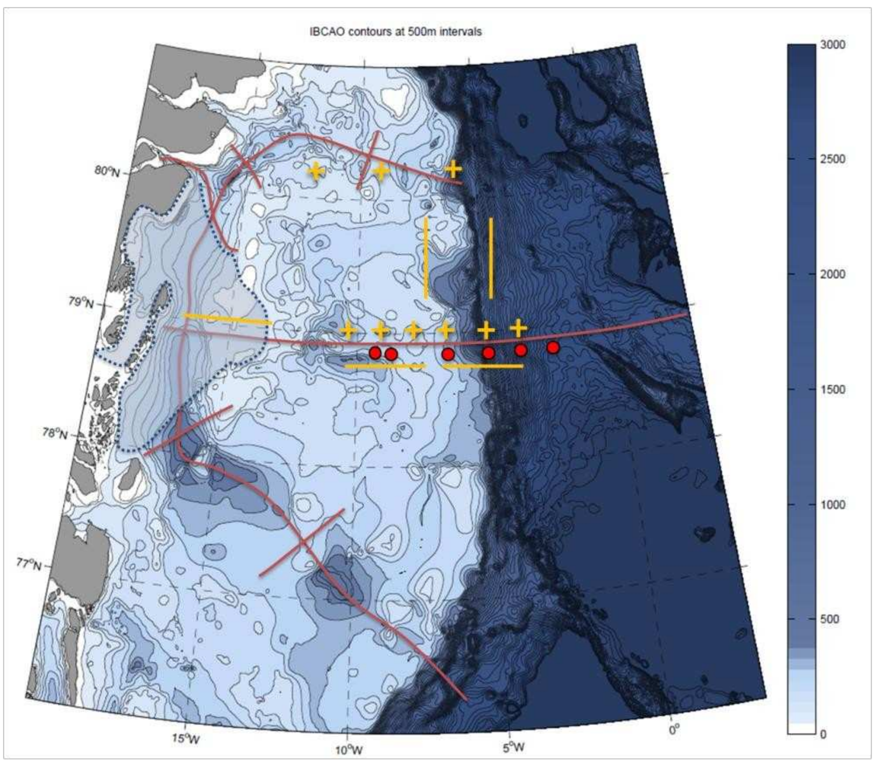
Cruise report
Fram Strait 22/8 – 15/9 2011
R/V Lance



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1. Cruise outline

The cruise took place in western Fram Strait. The main priority was to recover and redeploy the NPI moorings across the East Greenland Current at 78° 50 N, and to carry out the CTD, LADCP and tracer section across Fram Strait along the 78° 50 N line. In addition, sea ice physics work was made across the Transpolar Drift where it exits the Arctic. This included in situ work on the ice, and thickness sections made by helicopter and an EM bird instrument. Finally we made CTD sections that follow the assumed passage for warm Atlantic water to the Greenland coast, where it interacts with the floating glacier tongues through basal melting. The main cruise activities are illustrated in Figure 1.1, and listed in Table 1.1.

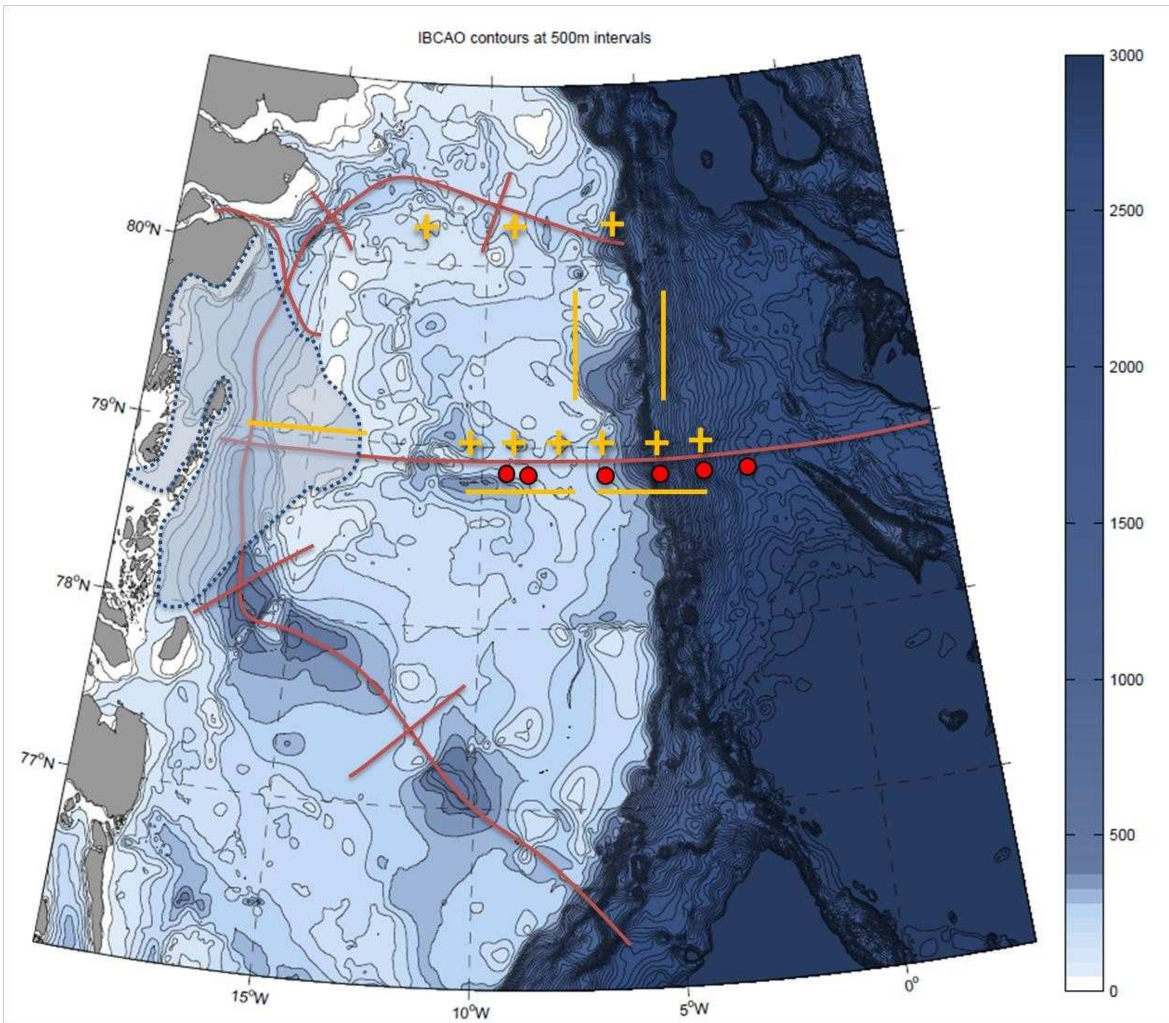

Figure 1.1. The main activities during the cruise. Red circles: mooring positions. Red lines: CTD, LADCP and tracer sections. Yellow crosses: Typical positions for sea ice work. Yellow lines: Typical EM bird sections. The blue dotted line illustrates the typical extent of the fast ice in recent years.

Table 1. 1 Overview of cruise activities. All times in GMT.

Date	Activity
Sun 21/8	-Picked up gear and clothing 1300 at NPI in Forskningsparken. -Loaded Lance. -Checked equipment and instruments, unpacked.
Mon 22/8	-Shooting training 0530-0800. -Arrival helicopter with EM bird 0800. -Final check equipment and instruments. -Departed Longyearbyen 1300. Sailed towards CTD no 1 in 78 55 N 10 E outside Forlandet. -Test of CTD revealed problems: Position data transfer over NMEA did not work properly, COM port conflicts, spikes in observations. -Error search, error fixes
Tue 23/8	-CTD error search and error fixes -Everything solved by the evening, starting on CTD transect across Fram Strait.
Wed 24/8	-CTD transect across Fram Strait.
Thu 25/8	-CTD transect across Fram Strait.
Fri 26/8	-Arrived F11 0600. -F11 released 0620, on deck 0800. -Again contact problems and spikes for the CTD. Stopped the CTD work at longitude 2° 30' W, and gave priority to mooring recovery (only one technician onboard). -Arrived F12 0910 -F12 released 1020, on deck 1130. -Arrived F13 1640. -Searched for F13 and located it precisely with the echo sounder. Much ice, waited for a lead/opening to drift by. -F13 released 1700, on deck 1845. -Sea ice station no 1 in position 78° 48.78' N 005° 06.90' W starting 1900.
Sat 27/8	-Sailed towards F14 during night, much sea ice. -Arrived F14 before breakfast. Much sea ice and poor visibility due to fog. -Searched for F14 0600-1000. No contact, nothing seen on echo sounders. -Difficult to search due to much sea ice and fog. -Sailing towards F17. Much sea ice, stopped in the afternoon to do sea ice work. -Sea ice station no 2 in position 78° 49.0' N 007° 52.5' W started after dinner. -CTD problems fixed; connection problems near the termination.
Sun 28/8	-Arrived F17 before breakfast. To much ice to release it, but we located the mooring exactly by using the echo sounder. -CTD station -Test flight with the helicopter, ice reconnaissance -Found a lead upstream of F17, after we had determined drift velocity and direction. Drifted with the lead until it was over the mooring. -F17 released 0915, on deck 0940. -RAS samplers put directly into the aft cargo room, for water sampling. Water sampling goes on until midnight.

	-Sea ice station no 3 in position 78° 49.97’ N 008° 005.33’ W started after lunch, continued until dinner. -Sailed towards F18. Arrived at the mooring site 1700, searched and located it with the echo sounder. -F18 released 1745, on deck 1800. -Sailed towards 78° 55’ N 02° 30 W’ to resume CTD work.
Mon 29/8	-Arrived position 78° 55’ N 02° 30 W’ before breakfast. Resumed CTD work. -CTD stations westward along the 78° 55’N line.
Tue 30/8	-CTDs westwards. Arrived F14 around breakfast. -New search, listened for it in a) a radius of 0.25 nm, and b) a radius of 0.5 nm. No response on our calls. -Released F14. No response. The mooring is lost. -Sailed west. -Sea ice station no 4 in position 78° 57’ N 007° 41’ W. -Prepared new moorings F17 and F18.
Wed 31/8	-Prepared new moorings F17 and F18. -Sea ice station no 5 in position 79° 08’ N 009° 26’ W. -Sailed west to the westernmost stations on the transect across Fram Strait. Much ice, slow progress. -Sea ice station no 6 in position 78° 56.6’ N 009° 55.3’ W. -CTDs from 12° W toward F18 deployment site.
Thu 1/9	-Prepared F17 and F18. -F18 deployed 1000-1045 in position 78° 48.202’ N 008° 04.097’ W, on depth 215 m. -Located the mooring after deployment by using the echosounder. Could see the anchor roughly 0.023 nm = 43 m straight southwest of the position above. -F17 deployed 1155-1230 in position 78° 50.507’ N 008° 08.571’ W, on depth 229 m. -Could see the mooring on the echo sounder throughout the deployment. The position should hence be correct within 20-30 m. -Did a CTD besides the deployment site. -Sailing towards 80° 30’ N 013° 00’ W.
Fri 2/9	-Sea ice station no 7. -Sea ice station no 8. -Two EM bird flights. -CTDs from Henrik Krøyers Holme across the “channel” or trough in the NEW polynya.
Sat 3/9	-CTDs from Henrik Krøyers Holme across the “channel”or troughs in the NEW polynya. -EM bird flight. -Moved to 80° 15° W, the beginning of the next CTD section. -CTD section across the trough outside the Dijmphna Sound opening. -Halfway through the cruise we had a 12 hour break, with Saturday dinner, and hot bath at the stern. Stopped the shifts, so that everybody could join in and after that even have a full nights sleep.
Sun 4/9	-Went on land on Holms Land for one hour after breakfast for sightseeing.

	-Resumed work by lunch. CTD section along the trough from the mouth of Dijmphna Sound towards the shelf break. Much ice and thick fog slowed our progress down..
Mon 5/9	-Continued the CTD section along the trough from the mouth of Dijmphna Sound towards the shelf break. Also this day much ice and thick fog slowed our progress down.. -Ended the section around breakfast time. -Sailed southeast towards F14 deployment site. Arrived 1745. Checked drift and ice conditions. -F14 deployed 1815 on depth 270 m in position 78° 48.841' N 006° 30.360' W. -The anchor is seen on the echo sounder directly below us, which means that the position is pretty correct. -Sailed towards F13 deployment site.
Tue 6/9	-EM bird flight. -Tried to deploy F13, but strong drift and sea ice prevented the first attempt. The full mooring was taken back on deck, and we sailed 2 nm upstream of the selected mooring site. -F13 deployed 1205 on depth 1014 m depth in position 78° 50.273' N 005° 00.000' W. -Due to the drift the mooring was hanging with a ~30 degree angle to NE-E. I should think the correct position for the anchor is 250-500 m in this direction, on depth ~1020 m. -CTD at deployment site. -Started to prepare F12. -Sailed west for ice station. -Ice station no 9.
Wed 7/9	-Three EM bird flights during the day. -Sea ice station no 10. -Moved further west. -Sea ice station no 11. -Moved east to ~7°, towards moorings.
Thu 8/9	-Sea ice station no 12 until lunch. -EM bird flight while Lance sailed through compact ice. -Sailed towards F12 deployment site. -F12 deployed 1930 on depth 1833 m in position 78° 48.095' N 004° 01.182 W. -Hanging with a large angle in NE direction; the real position of the anchor should be 100-300 m in this direction.
Fri 9/9	-Preparing F11. Bad weather, windy, drifted with 2 knots, waited for better conditions. -F11 deployed 1600 on depth 2470 m in position 78° 48.198' N 003° 04.720' W. -Sailed towards 78° 10 N 17° W, the start of last CTD section in the southern part of the trough system surrounding Belgica bank.
Sat 10/9	-Sailed towards 78° 10' N 17° W. Much sea ice encountered at around 9° W, the course was then set more southward. -Sea ice station no 13.

	-CTD section across the southern trough.
Sun 11/9	-CTD section across the southern trough. -EM bird flight. -Packed and stowed most scientific equipment. -CTD section along the southern trough.
Mon 12/9	-CTD section along the southern trough. -Ended the scientific work by lunch. -Started sailing towards Tromsø.
Tue 13/9	-Sailed towards Tromsø.
Wed 14/9	-Sailed towards Tromsø.
Thu 15/9	-Arrived Tromsø around noon.

2. Mooring work

Five moorings were recovered in good shape; see table 2.1 and Appendix 1. Mooring F14 was lost. We looked for it on two occasions (see cruise log), by searching for it with the echo sounder and trying to communicate with it via the deck unit. The search was made by circling around the assumed location and continuously increasing the radius of the search circle.The cause of the loss is not known, as the full mooring seemed to be gone. If the loss was due to damaged kevlar rope or corrosion in shackles or chains, the anchor and releaser would still be in place. A collision with an iceberg is a potential cause. One should also note that for the first time after ten consecutive annual cruises we met a fishing vessel in the region, most likely a shrimp trawler. We also encountered two seismic vessels accompanied by two ice breakers. Clearly the increased activity in the region poses a new type of risk to our moorings.

Six moorings were successfully deployed; see table 2.2 and Appendix 2. As some of them were deployed during strong drift, their actual positions are likely to differ from the position of the vessel at the instant of release. In such cases, the assumed deviation is indicated in the position field of table 2.2.

Table 2.1. Moorings recovered.

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 14:20	IPS	51062	59
					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 16:21	IPS	51063	75
					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 13:00	IPS	1047	50
					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 16:58	IPS	1048	46
LOST					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 11:15	SBE37	7062	58
					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 19:25	DL7	1649	73-107
					AR861	410	-

Table 2.2. Moorings deployed

Mooring	Latitude Longitude	Water depth (m)	Date and time of deployment	Instrument type	Serial number	Instrument depth (m)
F11-13	78 48.198 N 003 04.720 W	2470	09.09.2011 16:00 UTC	IPS SBE37 RDCP600 SBE37 RCM9 SBE37 RCM11 SBE37 RCM8 AR861	51062 7054 28 3996 1049 7061 538 8226 10069 499	53 58 62 301 305 1554 1557 2456 2459 2463
F12-13	78 48.095 N 004 01.182 W (due to large drift the anchor position is assumed to be 250-500 m NE)	1833	08.09.2011 19:30 UTC	IPS SBE37 RDCP600 Seaguard SBE37 RCM9 SBE37 RCM11 SBE37 RCM11 AR861	51063 7055 758 639 3994 836 2962 556 8227 117 500	50 54 58 60 311 314 1517 1520 1820 1823 1826
F13-13	78 50.273 N 004 59.999 W (due to large drift the anchor position is assumed to be 250-500 m NE-E)	1014	06.09.2011 12:05 UTC	IPS WHS300 RCM9 SBE37 SBE37 RCM9 SBE37 RCM8 AR861	1047 727 1175 7059 7060 1326 3995 12322 743	49 57 59 58 248 251 1001 1004 1007
F14-13	78 48.841 N 006 30.360 W	270	05.09.2011 18:50 UTC	IPS RCM9 SBE37 SBE37 RCM7 AR861	51064 1325 7058 7057 9464 568	51 57 59 257 260 263
F17-8	78 50.507 N 008 08.571 W	229	01.09.2011 12:30 UTC	SBE16 RAS WHS300 SBE16 RAS AR661	6693 7636 6694 501	59 59 110 113 113 222
F18-7	78 48.202 N 008 04.097 W	215	01.09.2011 10:45 UTC	DL7 AR861	1632 553	57-107 208

3. CTD Measurements

Station Locations

Table 3.1 lists the time, date and position of each station along with the depth determined from the ship echo sounder. Figure 3.1 shows the location of CTD stations occupied during FS2011. Figures 3.2 to 3.7 show temperature and salinity measurements along each section.

