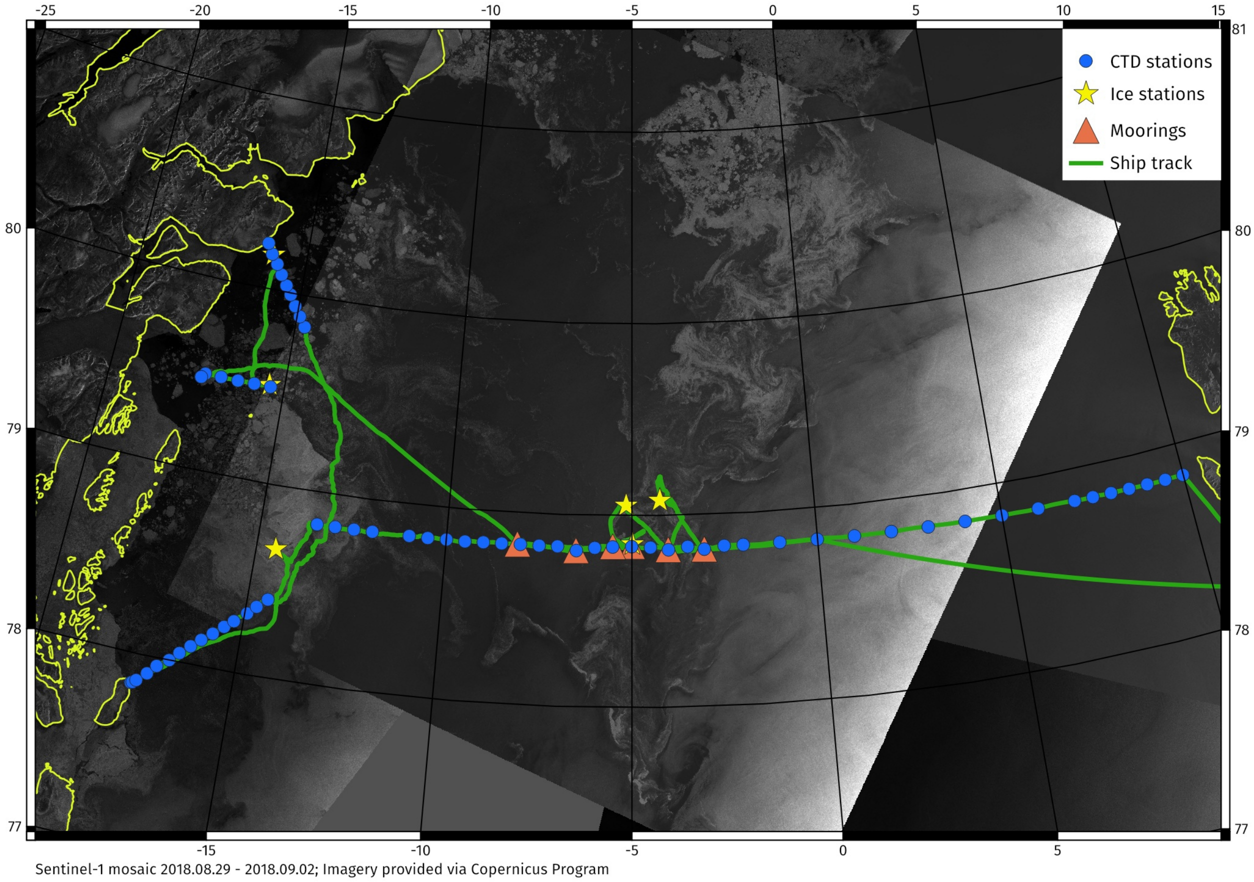
Fram Strait Cruise Report

25th August – 11th September 2018

Cruise no. 2018708



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1. Participants

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2. Cruise deputy Paul A. Dodd (NPI)

Chemistry
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4. Melissa Chierici (IMR)

CTD watches/water sampling/water sample analysis
5. Margot Debyser (University of Edinburgh)
6. Anne-Marie Wefing (ETH Zürich)
7. Charlotte Lautkötter (ETH Zürich)
8. Alicia Lianne Hamar (DTU)
9. Christian M. Rhode Kiær (DTU)

