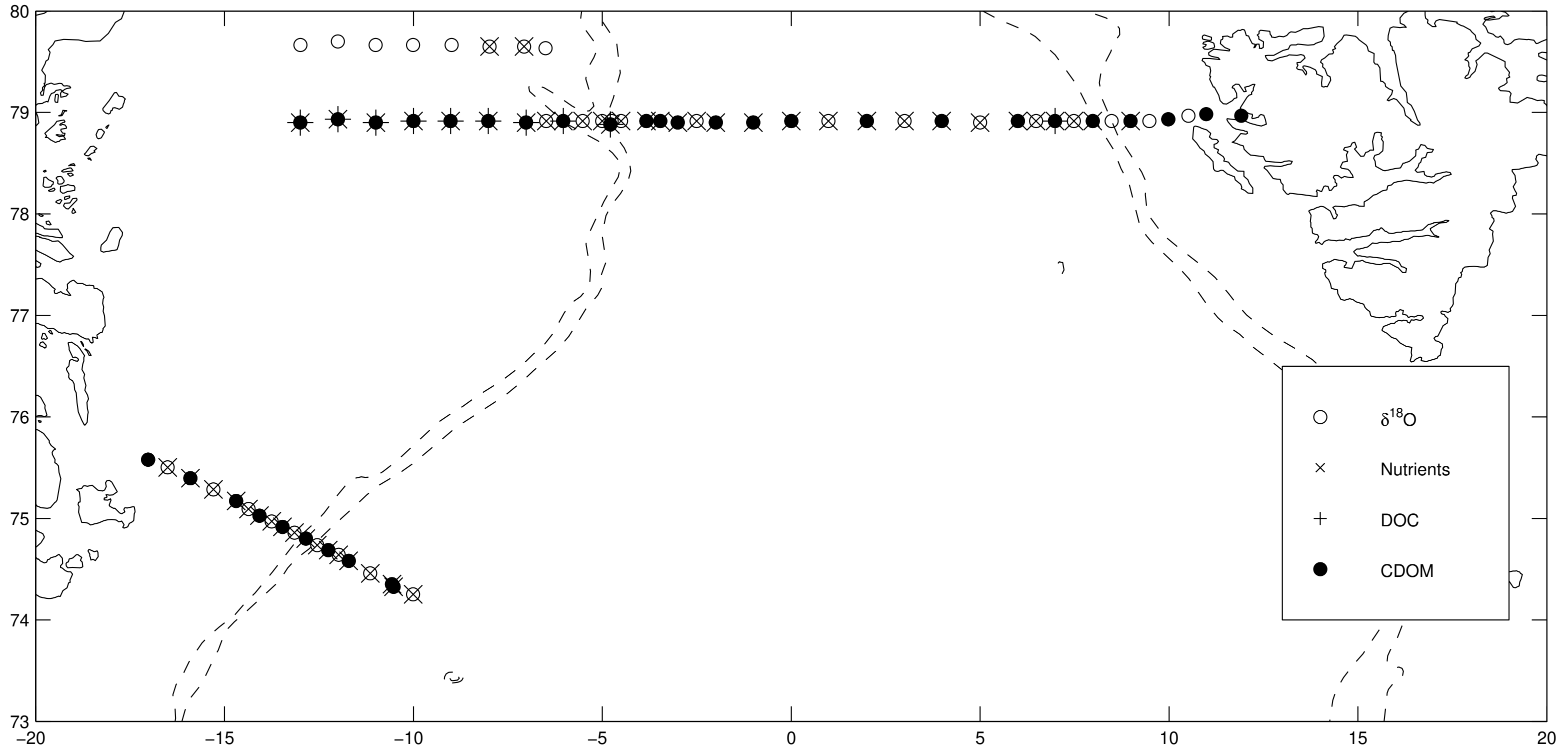


Figure 3.1: Chart showing the position of stations at which tracer samples were collected

3.2 Sampling procedures

3.2.1 Salinity samples

Materials required:

240 ml flat glass 'medicine' bottles of the type sold specifically for salinity sampling. The bottle should have a screw cap and a neck that can accept a disposable plastic insert.

Open wire bottle storage racks

Disposable plastic bottle inserts

Laboratory towel

Procedure:

1. Bottles were pre-labelled with a the cruise name and a serial number.
2. Rinse the bottle (including insert) 3 times with water from the Niskin bottle to be sampled.
3. Fill the bottle to just below the shoulder to allow room for expansion.
4. Insert the disposable plastic insert.
5. Dry the mouth of bottle and the insert thoroughly to avoid salt crystallisation around the cap. If this is not done crystals form as the bottle dries out that may fall into the sample when the disposable plastic insert is removed.
6. Attach the plastic screw cap over the disposable plastic insert.
7. After each cast place salinity samples in wire open crates in the analysis laboratory so that they begin to equilibrate with the temperature in the analysis laboratory as soon as possible.

Salinity samples were analysed at sea using a Guildline Portasal portable salinometer 48-72 hours after sampling when the temperature of samples had equilibrated with the temperature in the analysis laboratory.

3.2.2 Oxygen isotope ratio ($\delta^{18}O$) samples

Materials required:

30 ml glass vials with a narrow mouth and polypropolene cap with 2 mm butyl/PTFE liner

Roll of 50 mm wide Parafilm

Laboratory towel

Procedure:

1. Bottles were pre-labelled with a the cruise name and a serial number.
2. Rinse the bottle (including lid) 3 times with water from the Niskin bottle to be sampled.
3. Fill the bottle completely, and wet the inside of the lid.
4. Quickly attach the lid to the bottle so that the headspace is minimised.
5. Ensure that there is at least a small bubble in the sample to avoid the vials cracking due to expansion.
6. Dry the lid of the bottle thoroughly to avoid salt crystallisation around the cap.
7. Seal the lid of the bottle using a 50 mm length of 50 mm wide Parafilm tape. Parafilm should be applied in a warm environment as it does not adhere well when cold.
8. Store samples at room temperature away from direct heat.

After the cruise samples were placed in an aluminium Zarges box for protection, and transferred to the storage area at the Norwegian Polar Institute in Tromsø. Approximately two months later the samples were shipped to the analysing laboratory in aluminium Zarges box into which sheets of 40 mm thick expanded polystyrene had been inserted to provide padding and insulation. "Must not Freeze" and "Fragile: Liquid in Glass" labels were attached to the outside of the box.

3.2.3 Nitrate, phosphate & silicate samples

Materials required:

Disposable nitrile gloves

50 ml transparent high density polyethelene bottles

Procedure:

1. Use a new pair of nitrile gloves for each cast.
2. Label the bottle with a serial number 001, 002 etc using a marker pen.
3. Rinse the bottle (including lid) 3 times with water from the Niskin bottle to be sampled.
4. Fill the bottle with sample leaving a small headspace (the amount of headspace is not important).
5. Attach the lid.
6. Place samples in a freezer at -20 C immediately after the cast.

After the cruise samples were placed in an insulated expanded polystyrene box and transferred to a freezer at the Norwegian Polar Institute. Approximately three weeks later the samples were shipped the analysing laboratory by refrigerated road transport.

3.2.4 CDOM samples

Materials required:

Disposable laboratory gloves

40 ml amber glass vials with a Teflon cap

Disposable plastic syringes (60 ml capacity)

(0.8/0.2 m) membrane syringe filters

Procedure:

1. Use a new pair of disposable gloves for each cast.
2. Vials were pre-labelled with the cruise name and a serial number.

3. Rinse the syringe that is used thoroughly inside and out with seawater from the Niskin bottle containing the deepest sample that is going to be collected.

4. Fill the syringe with 10-20 ml of seawater, pull syringe open (to 60ml mark) and shake well to rinse the entire inside of syringe, discard water. Repeat this three times.

5. Fill the syringe with 20 ml of seawater, attach the syringe filter and push water slowly through the syringe filter to rinse the syringe filter. Discard this water.

6. Fill syringe with about 45 ml of seawater sample, attach syringe filter and fill the amber vial to the shoulders. Leave some headspace in vial! Close cap firmly.

7. Put vials with filtered water in a fridge (approx. +4 C) and store until the end of a cruise.

After the cruise samples were placed in an insulated box and transferred to a fridge at the Norwegian Polar Institute. Approximately 1 month later samples were shipped to the analysing laboratory by air freight.

3.2.5 TOC samples

Materials required:

40 ml glass vials with caps

Concentrated hydrochloric acid (HCl)

Micro pipette with disposable tips

Procedure:

1. Use a new pair of plastic laboratory gloves for each cast

2. Vials were pre-labelled with a cruise name and serial number

3. Open tap on Niskin bottle to be sampled and let water run for 5 seconds to rinse the nozzle.

4. Fill the vial carefully and slowly, leaving 2 cm of headspace. Put the cap on.

5. As soon as practical, and within 20 minutes add 60 μl of hydrochloric acid to each sample (with a micro pipette) and re-apply cap.
6. Store samples in a refrigerator (approx. +4 C) until the end of the cruise.

After the cruise samples were placed in an insulated box and transferred to a fridge at the Norwegian Polar Institute. Within 2 days samples were sent to the analysing laboratory by refrigerated cargo ship.

3.2.6 SPM samples

Materials required:

Disposable plastic laboratory gloves

2 litre opaque brown plastic bottles with wide neck and screw cap

GF/F filters (25 mm)

Plastic petri dishes

Procedure:

1. Use a new pair of plastic laboratory gloves for each cast.
2. Rinse the bottle 3 times with water from the Niskin bottle to be sampled.
3. Fill the bottle with approximately 1.5 l of seawater. Put the cap on
4. Store in a cool, dark place until filtration is possible.
5. As soon as practical, filter 0.8-1.5 l of the sample seawater through GF/F filters until some colour is observed on the filters.
6. Rinse filters with pre-filtered seawater.
7. Place filters into pre-labelled Petri dishes and wrap with aluminum foil.
8. Store samples in a freezer at -80 °C.

After the cruise samples were placed in an insulated box and transferred to a - 80 °C freezer at the Norwegian Polar Institute. Approximately 3 weeks later the samples were shipped to the analysing laboratory by refrigerated (-20 °C) road transport in an insulated container.

4. Navigation

4.1 Differential GPS

On 06 September the Seapath 3DGPS system on board Lance failed. During the morning of 06 September the Captain noticed that positions displayed by the Seapath system were several minutes away from position determined by the ships navigational GPS which was consistent with a number of hand held GPS units on board. The Seapath system was restarted a number of times but it continued to report incorrect positions. Four status lights on the front of the unit showed red and orange in numerous combinations at different times. These combinations indicated that the system was not receiving a signal from its antennae. Nobody on board had the knowledge required to repair the system. Between sections 2 and 3 the Seapath 3DGPS system began to display correct positions again. The system continued to display good positions during section 3. The quality of heading information provided by the Seapath 3DGPS system during section 3 has not been verified.

4.2 Hand held GPS

Following the failure of the Seapath 3DGPS system a hand held GPS located on the bridge was used to log the ships position every 10 seconds. A 10 second interval was chosen because the unit was able to store only 10000 data points. An interval of 10 seconds allowed data to be retrieved from the GPS daily. An interval of 1 second would have required the data to have been downloaded every few hours which was impractical with the limited number of personnel available and would likely have lead to data gaps. Figure 4.1 shows the cruise track during sections 1 and 2.