CTD stations were organized along 6 sections.

- **Section 1:** An east-west section along the mooring array line at 78º 50 N. This annually repeated section has been sampled annually in late summer since 2001, and also during April-May 2008.

- **Section 2:** A section along a trough on the East Greenland shelf north of the section 1. Sections 2 to 6 were conducted to look for warm Atlantic-derived water that may be transported onto the shelf and subsequently interact with glacial ice in East Greenland

- **Section 3:** A section across a trough on the East Greenland shelf north of the main transect at approximately 015 degrees east.

- **Section 4:** A section across a trough on the East Greenland shelf north of the main transect at approximately 011 degrees east.

- **Section 5**: A section across a trough on the East Greenland shelf south of the main transect at approximately 012 degrees east.

- **Section 6**: A section along a trough on the East Greenland shelf south of the main transect at approximately 012 degrees east.

Station	Latitude	Longitude	Depth	Date & Time
1	78.915	10.014	74	23-Aug-2011 19:39:12
2	78.915	9.504	204	23-Aug-2011 21:24:50
3	78.916	9.006	222	23-Aug-2011 22:52:43
4	78.918	8.495	453	23-Aug-2011 23:51:39
5	78.918	7.997	1038	24-Aug-2011 00:56:02
6	78.917	7.492	1178	24-Aug-2011 02:59:19
7	78.926	6.998	1312	24-Aug-2011 04:56:30
8	78.924	6.998	1314	24-Aug-2011 06:42:32
9	78.916	6.493	1758	24-Aug-2011 08:51:34
10	78.924	6.475	1754	24-Aug-2011 11:01:02
11	78.913	5.998	2324	24-Aug-2011 12:09:40
12	78.918	4.996	2581	24-Aug-2011 15:52:16
13	78.936	4.061	2754	24-Aug-2011 18:47:12

14	78.918	2.994	2331	24-Aug-2011 22:56:05
15	78.916	1.994	2331	25-Aug-2011 02:28:56
16	78.934	1.065	2506	25-Aug-2011 06:24:43
17	78.924	0.012	2435	25-Aug-2011 10:09:55
18	78.904	-0.164	2544	25-Aug-2011 13:16:23
19	78.916	-1.007	2662	25-Aug-2011 14:26:47
20	78.909	-1.99	2629	25-Aug-2011 17:25:27
22	78.83	-8.108	2629	28-Aug-2011 06:23:18
23	78.918	-2.476	2579	29-Aug-2011 06:52:33
24	78.917	-2.998	2456	29-Aug-2011 09:26:46
25	78.92	-3.517	2245	29-Aug-2011 13:26:53
26	78.917	-4.011	1962	29-Aug-2011 16:19:27
27	78.913	-4.514	1589	29-Aug-2011 19:03:03
28	78.912	-5.005	1192	29-Aug-2011 21:08:34
29	78.918	-5.5	790	29-Aug-2011 22:57:07
30	78.92	-5.999	386	30-Aug-2011 00:47:21
31	78.931	-6.009	392	30-Aug-2011 02:10:12
32	78.918	-6.499	295	30-Aug-2011 03:30:29
33	78.916	-6.993	257	30-Aug-2011 04:47:07
34	78.918	-9.986	220	31-Aug-2011 16:33:27
35	78.916	-9.975	219	31-Aug-2011 17:07:28
36	78.913	-11.009	255	31-Aug-2011 19:42:45
37	78.966	-11.857	218	31-Aug-2011 22:50:36
38	78.908	-8.987	286	01-Sep-2011 08:21:22
39	78.841	-8.172	234	01-Sep-2011 12:43:15
40	80.621	-13.608	86	02-Sep-2011 18:25:18
41	80.558	-13.442	243	02-Sep-2011 20:19:04
42	80.494	-13.284	293	02-Sep-2011 21:40:21
43	80.371	-12.954	248	03-Sep-2011 01:31:26
44	80.272	-12.74	149	03-Sep-2011 02:44:19
45	80.166	-12.528	231	03-Sep-2011 04:46:10
46	79.998	-14.995	172	03-Sep-2011 10:44:05
47	80.004	-15.341	227	03-Sep-2011 12:48:05
48	80.057	-15.485	291	03-Sep-2011 13:44:19
49	80.11	-15.703	227	03-Sep-2011 14:40:13
50	80.132	-15.905	211	03-Sep-2011 15:47:59
51	80.16	-16.184	253	03-Sep-2011 16:49:17
52	80.171	-16.37	148	03-Sep-2011 17:46:05
53	80.219	-15.873	281	04-Sep-2011 10:23:02
54	80.168	-15.066	265	04-Sep-2011 12:53:39
55	80.192	-14.584	300	04-Sep-2011 14:28:20
56	80.225	-14.137	266	04-Sep-2011 15:32:08
57	80.276	-13.702	232	04-Sep-2011 16:37:37
58	80.419	-12.935	276	04-Sep-2011 19:11:05
59	80.4	-11.163	300	04-Sep-2011 22:14:21
60	80.303	-9.845	360	05-Sep-2011 01:17:59
61	80.245	-8.537	284	05-Sep-2011 04:25:37
62	78.812	-6.498	265	05-Sep-2011 19:04:15
63	78.828	-5.074	926	06-Sep-2011 12:28:01
64	78.792	-4.056	1808	08-Sep-2011 19:57:16
65	78.782	-3.116	2446	09-Sep-2011 16:30:03
66	77.763	-11.342	237	10-Sep-2011 20:38:31
67	77.695	-11.642	241	10-Sep-2011 22:08:28

68	77.634	-11.888	325	10-Sep-2011 23:13:12
69	77.566	-12.115	371	11-Sep-2011 00:26:04
70	77.511	-12.383	511	11-Sep-2011 02:00:36
71	77.433	-12.67	270	11-Sep-2011 03:53:45
72	77.373	-12.947	250	11-Sep-2011 04:53:26
73	77.331	-13.164	263	11-Sep-2011 05:57:37
74	77.294	-13.315	264	11-Sep-2011 06:58:00
75	77.327	-11.406	457	11-Sep-2011 16:33:27
76	77.105	-10.336	468	11-Sep-2011 19:19:33
77	76.913	-9.503	346	11-Sep-2011 21:47:36
78	76.728	-8.579	342	12-Sep-2011 00:26:25
79	76.646	-8.238	326	12-Sep-2011 01:48:26
80	76.563	-7.887	313	12-Sep-2011 03:07:53
81	76.502	-7.602	669	12-Sep-2011 04:07:32
82	76.467	-7.376	974	12-Sep-2011 06:03:04
83	76.388	-7.004	974	12-Sep-2011 07:32:54

Table 3.1: List of CTD stations occupied during FS2011

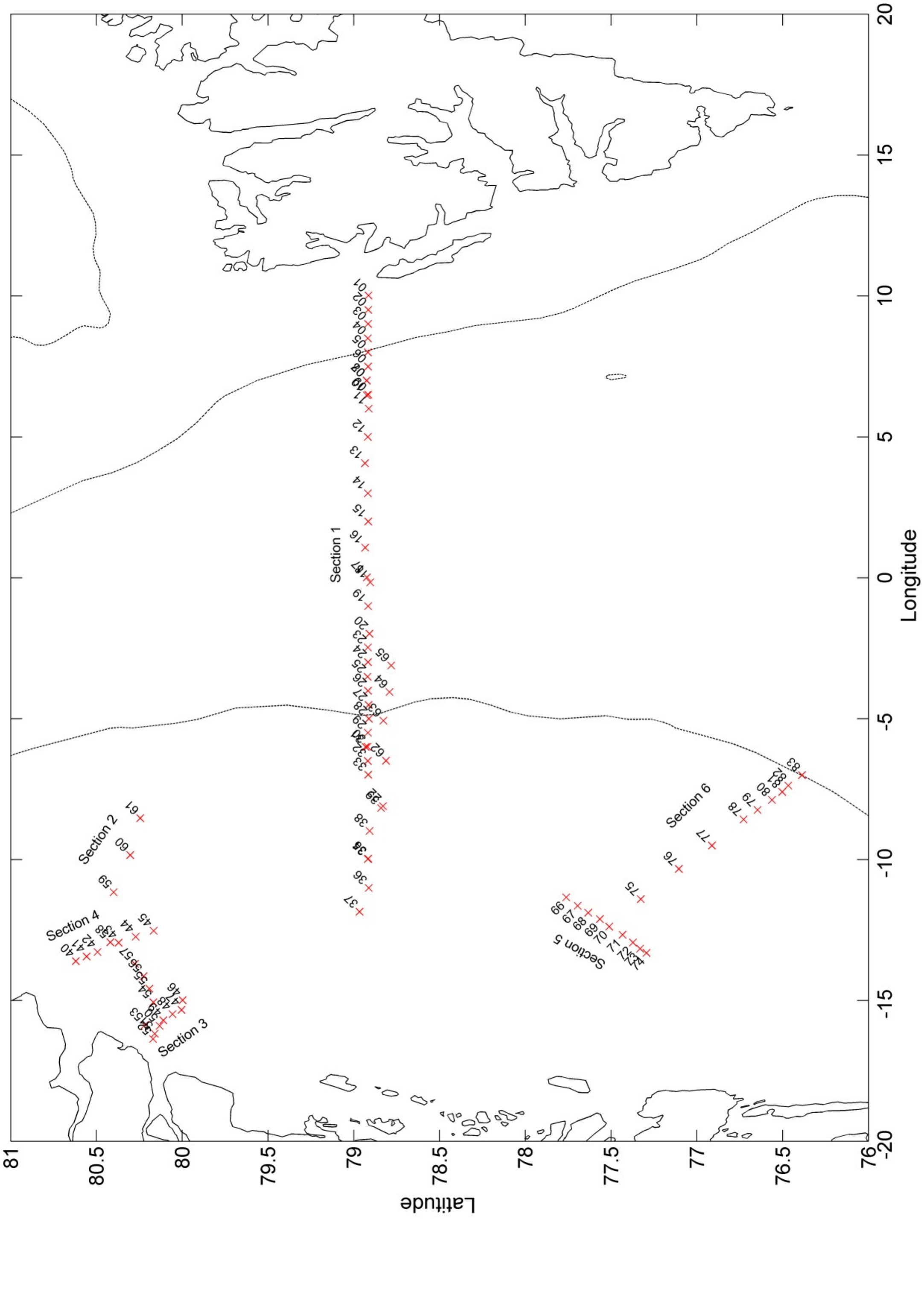

Figure 3.1: Map of CTD stations occupied during FS2011

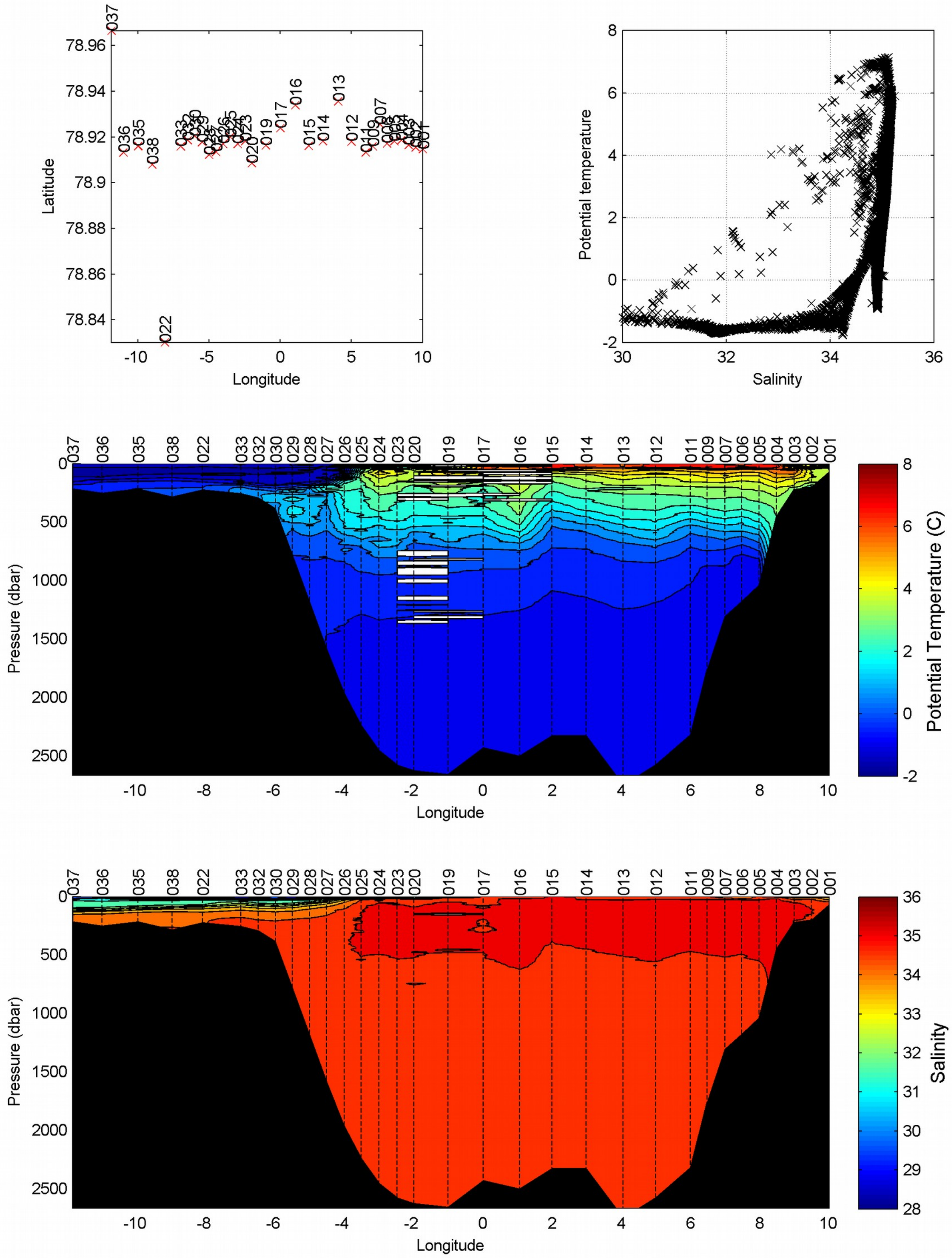

Figure 3.2: Temperature and salinity measurements collected along section 1.

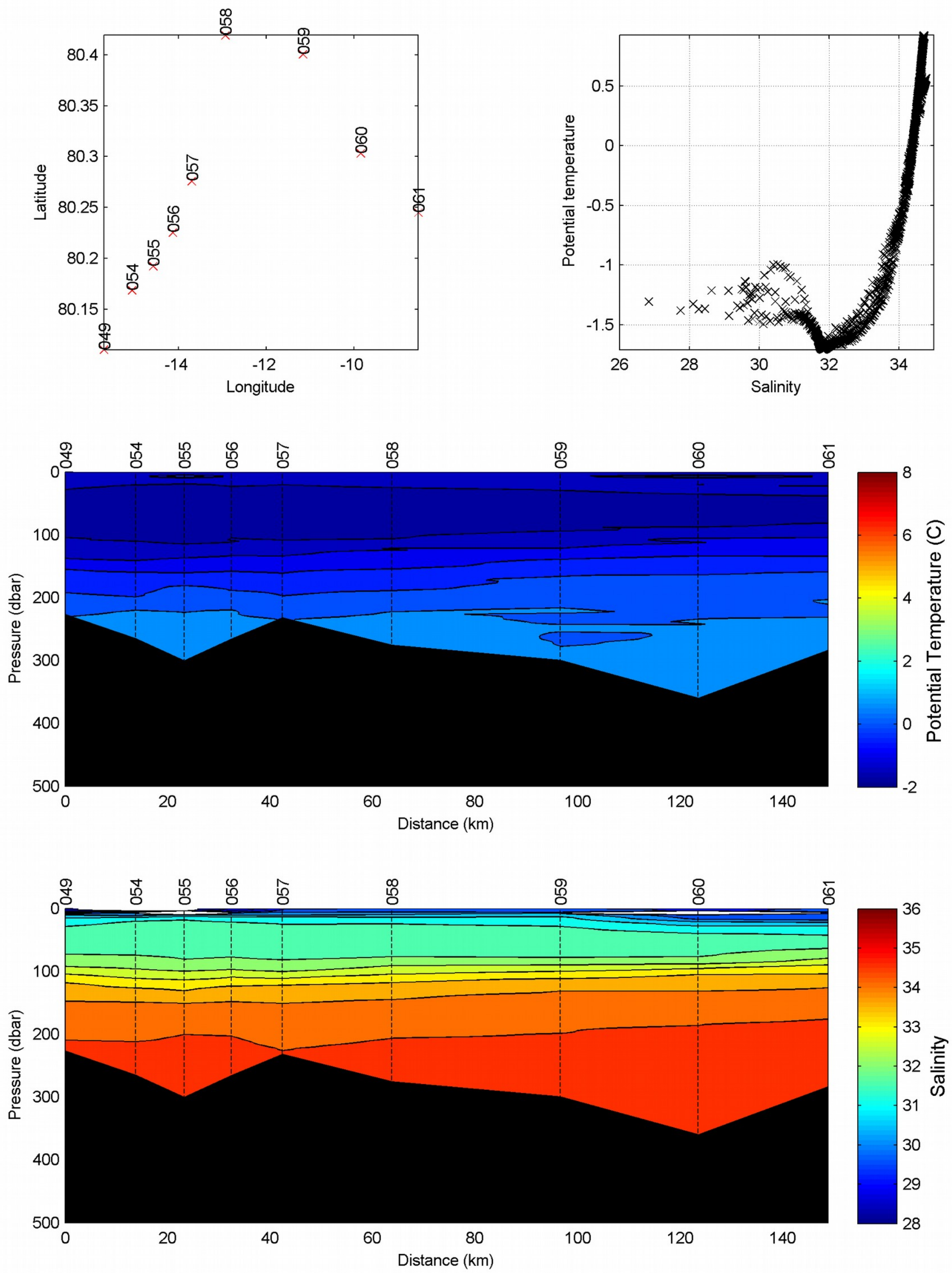

Figure 3.3: Temperature and salinity measurements collected along section 2.