Moorings and tech support
10. Kristen Fossan (NPI)
11. Marius Bratrein (NPI)

Sea Ice
12. Dmitry Divine (NPI)

Marine Mammals
13. Christian Lydersen (NPI)
14. Kit Kovacs (NPI)
15. Eirik Grønningsæter
16. Olga Sphak

Helicopter crew
17. Henning Hansen (pilot Airlift)
18. Kenneth Bergsjø (technician Airlift)

Guest (in prep for Southern Ocean cruise)
19. Harald Steen (NPI)

2. Sailing log

Date	Activities
Sat 25/08/2018	Checking in at 8:30. Unpack and install. Ready on board at 1300. Delayed because of azipod fixes. Departure from Longyear at 19:00 for tests in fjord. Deliver engineers back on shore and start real departure at 23:00 (local time).
Sun 26/08/2018	Steaming to 0°W, 78·50'N for first CTD at ~ 1800 (local time) Continue with CTDs overnight at 1°, 2°, 2.5°W. Steam to 3°W.
Mon 27/08/2018	Arrival at F11, release F11 at 7:38 UTC (9:38 local), all on deck 2 hours later. No sea ice at all, calm waters and weather. CTD at 3°W. Steam to F12, recover F12 at14:17 UTC, ice floes, no heavy ice. On deck by 16:36 UTC, little slow since wire got under ice floes. CTD at F12/4W. Evening/night: CTDs at 3.5°W and 4.5°W.
Tues 28/08/2018	Vessel went too far west, so first recovery of F13B (instead of F13) at 5.5°W. Release of F13B at 06:22 UTC, on deck by 07:20. IceCAT recovered! CTD at 5.5°W. Steam back to 5°W for F13. Release of F13 at 10:22 UTC, on deck by11:30 UTC. Little sea ice, scattered floes, good visibility. After mooring, flight helicopter flight at 12:35 UTC, reporting each half hour. After 45 mins, visibility around ship gets very bad and they have to return. Back at ~13:30. CTD at 5°W in the mean time (during heli flight). After dinner, set up for 2-hr sea ice station with small boat, just coring. Continue with CTDs at 6°W and 7°W overnight.
Wed 29/08/2018	Arrival at F14 at 6.5°W. Release F14 at 06:35 UTC, all on deck by 07:10 UTC. CTDs at 6.5°W, 7.5°W. Arrival at F17 at 8°W. Release F17 at 13:11 UTC, on deck by 13:40 UTC. Small to medium scattered floes, not much sea ice, very foggy, calm. Continue with CTDs at 8W and onward overnight: each 0.5° until nearly 13.7W / land-fast ice.
Thurs 30/08/2018	Slowed down during night so still CTDs between 12 -13.5W. Going very slow with a lot of thick pieces disintegrated land-fast ice. ~1400 UTC arrival at land-fast ice, park ship in ice. First a test on ice by Dima and Marius to see if OK but after 30 min. swell already breaks up the sea ice in large floes. Sea ice work cancelled. Instead ~2-hr flight after dinner for whale team, departure 18:10 UTC. Moving gradually south along fast ice and wait until next day
Fri 31/08/2018	6 am start breaking into land-fast ice to find suitable place for ice work. Park vessel into solid ice floe 1.10m thick and work all day here. 78°40.281'N, 14°28.951'W. Three groups: coring, EM-31, and ADCP calibrations. In addition, three flights during the day (morning, afternoon and evening). After dinner, head to the southwestern end of Isle de France section to start that after breakfast on Sat.
Sat 01/09/2018	Moving slower due to fog and ice. Steaming still to the SW end of the Isle de France section at 9 am. Start section at Isle de France at 10:15 UTC (12:15 local) in the south. One flight near SW IdF 11:30- 13:30 UTC. Thin ice station almost mid way. Continue into night to finish the IdF section
Sun 02/09/2018	Finishing up IdF CTD section at 07:00 UTC. Steam to Westwind 1 (we go east of the land-fast ice, even though passage west of it may have been possible - if we had a chart - since it is completely broken up and there is a lot of open water (but very bad visibility)). Steaming all night to WW1