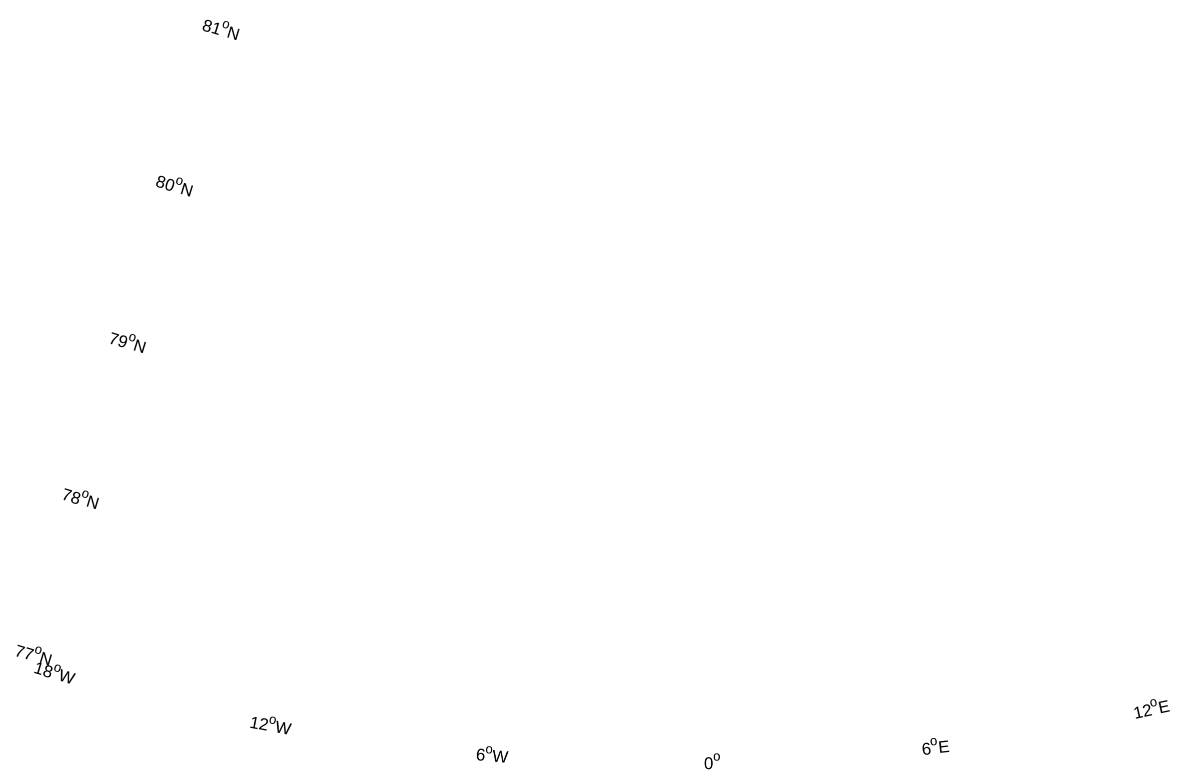


Figure 4.1: Radarsat image from 10 September showing ice conditions around CTD stations occupied during FS2010. CTD stations are shown as yellow circles. The ship track is plotted in red during periods when position information data from the Seapath system was usable and in blue when position information was collected using a handheld GPS located on the bridge.

5. ADCP Measurements

5.1 Lowered ADCP

An RDI Workhorse Sentinel lowered ADCP (LADCP) was deployed at every CTD station. The LADCP was deployed in a downward looking orientation using the same configuration parameters that were used during the 2008 and 2009 Fram Strait Cruises. The deployment script (included below) was used at all stations. The deployment script was edited before each station to change the name of the file in which data were stored. All other the parameters in the script remained constant for the duration of the cruise.

```
; Set to factory defaults:
CR1
; Record data internally:
CF11111
; Name data file (5 digits):
RN L001_
; Heading alignment set to 0 degrees:
EA0
; Heading bias:
EB-0360
; Set transducer depth to zero:
ED0
; Set salinity to 35ppt:
ES35
; Set system coordinate:
EX11111
; Set to use a fixed speed of the sound:
EZ1111111
; Set LADCP to output Velocity, Correlations, Amplitude, and Percent Good:
LD111100000
; Set blank to 176 cm (default value) (Use WF if LADCP option is not enabled):
LF0176
; Set to record 20 bins (Use WN if LADCP option is not enabled):
LN020
; Set one ping per ensemble (Use WP if LADCP option is not enabled):
LP1
; Set bin size to 400 cm. (Use WS if LADCP option is not enabled).
LS400
```

```
; Set max radial (along the axis of the beam) water velocity to 176 cm/sec
; (Use WV if LADCP option is not enabled):
LV175
; Set ADCP to narrow bandwidth and extend range by 10%:
LW1
; Set one ensemble/sec
TE00:00:01.00
; Set one second between pings
TP00:01.00
; Save set up:
CK
; Start pinging
CS;
```

Before the first CTD station the LADCP clock was synchronised with the UTC time displayed by the ships GPS. The CTD computer was synchronised to this ships' GPS at the same time.

5.2 Vessel Mounted ADCP

The vessel mounted ADCP was deployed using the S_300B4 configuration script designed by Pierre Jarracrd (4 metre bin size, standard range parameters, bottom tracking mode on). The same configuration was used for the duration of the cruise. The precise configuration can be determined from examination of the deployment script (below).

At the beginning of the cruise the vessel mounted ADCP electronics unit and the acquisition computer were synchronised to GPS UTC time. During the cruise the ADCP acquisition PC was monitored to prevent the number of data files in each directory from exceeding 999. If 1000 files are created in one directory the acquisition PC will crash. Each time the data directory was changed, the aquisition PC was resynchronised to GPS time. Directories were named sequentially F10A, F10B and F10C.

```
COMMUNICATIONS
{
ADCP         ( ON   COM2 38400 N 8 1 ) [ Port Baud Parity Databits Stopbits ]
ENSOUT       ( OFF  COM4 9600 N 8 1 ) [ Port Baud Parity Databits Stopbits ]
NAV          ( ON   COM1 9600 N 8 1 ) [ Port Baud Parity Databits Stopbits ]
REFOUT       ( OFF  COM4 4800 N 8 2 ) [ Port Baud Parity Databits Stopbits ]
EXTERNAL     ( ON   COM3 9600 N 8 1 ) [ Port Baud Parity Databits Stopbits ]
}

ENSEMBLE OUT
{
ENS CHOICE   ( N N N N N N N N )  [ Vel Corr Int %Gd Status Leader BTrack Nav ]
ENS OPTIONS  (BOTTOM   1   8   1   8 )  [ Ref First Last Start End ]
```

```
}

ADCP HARDWARE
{
Firmware       ( 5.46 )
Angle          (      30 )
Frequency      (     150 )
System         (    BEAM )
Mode           (       4 )
Orientation    (    DOWN )
Pattern        ( CONCAVE )
}

DIRECT COMMANDS
{
WS400
WF200
BX4000
WN045
WD111100000
WP00001
BP001
WM4
TP000010
BM5
TE00000050
EZ0000001
EP0
ER0
EH0
WB0
}

RECORDING
{
Deployment ( OAER )
Drive 1    (   C  )
Drive 2    (   C  )
ADCP       ( YES )
Average    ( YES )
Navigation ( YES )
}

CALIBRATION
{
ADCP depth                (    6.00 m      )
Heading / Magnetic offset (   0.00      0.00 deg )
Transducer misalignment   (    0.00 deg    )
Intensity scale           (    0.43 dB/cts )
Absorption                (   0.039 dB/m   )
Salinity                  (    35.0 ppt    )
Speed of sound correction (   NO   1500.0  )
Pitch & roll compensation (     YES        )
```

```
Tilt Misalignment         (    0.00 deg    )
Pitch_Offset              (    0.000 deg    )
Roll_Offset               (    0.000 deg    )
Top discharge estimate    (    CONSTANT    )
Bottom discharge estimate (    CONSTANT    )
Power curve exponent      (      0.1667   )
}

PROCESSING
{
Average every ( 300.00 s )
Depth sounder (  NO )
Refout_info (   1   8  30.00  1.000 0      1) [bins:1st last, limit, weight, format, delaysec]
External_formats  ( N N Y N )  [ HDT HDG RDID RDIE ]
External_decode   ( Y Y Y  N ) [ heading pitch roll temp ]
}

GRAPHICS
{
Units        ( SI )
Velocity Reference ( NAVIGATION )
East_Velocity      ( -100.0  100.0  cm/s )
North_Velocity     ( -100.0  100.0  cm/s )
Vert_Velocity      ( -100.0  100.0  cm/s )
Error_Velocity     ( -100.0  100.0  cm/s )
Depth              (      1     61   bin )
Intensity          (      0    200     dB)
Discharge          (  -1000   1000  m3/s )
East_Track         ( -107681 1191414     m )
North_Track        ( -910948 1357285     m )
Ship track         (  5 bin  100.0  cm/s )
Proj_Velocity      ( -100.0  100.0  cm/s )
Proj_Angle         (    0.0  deg from N )
Bad_Below_Bottom   (   NO  )
Line1              (                                                )
Line2              (                                                )
}

HISTORY
{
SOFTWARE       ( BB-TRANSECT )
Version        ( 2.72 )
}
```

5.3 Limits of the available navigation data

Following the failure of the Seapath 3DGPS navigation system (section 4.1) the ships position was only logged at 10 second intervals using a handheld GPS located on the bridge.

5.3.1 Low frequency of position records

Typically position records at one second intervals are used to remove ship movement from vessel mounted and lowered ADCP profiles. For most of the Fram Strait 2010 cruise the position was only logged accurately at 10 second intervals.

The principle impact of the lower frequency position record on ADCP data quality is that a less accurate estimate of the ships' movement will removed from ADCP profiles when the ship is accelerating or turning. Additional care should be taken during the processing of on-station vessel mounted ADCP data and lowerd ADCP data to identify times where the ship may have accelerated or turned rapidly.

The lower frequency position record may have less impact on the quality of underway vessel mounted ADCP data as the ship tends to maintain a constant speed and direction when underway.

5.3.2 Lack of 3DGPS heading information

Ideally a 3D GPS system should be used to determine the orientation of the vessel mounted ADCP transducer relative to the Earth. In lieu of such a system it is possible to use a record of the ships heading from the gyrocompass. The disadvantage of using the gyrocompass record is that the gyrocompass tends to oscillate for a period after the ship turns sharply and may occasionally lag the ships rotation. However both of these issues can be mitigated to some extent by using a suitable gyrocompass model.

6. Mooring Operations

6.1 Moorings Recovered

Recovery of all moorings went smoothly and under good ice conditions (table 6.1). F13 was not deployed in 2009 and was therefore not recovered in 2010.

6.2 Moorings Deployed

Table 6.2 and figure 6.2 summarise the array of instruments deployed in 2010. Good ice conditions facilitated the deployment of most moorings (figure 6.1). However, F12 was deployed while a strong wind was causing Lance to drift southeast. Lance drifted southeast at 1-2 kts for about 1 nm before F12 was released. Immediately before releasing, the angle of the wire between the block on the crane and the floats of IPS on the water surface was only about 5 degrees. However, the ship was moved close to the floats just before releasing the mooring. For much of the drift the wire angle was greater than 45 degrees. Five minutes after releasing, the mooring was located on the navigation echo sounder in almost the same position as it was released: N 78°48.4225', W 003°59.1441'. The 400 m floatation returned the strongest echo, but the top of the mooring was also detected.

Figures 6.3, 6.4, 6.5, 6.6, 6.7 and 6.8 are diagrams of the mooring deployed during FS2010.

6.3 Moored Water Samplers Deployed

RAS-500 water samplers were deployed at depths of 50 m (S/N 12239-02) and at 120 m (S/N 12239-01) on mooring F17. The samplers were programmed to sample according to the schedule listed in table 6.3. A preservative was added to half of the bags in the sampler at 120 m.