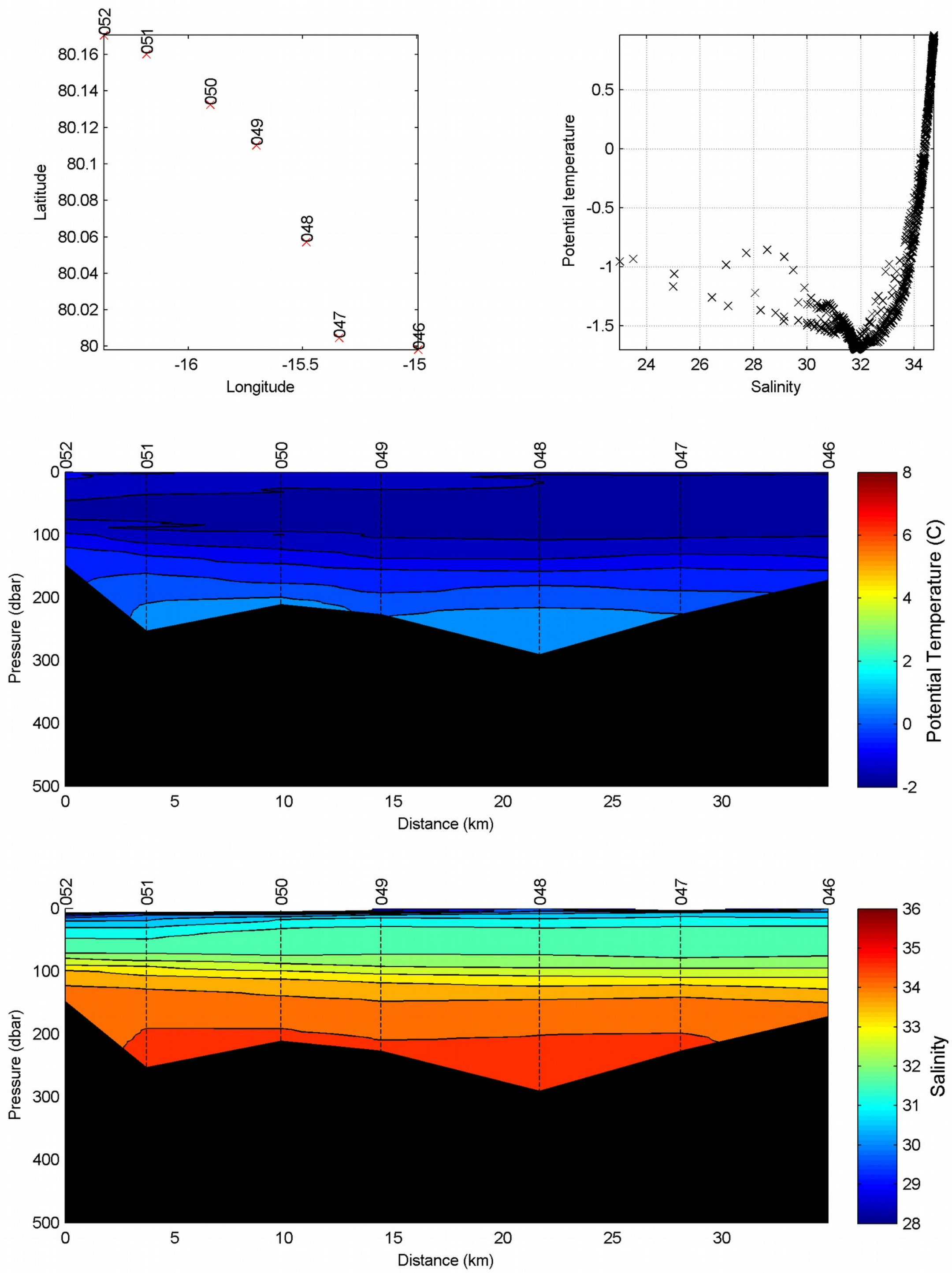

Figure 3.4: Temperature and salinity measurements collected along section 3.

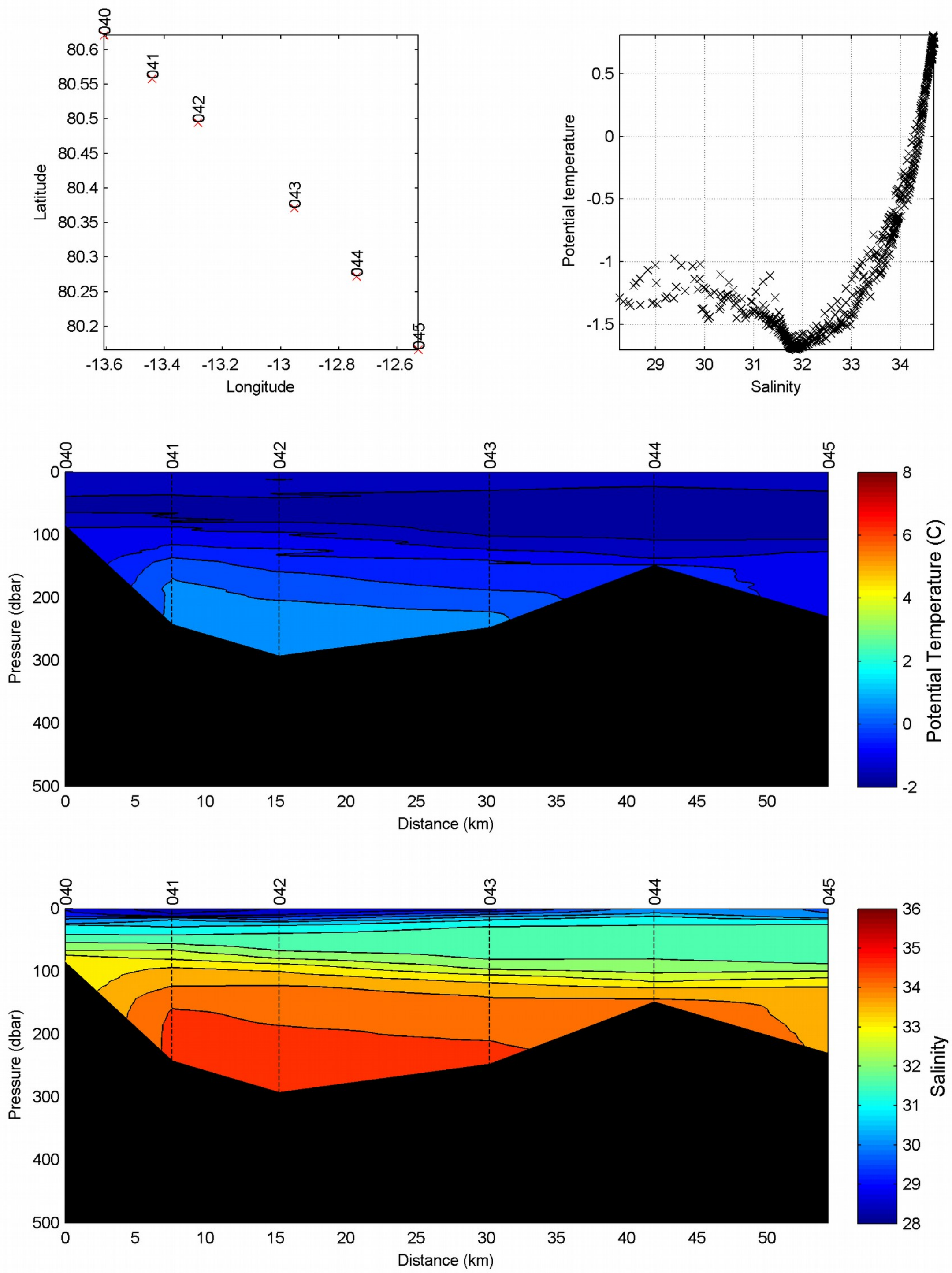

Figure 3.5: Temperature and salinity measurements collected along section 4.

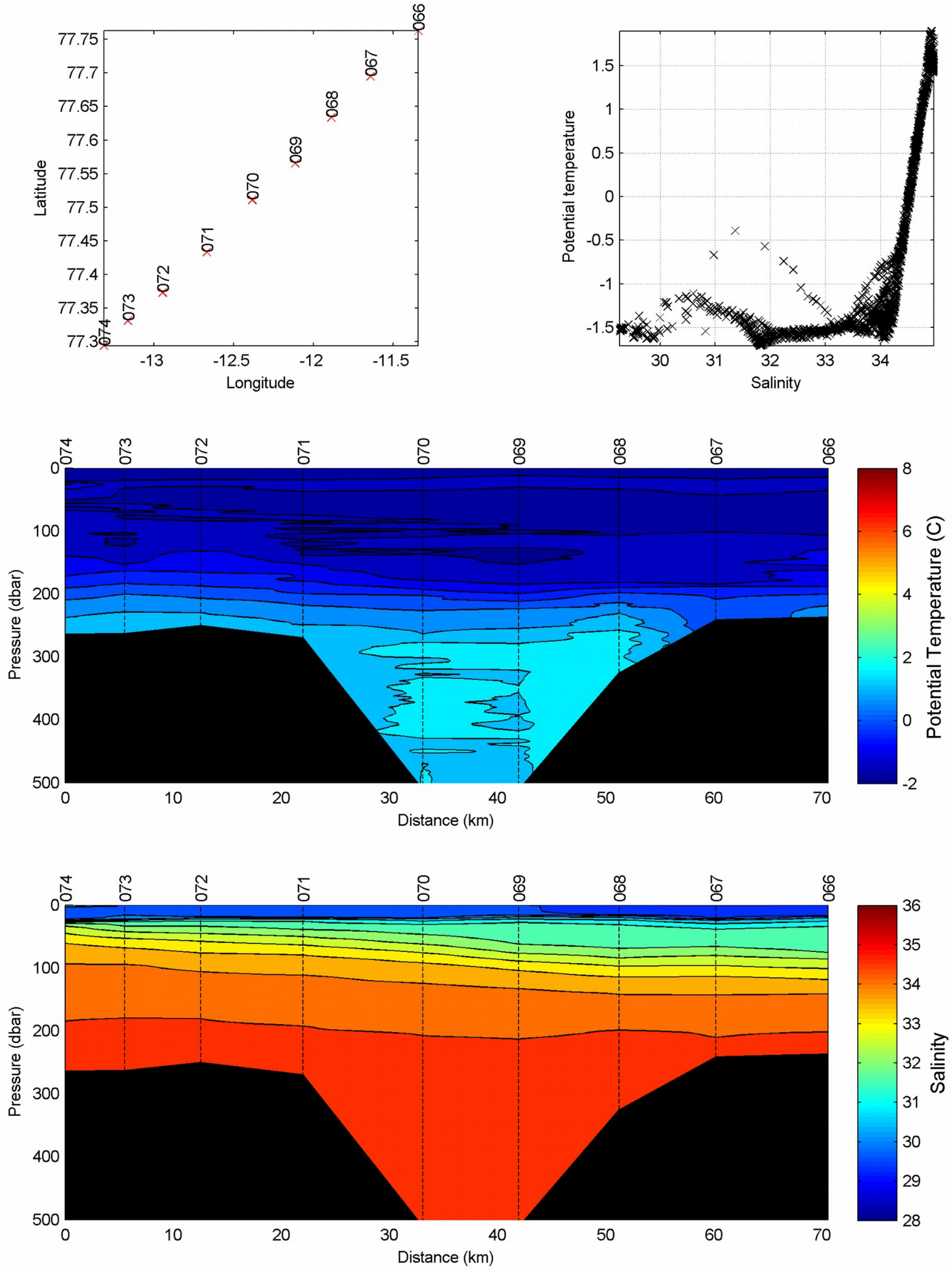

Figure 3.6: Temperature and salinity measurements collected along section 5.

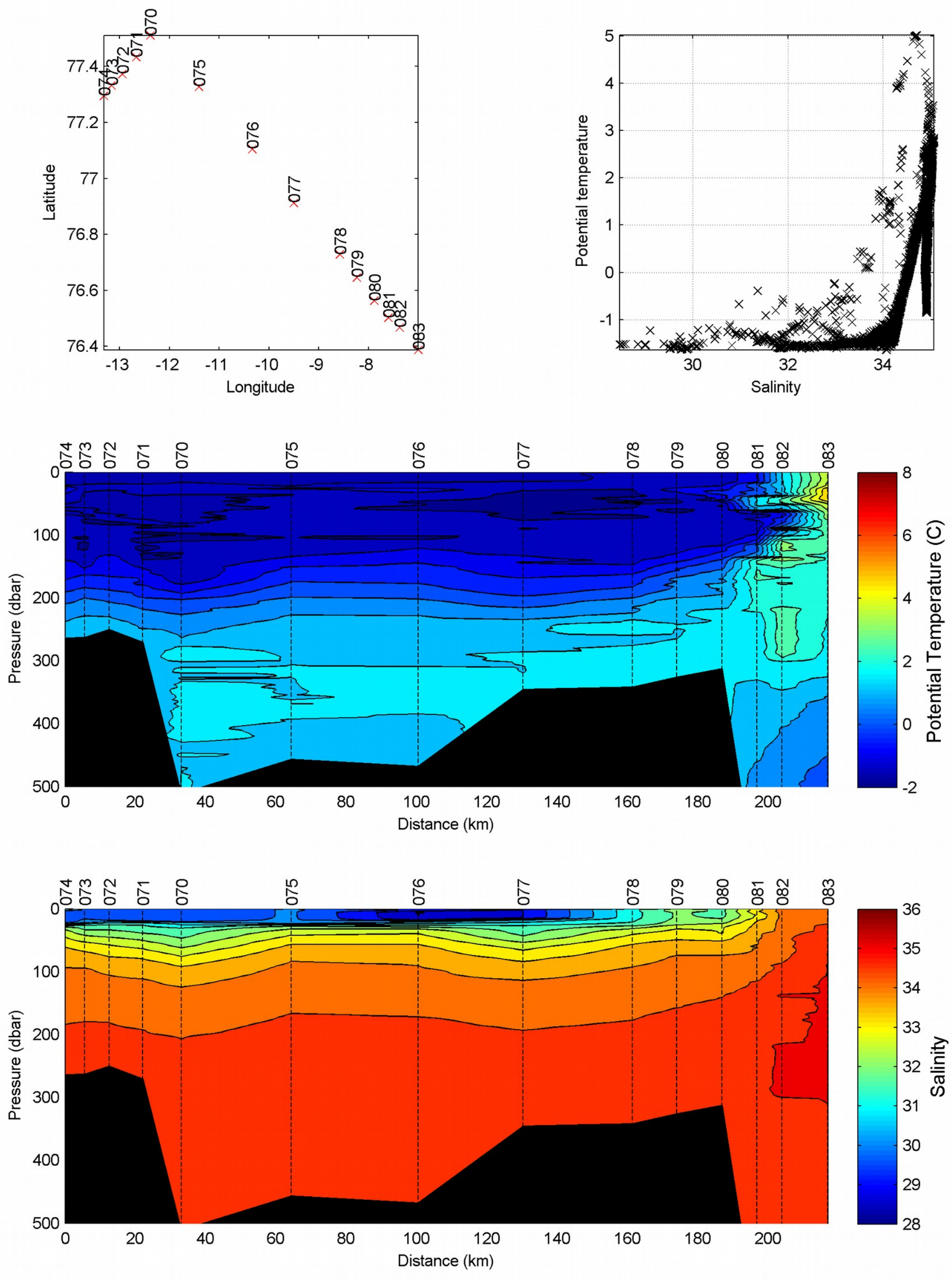

Figure 3.7: Temperature and salinity measurements collected along section 6.

Sensor Calibration

Water samples for laboratory salinity measurement were collected at all CTD stations. Where tracer samples were collected, salinity samples were collected at standard depths of 5, 15, 25, 50, 75, 100, 150, 200 and 300 dbar, plus two samples from the bottom of the water column. Where tracer samples were not collected, samples for salinity measurement were collected from deep parts of the water column where the salinity gradient was shallow. Deep regions provide the best data for conductivity sensor calibration as the water trapped in the Niskin bottles is the most similar to that sampled by the CTD. However as many CTD stations were over the shallow (typically 250 m) East Greenland Shelf relatively few deep samples could be collected.

Comparison of laboratory salinity measurements and CTD-salinity measurements revealed that the primary and secondary sensor packages sensors measured salinities 0.008 and 0.007 fresher than laboratory salinity measurements respectively (figure 3.8). These offsets are within the expected range. The offsets did not change significantly with salinity, pressure or time (station number).

Laboratory salinity samples were analysed abroad Lance using a Guildline Portasal portable salinometer which was standardised after every 24 measurements using IAPSO standard seawater.