Mon 03/09/2018	Start Westwind1 section at 01:45 UTC (03:45 local). Midway through section there is too much thick ice floes moving fast westward so that moonpool needs to be used. Three flights (12:45, 15:25 and 19:55 local time) for whale tagging all around 2 to 2.25 hours. Sea ice station in evening during one flight but not really successful since too much stress for ice group to get back on ship before heli comes back. Steam to 79.5N, 15.35W to do short east-west section here next day
Tues 04/09/2018	First CTD at the 79.5°N line at 7:20 local time followed by sea ice station (~8 am to 11:30). Continue the 79.5N section westward. Good visibility in the morning changes to very thick fog around noon, little ice but calm seas. Finish CTD section between 8-9 pm, cannot reach last station because of very thick fast ice. Start steaming to F17 at 9 pm local time
Wed 05/09/2018	Arrival at F17 around noon. Do a MB survey at a 4x4 km square around the mooring site (2.5 hrs at 6.5 knots). Deploy F17 at 14:03 UTC (16:03 local). No sea ice, vessel on DP while deploying anchor first. Steam slowly to F14 to deploy next day. Overnight start with MB survey over F14 site.
Thurs 06/09/2018	At F14 location 7 am. Deploy F14 at 08:35 UTC (10:35 local). No sea ice, calm seas, blue sky and good visibility. Steam to F13B. Deploy F13B at 12:53 UTC. Flight afterwards, little ice, just leftover ridges. Another flight after dinner and a sea ice station if suitable floe is found. Take extra CTD at F13B to check depth again, ADCP is a bit too shallow ~ 41 m, so IceCAT likely at 16 m... Hope it stays... Overnight steam to F13 and do MB survey around the site.
Fri 07/09/2018	F13 mooring site. Little sea ice, very calm, cloudy. Deploy F13 after 8:30 UTC. Target depth was 1020 m but that turned out to be too shallow (measuring the length of wire to deploy it with), so had to move 500 m east to get 1045 m (MB data)... top of mooring was at 50 m after that. Deployed at 10:44 UTC. After checking on echo sounder, steam north to try to find an ice floe for ice station and flying.
Sat 08/09/2018	3-8 am: take a CTD for sound speed and do MB survey at F12. Deploy F12 at 10:35 UTC. Quite some ice but only small broken up pieces. Head somewhat north to find ice to fly. Too much fog all day. No flying but find an ice floe to work on.
Sun 09/09/2018	3-8 am local time: CTD and MB survey at F11. Deploy F11 by 9:34 UTC. Calm weather, no sea ice. Steam and start CTDs at 1°E at around 17:30 pm
Mon 10/09/2018	CTDs all day on the main section, continue eastward from 1°E Some flying time for whales. Helicopter departs to Ny-Ålesund in the evening.
Tues 11/09/2018	Finish CTDs at 3am. Arrival LYR around noon (kulkaia). Packing and cleaning.
Wed 12/09/2018	Flights home

3. Mooring operations during FS2018

The 5 standard moorings from the Fram Strait Arctic Outflow Observatory (F11, F12, F13, F14 and F17) were serviced as well as the extra mooring F13B at 5.5°W for enhanced near-surface measurements. Mooring F10 at 2°W (abandoned by AWI, now taken over by NPI) was planned to remain in the water until recovery in 2019.

There was only one IceCAT deployed in 2017 (F13B-4). IceCAT SN 15910 at F13B-4 was recovered well and despite that the data on the Data Logger appeared to only have gone until June 2018, the data downloaded directly from the instrument (with SeatermV2), showed that it did continue logging until day of recovery. Data Logger likely ran out of battery.

SeaCAT SN 7339 at 105m on F17-14: the Turner-Cyclops was damaged, this likely caused a short circuit, emptied batteries and it stopped logging in May 2018. Hence also no good P,T,C data after that.