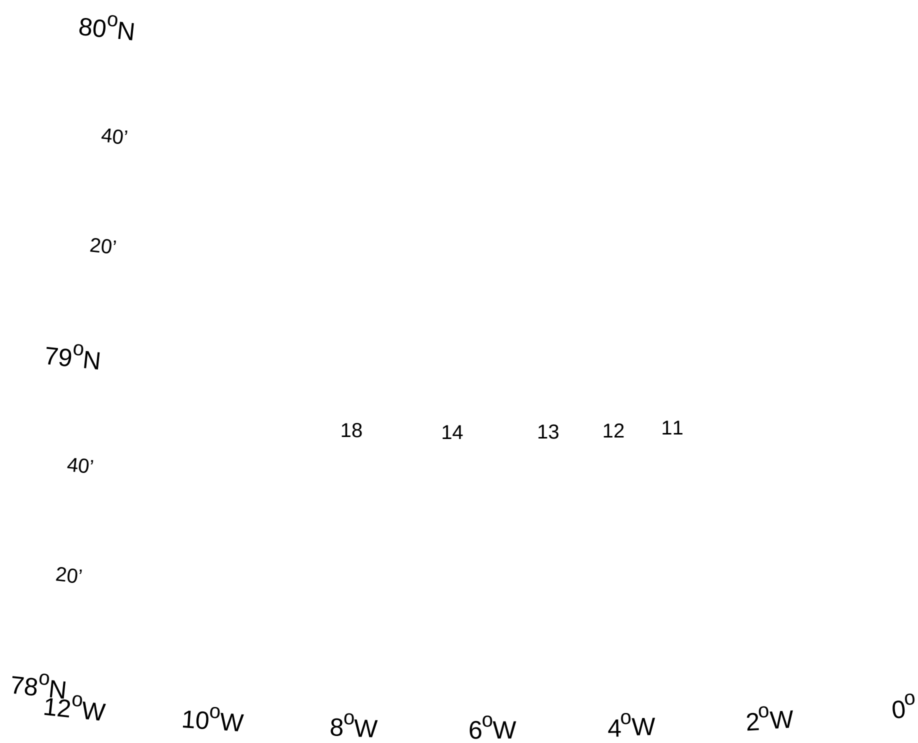


Figure 6.1: Radarsat image showing ice conditions around moorings deployed During FS2010. The red line indicates the ship track and the green circles indicate the position of the moorings deployed. At this scale F17 and F18 appear in the same location.

Mooring	Latitude	Longitude	Water Depth (m)	Time Date Released	Instrument Type	Serial Number	Instrument Depth (m)
F11-11	N 78 48.508'	W 003 04.625'	2416	04 Sept 2010	IPS	51062	55
				16:40	SBE37	7054	59
					RDCP600	198	65
					SBE37	7062	191
					RCM9	1049	300
					RCM11	538	1503
					RCM8	10069	2406
					AR861	499	2409
F12-11	N 78 50.467'	W 003 52.212'	1939	05 Sept 2010	IPS	51063	54
				06:40	SBE37	7055	59
					RDCP600	118	64
					RCM72	9464	69
					SBE37	7057	148
					RCM9	836	323
					RCM11	556	1527
					RCM11	117	1929
					AR861	500	1932
F14-11	N 78 48.792'	W 006 30.387'	271	05 Sept 2010	IPS	1048	44
				16:45	SBE37	7058	48
					RDCP600	71	52
					SBE37	157	157
					RCM9	1326	261
					AR861	569	264
F17-06	N 78 50.156'	W 008 06.934'	227	05 Sept 2010	WHS300	727	114
				21:40	SBE37	7059	117
					AR661	501	220
F18-05	N 78 48.220'	W 008 04.162'	212	06 Sept 2010	DL7	1632	53-108
				00:00	AR861	553	205

Table 6.1: Moorings recovered during FS2010. All times are UTC.

Mooring	Latitude	Longitude	Water Depth (m)	Time Date Released	Instrument Type	Serial Number	Instrument Depth (m)
F11-12	N 78 48.1262’	W 003 04.0232’	2470	15 Sept 2010	IPS	51062	59
				14:20	SBE37	3490	63
					RDCP600	199	67
					SBE37	4702	261
					RCM11	228	264
					SBE37	3552	1463
					RCM11	494	1467
					RCM8	10071	2460
					AR861	287	-
F12-12	N 78 48.4225’	W 003 59.1441’	1860	14 Sept 2010	IPS	51063	75
				16:21	SBE37	3489	80
					RDCP600	28	84
					SBE37	4837	339
					RCM7	11475	344
					SBE37	3554	1542
					RCM11	235	1547
					RCM8	11625	1850
					AR861	182	-
F13-00	N 78 50.1916’	W 005 00.6929’	1007	13 Sept 2010	IPS	1047	50
				13:00	SBE37	7056	52
					ADCP300	727	70
					Whale	old	75
					SBE37	3993	245
					RCM9	1327	250
					SBE37	3551	1003
					RCM11	561	1007
					AR861	053	-
F14-12	N 78 48.7774’	W 006 30.2751’	1276	11 Sept 2010	IPS	1048	46
				16:58	RCM9	834	50
					SBE37	2158	51
					Whale	new	52
					SBE37	7053	256
					RCM7	12644	260
					AR861	290	-
F17-07	N 78 50.2601’	W 008 06.3600’	229	09 Sept 2010	SBE37	7062	58
				11:15	RAS500	12239-02	58
					ADCP300	7636	109
					SBE37	7061	112
					RAS500	12239-01	112
					AR661	110	-
F18-06	N 78 48.1	W 008 04.75’	215	08 Sept 2010	DL7	1649	73-107
				19:25	AR861	410	-

Table 6.2: Moored instruments deployed during FS2010. All times are UTC.

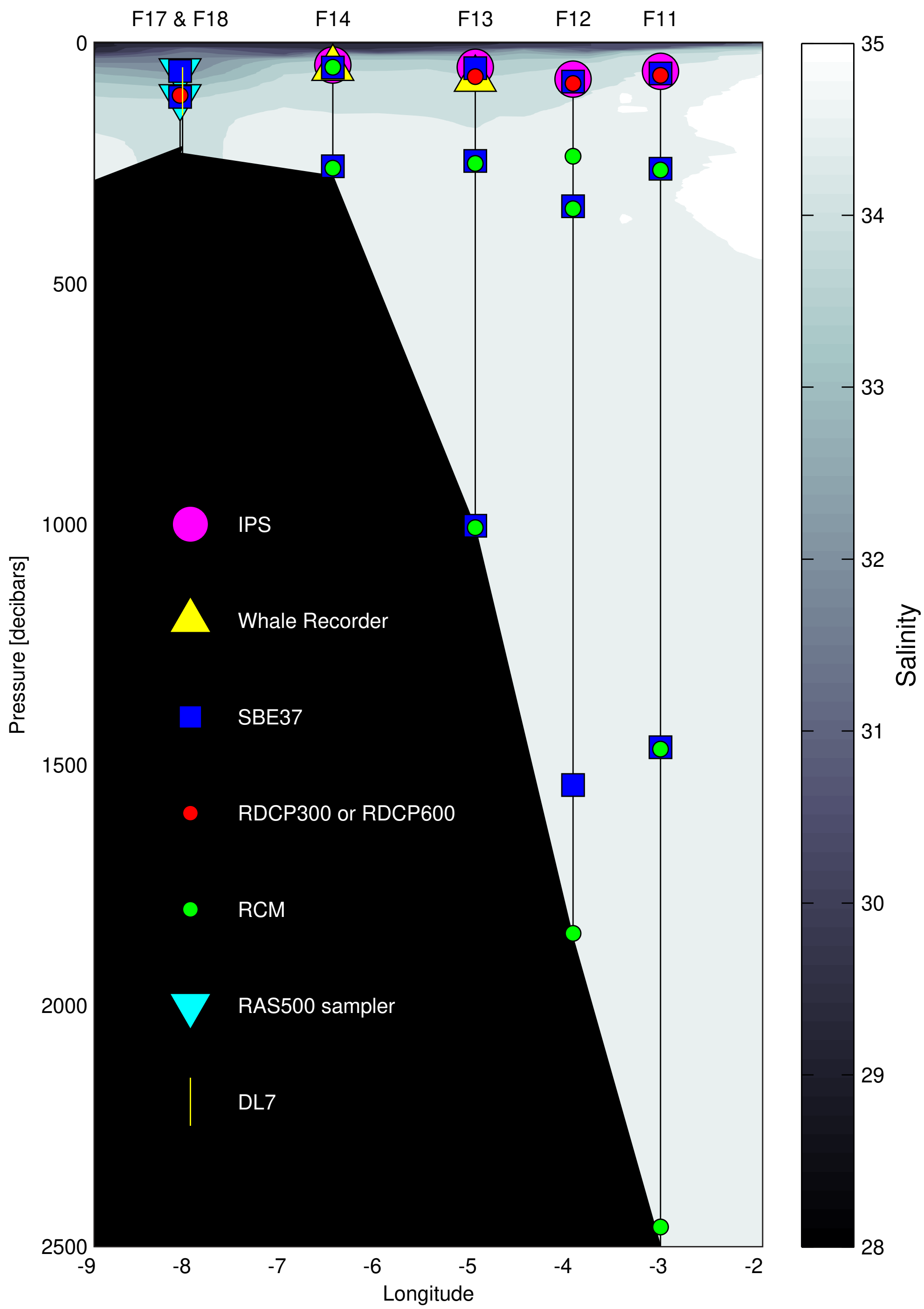
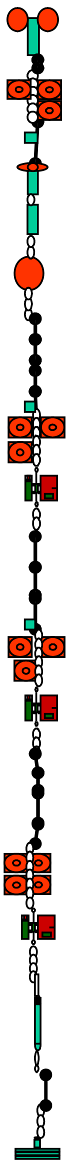


Figure 6.2: Schematic diagram showing the array of moored instruments deployed in 2010

Rigg F11-12

Satt ut 15 SEP 2010 kl 14:20 78 48,1262N 003 04,0232W



		Dyp:	Fra bunn:	Ut:
IPS	SNR. 51062	59	2411	14:15
3 Glasskuler				
2 m Kjetting galv.				
SBE37	SNR. 3490	63	2407	14:12
5 M Kevlar				
RDCP600	SNR: 199	67	2403	14:12
Batteribeholder til RDCP				
1 m Kjetting galvanisert				
Stålkule 37 (snr 596) McLane 7		71	2399	
2 m Kjetting galvanisert				
40 m Kevlar				
40 m Kevlar				
50 m Kevlar				
10 m Kevlar				
50 m Kevlar				
SBE37	SNR. 4702	261	2209	14:03
3 Glasskuler				
2 m Kjetting galvanisert				
RCM11	SNR.228	264	2206	14:03
0,5 m Kjetting galv				
200 m Kevlar				
500 m Kevlar				
500 m Kevlar				
SBE37	SNR. 3552	1463	1007	13:41
3 Glasskuler				
3 m Kjetting galvanisert				
RCM11	SNR.494	1467	1003	13:41
0,5 m Kjetting galv				
500 m Kevlar				
200 m Kevlar				
100 m Kevlar				
100 m Kevlar				
40 + 50 m Kevlar				
4 Glasskuler				
2 m Kjetting galvanisert				
RCM8	SNR.10071	2460	10	13:22
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 287	Pinger på: Pinger av: Release: Release m/ping:		
5 m Kevlar				
2 m Kjetting galvanisert				
ANKER	1140/(980) kg	2470	0	