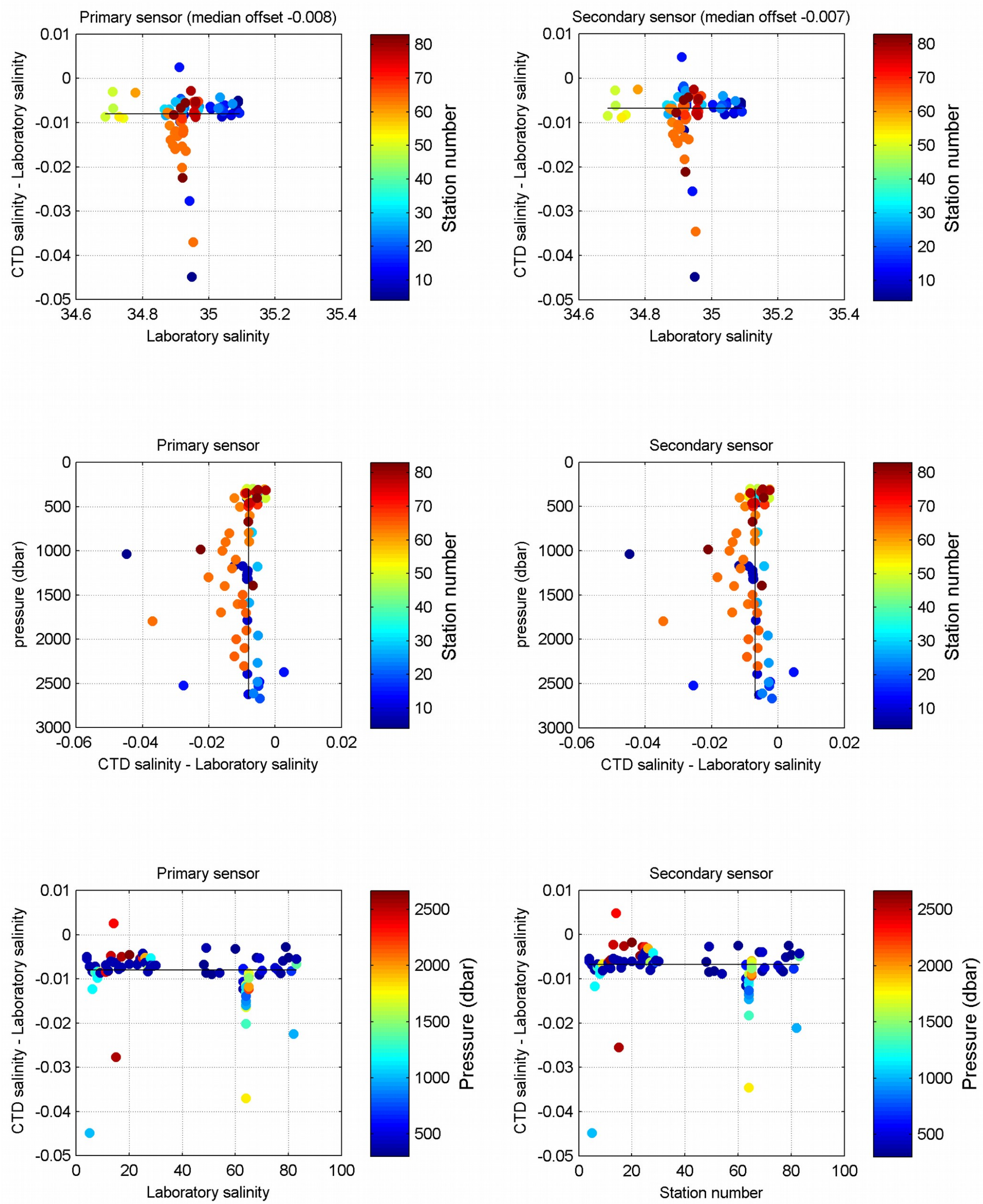

Figure 3.8: comparison of CTD and laboratory salinity measurements. Only data below 250 m are included, due to step salinity gradients at the surface. Wild data (CTD salinity – lab salinity > 0.5) are also excluded; these are typically the result of sampling or labeling errors.

Tracer Sampling Program

δ^{18}O and Dissolved Nutrient Concentration Samples

Samples for δ^{18}O isotope ratio analysis and nutrient concentration measurement were collected along the east-west transect at 79º 50 N which follows the mooring line and along the east-west transect at 80º N which crosses the East Greenland Shelf. δ^{18}O samples will be used to distinguish between freshwater originating from sea ice melting and freshwater of meteoric origin (such as river water, glacial ice meltwater, precipitation). The ratio of (Nitrate + Nitrate) : Phosphate can be used to identify freshwater of pacific origin which reaches Fram Strait primarily via the transpolar drift after passing through the Bearing Strait. The primary reason for collecting these samples is to further constrain the freshwater budget of the East Greenland Current.

Samples for δ^{18}O isotope ratio analysis and nutrient concentration measurement were collected at standard pressures of 5, 15, 25, 50, 75, 100, 150, 200 and 300 decibars with an additional sample being collected from the bottom of the water column along the main section. Along sections 2 to 6 samples were collected at standard pressures of 5 and 20 decibars with an additional sample being collected from the bottom of the water column.

CDOM and DOC Samples

Dissolved organic carbon (DOC) and dissolved organic matter absorption and fluorescence (CDOM) samples were collected on all transects in order to map water masses with different DOC/CDOM content. During the east-west transect samples were collected at every two degrees of longitude from 10°E to 2°W and at every degree of longitude from 2°W to 11.83°W. Samples were collected at the standard pressures. The collected water were filtered through a 0.22 µm filter (Millipore Opticap 4) directly from the Niskin bottles. The filter was rinsed with 100-250 mL seawater before collecting water from each Niskin bottle. CDOM samples were collected in 50 mL acid cleaned amber glass bottles and stored in the cook's fridge at about 4 °C. DOC samples were collected in acid cleaned glass bottles and adjusted to pH 2 by adding HCl (approximately 150 µL HCl to 20 mL filtered seawater). DOC samples were closed with a cap wrapped in parafilm and stored in the fridge together with TA/DIC samples at about 5 °C.

Bacterial abundance and bacterial production samples

Bacterial abundance (BA) and productivity (BP) were measured along the east-west transect at 10°E, 7°E, 4°E, 0°, 3°W, 6°W, 10°W and 11.83°W. Samples will be used to map the biological activity along the transect and to hypothesize on the lability of DOM from different water masses. BA samples were collected in duplicates at each depth and consisted of 1 mL seawater and 20 µL glutaraldehyde in a 2 mL cryo vial. After collection, the samples were stored in the freezer at approximately -20 °C. BP samples were taken in triplicates at each depth along with a blank sample at every other depth. The samples were collected in 20 mL plastic vials and consisted of 10 mL seawater and 50 µL Thymidine working solution (10 nM Thymidine). The blanks were fixated with 0.5-1 mL TCA before Thymidine was added. All samples incubated at *in situ* temperature (±3.5 °C) for 3-4 hours before being fixated with 1 mL TCA. After fixation the samples were stored in the lab at approximately 15-17 °C.

DOM lability samples

Five 20 L water samples were collected at four different stations along the east-west transect. The samples will be used in a long-term degradation experiment to investigate the degradation kinetics of DOM from different water masses: North Atlantic water (7 °E), Arctic water (10 °W) and a mix of the two water masses (0° and 6 °W). At 7 °E water were collected at 100 and 1318 m, while it was collected at 50 m at the rest of the stations. Immediately after collection water was filtered through a 0.22 µm filter (Millipore Opticap 4) and stored in the cook's fridge at about 4 °C.

TA and DIC Samples

Samples for total alkalinity (TA) and dissolved inorganic carbon (DIC) were collected at selected stations, mainly along the main transect across Fram Strait (section 1), coincident with other tracer sampling (see above and below). Some additional TA/DIC samples were collected at the other stations (see Table 3.2). For the latter we targeted selected depths at the surface, to look at apparent freshwater end-members.

Samples were collected according to the guidelines for carbonate system sampling, into 250 ml glass bottles using silicone tubing to avoid contact with the atmosphere. Bottles were sealed with grease and stored cool and dark for analysis after the cruise at Institute of Marine Research in Tromsø.

TA can be used as an alternative tracer of freshwater components to O18 (see above). Comparison of the derived fractions of freshwater using eitherTA or O18 can help in understanding uncertainties in freshwater estiamtes between the two methods. While TA and DIC can be used to calculate the calcium carbonate saturation state, pCO2 and pH, and used to look at the current status of ocean acidification in Fram Strait.

List of Tracer Samples

Table 3.2 lists the tracer samples collected during FS2011:

Station	Section	Depth	Salinity	D18O Sample #	Nutrient Sample #	CDOM & DOC sample #	TA & DIC sample #
1	1	59	34.821	1	1	1	1
1	1	51	34.823	2	2	2	2
1	1	35	34.312	3	3	3	3
1	1	18	33.746	4	4	4	4
1	1	10	33.578	5	5	5	5
1	1	4	32.969	6	6	6	6
2	1	196	34.950	7	7	-	-
2	1	173	34.969	8	8	-	-
2	1	139	35.021	9	9	-	-
2	1	103	34.999	10	10	-	-
2	1	69	34.900	11	11	-	-
2	1	52	34.745	12	12	-	-
2	1	34	34.649	13	13	-	-
2	1	16	34.446	14	14	-	-
2	1	10	34.351	15	15	-	-

2	1	3	33.956	16	16	-	-
3	1	211	34.999	17	27	-	-
3	1	173	35.072	18	26	-	-
3	1	139	35.076	19	25	-	-
3	1	104	35.146	20	24	-	-
3	1	69	35.172	21	23	-	-
3	1	52	35.047	22	22	-	-
3	1	35	34.578	23	21	-	-
3	1	18	34.275	24	20	-	-
3	1	11	33.975	25	19	-	-
3	1	3	32.975	26	18	-	-
3	1	1	32.504	27	17	-	-
4	1	454	35.089	28	28	-	-
4	1	400	35.089	29	29	-	-
4	1	251	35.114	30	30	-	-
4	1	200	35.132	31	31	-	-
4	1	150	35.151	32	32	-	-
4	1	101	35.179	33	33	-	-
4	1	76	35.196	34	34	-	-
4	1	50	35.175	35	35	-	-
4	1	26	35.147	36	36	-	-
4	1	15	34.908	37	37	-	-
4	1	6	34.485	38	38	-	-
5	1	1039	34.949	39	39	17	7
5	1	400	35.081	40	40	16	8
5	1	249	35.100	41	41	15	9
5	1	202	35.100	42	42	14	10
5	1	151	35.121	43	43	13	11
5	1	101	35.135	44	44	12	12
5	1	76	35.159	45	45	11	13
5	1	49	35.114	46	46	10	14
5	1	24	34.960	47	47	9	15
5	1	16	34.758	48	48	8	16
5	1	6	34.754	49	49	7	17
6	1	1169	34.917	50	50	-	-
6	1	401	35.068	51	51	-	-
6	1	250	35.113	52	52	-	-
6	1	201	35.132	53	53	-	-
6	1	151	35.135	54	54	-	-
6	1	99	35.149	55	55	-	-
6	1	75	35.146	56	56	-	-
6	1	51	35.154	57	57	-	-
6	1	24	34.886	58	58	-	-
6	1	15	34.149	59	59	-	-
6	1	5	34.112	60	60	-	-
7	1	1318	34.913	61	61	-	-
7	1	399	35.086	62	62	-	-
7	1	252	35.074	63	63	-	-
7	1	203	35.089	64	64	-	-
7	1	152	35.113	65	65	-	-
7	1	102	35.142	66	66	-	-
7	1	76	35.167	67	67	-	-
7	1	50	35.186	68	68	-	-

7	1	26	35.000	69	69	-	-
7	1	15	34.810	70	70	-	-
7	1	5	34.217	71	71	-	-
8	1	1320	-	-	-	-	18
8	1	1320	-	-	-	-	19
8	1	1321	34.913	-	-	-	20
8	1	1275	34.913	-	-	-	-
8	1	1249	34.913	-	-	-	-
8	1	1223	34.913	-	-	-	-
8	1	1172	34.914	-	-	-	-
8	1	101	-	-	-	-	21
8	1	101	-	-	-	-	22
8	1	101	35.139	-	-	-	23
9	1	1784	34.914	72	72	-	-
9	1	401	35.040	73	73	-	-
9	1	252	35.105	74	74	-	-
9	1	202	35.128	75	75	-	-
9	1	152	35.096	76	76	-	-
9	1	101	35.149	77	77	-	-
9	1	75	35.157	78	78	-	-
9	1	51	35.161	79	79	-	-
9	1	26	35.036	80	80	-	-
9	1	16	35.729	81	81	-	-
9	1	6	34.728	82	82	-	-
11	1	2390	34.924	83	83	18	24
11	1	403	35.007	84	84	19	25
11	1	252	35.079	85	85	20	26
11	1	203	35.095	86	86	21	27
11	1	151	35.086	87	87	22	28
11	1	102	35.110	88	88	23	29
11	1	76	35.153	89	89	24	30
11	1	51	35.066	90	90	25	31
11	1	26	34.898	91	91	26	32
11	1	15	34.640	92	92	27	33
11	1	5	34.617	93	93	28	34
12	1	2625	34.924	94	104	-	-
12	1	408	35.067	95	94	-	-
12	1	252	35.074	96	95	-	-
12	1	201	35.077	97	96	-	-
12	1	152	35.089	98	97	-	-
12	1	103	35.139	99	98	-	-
12	1	76	35.139	100	99	-	-
12	1	49	35.153	101	100	-	-
12	1	24	34.882	102	101	-	-
12	1	14	34.804	103	102	-	-
12	1	5	34.801	104	103	-	-
13	1	2482	34.913	105	105	29	35
13	1	403	35.047	106	106	30	36
13	1	251	35.079	107	107	31	37
13	1	201	35.045	108	108	32	38
13	1	150	35.112	109	109	33	39
13	1	100	35.139	110	110	34	40
13	1	73	35.145	111	111	35	41

13	1	50	35.165	112	112	36	42
13	1	25	35.023	113	113	37	43
13	1	13	35.023	114	114	38	44
13	1	4	35.021	115	115	39	45
14	1	2370	34.911	116	116	-	-
14	1	400	35.042	117	117	-	-
14	1	252	35.086	118	118	-	-
14	1	203	35.087	119	119	-	-
14	1	151	35.093	120	120	-	-
14	1	101	35.095	121	121	-	-
14	1	75	35.141	122	122	-	-
14	1	51	35.165	123	123	-	-
14	1	25	34.964	124	124	-	-
14	1	14	34.962	125	125	-	-
14	1	5	34.958	126	126	-	-
15	1	2523	34.942	127	127	40	46
15	1	400	35.004	128	128	41	47
15	1	250	35.055	129	129	42	48
15	1	202	35.079	130	130	43	49
15	1	151	35.079	131	133	44	50
15	1	99	35.108	132	131	45	51
15	1	75	35.121	133	132	46	52
15	1	49	35.136	134	134	47	53
15	1	25	35.105	135	135	48	54
15	1	13	35.104	136	136	49	55
15	1	5	35.103	137	137	50	56
16	1	2538	35.924	138	138	-	-
16	1	404	35.092	139	139	-	-
16	1	249	35.095	140	140	-	-
16	1	200	35.113	141	141	-	-
16	1	150	35.119	142	142	-	-
16	1	100	35.167	143	143	-	-
16	1	76	35.179	144	144	-	-
16	1	50	35.189	145	145	-	-
16	1	24	35.188	146	146	-	-
16	1	15	34.686	147	147	-	-
16	1	4	34.677	148	148	-	-
17	1	2528	34.920	149	149	51	57
17	1	402	35.044	150	150	52	58
17	1	253	34.995	151	151	53	59
17	1	201	35.000	152	152	54	60
17	1	151	35.082	153	153	55	61
17	1	102	35.031	154	154	56	62
17	1	75	34.989	155	155	57	63
17	1	51	34.886	156	156	58	64
17	1	26	34.851	157	157	59	65
17	1	16	34.787	158	158	60	66
17	1	5	34.774	159	159	61	67
18	1	50	-	-	-	-	70
18	1	50	-	-	-	-	69
18	1	50	-	-	-	-	72
19	1	2655	34.595	160	160	-	-
19	1	400	33.977	161	161	-	-

19	1	252	35.081	162	162	-	-
19	1	200	35.088	163	163	-	-
19	1	150	35.058	164	164	-	-
19	1	101	35.150	165	165	-	-
19	1	75	35.145	166	166	-	-
19	1	50	35.076	167	167	-	-
19	1	25	34.595	168	168	-	-
19	1	137	33.977	169	169	-	-
20	1	2668	34.915	170	170	63	74
20	1	400	35.032	171	171	64	75
20	1	249	35.053	172	172	65	76
20	1	201	35.037	173	173	66	77
20	1	150	35.068	174	174	67	78
20	1	99	35.038	175	175	68	79
20	1	76	34.957	176	176	69	80
20	1	51	34.758	177	177	70	81
20	1	25	34.571	178	178	71	82
20	1	15	33.320	179	179	72	83
20	1	5	31.050	180	180	73	84
20	1	1	31.027	181	181	-	-
22	1	218	34.465	182	182	74	85
22	1	150	34.226	183	183	75	86
22	1	100	33.437	184	184	76	87
22	1	74	32.352	185	185	77	88
22	1	50	31.812	186	186	78	89
22	1	24	31.552	187	187	79	90
22	1	14	30.652	188	188	80	91
22	1	2	29.431	189	189	81	92
23	1	2613	34.926	274	274	-	-
23	1	400	35.028	278	278	-	-
23	1	200	35.069	282	282	-	-
23	1	150	35.086	-	283	-	-
23	1	100	35.090	-	284	-	-
23	1	75	35.031	-	285	-	-
23	1	49	34.994	286	286	-	-
23	1	25	34.542	287	287	-	-
23	1	15	34.362	288	288	-	-
23	1	5	31.953	289	289	-	-
23	1	1	30.688	290	-	-	-
24	1	2484	34.922	292	291	82	93
24	1	400	35.072	293	292	83	94
24	1	250	35.076	294	293	84	95
24	1	200	35.091	295	294	85	96
24	1	150	35.106	296	295	86	97
24	1	100	35.081	297	296	87	98
24	1	75	35.043	298	297	88	99
24	1	50	35.024	299	298	89	100
24	1	25	34.613	300	299	90	101
24	1	15	34.237	301	300	91	102
24	1	5	31.213	302	301	92	103
25	1	2266	34.922	304	303	-	-
25	1	400	35.034	305	304	-	-
25	1	246	35.022	306	305	-	-