All other instruments were recovered in good shape. Both recoveries and deployments went extremely smooth since there was hardly any sea ice at all in the EGC during the cruise

3.1 Moorings recovered during FS2018

Mooring	Position	Depth (m)	Date and time (UTC)	Instrument	Serial #	Instrument depth (m)
No F10	recovery this	year!!	Leave in until	2019	N/A	N/A
F11-19	N 78° 49.147' W 03° 3.189'	2453	Deployed: 9 Sept 2017, 18:42 UTC Recovered: 27 Aug 2018, 07:38 UTC	IPS **SBE37** ADCP **SBE37** RCM9 **SBE37** RCM11 **SBE37** RCM Seaguard AR861	**51062** **3492**** 18070 **3996** 1049 **7061** 538 **8226** 834 499	55 **57** 59 **270** 273 **1540** 1542 **2442** 2445 2450
F12-19	N 78° 49.283' W 04° 01.373	1842	Deployed: 9 Sept 2017, 09:05 UTC Recovered: 27 Aug 2018, 14:17 UTC	**IPS5** **SBE37** ADCP **SBE37** RCM9 **SBE37** RCM11 **SBE37** RCM11 AR861	**51167** **7055** 18151 **3994** 836 **13505** 556 **10294** 117 500	**60** **62** 66 **280** 283 **1488** 1490 **1830** 1832 1835
F13-19	N 78° 50.324' W 05°00.146'	1022	Deployed: 6 Sept 2017, 13:45 UTC Recovered: 28 Aug 2018, 10:22 UTC	**IPS** ADCP **SBE16** AURAL **SBE37** **SBE37** RCM9 **SBE37** RCM Seaguard AR861	**51064** 20021 **7253** NA **3995** **7060** 1326 **13504** 345 743	**52** 55 **58** 75 **145** **245** 252 **997** 1000 1010

F13B-4	N 78° 50.260' W 05° 30.926'	524 m	Deployed: 6 Sept. 2017, 09:43 UTC Recovered: 28 Aug 2018, 06:22 UTC	**SBE37-IM weak link** ICEBOX ADCP **SBE37** **SBE37** RCM Seaguard **SBE37** AR661	**15910** n/a 17462 **9853** **9852** 883 **7059** 410	**25** 58 60 **63** **102** 104 **160** 510
F14-19	N 78° 48.848' W 06° 30.058'	273	Deployed: 5 Sept 2017, 13:47 UTC Recovered: 29 Aug 2018, 06:35 UTC	**IPS** **SBE37** ADCP **SBE56** **SBE56** **SBE37** RCM9 AR861	**51127** **7058** 24385 **3943** **3942** **7057** 1325 568	**58** **62** 66 **197** **227** **257** 261 265
F17-14	N 78° 50.186' W 08° 4.892'	226	Deployed: 5 Sept 2017, 10:26 UTC Recovered: 29 Aug 2018, 13:11 UTC	**SBE16** **SBE37** ADCP **SBE16** **SBE56** **SBE37** AR661	**7212** **13252** 17461 **7339** 3944 **14099** 501	**55** **75** 100 **105** **190** **210** 218

*** Note: SBE37 sn 3492 was re-deployed in 2017 (i.e. not calibrated in 2017!)*

***Table 2:** Moorings recovered during FS2018.*

3.2. Moorings deployed during FS2018

Mooring	Position	Depth (m)	Date and time (UTC)	Instrument	Serial #	Instrument depth (m)
F10-15 **STAY IN WATE R!**	N 78° 49.624' W 02° **STAY IN WATER!**	2650 **STAY IN WAT ER!**	**STAY IN WATER!**	ADCP RCM7 **SBE37** RCM Seaguard **SBE37** **SBE37** RCM8 AR861	16831 1174 **13253** 1846 **14100** **8227** 12733 1424	50 52 **55** 251 **253** **2642** 2645 2647
F11-20	N 78° 49.161' W 03° 3.248'	2474 m at EK80 vs 2488 m at MB	Deployed: 9 Sept 2018, 09:34 UTC	IPS **SBE37** ADCP **SBE37** RCM9 **SBE37** RCM11 **SBE37** RCM8 AR861	**51062** **3490** 18070 **4702** 1324 **3552** 491 **8821** 10071 287	55 **58** 60 **276** 273 **1540** 1542 **2442** 2445 2450
F12-20	N 78° 49.270' W 04° 1.327'	1862	Deployed: 8 Sept 2018, 09:25 UTC	**IPS5** **SBE37** ADCP **SBE37** **SBE37** RCM9 **SBE37**	**51167** **3489** 18151 **7074** **4837** 884 **3554**	**53** **55** 60 150 **276** 283 **1488**