Figure 6.3 Schematic diagram showing mooring F11-12

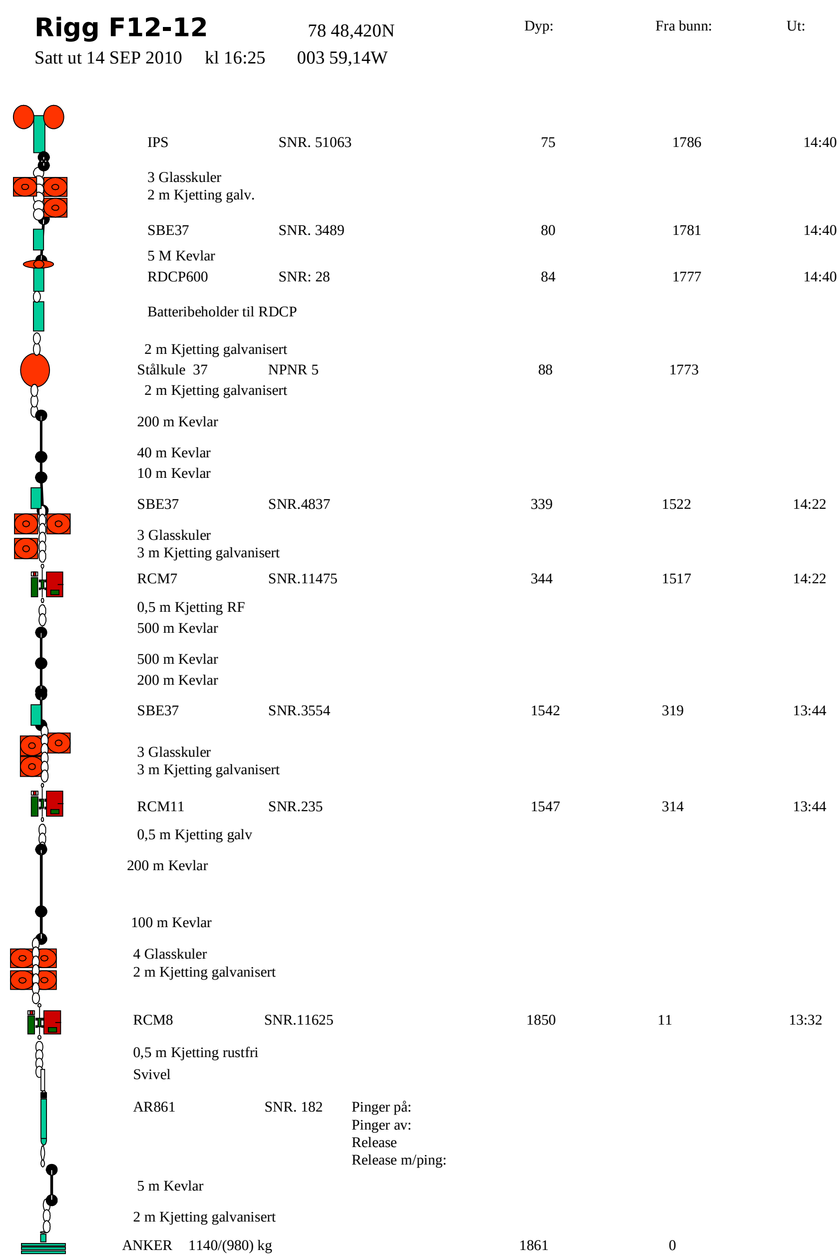
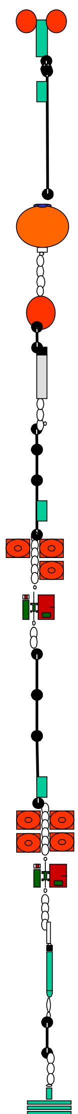


Figure 6.4Schematic diagram showing mooring F12-12

Rigg F13-10 78 50.191N

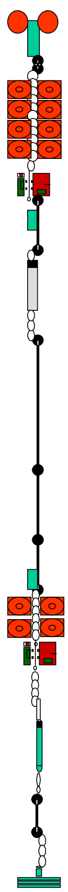
Settes ut 13 SEP 2010, kl 13:00 005 00.692W



		Dyp:	Fra bunn:	Ned i vann:
IPS4	SNR. 1047	50	967	13:00
SBE37	SNR. 7056	52	965	13:00
20 M Kevlar				
ADCP300	SNR: 727	70	947	12:52
2 m Kjetting galv.				
Stålkule 37	SNR.	73	944	
2 m Kevlar				
Hvallydopptaker		75	942	12:52
2 m Kjetting galv				
20 m Kevlar				
50 m Kevlar				
100 m Kevlar				
SBE37	SNR.3993	245	772	12:42
3 Glasskuler				
3 m Kjetting galv.				
RCM9	SNR.1327	250	767	12:42
0,5 m Kjetting galv				
500 m Kevlar				
200 m Kevlar				
50 m Kevlar				
SBE37	SNR.3551	1003	14	12:24
4 Glasskuler				
2 m Kjetting galv.				
RCM11	SNR. 561	1007	10	12:24
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 053	Ping på: Ping av: Release: Release m/ping:		
5 m Kevlar				
2 m Kjetting galvanisert				
ANKER 1000/(900) kg		1017	0	

Figure 6.5: Schematic diagram showing mooring F13-12

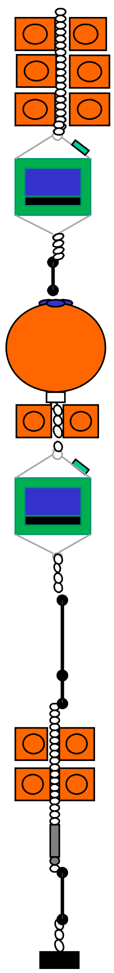
Rigg F14-12 78 48.77N
Satt ut 11 SEP 2010, kl 16:56 006 30,3W



			Dyp:	Fra bunn:	Ned i vann:
IPS	SNR. 1048		46	224	16:55
8 Glasskuler 3 m Kjetting galv.					
RCM9	SNR: 834		50	220	16:53
SBE37	SNR: 2158		51	219	16:53
2 M Kevlar					
Hvallydopptaker ny			52	218	16:53
0,5 m Kjetting Galv.					
100 m Kevlar					
100 m Kevlar					
5 m Kevlar					
SBE37	SNR.7053		256	14	16:27
4 Glasskuler 3 m Kjetting Galv.					
RCM7	SNR. 12644		260	10	16:25
Svivel					
AR861	SNR. 290	Range: Release:			
5 m Kevlar					
2 m Kjetting					
ANKER 800/(700) kg			270	0	

Figure 6.6: Schematic diagram showing mooring F14-12

Rigg F17-7 78 50.26 N
Satt ut 9 SEP 2010, kl 11:15 008 06.360W



			Dyp:	Fra bunn:	Ut:
6 Glasskuler Gule 2 m Kjetting galv.			56	172	10:50
SBE37	SNR. 7062		58	170	10:50
Vannhenter					
0,5 m Kjetting galv					
50 m Kevlar					
ADCP	SNR.7636		109	119	10:42
1 m Kjetting rustfri 2 Glasskuler Gule					
SBE37	SNR.7061		112	116	10:42
Vannhenter					
0,5 m Kjetting galv.					
100 m Kevlar					
5 m Kevlar					
2 m Kjetting galv.					
4 Glasskuler oransje			218	10	10:33
AR661	SNR. 110	Ping on: Release:			
5 m Kevlar.					
2 m Kjetting galv.					
ANKER	580/(500)kg		228	0	

Figure 6.7 Schematic diagram showing mooring F17-7

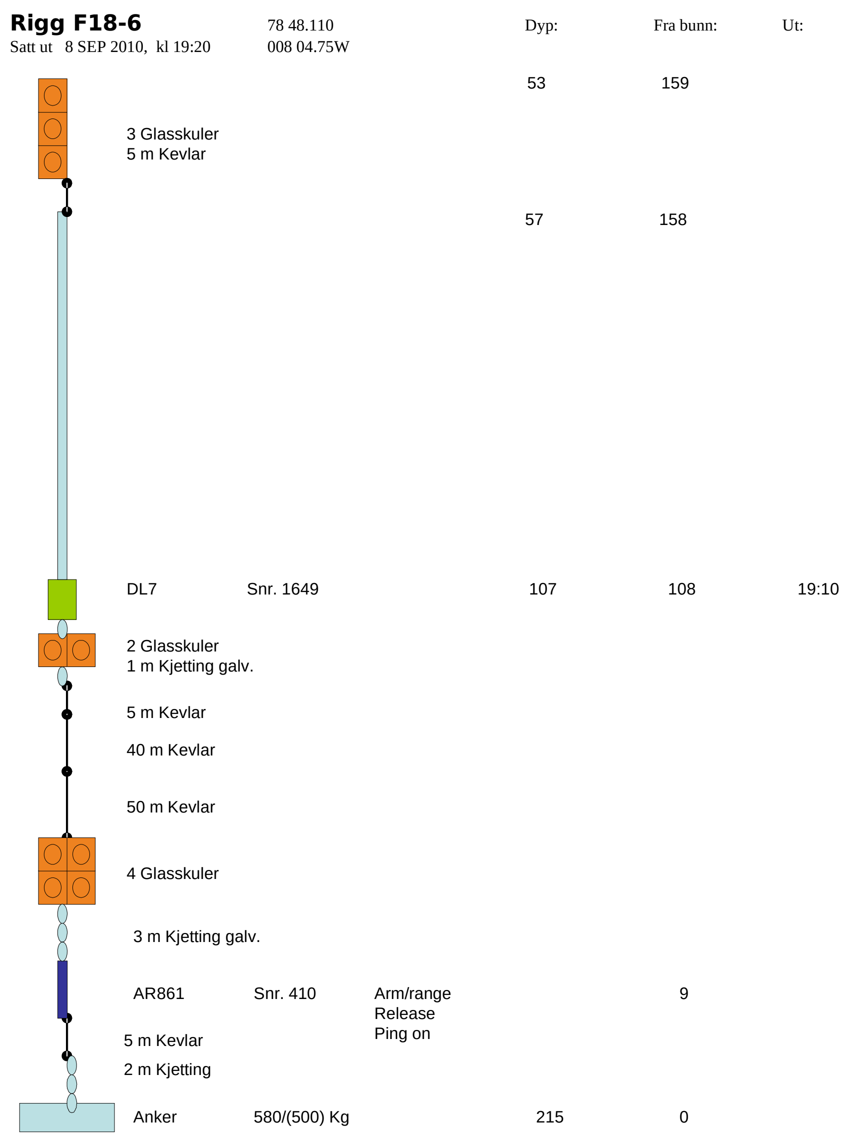


Figure 6.8 Schematic diagram showing mooring F18-6

Sample	Date	Time	Preservative (120 m)	Preservative (50 m)
01	09/09/2010	22:00:00	No	No
02	09/17/2010	16:22:58	Yes	No
03	09/25/2010	10:45:56	No	No
04	10/03/2010	05:08:54	Yes	No
05	10.10.2010	23:31:52	No	No
06	10/18/2010	17:54:50	Yes	No
07	10/26/2010	12:17:48	No	No
08	11/03/2010	06:40:46	Yes	No
09	11.11.2010	01:03:44	No	No
10	11/18/2010	19:26:42	Yes	No
11	11/26/2010	13:49:40	No	No
12	12/04/2010	08:12:38	Yes	No
13	12.12.2010	02:35:36	No	No
14	12/19/2010	20:58:34	Yes	No
15	12/27/2010	15:21:32	No	No
16	01/04/2011	0,440475	Yes	No
17	01/12/2011	04:07:28	No	No
18	01/19/2011	22:30:26	Yes	No
19	01/27/2011	16:53:24	No	No
20	02/04/2011	11:16:22	Yes	No
21	02/12/2011	05:39:20	No	No
22	02/20/2011	00:02:18	Yes	No
23	02/27/2011	18:25:16	No	No
24	03/07/2011	12:48:14	Yes	No
25	03/15/2011	07:11:12	No	No
26	03/23/2011	01:34:10	Yes	No
27	03/30/2011	19:57:08	No	No
28	04/07/2011	14:20:06	Yes	No
29	04/15/2011	08:43:04	No	No
30	04/23/2011	03:06:02	Yes	No
31	04/30/2011	21:29:00	No	No
32	05/08/2011	0,727928	Yes	No
33	05/16/2011	10:14:56	No	No
34	05/24/2011	04:37:54	Yes	No

Continued on next page

Sample	Date	Time	Preservative (120 m)	Preservative (50 m)
35	05/31/2011	23:00:52	No	No
36	06/08/2011	17:23:50	Yes	No
37	06/16/2011	11:46:48	No	No
38	06/24/2011	06:09:46	Yes	No
39	07/02/2011	00:32:44	No	No
40	07/09/2011	18:55:42	Yes	No
41	07/17/2011	13:18:40	No	No
42	07/25/2011	07:41:38	Yes	No
43	08/02/2011	02:04:36	No	No
44	08/09/2011	20:27:34	Yes	No
45	08/17/2011	14:50:32	No	No
46	08/25/2011	09:13:30	Yes	No
47	09/02/2011	03:36:28	No	No
48	09/09/2011	21:59:26	Yes	No

Table 6.3: Sampling schedule for the RAS-500 water samplers deployed at mooring F17

ML12239-02 was programmed to flush the rotary valve with 10 ml of acid followed by 100 ml of ambient seawater before collecting each sample. Samples from ML12239-02 will therefore lag samples from ML12239-01 by a few minutes. The exact lag time will slowly increase as the battery is depleted. The deployment configuration for each sampler is summarised below.