25	1	200	35.033	307	306	-	-
25	1	151	35.011	308	307	-	-
25	1	100	34.984	309	308	-	-
25	1	75	34.945	310	309	-	-
25	1	51	34.749	311	310	-	-
25	1	26	34.581	312	311	-	-
25	1	15	33.878	313	312	-	-
25	1	1	30.421	303	302	-	-
26	1	1956	34.923	314	313	93	104
26	1	400	34.971	315	314	94	105
26	1	251	34.988	316	315	95	106
26	1	201	34.985	317	316	96	107
26	1	151	34.892	318	317	97	108
26	1	100	34.498	319	318	98	109
26	1	74	34.273	320	319	99	110
26	1	49	34.005	321	320	100	111
26	1	24	33.222	322	321	101	112
26	1	14	32.141	323	322	102	113
26	1	4	29.880	324	323	103	114
26	1	1	29.549	325	324	-	-
27	1	1584	34.919	326	325	-	-
27	1	400	34.870	327	326	-	-
27	1	252	34.812	328	327	-	-
27	1	200	34.830	329	328	-	-
27	1	150	34.447	330	329	-	-
27	1	100	34.205	331	330	-	-
27	1	76	33.928	332	331	-	-
27	1	49	33.237	333	332	-	-
27	1	25	32.019	334	333	-	-
27	1	15	31.617	335	334	-	-
27	1	5	29.806	336	335	-	-
27	1	1	29.513	337	336	-	-
28	1	1175	34.900	338	337	104	115
28	1	400	34.920	339	338	105	116
28	1	250	34.797	340	339	106	117
28	1	200	34.627	341	340	107	118
28	1	101	33.982	342	341	108	119
28	1	75	33.519	343	342	109	120
28	1	25	31.462	344	343	110	121
28	1	15	30.838	345	344	111	122
28	1	5	29.433	346	345	112	123
29	1	791	34.880	347	346	-	-
29	1	400	34.969	348	347	-	-
29	1	250	34.762	349	348	-	-
29	1	200	34.539	350	349	-	-
29	1	150	34.238	351	350	-	-
29	1	100	-	352	351	-	-
29	1	76	33.100	353	352	-	-
29	1	50	31.922	354	353	-	-
29	1	25	31.001	355	354	-	-
29	1	15	30.099	356	355	-	-
29	1	4	29.386	357	356	-	-
30	1	387	34.866	358	357	113	124

30	1	250	34.748	359	358	114	125
30	1	200	34.494	360	359	115	126
30	1	150	34.149	361	360	116	127
30	1	99	33.569	362	361	117	128
30	1	75	32.685	363	362	118	129
30	1	50	31.842	364	363	119	130
30	1	25	31.174	365	364	120	131
30	1	15	30.230	366	365	121	132
30	1	5	29.564	367	366	122	133
31	1	51	-	-	-	-	134
31	1	51	-	-	-	-	136
31	1	51	-	-	-	-	138
32	1	296	34.829	368	367	-	-
32	1	250	34.797	369	368	-	-
32	1	201	34.517	370	369	-	-
32	1	150	34.204	371	370	-	-
32	1	100	33.666	372	371	-	-
32	1	75	32.903	373	372	-	-
32	1	49	31.907	374	373	-	-
32	1	24	31.086	375	374	-	-
32	1	15	30.470	376	375	-	-
32	1	4	29.671	377	376	-	-
33	1	254	34.775	378	377	123	140
33	1	200	34.699	379	378	124	141
33	1	150	34.280	380	379	125	142
33	1	100	33.790	381	380	126	143
33	1	75	33.234	382	381	127	144
33	1	50	32.380	383	382	128	145
33	1	25	31.300	384	383	129	146
33	1	15	30.403	385	384	130	147
33	1	5	29.340	386	385	131	148
33	1	1	29.177	387	386	-	-
34	1	50	-	-	-	-	149
34	1	50	-	-	-	-	151
34	1	50	-	-	-	-	153
35	1	220	34.504	391	387	132	155
35	1	150	34.188	392	388	133	156
35	1	100	32.868	393	389	134	157
35	1	75	31.947	394	390	135	158
35	1	50	31.786	395	391	136	159
35	1	25	31.334	396	392	137	160
35	1	15	30.492	397	393	138	161
35	1	5	29.703	398	394	139	162
35	1	1	29.272	399	395	-	-
36	1	244	34.409	400	396	140	163
36	1	200	34.354	401	397	141	164
36	1	150	34.035	402	398	142	165
36	1	101	32.242	403	399	143	166
36	1	76	31.803	404	400	144	167
36	1	51	31.724	405	401	145	168
36	1	25	31.343	406	402	146	169
36	1	15	30.933	407	403	147	170
36	1	5	29.772	408	404	148	171

36	1	1	29.721	409	405	-	-
37	1	208	34.394	411	406	149	172
37	1	150	33.971	412	407	150	173
37	1	102	32.233	413	408	151	174
37	1	75	31.837	414	409	152	175
37	1	50	31.758	415	410	153	176
37	1	25	31.491	416	411	154	177
37	1	15	31.087	417	412	155	178
37	1	5	29.758	418	413	156	179
37	1	1	29.752	419	414	157	180
38	1	281	34.540	420	415	158	181
38	1	200	34.443	421	416	159	182
38	1	151	34.236	422	417	160	183
38	1	100	33.235	423	418	161	184
38	1	75	32.136	424	419	162	185
38	1	50	31.806	426	420	163	186
38	1	25	31.066	427	421	164	187
38	1	15	29.870	428	422	165	188
38	1	5	29.446	429	423	166	189
38	1	1	29.408	430	424	167	190
39	mooring	110	33.662	440	425	-	-
39	mooring	50	31.828	441	426	-	-
40	4	15	29.872	427	192	-	-
40	4	5	29.112	428	193	-	-
41	4	236	34.694	432	429	-	-
41	4	15	30.160	433	430	170	194
41	4	5	28.457	434	431	171	195
42	4	297	34.689	435	432	172	196
42	4	250	34.661	436	433	173	197
42	4	200	34.557	437	434	174	198
42	4	150	34.344	438	435	175	199
42	4	100	33.584	439	436	176	200
42	4	75	32.509	442	437	177	201
42	4	50	31.752	443	438	178	202
42	4	25	30.977	444	439	179	203
42	4	15	30.102	445	440	180	204
42	4	5	28.675	446	441	181	205
43	4	252	34.619	447	442	-	-
43	4	15	30.906	448	443	182	206
43	4	4	29.702	449	444	183	207
44	4	157	34.243	450	445	-	-
44	4	15	31.287	451	446	184	208
44	4	4	30.486	452	447	185	209
45	4	235	33.974	453	448	-	-
45	4	15	30.741	454	449	186	210
45	4	5	29.996	455	450	187	211
46	3	176	34.365	459	451	-	-
46	3	15	31.072	460	452	188	212
46	3	5	30.408	461	453	189	213
47	3	236	34.915	162	454	-	-
47	3	15	33.977	163	455	190	214
47	3	5	34.915	164	456	191	215
48	3	300	34.711	465	457	-	-

48	3	15	31.082	466	458	192	216
48	3	5	30.466	467	459	193	217
49	3	405	34.710	471	460	194	218
49	3	300	34.687	472	461	195	219
49	3	251	34.634	473	462	196	220
49	3	200	34.438	474	463	197	221
49	3	150	34.138	475	464	198	222
49	3	100	33.005	476	465	199	223
49	3	75	32.157	477	466	200	224
49	3	50	31.780	478	467	201	225
49	3	25	31.491	484	468	202	226
49	3	15	31.232	485	469	203	227
49	3	5	30.003	486	470	204	228
49	3	1	8.434	487	471	205	229
50	3	213	34.649	479	472	-	-
50	3	16	31.044	480	473	206	230
50	3	5	29.803	481	474	207	231
51	3	332	34.742	482	475	-	-
51	3	15	30.451	493	476	208	232
51	3	5	27.541	488	477	209	233
52	3	148	34.255	489	478	-	-
52	3	15	30.391	490	479	-	234
52	3	5	28.162	491	480	210	235
53	none	272	34.701	492	481	-	-
53	none	15	30.493	493	482	211	236
53	none	5	27.167	494	483	212	237
54	2	385	34.729	495	484	-	-
54	2	15	31.419	496	485	213	238
54	2	5	29.721	497	486	214	239
55	2	294	34.699	499	487	-	-
55	2	15	31.485	500	488	215	240
55	2	5	29.528	501	489	216	241
56	2	254	34.655	502	490	-	-
56	2	15	31.300	503	491	217	242
56	2	5	29.558	504	492	218	243
57	2	234	34.549	505	493	-	-
57	2	15	31.250	506	494	220	244
57	2	5	30.011	507	495	221	245
58	2	278	34.674	508	496	-	-
58	2	15	31.317	509	497	-	-
58	2	5	30.413	510	498	-	-
59	2	296	34.751	511	499	-	-
59	2	15	31.108	512	500	-	-
59	2	4	30.064	513	501	-	-
60	2	305	34.778	514	502	-	-
60	2	15	30.323	515	504	-	-
60	2	5	29.523	516	503	-	-
61	2	277	34.783	517	505	-	-
61	2	15	29.994	518	506	-	-
61	2	4	29.691	519	507	-	-
63	mooring	894	34.882	-	-	-	-
63	mooring	798	34.878	-	-	-	-
63	mooring	701	43.874	-	-	-	-

63	mooring	600	34.874	-	-	-	-
63	mooring	500	34.881	-	-	-	-
63	mooring	401	34.897	-	-	-	-
64	mooring	1797	34.953	-	-	-	-
64	mooring	1698	34.931	-	-	-	-
64	mooring	1600	34.923	-	-	-	-
64	mooring	1500	29.858	-	-	-	-
64	mooring	1399	34.919	-	-	-	-
64	mooring	1299	34.919	-	-	-	-
64	mooring	1199	34.906	-	-	-	-
64	mooring	1101	34.900	-	-	-	-
64	mooring	1000	34.898	-	-	-	-
64	mooring	899	34.891	-	-	-	-
64	mooring	800	34.884	-	-	-	-
65	mooring	2302	34.919	-	-	-	-
65	mooring	2196	34.922	-	-	-	-
65	mooring	2101	34.920	-	-	-	-
65	mooring	2001	34.924	-	-	-	-
65	mooring	1901	34.918	-	-	-	-
65	mooring	1800	35.919	-	-	-	-
65	mooring	1701	34.913	-	-	-	-
65	mooring	1600	34.916	-	-	-	-
65	mooring	1498	34.916	-	-	-	-
66	5	232	34.703	468	508	-	-
66	5	15	30.226	469	509	-	-
66	5	5	29.297	470	510	-	-
67	5	240	34.556	410	511	-	-
67	5	15	29.346	522	512	-	-
67	5	5	29.298	524	513	-	-
68	5	320	34.969	525	514	-	-
68	5	15	30.274	526	515	-	-
68	5	4	29.286	527	516	-	-
69	5	476	34.955	528	517	221	246
69	5	350	34.920	529	518	222	247
69	5	250	34.722	530	519	223	248
69	5	201	34.414	531	520	224	249
69	5	150	34.143	532	521	225	250
69	5	100	33.531	533	522	226	251
69	5	75	32.690	534	523	227	252
69	5	50	31.852	535	524	228	253
69	5	25	31.491	536	525	229	254
69	5	15	30.534	537	526	230	255
69	5	5	29.580	538	527	231	256
70	5	498	34.961	539	528	-	-
70	5	15	29.674	540	529	-	-
70	5	5	29.584	541	530	-	-
71	5	261	34.839	542	531	-	-
71	5	15	29.817	543	532	-	-
71	5	5	29.549	544	533	-	-
72	5	249	34.880	545	534	-	-
72	5	15	30.005	548	535	-	-
72	5	4	29.760	549	536	-	-
73	5	261	34.888	550	537	-	-

73	5	15	30.060	551	538	-	-
73	5	5	29.890	552	539	-	-
74	5	261	34.871	553	540	-	-
74	5	15	29.739	554	541	-	-
74	5	5	29.615	555	542	-	-
75	6	455	34.956	556	543	-	-
75	6	16	30.111	557	544	-	-
75	6	5	29.946	558	545	-	-
76	6	463	34.954	560	546	-	-
76	6	14	29.303	561	547	-	-
76	6	5	28.530	562	548	-	-
77	6	348	34.960	563	549	-	-
77	6	15	29.569	564	550	-	-
77	6	5	29.025	565	551	-	-
78	6	337	34.959	566	552	-	-
78	6	15	31.407	567	553	-	-
78	6	5	31.358	568	554	-	-
79	6	314	34.946	569	555	-	-
79	6	14	32.214	570	556	-	-
79	6	5	32.189	571	557	-	-
80	6	308	34.960	572	558	-	-
80	6	14	32.027	573	559	-	-
80	6	7	31.878	574	560	-	-
81	6	671	34.894	575	561	-	-
81	6	14	33.422	576	562	-	-
81	6	4	33.331	577	563	-	-
82	6	984	34.921	578	564	-	-
82	6	16	34.225	579	565	-	-
82	6	5	34.206	580	566	-	257
83	6	1390	34.915	581	567	-	-
83	6	401	34.929	582	568	-	-
83	6	251	34.998	583	569	-	232
83	6	200	35.002	584	570	-	233
83	6	151	35.021	585	571	-	234
83	6	100	35.052	586	572	-	235
83	6	75	35.036	587	573	-	236
83	6	52	34.914	588	574	-	237
83	6	27	34.496	589	575	-	238
83	6	13	34.221	590	576	-	239
83	6	6	34.212	591	577	-	240

Table 3.2: Tracer samples collected during FS2011:

RAS-500 Moored Water Samplers

Recovery

In September 2010 two 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. Before deployment a preservative was added to half of the bags in the sampler at 120 m to preserve dissolved nutrient concentrations. See the cruise report from FS2010 for further details of the deployment. Mooring F17 was released on 28 August 2011, this was earlier than anticipated when the moorings were deployed. Samples were not collected in the last two bags (on ports 47 and 48) because the samplers were recovered before the sampling program had finished.

After recovery the samplers were transferred to a heated tent on deck where they were washed with a warm water hose to remove as much salt and bio-fouling as possible before they were lowered into the main hold for sampling. After recovery from the samplers sample bags were weighed to determine the volume of each sample (this was possible as the ship was stationary in the ice). Although the samplers had been programmed to collect 475 ml of sample most bags weighed only 350 – 400 g. The cause of the low sample volume has not yet been determined. The bag on port 6 of the 50 m sampler was empty on recovery. This bag featured a small tap at which tap was not opened before the bag was attached to the sampler.

Tables 3.3 and 3.4 list the tracer samples collected from each sampler.