				RCM11	235	1490
				SBE37	8822	1830
				RCM11	228	1832
				AR861	182	1835
F13-20	N 78° 50.392' W 04° 59.485'	1045 **	Deployed: 7 Sept 2018, 10:44 UTC	IPS	51064	47
				SBE37	20021	55
				ADCP	7056	50
				AURAL	NA	82
				SBE37 (extra...)	12234	100
				SBE37	12232	165
				SBE37	3993	270
				RCM9	1327	273
				SBE37	3551	1018
				RCM Seaguard	561	1020
				AR861	053	1025
F13B-5	N 78° 50.261' W 05° 30.848'	530 m	Deployed: 6 Sept 2018, 12:53 UTC	**SBE37-IM weak link**	**13506**	**25**
				ADCP	727	50
				ICEBOX	N/A	58
				SBE37 - N/A	Forgotten	N/A
				SBE37	12233	102
				RCM Seaguard?	7718	115
				SBE37	10295	166
				AR661	291	520
F14-20	N 78° 48.870' W 06° 30.055'	272	Deployed: 6 Sept 2018, 08:35 UTC	IPS	51138	58
				SBE37	14097	62
				ADCP	16876	65
				SBE37	14098	106
				SBE56	3943	209
				SBE56	3944	234
				SBE37	3992	259
				RCM9	1046	261
				AR861	506	265
F17-15	N 78° 50.175' W 08° 4.879'	226	Deployed: 5 Sept 2018, 14:03 UTC	**SBE37-IM (but without DL)**	**15910**	**30**
				SBE16	6693	55
				SBE37	2962	75
				ADCP	7636	105
				SBE16	6694	108
				SBE56	3944	190
				SBE37	7062	213
				AR661	110	218

Table 2: *Moorings deployed during FS2018.*
***too deep, was the mooring length off .or EK80 off?? ADCP at 50m. MB agreed with 2017 data.*

Notes:

- On F17 the IM Microcat is programmed as a regular SBE37 and has no Data Logger (we did not have sufficient batteries for the DL). It has 2 weak links to the mooring and 1 weak link to the small orange top floats so it will likely be saved even if the float is torn off.
- We forgot to put SBE37 at 60 m on F13B
- All ADCPs were calibrated prior to deployment (see details below)

3.2.1 ADCP calibrations

The ADCPs that were deployed on the moorings in 2018 were all calibrated prior to deployment. That was done either on land (in Tromsø in June) or on land-fast ice during the cruise. This was the first time that all were fully and successfully calibrated prior to deployment since there were more ADCPs to change out and since there was time and good land-fast ice during the cruise to do the remaining ADCPs during the cruise.

3 ADCPs at NPI calibrated in Tromsø on 25th June, 2018:

SN 727 (F13B), SN 16876 (F14), SN 7636 (F17)

3 ADCPs (recovered on FS2018) calibrated on land-fast ice 31st Aug at 78°40.281'N, 14°28.951'W

On land-fast ice station (31/8): Tried to calibrate SN 17462 and SN 17461 but both failed to get through more than 1 quadrant in the calibration procedure (BBtalk, command AF, option a). For SN 17462 we tried again after rotating the battery 180° but it did not help. These may need to be checked in TOS if it goes well there. Else check with RDI?

SN 24385, SN 18070, and SN 20021 were successfully calibrated on (non-moving) 'land/iceberg-fast' ice on Belgica Bank. SN 20021 however, showed a large offset in the compass verification (going through 360° at 20° increments and compare actual degrees with ADCP heading). It compared well at north and south, but going through east and west offset was over 20°. This means that a post-correction will need to be carried out on the data to be recovered in 2019. Therefore, decided to put this one at F14 (smallest velocities but with Bottom Track for sea ice).