6.3.1 120 m RAS (S/N 12239-01) Configuration

```
Header A| 120 M RAS Deployment at F17
       B| serial number 12239-01
       C| Deployed by P. A. Dodd

Acid   D| Pre-sample acid flush:    Enabled
       E| Flushing volume     =       10  [ml]
       F| Flushing time limit =        1  [min]
       G| Exposure time delay =        1  [min]

Water  H| Flushing volume     =      100  [ml]
       I| Flushing time limit =        5  [min]

Sample J| Sample volume       =      475  [ml]
       K| Sample time limit   =       24  [min]
```

```
Acid   L| Post-sample acid flush:   Disabled
       M| Flushing volume     =       NA  [ml]
       N| Flushing time limit =       NA  [min]

Timing P| Pump data period    =        1  [min]
```

6.3.2 50 m RAS (S/N 12239-02) Configuration

```
Header A| 50 M RAS deployed on F17
       B| Serial 12239-02
       C| Deployed by P. A. Dodd

Acid   D| Pre-sample acid flush:    Disabled
       E| Flushing volume     =       NA  [ml]
       F| Flushing time limit =       NA  [min]
       G| Exposure time delay =       NA  [min]

Water  H| Flushing volume     =      100  [ml]
       I| Flushing time limit =        5  [min]

Sample J| Sample volume       =      475  [ml]
       K| Sample time limit   =       24  [min]

Acid   L| Post-sample acid flush:   Disabled
       M| Flushing volume     =       NA  [ml]
       N| Flushing time limit =       NA  [min]

Timing P| Pump data period    =        1  [min]
```

6.3.3 Sampler Preparation

Both samplers were primed with natural seawater (S = 34.7) obtained using the CTD rosette. After collection the seawater was filtered with Whatman GF/F filters to retard bio-fouling and to ensure that suspended particles would not clog the sampler.

More than 60 litres of prime water was required to prepare the two samplers. The prime was stored in a large number of 4-litre polycarbonate bottles before use. Two of these containers were labelled 'Prime A' and 'Prime B' and sampled for salinity, oxygen isotope ratio and (in duplicate) for dissolved nutrient concentrations. Only prime from these containers was used in situations where it had the potential to enter sample bags (priming the valve, the lines between the valve and the sample tubes, and the filters above the sample tubes). Prime A was used to prepare ML12239-02 and prime B was used to prepare ML12239-01. Dissolved nutrient samples of the prime were stored adjacent to the samplers before deployment. After deployment one of each duplicate dissolved nutrient samples was refrigerated at +4 C (labelled Prime A+4; Prime B+4) in a dark environment and one was frozen at -20C (labelled Prime A-20, Prime B-20). The preservative used with the samplers was a saturated solution of mercury (II) chloride (HgCl2). The preservative was prepared by dissolving 10.25g of HgCl2 in 200 ml of milliQ water. 5 ml of solution was injected into sample bags using a calibrated micropipette. The acid used with the samplers was 8 % hydrochloric acid, prepared by adding an appropriate volume of 38% HCl stock solution to MilliQ water. A concentration of 8% was chosen so that the acid would not freeze in the acid reservoir. The freezing point of 8% HCl is approximately -4C. The samplers were prepared in the main hold and transferred to the deck two hours before deployment. Once on deck the samplers were stored inside the heated CTD tent until immediately before deployment. Figure 6.9 shows the deployment of 12239-02 at Mooring F17.

Figure 6.9: RAS 12239-02 being deployed anchor-first at mooring F17. A Microcat temperature and salinity instrument has been attached to the top of the frame containing the RAS.

7. Sea Ice Studies

7.1 Overview of sea ice studies

In situ sea ice studies were performed during the entire cruise to the Fram Strait on RV Lance, starting in Longyearbyen 3rd September 2010, returning to Longyearbyen on 18th September 2010. NPI followed up work as a part of the long term monitoring of sea ice properties in the Fram Strait (project Sea ice physics in the Fram Strait). We also took the opportunity to test and learn the operation of the EM-bird under supervision of Justin Beckers, data which is also invaluable under Cryosat cal/val. The UNIS/NTNU participants studied the thermo-mechanical properties of sea ice, with focus on ridges. This was a continuation of work begun in 2006 and 2007.

Work at 11 sea ice stations (table 7.1 and figure 7.1) on drift ice with duration up to 7 hours was carried out. The ice stations were approached either using two Zodiac rubber boats, or by working on an ice floe next to RV Lance accessing the ice by ladder. On each ice station, a position was measured with GPS at the beginning and at the end of the station, and the GPS track was logged, in order to determine the average drift of the floe. For each site a general description of the floe and weather conditions was made.

7.2 Ice observations from the bridge

In total 85 regular ice observations were made (every 3 hrs in areas with sea ice) by filling out a sheet with various sea ice parameters (ice types, floe sizes, snow cover, ridges, rafting, etc.), digital photography (3 images, port, bow, and starboard, see example in figure 7.2), available meteorological data (air and water temperature, air pressure) plus ship data (position, speed, heading). Towards the end of the cruise the night observations were dropped when it became too dark. In addition the IceCam, an automatic system

Date	Lat	Lon	Station ID	Drift	Thickness	EM31	Trans - mission	TS Coring	Archive Core	on ice CTD	Snow pit	HEM bird	Ridge morph.	BHJ	Ice Friction
04.09	N 78 48.578	W 03 06.010	FS10 1	✓	✓	✓		✓	✓	✓	✓			✓	
05.09	N 78 50.556	W 03 52.053	FS10 2	✓	✓	✓		✓	✓	✓	✓	✓	✓		
06.09	N 79 05.427	W 13 05.331	FS10 3	✓	✓	✓		✓	✓	✓	✓	✓	✓		
08.09	N 78 54.457	W 06 37.269	FS10 4		✓	✓		✓	✓	✓	✓		✓	✓	
08.09	N 78 54.457	W 06 37.269	FS10 5		✓	✓		S only							
09.09	N 78 50.166	W 08 06.912	FS10 6	✓	✓	✓					✓				✓
10.09	N 79 38.010	W 06 49.484	FS10 7	✓	✓	✓		✓	3 pieces	✓	✓			✓	
11.09	N 78 49.147	W 06 32.556	FS10 8										✓	✓	
13.09	N 78 50.077	W 05 02.936	FS10 9	GPS track			✓		last part missing				✓		
14.09	N 78 50.78	W 03 56.353	FS10 10		✓	✓	✓	✓			✓			✓	
15.09	N 78 58.051	W 04 21.336	FS10 11	GPS track	✓	✓		✓			✓	✓			✓

Table 7.1: Overview of sea ice stations and measurements made.

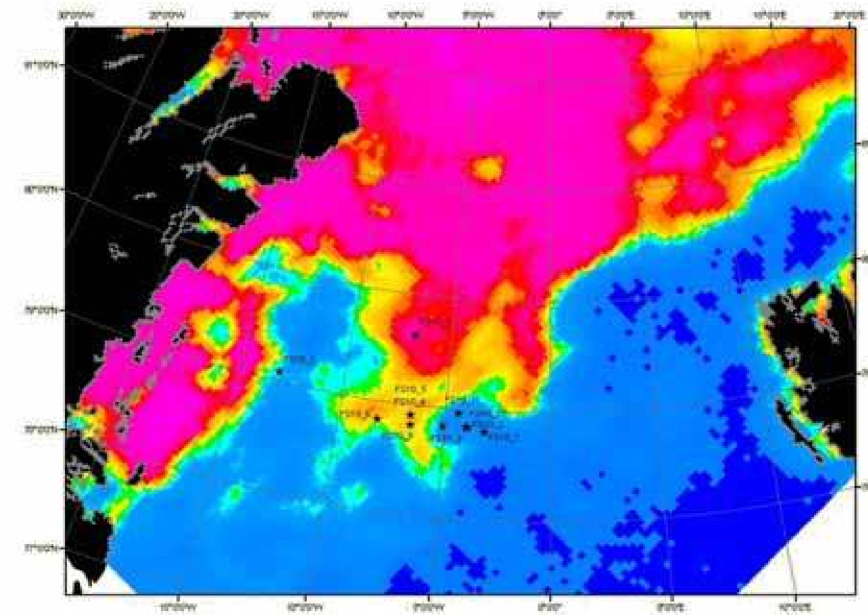


Figure 7.1: Map of sea ice concentration from AMSR-E 15th September 2010 with sea ice stations during the cruise FS10. Labels correspond with the station IDs in table 7.1

installed onboard Lance that takes images every 5 to 10 minutes depending on the set up in front/starboard direction (with parallel logging of position), was operative. There were some problems with this system as the software had recently been upgraded, and this needs to be fixed. The IceCam stopped taking and recording images on the 3rd of September. A fix was found and automatic logging resumed on the 8th until the end of the sea ice part with images taken every 30 minutes. During the period 3-8 September, images were taken manually every 1-2 hours.

During adverse weather conditions, the meteorological instruments on Lance can freeze over and sea spray can affect measurements. This occurred also during FS2010 and the data logged during the ice observations have to be treated with care. Also, part way through the cruise the Seatex Seapath failed and provided wrong ship positions which affected not only the position data but also ship speed, heading, and wind speed. When the error became known, positions were taken from the bridge's navigation system.

The ice observations were reported to the Norwegian Meteorological Institute daily for validation of ice charts and to Jenny Hutchings as contribution for the SEARCH 2010 Arctic sea ice outlook and the ship based Arctic

Figure 7.2: Example of a sea ice observation image.

sea ice observations database.

7.3 On ice work

7.3.1 Snow and ice thickness profiling

Snow and ice thickness was measured directly (drillings) and indirectly (Geonics EM31, figure 7.3) for quantifying the ice thickness of sea ice in the research area. The data is also used for validation purposes of the upward-looking sonar measurements. By doing corresponding surveys every year in September in the Fram Strait, the inter-annual variability can be documented. The measurement principle of the indirect measurements is electromagnetic induction. By measuring the electrical conductivity in the half-space under the instrument (penetration depth over sea ice about 6 m), distance of the instrument to the seawater and by that, the ice plus snow thickness can be derived. The EM31 is placed on a sledge and pulled over the ice. The data is logged at a frequency of 0.5 Hz to an Allegro field computer together with GPS position from a Garmin handheld GPS instrument. Thickness drilling was made on selected spots for calibration and validation purposes. The ice plus snow thickness is calculated using an empirical function. In total 26 profiles were measured covering a total

Figure 7.3: Use of the Geonics EM31 for indirect ice plus snow thickness measurements.

of ca. 4000 m of electromagnetic profiles. Along these profiles snow thicknesses were measured with a metal pole every 5m. In total 41 holes were drilled for direct thickness measurements, using a Kovacs thickness gauge (measurement of snow thickness, ice thickness and freeboard).