50 m sampler (S/N 12239-02)								
Port	Depth	HgCl2	Bag weight (g)	Salinty sample #	d18O sample #	Nutrient sample #	CDOM & DOC sample #	TA & DIC sample #
1	55	no	365	1001	190	190	-	900
2	55	no	379	1002	191	191	-	901
3	55	no	359	1003	192	192	-	902
4	55	no	370	1004	193	193	-	903
5	55	no	337	1005	194	194	-	904
6	55	no	empty	-	-	-	-	-
7	55	no	335	1007	195	195	-	905
8	55	no	372	1008	196	196	-	906
9	55	no	360	1009	197	197	-	907
0	55	no	377	1010	198	198	-	908
1	55	no	361	1011	199	199	-	909
2	55	no	381	1012	200	200	-	910
13	55	no	346	1013	201	201	-	911
14	55	no	366	1014	202	202	-	912
15	55	no	329	1015	203	203	-	913
16	55	no	374	1016	204	204	-	914
17	55	no	347	1017	205	205	-	915
18	55	no	364	1018	206	206	-	916
19	55	no	359	1019	207	207	-	917

20	55	no	374	1020	208	208	-	918
21	55	no	341	1021	209	209	-	919
22	55	no	337	1022	210	211	-	920
23	55	no	396	1023	211	210	-	921
24	55	no	377	1024	212	212	-	922
25	55	no	360	1025	213	213	-	923
26	55	no	352	1026	214	214	-	924
27	55	no	403	1027	215	215	-	925
28	55	no	338	1028	216	216	-	926
29	55	no	322	1029	217	217	-	927
30	55	no	173	1030	218	-	-	-
31	55	no	335	1031	220	218	-	928
32	55	no	385	1032	232	220	-	929
33	55	no	356	1033	231	231	-	930
34	55	no	382	1034	230	230	-	931
35	55	no	374	1035	229	229	-	932
36	55	no	370	1036	228	228	-	933
37	55	no	366	1037	227	227	-	934
38	55	no	403	1038	233	233	-	935
39	55	no	384	1039	245	245	-	936
40	55	no	402	1040	244	244	-	937
41	55	no	371	1041	258	258	-	938
42	55	no	139	1042	-	-	-	-
43	55	no	394	1043	239	239	-	939
44	55	no	385	1044	240	240	-	940
45	55	no	397	1045	241	241	-	941
46	55	no	210	1046	242	242	-	-
47	55	no	empty	-	-	-	-	-
48	55	no	empty	-	-	-	-	-

Table 3.3 : Samples collected from S/N 12239-02 deployed at 50 m

120 m sampler (S/N 12239-01)								
Port	Depth	HgCl2	Bag weight (g)	Salinty sample #	d18O sample #	Nutrient sample #	CDOM & DOC sample #	TA & DIC sample #
1	110	no	324	2001	221	221	-	221
2	110	yes	317	2002	219	219	-	219
3	110	no	330	2003	223	223	-	223
4	110	yes	373	2004	235	235	-	235
5	110	no	324	2005	234	234	-	234
6	110	yes	330	2006	247	247	-	247
7	110	no	381	2007	224	224	-	224
8	110	yes	347	2008	246	246	-	246

9	110	no	399	2009	225	225	-	225
10	110	yes	367	2010	226	226	-	226
11	110	no	331	2011	236	236	-	236
12	110	yes	389	2012	259	259	-	259
13	110	no	344	2013	248	248	-	248
14	110	yes	406	2014	237	237	-	237
15	110	no	353	2015	249	249	-	249
16	110	yes	472	2016	260	260	-	260
17	110	no	281	2017	261	261	-	261
18	110	yes	406	2018	238	238	-	238
19	110	no	363	2019	262	262	-	262
20	110	yes	353	2020	250	250	-	250
21	110	no	326	2021	251	251	-	251
22	110	yes	418	2022	252	252	-	252
23	110	no	371	2023	263	263	-	263
24	110	yes	385	2024	264	264	-	264
25	110	no	372	2025	265	265	-	265
26	110	yes	414	2026	266	266	-	266
27	110	no	427	2027	243	243	-	243
28	110	yes	412	2028	254	254	-	254
29	110	no	369	2029	253	253	-	253
30	110	yes	397	2030	267	267	-	267
31	110	no	360	2031	255	255	-	255
32	110	yes	413	2032	268	268	-	268
33	110	no	376	2033	256	256	-	256
34	110	yes	426	2034	257	257	-	257
35	110	no	386	2035	269	269	-	269
36	110	yes	440	2036	270	270	-	270
37	110	no	341	2037	279	279	-	279
38	110	yes	417	2038	275	275	-	275
39	110	no	346	2039	271	271	-	271
40	110	yes	419	2040	280	280	-	280
41	110	no	370	2041	276	276	-	276
42	110	yes	431	2042	272	272	-	272
43	110	no	393	2043	281	281	-	281
44	110	yes	421	2044	277	277	-	277
45	110	no	402	2045	273	273	-	273
46	110	yes	439	2046	222	222	-	222
47	110	no	empty	-	-	-	-	-
48	110	yes	empty	-	-	-	-	-

Table 3.4 : Samples collected from S/N 12239-02 deployed at 50 m

Deployment

Both RAS-500 water samplers were re-deployed at the same 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 3.5. A preservative was added to odd numbered bags in both samplers. Both samplers were programmed to flush the rotary valve with 10 ml of acid followed by 100 ml of ambient seawater before collecting each sample. The deployment configuration for each sampler is summarized below. Before deployment the clocks of both RAS-500 samplers were synchronized with the UTC time displayed by a GPS.

Both samplers were primed with natural seawater (S ~= 34.7) obtained using the CTD rosette. After collection the seawater was filtered with a 0.2 micrometer Millipore Opticap filter to retard bio-fouling and to ensure that suspended particles would not clog the sampler.

More than 60 litres of prime water were required to prepare the two samplers. After collection the prime was stored in three 25-litre carboys before use. A peristaltic pump was used to transfer water from these carboys to three empty carboys via the filter and a length of Tygon tubing. The pump ran at a rate of 1 litre per hour and filtered the water over the course of several days. 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). The same prime water was used to prime ML12239-02 and ML12239-01. Dissolved nutrient samples of the prime were collected during preparation and stored frozen at -20 C.

The preservative used with the samplers was a saturated solution of mercury (II) chloride ($HgCl_2$). The preservative was prepared by dissolving 10.25g of $HgCl_2$ 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 -4°C.

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.

The batteries in the samplers were not replaced until immediately before deployment. Therefore the batteries used in the 2010 – 2011 deployment were used to flush and prime the samplers to be deployed in 2011-2012. During the flushing and priming operation the rotary valve of the 50 m sampler (S/N 12239-02) sometimes failed to align to the home port. We suspect this may be due to the low voltage provided by the almost depleted battery pack.

During the priming and flushing procedure two of the sample tubes were destroyed. In the first case the tube was dropped on to the deck and cracked. In the second case the blue screw-cap was cracked due to over-tightening. The samplers were re-configured so that each had a broken tube located at port 48 and programmed to collect only 47 samples. Port 48 was sealed with a blanking plug to prevent the ingress of bio-fouling.

Deployment summary for RAS deployed at 50 m (S/N 12239-02)

```
Header A| 50 M RAS deployed on F17
       B| Serial 12239-02
       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 =        5  [min]

Water  H| Flushing volume     =      100  [ml]
       I| Flushing time limit =        6  [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]
```

Deployment summary for RAS deployed at 120 m (S/N 12239-01)

```
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 =        5  [min]

 Water  H| Flushing volume     =      100  [ml]
        I| Flushing time limit =        6  [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]
```

Sample	Date	Time (UTC)
1 of 47	09/04/2011	12:00:00
2 of 47	09/12/2011	10:57:23
3 of 47	09/20/2011	09:54:46
4 of 47	09/28/2011	08:52:09
5 of 47	10/06/2011	07:49:32
6 of 47	10/14/2011	06:46:55
7 of 47	10/22/2011	05:44:18
8 of 47	10/30/2011	04:41:41
9 of 47	11/07/2011	03:39:04
10 of 47	11/15/2011	02:36:27
11 of 47	11/23/2011	01:33:50
12 of 47	12/01/2011	00:31:13
13 of 47	12/08/2011	23:28:36
14 of 47	12/16/2011	22:25:59
15 of 47	12/24/2011	21:23:22
16 of 47	01/01/2012	20:20:45
17 of 47	01/09/2012	19:18:08
18 of 47	01/17/2012	18:15:31
19 of 47	01/25/2012	17:12:54
20 of 47	02/02/2012	16:10:17
21 of 47	02/10/2012	15:07:40
22 of 47	02/18/2012	14:05:03
23 of 47	02/26/2012	13:02:26
24 of 47	03/05/2012	11:59:49
25 of 47	03/13/2012	10:57:12
26 of 47	03/21/2012	09:54:35
27 of 47	03/29/2012	08:51:58
28 of 47	04/06/2012	07:49:21
29 of 47	04/14/2012	06:46:44
30 of 47	04/22/2012	05:44:07
31 of 47	04/30/2012	04:41:30
32 of 47	05/08/2012	03:38:53
33 of 47	05/16/2012	02:36:16
34 of 47	05/24/2012	01:33:39
35 of 47	06/01/2012	00:31:02
36 of 47	06/08/2012	23:28:25
37 of 47	06/16/2012	22:25:48
38 of 47	06/24/2012	21:23:11
39 of 47	07/02/2012	20:20:34
40 of 47	07/10/2012	19:17:57
41 of 47	07/18/2012	18:15:20
42 of 47	07/26/2012	17:12:43
43 of 47	08/03/2012	16:10:06
44 of 47	08/11/2012	15:07:29
45 of 47	08/19/2012	14:04:52
46 of 47	08/27/2012	13:02:15
47 of 47	09/04/2012	11:59:38

Table 3.5: RAS-500 sampling schedule. Both RAS samplers were programmed to sample according to this schedule.

4. NPI cruise Fram Strait 2011: Report of the sea ice activities - Snow and Ice Physics, and Ice Mechanics

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Overview

During the FS2011 cruise onboard RV Lance (22 August - 15 September 2011), in situ sea ice measurements were carried out as part of the long term monitoring of sea ice properties in the Fram Strait, NPI project " Sea ice physics in the Fram Strait". Large scale distribution of sea ice thickness was measured using NPI's helicopter-borne electromagnetic instrument (EM-bird), following campaigns in the same area in 2005, 2008, and 2010. Morphology of pressure ridges and the mechanical properties of sea ice were studied by the NTNU/UNIS cruise participants.

In total, 13 sea ice stations were occupied (Fig. 4.1 and Table 4.1), with duration of up to 6 hours. Station FS2011 1 was approached using two Zodiac rubber boats in open drift ice. On all other stations, the ice floes were accessed by ladder from RV Lance. On all stations, position at start and end of the station were measured with a handheld GPS and the GPS track was logged in order to record the drift of the ice floe. For each site, a general description of the floe and the weather conditions was made.

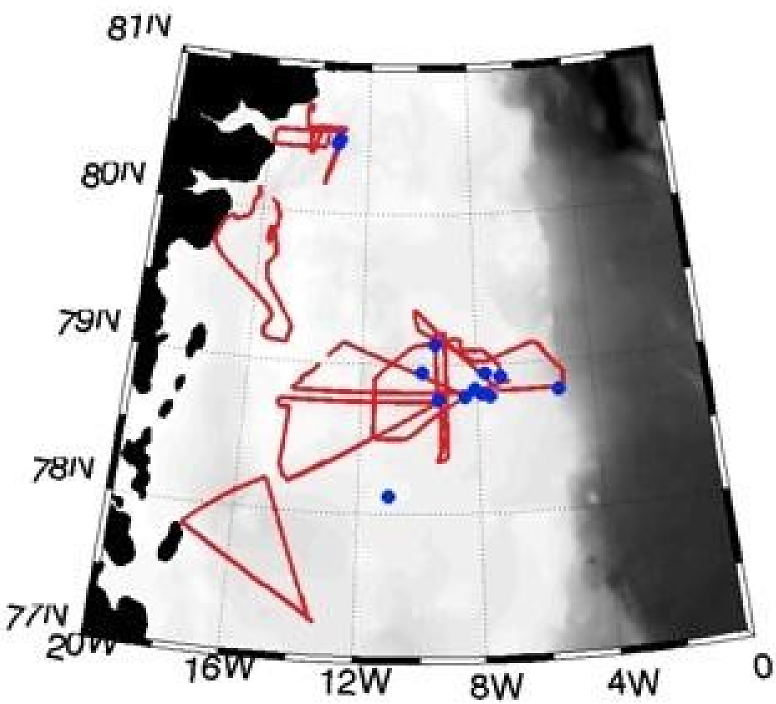


Fig. 4.1: Map of sea ice stations (blue dots) and HEM flight tracks (red lines) during FS2011.

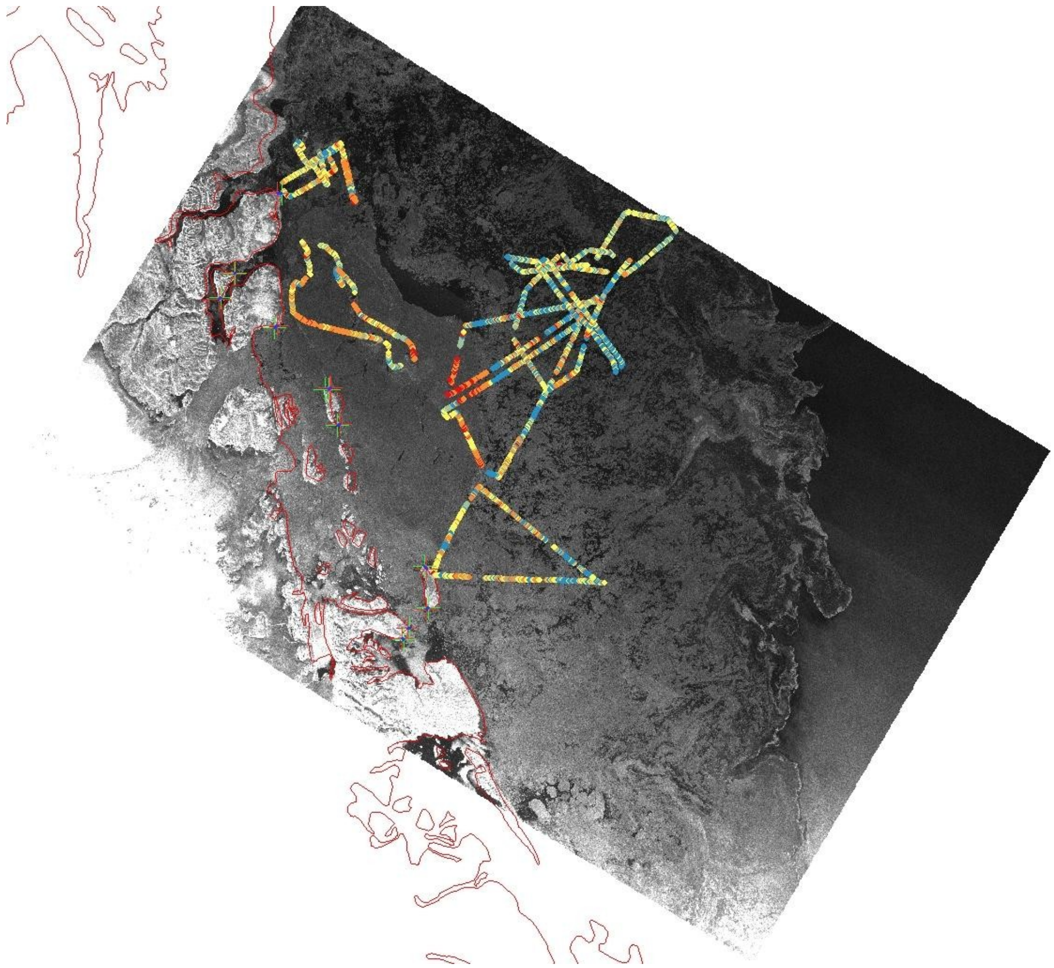


Fig. 4.2: ENVISAT WSM SAR image of the sea ice cover in the study region from the 30 August 2011 with the HEM tracks colour coded by ice thickness. By the time of the flights, the drift ice had opened up further and parts of the fast ice in the north had broken off.

Similar to 2010, the sea ice cover was dominated by young ice. Large parts of the transect along N 79° were covered by open drift ice with mostly small floes. In the beginning of the cruise, melt ponds were open, and refreezing started during the period of the cruise leading to solid and walkable ice layers on melt ponds and channels.

Table 4.1: Overview of sea ice stations with position and type of measurements made.

Date	Lat	Lon	Ice stn. ID	Drift	Snow & ice thickness	EM31	Coring for T & S	Archive core	Snow pit	Melt ponds	Bird obs.	Ridge morphology (NTNU)	BHJ (NTNU)
26/08/2011	N 78 48.278	W 05 10.811	FS2011 1										
27/08/2011	N 78 47.731	W 07 50.948	FS2011 2										
28/08/2011	N 78 49.801	W 08 04.349	FS2011 3										
30/08/2011	N 78 56.266	W 07 42.842	FS2011 4										
31/08/2011	N 79 08.047	W 09 25.646	FS2011 5										
31/08/2011	N 78 56.670	W 09 54.610	FS2011 6										
02/09/2011	N 80 29.850	W 13 10.667	FS2011 7					T core					
02/09/2011	N 80 27.837	W 13 13.795	FS2011 8										
06/09/2011	N 78 46.805	W 07 33.694	FS2011 9		2 floes								
07/09/2011	N 78 46.816	W 08 24.080	FS2011 10										
07/09/2011	N 78 45.885	W 09 21.004	FS2011 11										
08/09/2011	N 78 54.646	W 07 10.935	FS2011 12		3 floes								
10/09/2011	N 78 07.001	W 10 59.225	FS2011 13					top 73 cm only					

During long periods of the cruise, the weather was overcast with persistent fog, particularly during the first week in the ice. The moisture in the air and additional rain fall transformed the snow cover into refrozen snow with similar structure to snow after cycles of melting and refreezing, or to brittle snow.

Ice observations from the bridge

Sea ice conditions are observed every three hours from the bridge of RV Lance. In total 106 observations were made and various sea ice parameters including sea ice types, floe sizes, snow cover, ridges, rafting etc. were recording along with ship data (position, speed, and heading) and meteorological data (air and water temperature, air pressure, wind speed and direction, and humidity). Digital photos were taken with each observation (3 photos, looking out towards port, bow, and starboard. In addition, the IceCam, an automated system installed onboard Lance, recorded a series of five images from port to starboard every 30 minutes with parallel logging of position.

Mass balance of sea ice in Fram Strait (NPI)

1. On ice work

(Angelika Renner, Mats Granskog, Are Bjørdal, Liqiong Shi, Ella Darlington)

Snow and ice thickness profiling

Snow and ice thickness was measured directly from drillings and indirectly using a Geonics EM31-MK2, providing ground data to quantify the ice thickness in the study region. The measurements are part of repeated annual surveys in August/September in Fram Strait and enable the assessment of interannual variability. The EM31 is based on the principle of electromagnetic induction. By measuring the electrical conductivity in the half-space under the instrument (penetration depth over sea ice about 6 m), the 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 drillings were done on selected spots for calibration and validation, and ice and snow thickness and freeboard were measured with a Kovacs thickness gauge. The snow thickness was measured with a metal pole every 5 m along the EM31 tracks. In total, ca. 9200 m of electromagnetic profiles were covered and 93 holes (not including holes for melt pond characterisation) drilled for direct thickness measurements (55 of which for EM31 calibration).