F17	F14	F13B	F13	F12	F11	F10
ADCP calibration in TOS	ADCP calibration on ice BOTTOM TRACK *	ADCP calibration in TOS	ADCP calibration in TOS ICE TRACK *	ADCP calibration on ice ICE TRACK *	ADCP calibration on ice BOTTOM TRACK *	Installed FS2017. Land fast ice calibration Added RCM since error > 5° in 2017
error after cal: 1.6°	error after cal: 3.2° but heading offset with actual dir!!	error after cal: 1.7°	error after cal: 3°	error after cal: 2.5°	error after cal: 4.6°	error after cal: 5.8°
SN 7636	SN 20021	SN 727	SN 16876	SN 24385	SN 18070	SN 16831
deploy	deploy	deploy	deploy	deploy	deploy	REMAINS!

* BT track or ICE track

4. CTD Measurements

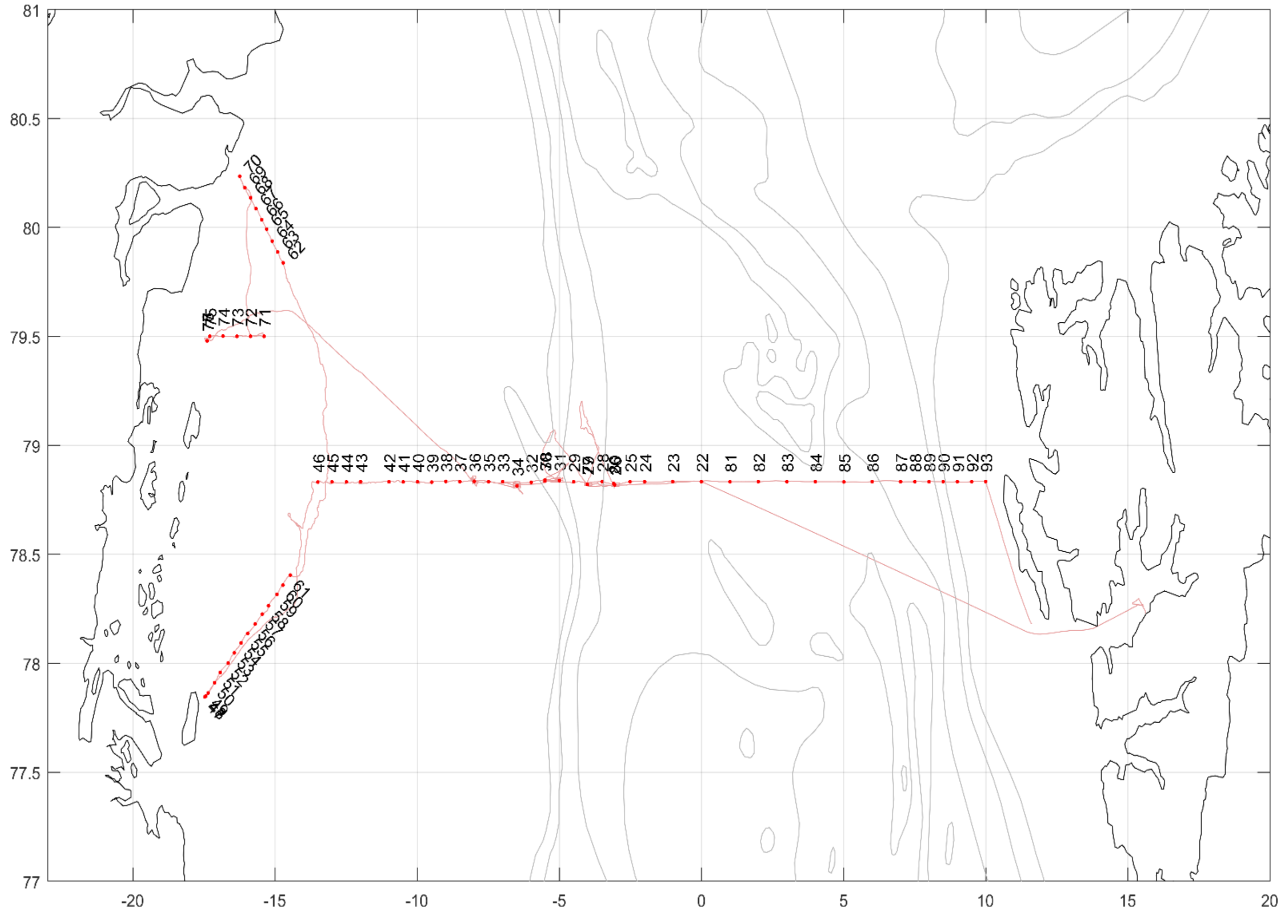


Figure 4.1. CTD stations during FS2018

4.1 General Approach

The CTD used was an SBE911+ unit. The CTD was flushed with Triton-X and freshwater between stations. At the beginning of stations the CTD was lowered to 10 dbar and allowed to soak until sensors stabilised, before being brought to the surface and then lowered to 10 m above the seabed. Data acquisition was initiated with the CTD on deck and allowed to run until the CTD was back on deck at the end of the cast.