7.3.2 Snow pits

On all major ice stations a snow pit was dug for snow classification, stratigraphy, grain size, and temperature. Density, moisture, and hardness measurements were possible on only some of the stations due to thin snow cover. Typical snow thicknesses were approximately 0.10 m. Snow classes were defined using the scheme of LaChapelle from 1982. Snow grains were inspected with a magnifying class on a mm pad, and they were also photographed (figure 7.4). Snow types and grain sizes are important for the spectral albedo of the snow & sea ice surface.

7.3.3 Ice coring in level ice

At 10 stations (see table 7.1) level sea ice, ice cores (4" diameter) were obtained in order to quantify the vertical distribution of sea ice salinity and temperature, as well as for texture analysis. A simple stratigraphic

Figure 7.4: Example of snow pit stratigraphy and instruments.

description of the cores was made in the field. Some cores stored at -18C and transported to the ice lab at the Norwegian Polar Institute in Tromsø. Temperature of the ice was measured in small drill holes using an electronic thermometer (spacing 10 cm). Sea ice salinity is derived from electrolytic measurements on melted ice samples (typically 6-7 cm thick), using a conductivity meter (WTW 340) in the laboratory on RV Lance.

7.3.4 Spectral radiation

Optical observations were done at two ice stations (see table 7.1). A pair of TriOS Ramses spectral radiometers were used: one for surface reference (figure 7.5) and one for underwater measurements. The thickness of ice did not allow to carry out observations from the middle of the floes. Therefore, observations of light transmission through the water column were made from the edge of ice floes at both sites. Finally, the upper ocean layer was profiled with ca. 1 m intervals down to 40 m depth.

7.3.5 High resolution CTD measurements

On selected sea ice stations (see table 7.1), measurements of the properties of the sea water directly below the ice were made using a portable CTD instrument. The Idronaut Ocean Seven 316Plus CTD is equipped with

Figure 7.5: Using an upwards looking TriOS Ramses spectral radiometer for incoming radiation

pump free sensors for conductivity, temperature, depth, and chlorophyll. With a diameter of 89 mm, the probe can be deployed through holes drilled e.g. with a Kovacs Mark II or Mark III corer as used on this cruise, making it ideal to use on sea ice stations in conjunction with the standard ice work. For all deployments, the CTD was set to log autonomously at a sampling rate of approximately 6 Hz. The data are recorded and stored internally and were downloaded afterwards on the ship. The high resolution enables detailed measurement of the upper 5-10 m. The maximum depth for the probe is 100 m. However, because of the deployment procedure (lowering on a rope) and the focus on the upper 25 m, typical casts went to 30 or 60 m depth.

During FS2010, most deployments were on an opportunistic base making use of core holes from temperature or salinity cores (stations 1-4). On station 3 on a floe off the Greenland fast ice with heavy ridging, an effort was made to investigate changes occurring due to the disturbance of the coring. There, a hole was drilled on a refrozen meltpond and the CTD deployed immediately afterwards with repeat casts 30 min, 1.5 h, and 3 h later. On station 9 the instrument was again deployed in a hole directly after coring, and left in the water just below the ice for 1.5 h followed by a repeat cast.

On stations with HEM flights at the same time or in the same region (stn.

1-4, 7-9), the CTD was lowered over the ice edge to get accurate conductivity values of the surface water for calibration of the helicopter borne EM data.

7.4 Helicopter ice thickness profiling

Sea ice thickness remains poorly parameterised due to logistical difficulties and its large spatial and temporal variability. The helicopter borne electromagnetic induction system (Helicopter Electromagnetic Bird or HEM) employed during the Fram Strait 2010 cruise provides accurate sea ice thickness measurements over large transects. The HEM is easily deployed by helicopter from land or ship. Furthermore, airborne EM systems are an excellent tool for the validation of the recently launched Cryosat-2 radar altimeter. During the NPI Fram Strait 2010 scientific cruise, 8 HEM sea ice thickness survey flights covering over 500km were performed (table 7.2). One flight was conducted in the footprint of a high-resolution quad-polarization RadarSat-2 (satellite imaging radar) image over the Greenland fast ice, and two flights performed along Cryosat-2 tracks. During the Cryosat-2 passes, ice station measurements (described above) were also collected. Figures 7.6 and 7.7 show the measurements tracks completed during FS2010 and ICE2010 respectively.

With NPI's HEM system not completed at the time of the Fram Strait 2010 cruise, an HEM was borrowed from Dr. Christian Haas (University of Alberta, Edmonton, Canada). Justin Beckers, a Master's student from the University of Alberta, joined the Fram Strait cruise on behalf of Dr. Haas to perform the measurements and to provide training on the operation of the HEM system to various members of the NPI group.

7.4.1 Example data

The figures below show a colour gradient thickness map HEM flight(7.8), and a histogram and profile of thickness measurements for one section of the complete flight 7.9. The histogram shows four important peaks representing open water, thin new ice, first year ice, and thick multi-year ice.

7.5 Sea ice mechanics

Multiyear ice presents a major concern when designing offshore structures for Arctic waters, and may also represent a challenge for maritime navigation

DD/MM/YY	Time Start	Time End	Laser	GPS Base	Start Lat	Start Long	Comments
04/09/10	22:06	22:52	YES	YES	78.77844	-3.01185	Regular HEM Flight
05/09/10	9:30	10:25	YES	YES	78.84386	-3.88023	Regular HEM Flight
06/09/10	13:15	14:50	YES	NO	79.10941	-13.14362	Over Greenland Fast Ice Over Ice Station In Q-POL RSAT-2 Image
08/09/10	13:00	13:41	YES	YES	78.90666	-6.70977	Cryosat Flight (close to line, correct time) ★
09/09/10	9:30	10:10	YES	YES	78.83527	-8.14045	Regular HEM Flight;
10/09/10	13:16	13:51	YES	YES	79.58615	-6.84842	Cryosat Flight (on line, correct time) ★
12/09/10	12:53	13:37	YES	NO	78.90429	-3.23032	Regular HEM flight
13/09/10	15:25	16:25	YES	YES	78.84224	-5.04176	Regular HEM Flight

Table 7.2: Overview of HEM flights.

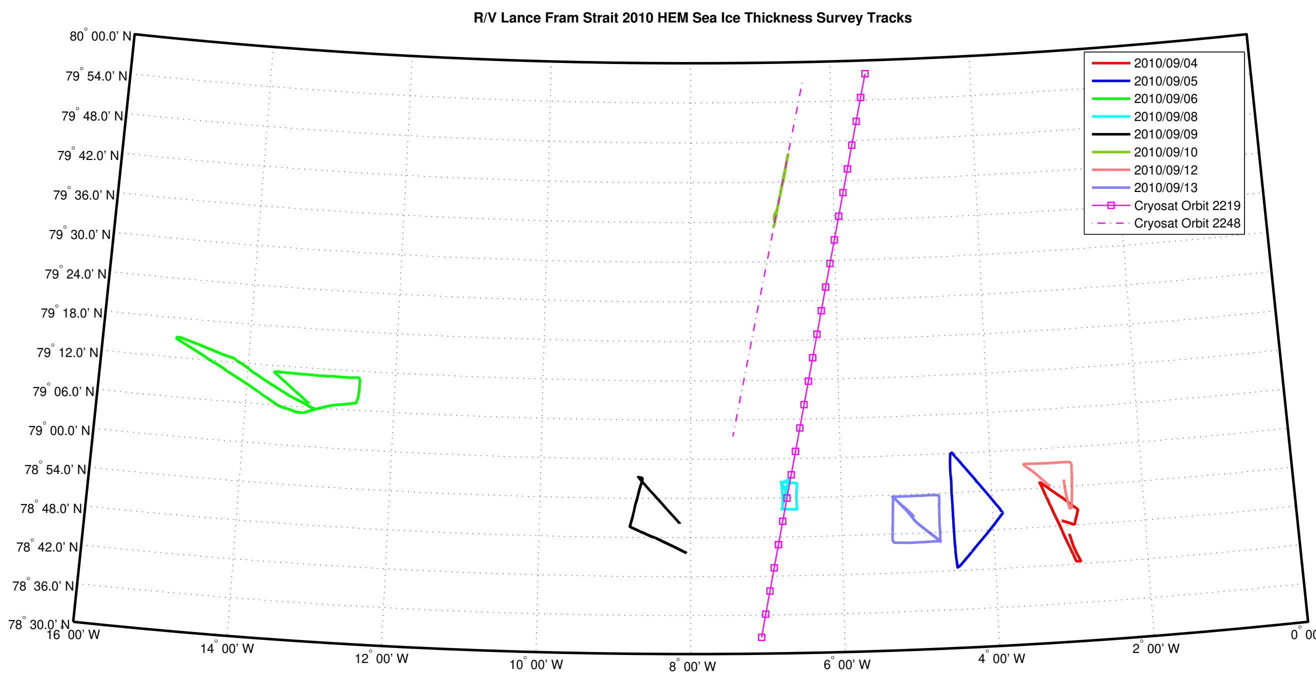


Figure 7.6: All HEM measurement tracks during FS2010

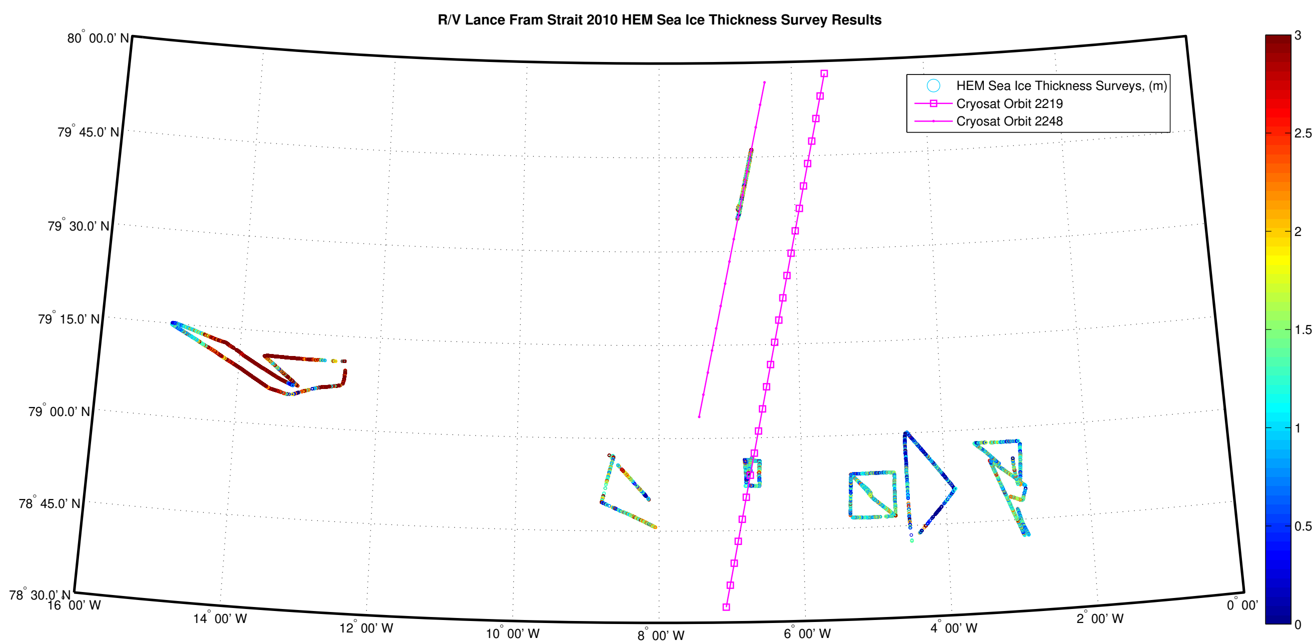


Figure 7.7: ICE2010 HEM Sea Ice Thickness survey. Preliminary results are shown with thickness range from 0.0m-3.0m+ shown in colour gradient