Fig. 4.3: Liqiong and Ella measuring snow and ice thickness at a calibration drilling.

Snow pits

Snow pits were done on all but the first station. Snow properties recorded include snow classification, stratigraphy, grain size, and temperature. Density and moisture measurements were not possible due to thin snow cover. Snow classes were defined using the scheme of LaChapelle (1982). Grain were inspected with a magnifying glass on a mm pad.

Ice coring on level ice

At all stations, ice cores were taken for vertical temperature and salinity profiles of the ice and archive cores were kept for texture analysis in the lab. Coring was performed in collaboration with the NTNU group on floes on which they performed borehole jack measurements.

Temperature was measured in small drill holes using an electric thermometer at a spacing of 10 cm. Sea ice salinity was derived onboard Lance from melted samples of typically 12 cm thick core pieces, using a WTW 340 conductivity meter.

Fig. 4.4: Salinity measurements of melted ice core samples onboard Lance.

Melt pond characterisation

At the beginning of the cruise we could observe open meltponds, but when sea ice work really started the majority had started to freeze over. Nevertheless some melt ponds were mapped during the cruise, although to a lesser extent than planned. A few melt ponds were mapped on ice station 2, 4 and 6. The floe at ice station 2 had a well developed and interconnected melt pond system (Figure 4.5) We mapped two melt ponds on this floe, and an example is shown in Figure 4.6, where the depth of the melt pond (relative to the surface water level in the melt pond) was measured along the long axis of the melt pond, and once across the long axis. Some information of melt pond extent will be gained from the photography from the EM bird flights, as well as to a more limited extent from the visual ice observations made on board the ship.

Figure 4.5: Photo of measuring the pond depth at Ice Station 2. In the background the well developed melt pond system.

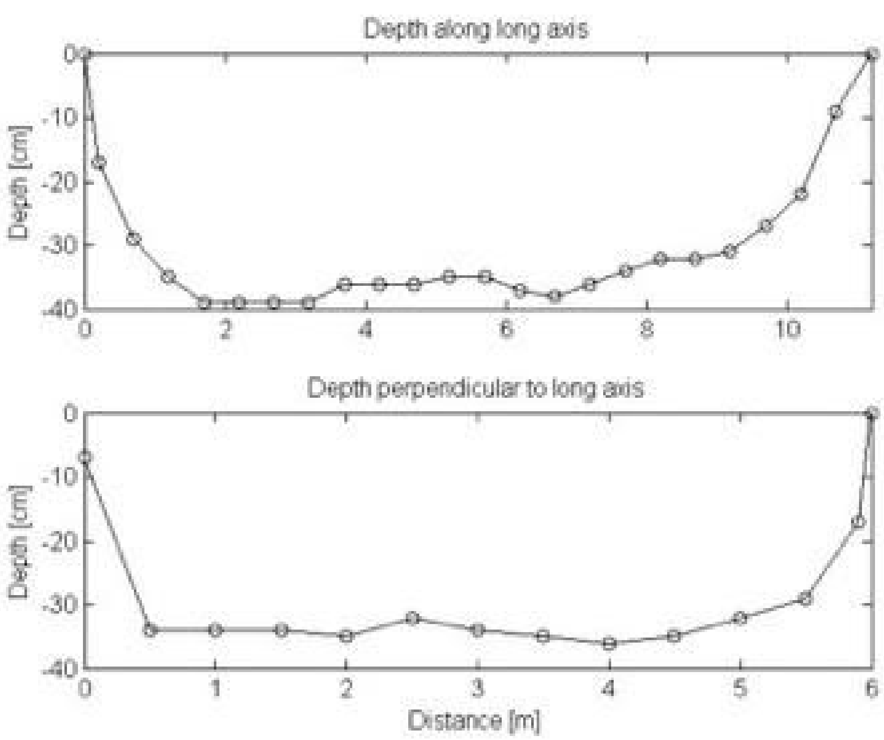


Figure 4.6: Graphs showing the melt pond depth along the long axis and perpendicular to the long axis on Ice Station 2.

2. **Airborne work** - *Helicopter-borne sea ice thickness profiling*
(Angelika Renner; pilot: Bjørn Frode Amundsen, technician: Dante Fontana)

Sea ice thickness is a vital yet on large scales difficult to measure parameter to assess the state of the Arctic ice cover. Although new methods are being developed to measure ice thickness from satellites such as Cryosat-2 and first result have recently been presented, helicopter-borne measurement using electromagnetic induction with the so-called EM-bird remain the most accurate means for collecting large-scale (several hundreds of kilometers) ice thickness information.

The Fram Strait 2011 cruise has been the third campaign with NPI’s own EM-bird. The instrument worked very reliably throughout the cruise, however, the previously experienced problems with the network connection remain (see cruise reports from KVS2011 and ICE11-03). The wireless LAN signal is not strong enough for a continuous connection between operator laptop and EM-bird. Tests should be made with other WLAN hardware. Due to the continuous connection drop outs, the altimeter display for the pilot did not work and was disconnected after a few flights. The pilot used the helicopter’s radar altimeter for height orientation instead keeping the helicopter at a height of 90 to 100 ft (a 20 m towline was used for the EM-bird). To avoid spending valuable flight time with restarting the EM-bird handling software after connection problems, the bird was operated during most of the flights directly through the Remote Desktop and Panel, including calibrations.

Fig. 4.7: Photo of the EM-bird over nilas and a narwhale taken with the GoPro mounted under the helicopter.

To make EM-bird easier to distinguish from ice and open water during the processing of the digital photographs, the cloth panels on the tail were exchanged and new, red panels fitted (Fig. 4.7).

Table 4.2: Overview of EM-bird flights. Times in local time (GMT +2) from Airlift flight log.

Date	*Time start*	*Time end*	*GoPro photos*	*GoPro video*	*Start Lat*	*Start Lon*	*Comments*
02/09/2011	10:14	11:50	Y	Y	N 80.490	W 13.166	fault in connector plug during second half of flight
02/09/2011	19:45	21:43	N	N	N 80.602	W 13.758	
03/09/2011	17:00	19:20	Y	Y	N 80.068	W 15.652	attempt to reach RS2 scene => too much fog
06/09/2011	08:28	10:48	Y	Y	N 78.835	W 5.131	
07/09/2011	08:49	11:00	Y	Y	N 78.809	W 8.379	
07/09/2011	13:48	16:17	Y	Y	N 78.773	W 9.295	
07/09/2011	19:10	21:00	Y	Y	N 78.762	W 9.330	
08/09/2011	12:33	14:41	Y	only first 25 min.	N 78.953	W 7.211	
11/09/2011	10:46	13:05	Y	Y	N 77.285	W 13.349	

A total of 9 EM-bird flights were completed, covering a flight track of over 2400 km (Fig. 4.1, 4.2 and 4.8, Table 4.2). The flights focussed on two separate sea ice regimes (Fig. 4.2 and 4.9): Firstly, tracks were chosen to either cover as much of the east-west extent along approx. N 79° to enable comparisons with previous EM-bird campaigns and with mooring data. Secondly, the fast ice off Greenland at N 78° - 81° was mapped extensively for assessment of the ice properties and for comparison with remote sensing data. Despite persistent fog during the first week of the cruise, a large area could be covered in the following week thanks to the excellent work of and cooperation with the Airlift crew.

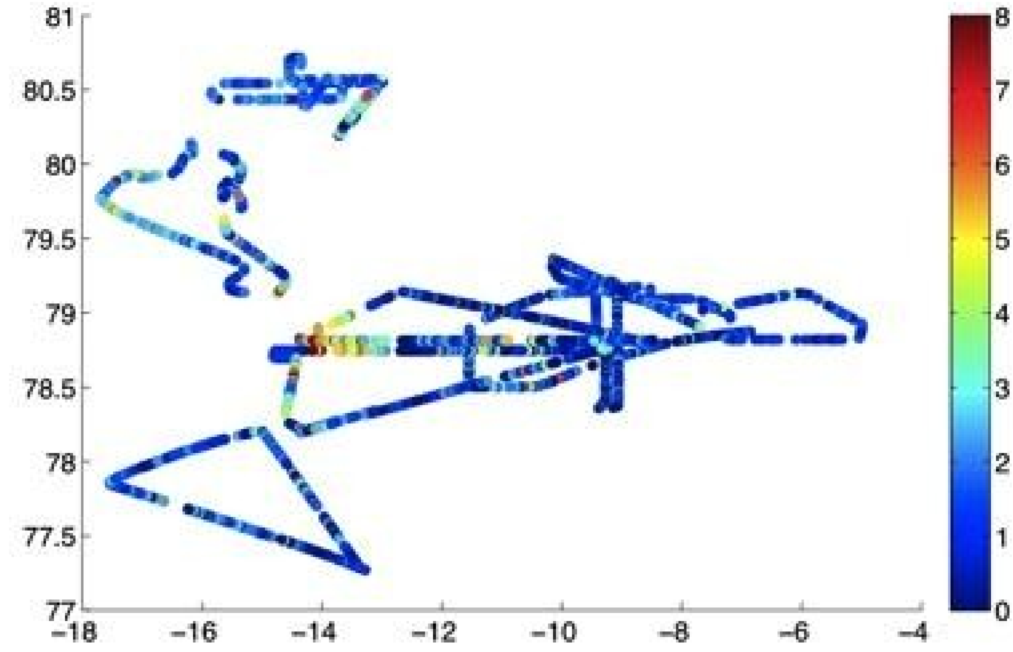


Fig. 4.8: Preliminary ice thicknesses measured during HEM flights. The colour scale is capped at 8 m for greater details of thin ice.

The sea ice in the western half of the study region was dominated by small to medium sized floes in partially very open drift. The floes were mostly FYI with some thick MYI in between. Near the fast ice, some vast floes were encountered which consisted predominantly of level FYI with extensive melt pond coverage. Some large floes which probably originate from the fast ice were overflown and show similar properties to large parts of the fast ice with a very variable surface. In the fast ice at approx. N 78.75, W 14.6, a rectangular patch of very thin, very level ice was observed. This patch was clearly distinguishable from the surrounding thick and ridged fast ice and even visible on SAR imagery from the Envisat ASAR satellite.

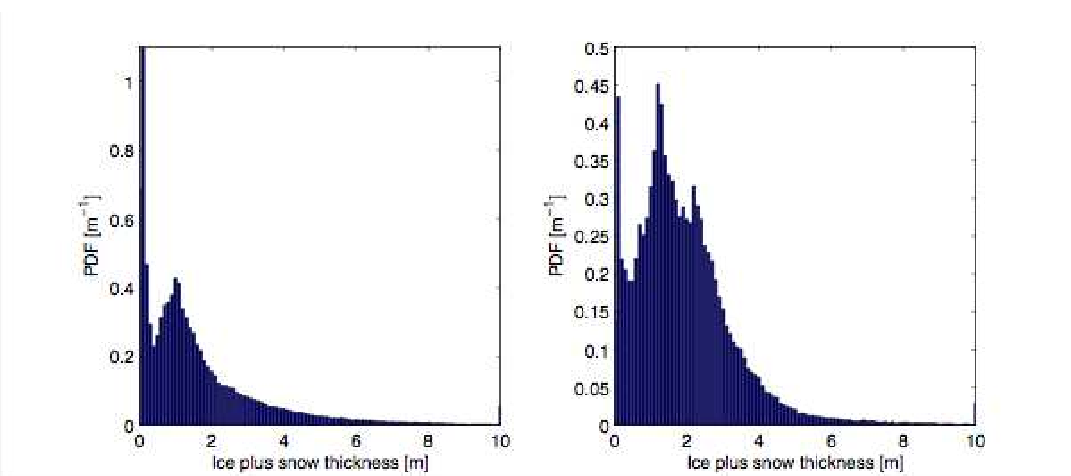


Fig. 4.9: Ice thickness distributions of flights over predominantly drift ice (left) and predominantly fast ice close to Greenland (right) after preliminary data processing.

Nilas started to form at the beginning of the cruise and during the flights on the 06 & 07/09/2011, most of the leads were covered by nilas or young grey ice, leaving almost no open water. Increasing winds led to the nilas being blown out again on the 08/09/2011, but it reformed until the last flight, when again, open water in leads was encountered only in the southern end of the track.

Sea ice mechanics (NTNU/UNIS)

(Aleksey Shestov and Ole-Christian Ekeberg)
A detailed data report is available from NTNU/UNIS.

Ridge Morphology - Set-up and techniques

The ridge morphology mapping was investigated by the technique of cross section drilling over the ridge with 2 inch augers driven by an engine machine. Sequentially, the mapping of a column was performed measuring the length of penetrating during the drilling while putting a new auger after a previous one penetrated into the ridge. Drilling across the ridge a number of 2 inch holes N with spacing d between them, we were measuring the length of a column H and measuring the freeboard F. Thus later we were able to reconstruct the sail surface $h_{sail} = F$ and the keel surface $h_{keel} = F - H$ relatively to the water level. In addition to that the snow thickness h_{snow} on the sail surface was measured. Based on these direct measurements a number of different geometrical properties of ridges was calculated later: maximum sail height $h_{sail}^{\max}$, maximum keel depth $h_{keel}^{\max}$, average keel depth across the ridge h_{keel}^{avr}, ratio of maximum keel depth to maximum sail height $h_{keel}^{\max} / h_{sail}^{\max}$, ratio of average keel depth to maximum sail height $h_{keel}^{avr} / h_{sail}^{\max}$ and average snow depth across the ridge h_{snow}^{avr}.

In addition to this during the morphology mapping process we logged gaps if we met them and hardness of the drilling, encountered along the hole, and measured it qualitatively by the muscles with a division on four levels: super soft, soft, medium and hard. That would allow us to estimate the macroporosity η of the ridges by calculating the ratio of all gaps total length to all drilled holes total length over the ridge.

Fig. 4.10: Work spot of ice ridge morphology mapping and ice coring

After completing morphology mapping we were coring a sample for temperature (*T*), density (*D*) and salinity (*S*) profile in the thickest part of the ridge closest to the sail peak. Ice coring sampling was performed with a 7.5 centimetres core drill from the Kovacks Enterprises. After the each part of core appearance its temperature distribution was measured, density and salinity samples were taken for a vertical distribution to be measured. Temperature, density and salinity measurements were made at different depth intervals (L_T, L_D and L_S respectively). For density and salinity measurements we used 10 cm long samples taken from corresponding depths of the core. One fully through ridge core was performed for each ridge. A typical work spot, the coring procedure and temperature-salinity measurements have shown on Fig. 4.10 and Fig. 4.11.

Fig. 4.11: Temperature, density, salinity measurements

In Table 4.3 both directly measured and calculated, based on measured ones, geometrical properties of investigated ridges have been collected together.

Table 4.3: Geometrical properties of ice ridges, N - number of 2 inch holes across the ridge, d – distance between 2 inch holes, $h_{sail}^{\max}$ - maximum sail height ≡ maximum freeboard, $h_{keel}^{\max}$ - maximum keel depth, h_{keel}^{avr} - average keel depth.

ID	N, [1]	d, [m]	$h_{sail}^{\max}$, [m]	$h_{keel}^{\max}$, [m]	h_{keel}^{avr}, [m]	$h_{keel}^{\max} / h_{sail}^{\max}$, [1]	$h_{keel}^{avr} / h_{sail}^{\max}$, [1]	h_{snow}^{avr}, [cm]
FS11_1	10	1	1.07	4.75	3.93	4.4	3.7	7
FS11_2	9	1	1.38	3.69	3.18	2.7	2.3	3
FS11_3	10	1	1.02	3.00	2.60	2.9	2.5	6
FS11_3	11	1	1.10	3.57	2.63	3.2	2.4	9
FS11_0	1	-	0.92	3.68	-	4.0	-	-
FS11_7	11	2	1.40	6.28	4.60	4.5	3.3	1

Borehole Jack Measurements

Bore hole jack (BHJ) is a device which makes it possible to test the ice strength in situ instead of the conventional solution which is to drill an ice core and test it in a compression machine on location or in a lab. The version used here is one developed by NTNU and contains three parts, a pump, a logger which logs the pressure in the system and the displacement of the piston and the boreholejack piston (see Figure 4.12 and Figure 4.13). For all test sites the ice characteristics are found by measuring salinity, density and temperature of the ice for the tested depths. Generally all tests were done on what seemed to be level ice and only the first meter of ice was used for tests. This was due to practical limitations with respect to the corer and its extension.

At the moment the BHJ is in a test-phase and different testing schemes were applied to cover a range of test-conditions. This means that we tested different speeds, depths, directions as well as some testing without load on the piston. The results are intended to be processed by a master or phd student in collaboration with Ole-Christian Ekeberg.

It is believed that the results obtained were good though some issues with respect to displacement measurements must be investigated.

Figure 4.12: The boreholejack head. Here it can be seen that the piston is extended and the ice has cracked.

Figure 4.13: The setup of the boreholejack where the orange box is the logger, the equipement on the sled is the pump.