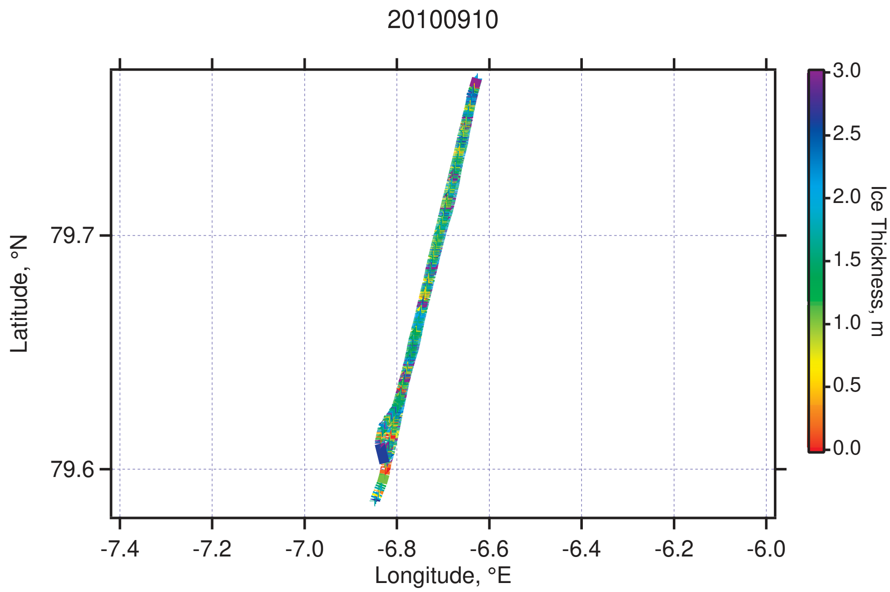


Figure 7.8: HEM sea ice thickness profile for 2010/09/10 flight 2 (flight 6 of 8). The flight pattern was chosen to perform measurements along Cryosat-2 Orbit 2248

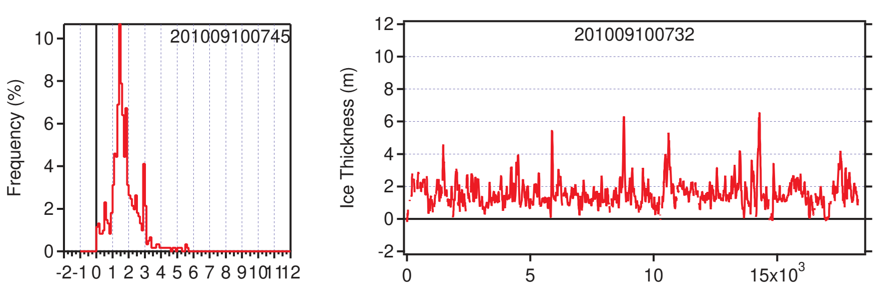


Figure 7.9: HEM sea ice thickness profile for one section of the survey flight conducted on 2010/09/10. The thickness histogram shows an open water peak, a peak for thin new ice, for 1st year and for thick multiyear ice

in the Arctic. In situ measurements of mechanical properties of multiyear ice are therefore important in order to develop safe and reliable structures that can resist actions from the ice cover. During the cruise, investigations of ice ridge morphology, ice strength and ice friction were conducted at the ice stations listed in table 7.1.

7.5.1 Ice ridge morphology

The size and geometry of ice ridges, as well as their degree of consolidation, are some parameters that affect the magnitude of the loads that arise during interaction with offshore structures. In the Fram Strait cruise, mapping of the depth and the macro porosity of ice ridges were performed by direct measurements with two inch augers. The depth of each ridge was measured at regular intervals in a cross-section along the width of the ridge. The operator of the drill constantly reported the hardness of the ice, and this information was logged. When a gap between ice blocks was encountered, the length of the gap and its location was noted in order to map the macro porosity of the ridge. Temperature and salinity profiles of the ice ridges were obtained using a core drill.

Five ridges were investigated during the cruise. Common for all the ridges was their high degree of consolidation. Few gaps were encountered inside the ridges, and the length of each gap was usually less than 5 cm. The salinity profiles were also comparable in all cases, increasing from zero salinity in the top of the sail to around 3 ppm in the bottom part of the keel.

Figure 7.11 shows one of the ridges that were mapped during the cruise. This ridge was found at ice station 3, and its depth was measured at 8 different points with 1 m spacing between each point. The maximum depth of the ridge keel was found to be 6.95 m. Temperature and salinity profiles of the ridge are presented in figure 7.10.

7.5.2 Ice strength measurements

Measurements of the horizontal compressive strength of the sea ice were made using a Borehole Jack (BHJ), a device that works in the following way: A hydraulic jack is lowered down into a 15 cm diameter borehole made in the ice (figure 7.12). Driven by hydraulic pressure, a piston then moves horizontally out of the jack and pushes out on the walls of the borehole. The displacement of the piston, as it penetrates into the ice, and the hydraulic

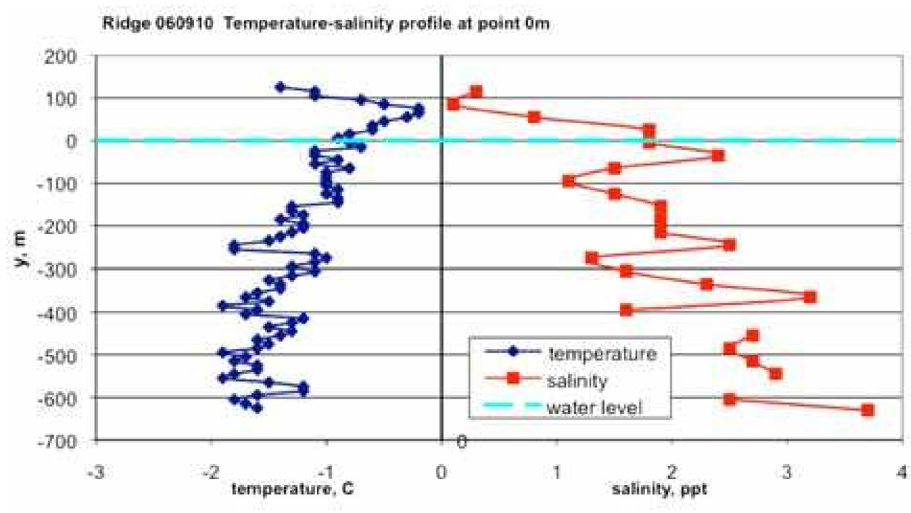


Figure 7.10: Temperature and salinity profiles of the ice ridge at ice station 3.

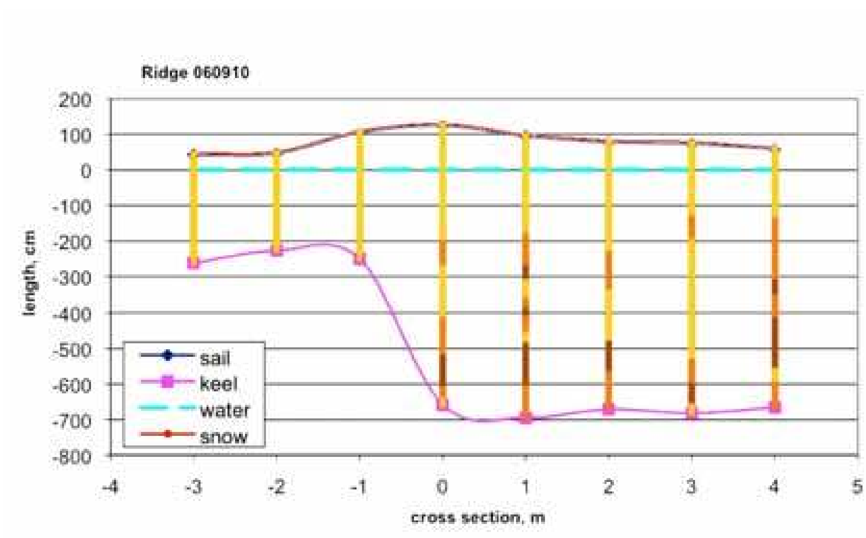


Figure 7.11: Morphology map of the ice ridge at ice station 3 (The colours represent the ice hardness: yellow - soft, orange - medium, brown - hard.

Figure 7.12: Borehole hydraulic jack lowered down into a borehole.

pressure are sampled and stored on a data logger. A generator supplies the hydraulic pump with power. Tests were carried out in both ice ridges and in relatively flat sea ice.

By interpreting the pressure-displacement curves that were obtained, one can say something about the strength and the stiffness of the sea ice that was encountered in the Fram Strait. However, interpreting these data is not a straightforward procedure, and more research is needed in order to get a proper understanding of the processes taking place in the ice during a BHJ test. Examples of pressure-displacement curves from ice station 10 are presented in figure 7.13. Figure 7.13 shows pressure records from four adjacent boreholes in level ice. The solid lines represent tests carried out at a depth of 38 cm, whereas the stippled lines represent tests at a depth of 72 cm in the same boreholes. This figure shows that the ice is stronger in its top layer, and that the capacity of the BHJ was reached in some of the tests, indicating very strong ice.

7.5.3 Ice friction

A simple ice friction experiment was carried out in order to investigate the friction coefficient between two ice surfaces. Using a mechanical winch

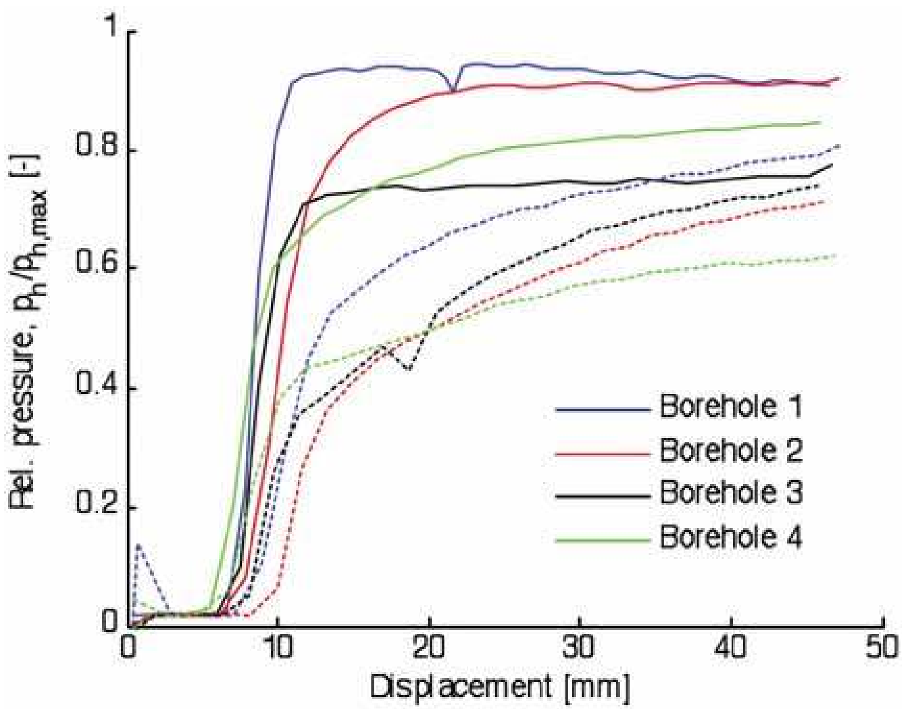


Figure 7.13: Pressure as a fraction of the BHJ capacity versus displacement at two different depths in level ice at ice station 10