Satellite imagery (NPI)
(Angelika Renner, Are Bjørdal)

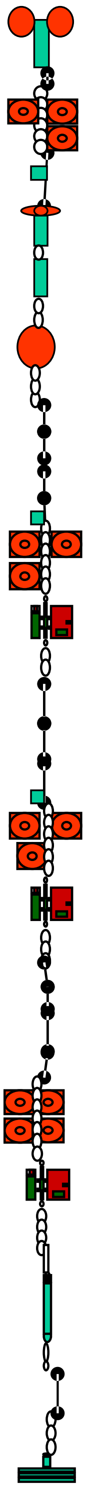
Satellite imagery is available onboard RV Lance to aid navigation and planning in ice covered seas. AMSR-E ice concentration maps were downloaded using software developed by the Danish Technical University and available at http://www.seaice.dk/zipfiles/install/. They can then be displayed offline together with the ship's position or other points of interest. ENVISAT ASAR images were available for our region almost daily from www.polarview.aq as JPEG2000, allowing for easy download over low bandwidth (Fig. 2). These images were displayed in OziExplorer together with the moving ship track from a handheld GPS to help with navigation around large floes or heavy ice as described earlier for the FS2010 cruise.

Appendix 1: Recovered moorings

Rigg F11-12

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

Tatt opp 26 AUG 2011 kl 08:25



		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	

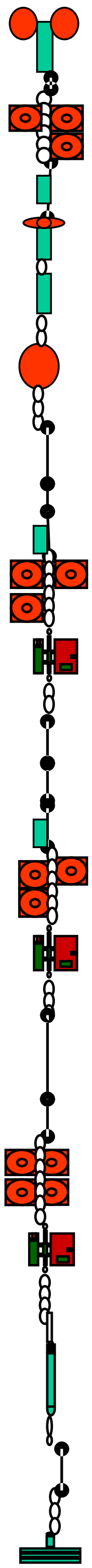
Rigg F12-12

Satt ut 14 SEP 2010 kl 16:25

Tatt opp 26 AUG 2011 kl 12:20

78 48,420N

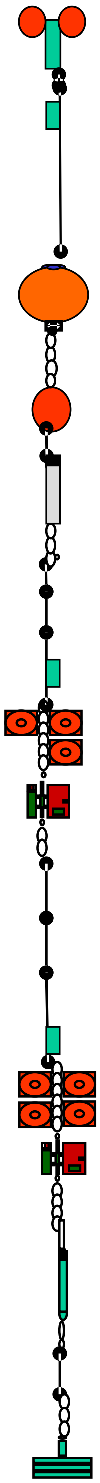
003 59,14W



		Dyp:	Fra bunn:	Ut:
IPS	SNR. 51063	75	1786	14:40
3 Glasskuler				
2 m Kjetting galv.				
SBE37	SNR. 3489	80	1781	14:40
5 M Kevlar				
RDCP600	SNR: 28	84	1777	14:40
Batteribeholder til RDCP				
2 m Kjetting galvanisert				
Stålkule 37	NPNR 5	88	1773	
2 m Kjetting galvanisert				
200 m Kevlar				
40 m Kevlar				
10 m Kevlar				
SBE37	SNR.4837	339	1522	14:22
3 Glasskuler				
3 m Kjetting galvanisert				
RCM7	SNR.11475	344	1517	14:22
0,5 m Kjetting RF				
500 m Kevlar				
500 m Kevlar				
200 m Kevlar				
SBE37	SNR.3554	1542	319	13:44
3 Glasskuler				
3 m Kjetting galvanisert				
RCM11	SNR.235	1547	314	13:44
0,5 m Kjetting galv				
200 m Kevlar				
100 m Kevlar				
4 Glasskuler				
2 m Kjetting galvanisert				
RCM8	SNR.11625	1850	11	13:32
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 182 Pinger på: Pinger av: Release Release m/ping:			
5 m Kevlar				
2 m Kjetting galvanisert				
ANKER 1140/(980) kg		1861	0	

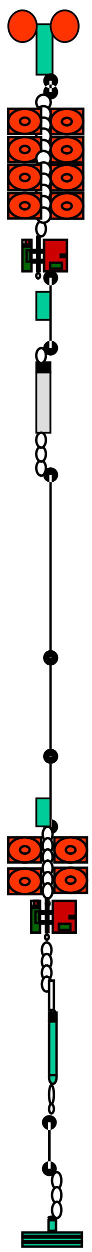
Rigg F13-10

78 50.191N
Settes ut 13 SEP 2010, kl 13:00 005 00.692W
Tatt opp 26 AUG 2011 kl 19:00



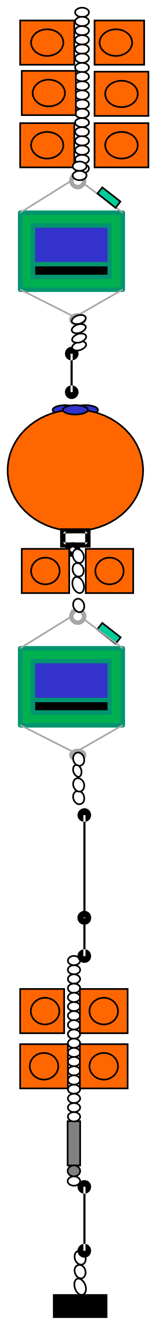
			Dyp:	Fra bunn:	Ned i vann:
IPS4	SNR. 1047		50	967	13:00
SBE37	SNR. 7056		52	965	13:00
20 M Kevlar					
ADCP300	SNR: 727		70	947	12:52
2 m Kjetting galv.					
Stålkule 37	SNR.		73	944	
2 m Kevlar					
Hvallydopptaker			75	942	12:52
2 m Kjetting galv					
20 m Kevlar					
50 m Kevlar					
100 m Kevlar					
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	

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



			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	

Rigg F17-7 78 50.26 N Dyp: Fra bunn: Ut:
Satt ut 9 SEP 2010, kl 11:15 008 06.360W
Tatt opp 28 AUG 2011 kl 11:15



			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	

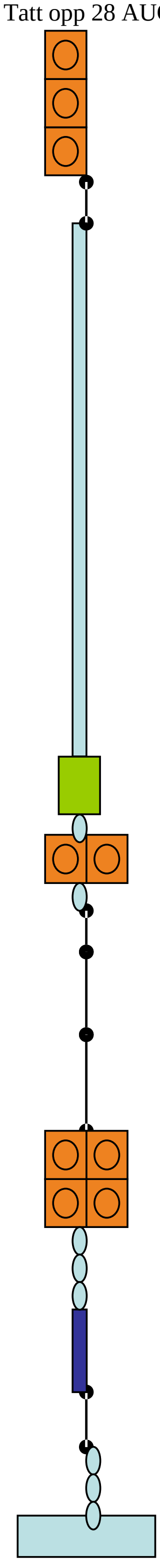
Rigg F18-6

Satt ut 8 SEP 2010, kl 19:20

Tatt opp 28 AUG 2011 kl 19:45

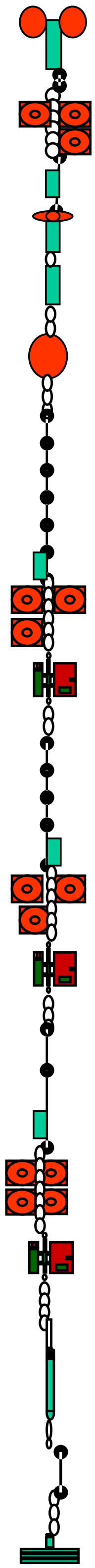
78 48.110

008 04.75W



			Dyp:	Fra bunn:	Ut:
			53	159	
3 Glasskuler					
5 m Kevlar					
			57	158	
DL7	Snr. 1649		107	108	19:10
2 Glasskuler					
1 m Kjetting galv.					
5 m Kevlar					
40 m Kevlar					
50 m Kevlar					
4 Glasskuler					
3 m Kjetting galv.					
AR861	Snr. 410	Arm/range Release Ping on		9	
5 m Kevlar					
2 m Kjetting					
Anker	580/(500) Kg		215	0	

Appendix 2: Deployed moorings



Rigg F11-13

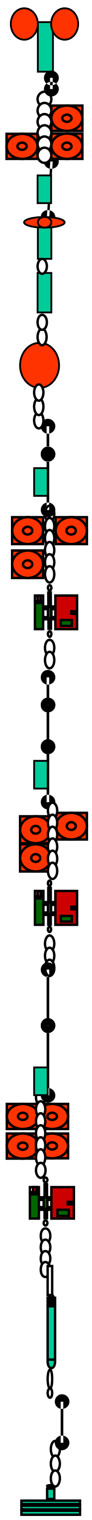
Satt ut 9 SEP 2011 kl 16:00

78 48,198N
003 04,720W

		Dyp:	Fra bunn:	Ut:
IPS	SNR. 51062	53	2417	15:58
3 Glasskuler gule				
2 m Kjetting galv.				
SBE37	SNR. 7054	58	2412	15:57
RDCP600	SNR: 28	62	2408	15:55
5 M Kevlar				
Batteribeholder til RDCP				
1 m Kjetting galvanisert				
Stålkule 37	McLane gul E	66	2404	
2 m Kjetting galvanisert				
10 m Kevlar				
100 m Kevlar				
50 m Kevlar				
20 m Kevlar				
50 m Kevlar				
5 m Kevlar				
SBE37	SNR. 3996	301	2169	15:41
3 Glasskuler oransje				
2 m Kjetting galvanisert				
RCM9	SNR.1049	305	2165	15:40
0,5 m Kjetting galv				
200 m Kevlar				
500 m Kevlar				
500 m Kevlar				
SBE37	SNR. 7061	1554	916	15:05
50 m Kevlar				
3 Glasskuler gule				
2 m Kjetting galvanisert				
RCM11	SNR.538	1557	913	15:04
0,5 m Kjetting galv				
500 m Kevlar				
200 m Kevlar				
200 m Kevlar				
SBE37	SNR. 8226	2456	14	14:38
4 Glasskuler gule				
2 m Kjetting galvanisert				
RCM8	SNR.10069	2459	11	14:37
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 499 Pinger på: Pinger av: Release: Release m/ping:			
5 m Kevlar				
2 m Kjetting galvanisert				
ANKER 1100/(950) kg		2470	0	

Rigg F12-13 78 48,095N

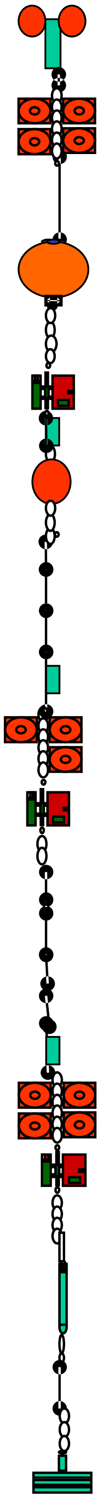
Satt ut 8 SEP 2011 kl 19:35 004 01,182W



			Dyp:	Fra bunn:	Ut:
IPS	SNR. 51063		50	1783	19:33
3 Glasskuler gule					
2 m Kjetting galv.					
5 M Kevlar					
SBE37	SNR. 7055		54	1779	19:00
RDCP600	SNR: 758		58	1775	19:00
SEAGUARD	SNR: 639				
1 m Kjetting galv./rustfri					
Stålkule 37	McD		60	1773	
2 m Kjetting galvanisert					
50 m Kevlar					
200 m Kevlar					
SBE37	SNR.3994		311	1522	
3 Glasskuler					
2 m Kjetting galvanisert					
RCM9	SNR.836		314	1519	18:40
0,5 m Kjetting galv					
500 m Kevlar					
500 m Kevlar					
200 m Kevlar					
SBE37	SNR.2962		1517	316	
3 Glasskuler					
2 m Kjetting galvanisert					
RCM11	SNR.556		1520	313	18:12
0,5 m Kjetting galv					
200 m Kevlar					
100 m Kevlar					
SBE37	SNR.8227		1820	13	
4 Glasskuler					
2 m Kjetting galvanisert					
RCM11	SNR.117		1823	10	18:00
0,5 m Kjetting rustfri					
Svivel					
AR861	SNR. 500	Pinger på: Pinger av: Release: Release m/ping:			
5 m Kevlar					
2 m Kjetting galvanisert					
ANKER	1100/(950) kg		1833	0	

Rigg F13-13
Satt ut 6 SEP 2011, kl 12:05

78 50.273N
004 59.999W

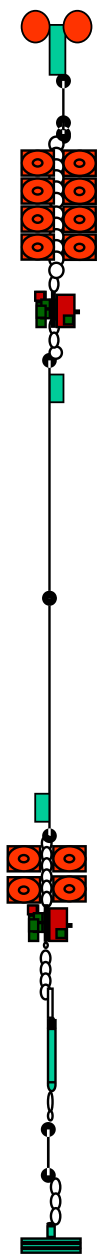


			Dyp:	Fra bunn:	Ned i vann:
IPS4	SNR. 1047		49	965	11:05
4 Glasskuler gule					
2 m Kjetting galv.					
5 M Kevlar					
ADCP300	SNR: 727		57	957	11:00
2 m Kjetting galv.					
RCM 9	SNR: 1175		59	955	10:59
SBE37	SNR. 7059		58	956	10:59
2 m Kevlar					
Stålkule 37	SNR.		57	957	
2 m Kjetting galv					
20 m Kevlar					
20 m Kevlar					
50 m Kevlar					
100 m Kevlar					
SBE37	SNR.7060		248	766	10:50
3 Glasskuler					
2 m Kjetting galv.					
RCM9	SNR.1326		251	763	10:50
0,5 m Kjetting galv					
500 m Kevlar					
100 m Kevlar					
50 m Kevlar					
40 m Kevlar					
50 m Kevlar					
10 m Kevlar					
SBE37	SNR.3995		1001	13	10:30
4 Glasskuler					
2 m Kjetting galv.					
RCM8	SNR. 12322		1004	10	10:30
0,5 m Kjetting rustfri					
Svivel					
AR861	SNR. 743	Ping på: Ping av: Release: Release m/ping:			
5 m Kevlar					
2 m Kjetting galvanisert					
ANKER	1000/(900) kg		1014	0	

Rigg F14-13

Satt ut 5 SEP 2011, kl 18:50

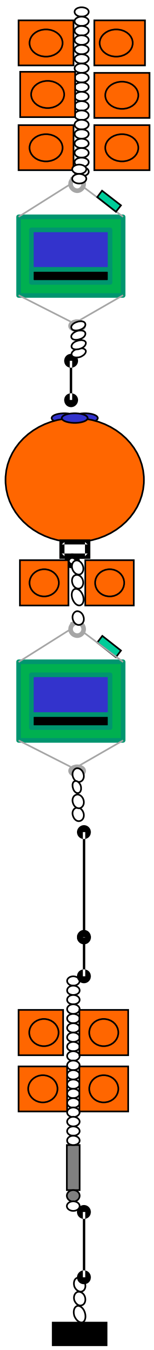
78 48.841N
006 30,360W



			Dyp:	Fra bunn:	Ned i vann:
IPS	SNR. 51064		51	219	18:50
2 M Kevlar					
8 Glasskuler 3 m Kjetting galv.					
RCM 9	SNR: 1325		57	213	18:49
SBE37	SNR. 7058		59	211	18:49
10 m Kevlar					
200 m Kevlar					
SBE37	SNR.7057		257	13	18:26
4 Glasskuler					
2 m Kjetting Galv.					
RCM 7	SNR. 9464		260	10	18:25
Svivel					
AR861	SNR. 568	Ping på: Ping av: Release: Release m/ping:			
5 m Kevlar					
2 m Kjetting					
ANKER 770/(620) kg			270	0	

Rigg F17-8 78 50.507N

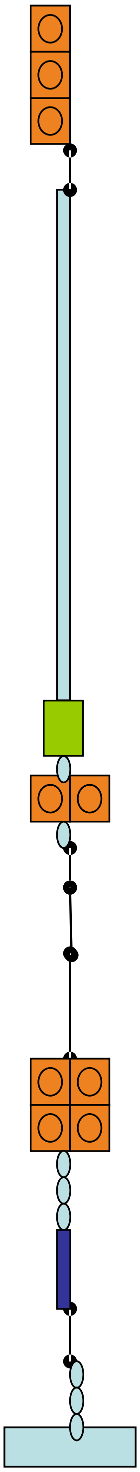
Satt ut 1 SEP 2011, kl 12:33 008 08.571W



			Dyp:	Fra bunn:	Ut:
6 Glasskuler Gule 2 m Kjetting galv.			57	172	12:32
SBE16	SNR. 6693		59	170	12:32
Vannhenter					
0,5 m Kjetting galv					
50 m Kevlar					
ADCP	SNR.7636		110	119	12:20
1 m Kjetting rustfri 2 Glasskuler Gule					
SBE16	SNR.6694		113	116	12:20
Vannhenter					
0,5 m Kjetting galv.					
100 m Kevlar					
5 m Kevlar					
2 m Kjetting galv.					
4 Glasskuler oransje			219	10	12:05
AR661	SNR. 501	Ping on: Release: Arm:			
5 m Kevlar.					
2 m Kjetting galv.					
ANKER	700/(560)kg		229	0	

Rigg F18-7 78 48.202N

Satt ut 1 SEP 2011, kl 10:50 008 04.097W



			Dyp:	Fra bunn:	Ut:
			52	163	
3 Glasskuler 5 m Kevlar					
			57	158	
DL7	Snr. 1632		107	108	10:35
2 Glasskuler 1 m Kjetting galv.					
5 m Kevlar					
40 m Kevlar					
50 m Kevlar					
4 Glasskuler					
3 m Kjetting galv.					
AR861	Snr. 553	Arm/range Release Ping on		9	
5 m Kevlar					
2 m Kjetting					
Anker	690/(560) Kg		215	0	