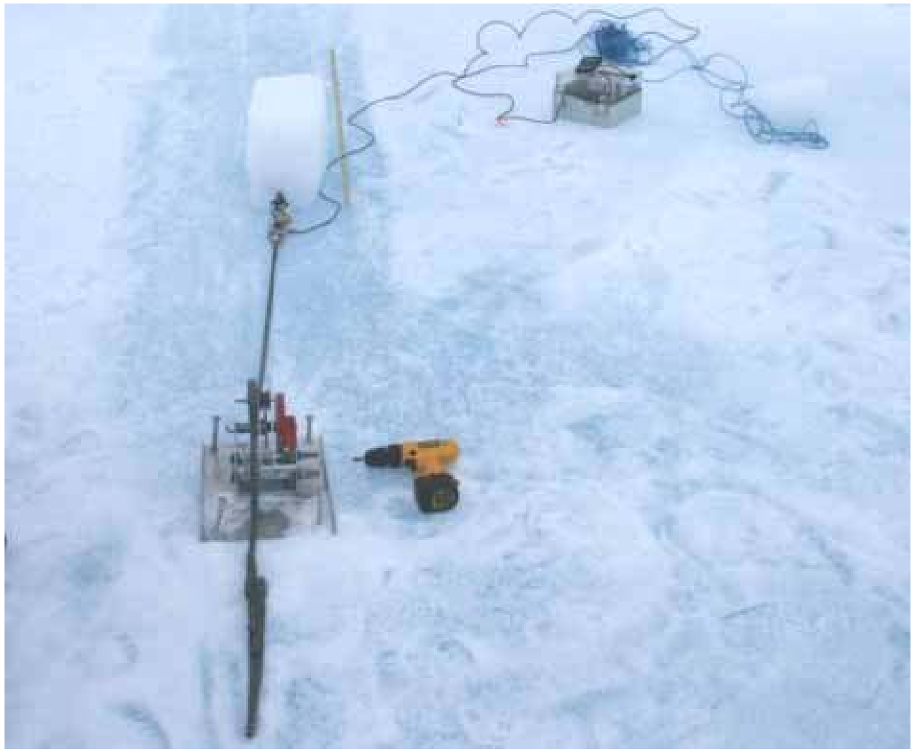


Figure 7.14: Sea ice friction test set up.

driven by an electric drill, an ice block was pulled along a relatively flat ice surface. The force needed to pull the ice block at a certain velocity was measured with a load cell, and the weight of the ice block as well as the size of its bottom surface was also measured. Tests with different velocities were conducted. The test set-up is illustrated in figure 7.14.

8. Satellite Images

8.1 Satellite images obtained during the cruise

Satellite images have been readily available to aid navigation in ice infested waters for several years now. We continue to use the satellite image viewing software developed by the Danish Technical University. The system allows users to access and download small images specific to the area of interest via the ships internet connection. Images can be viewed off line and may be imported into into a program called OziExplorer. OziExplorer allows the ships position to be plotted on images in real time when a compatible GPS is connected to the computer on which it is running.

Figure 8.1 demonstrates how a SAR image was used to identify open water avoiding drift ice. It also shows the ship track around two large ice floes that had drifted ca. 5 nm south since the image was taken.

Available imagery consisted of daily AMSR ice concentration with a resolution of 3.25 km. In addition we also had access to almost daily Radarsat images and to two ENVISAT high resolution images available via KSATs new IAS Java viewer accessible at `http://nut.tss.no/ksat/welcome.faces`, which allows the user to download high resolution imagery over low band widths. See 8.1 for the list of imagery available, and figures 8.2 and 8.3 for examples of AMSR-E imagery and Radarsat SCW imagery, respectively.

AMSR images were viewed using software downloaded from `http://`

Satellite	Sensor	Resolution	Date	Source
Aqua	AMSR-E	3.25 km	Daily	`http://www.seaice.dk/zipfiles/Fram/`
Radarsat	SAR SCW	500 m	Daily	KSAT IAS Web Viewer
ENVISAT	ASAR	150 m (wide swath mode)	02 and 09 Sep. 2010	KSAT IAS Web Viewer

Table 8.1: Satellites images obtained during FS 2010.

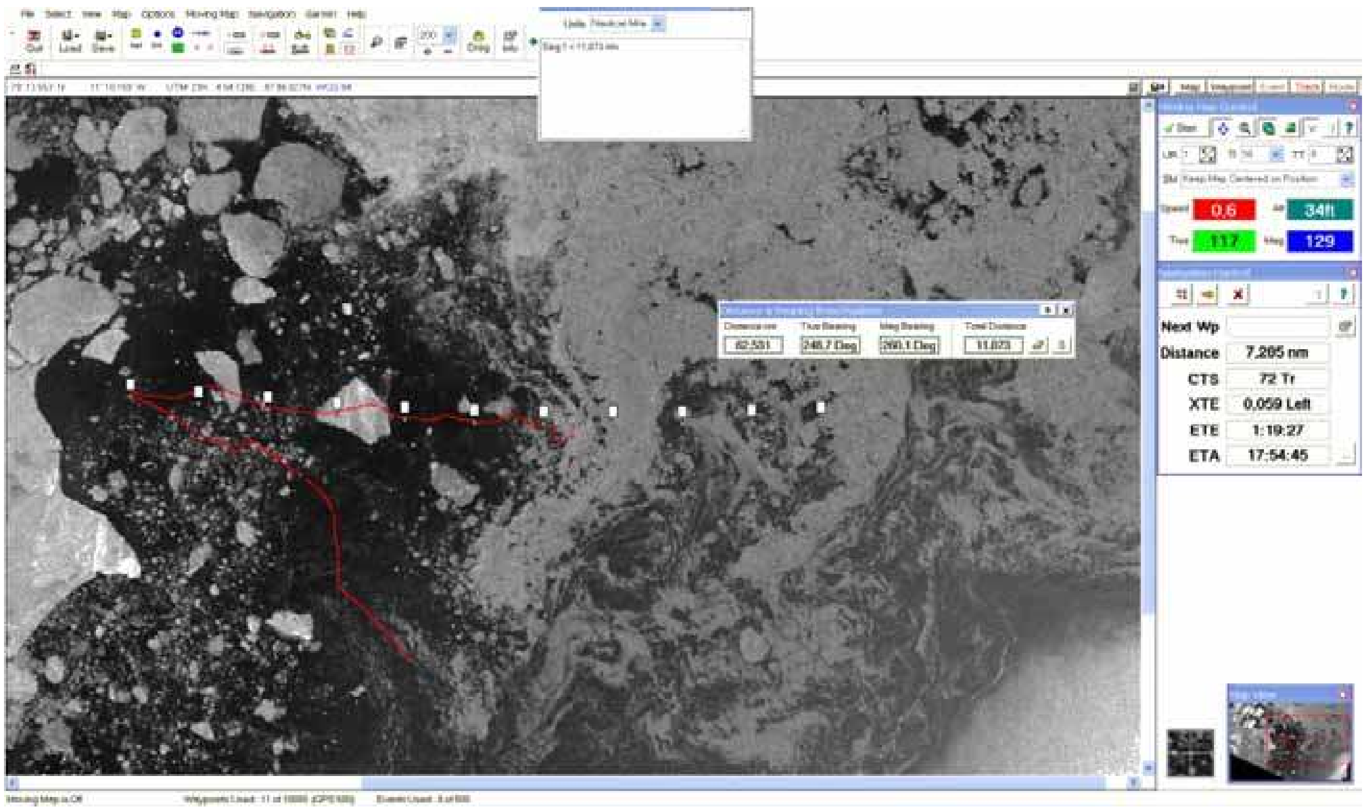


Figure 8.1: Screen shot of Ozi Explorer displaying a ship track plotted on a SAR image.

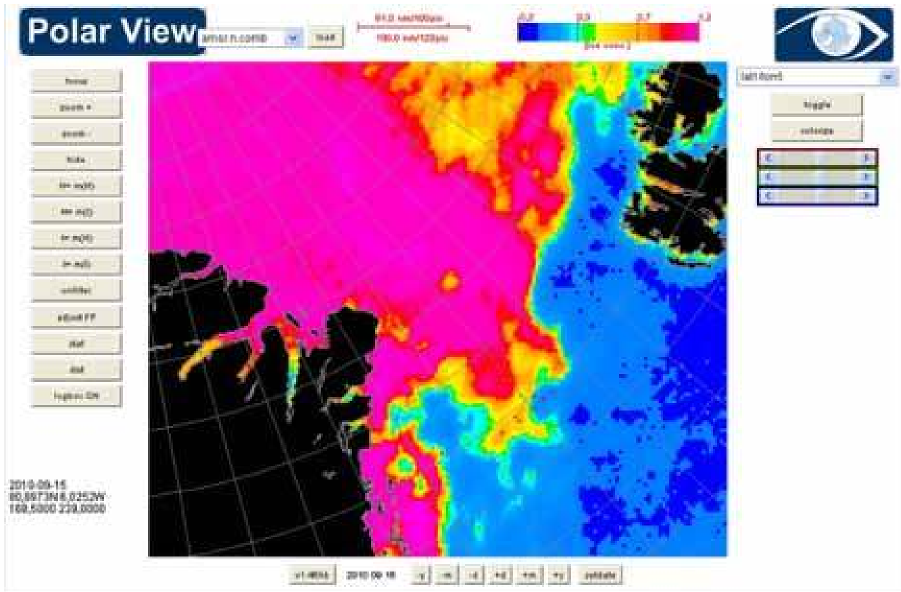


Figure 8.2: Screen shot of Polar View displaying AMSR-E data in the Fram Strait.

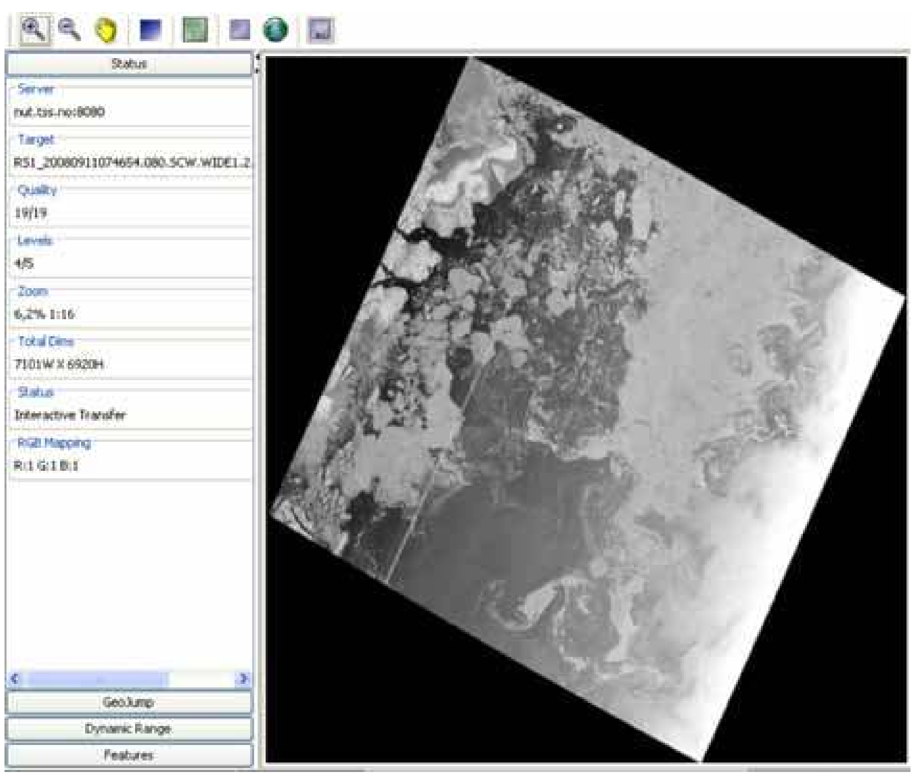


Figure 8.3: Screen shot showing a Radarsat SCW image.

www.seaice.dk/zipfiles/install/, but they can also be viewed in an online application at the same URL.