Where possible the CTD was lowered over the side of the ship in the conventional way. Due to dense ice along the Westwind and Nioghalvfjerdsbreen sections the CTD was lowered though the moon pool. The lower aperture of the moon pool was 10 m below the surface, so the upper 10 m of these profiles describes water trapped in the moon pool rather than the natural environment. Niskin bottles were closed using the bottle fire command within the Sea-Bird acquisition software so that a .bl file was created for each deployment when bottles were fired. NMEA time and position information was fed to the acquisition computer and added to each scan line of the data files. Cast starting times were automatically added to the header of all data files.

Table 4.2 lists the water samples collected at each CTD station. During the cruise a paper log sheet was completed at each CTD station listing the depths at which bottles were fired and the samples taken from each bottle. Times, depths and positions manually recorded on log sheets are indented as a backup in the case of a problem with the data acquisition, not a replacement for electronically

logged time and position data. There were no problems with time or position data during the cruise, but an unresolved technical problem meant that Seasave very frequently failed to confirm that bottles were fired. After clicking the fire bottle control, a line did not appear on the plot display as it should, and no entry was written to the *.bl file. When this problem occurred bottle files were manually corrected in a text editor immediately after the cast, using information from paper log-sheets.
Note that the first CTD station completed during Fram Strait 2018 has the number 22 and not 01. The vessel operators specify numbers assigned to CTD stations. The first cast each year has the number 1 and subsequently casts are numbered sequentially.

CTD Package Configuration

Channel	Sensor	Serial Number	Last Calibration
Frequency	Temperature	6275	06-Dec-17
Frequency	Conductivity	4726	06-Dec-17
Frequency	Pressure	141612	19-Dec-17
Frequency	Temperature 2	6289	06-Dec-17
Frequency	Conductivity 2	4727	06-Dec-17
A/D Voltage 0	SBE43 Oxygen 1	3636	05-Dec-17
A/D Voltage 1	Altimeter	73084	24-Dec-17
A/D Voltage 2	CDOM Flourometer	4885	23-Oct-17
A/D Voltage 3	Free	-	-
A/D Voltage 4	SBE43 Oxygen 2	1740	27-Apr-2017
A/D Voltage 6	Transmissometer	TBC	TBC
A/D Voltage 7	Chl. Flourometer	1547	01-Apr-2016

Table 4.1: CTD package configuration during FS2018. Note that the transmissometer and chlorophyll flourometer were added between stations 26 and 27 in order to detect the cholorphyll maximum, which was the target of silicon isotope ratio sampling. Other than this, the package configuration was not altered during the cruise.

4.2 CTD Sections

Very open drift ice conditions on the East Greenland Shelf allowed the vessel to move along four sections during the cruise (Figure 4.1). Station times and the types of samples collected are summarized in Table 4.1:

1. Main Fram Strait Section (Figure 4.2): An east-west section along the Fram Strait mooring array line at 78º 50'N, which is repeated annually. During Fram Strait 2018, stations were completed between 010°E and 013.5°W. Station spacing was 20 km for most of the section and 10 km in the cores of the inflow and outflow and over the East Greenland Shelf. Figure 4.2 shows hydrographic measurements collected along the Main Fram Strait Section.

2. Isle de France Section (Figure 4.3): A high-resolution section across the Belgica-Norske Trough on the East Greenland continental shelf close to Isle de France. This section begins at the tip of Isle de France and crosses the complete trough. The Isle de France section has been completed annually since 2013 and serves an extension to the main section, which cannot be extend west of about 14°W due to perennial fast ice.

3. Westwind Trough Section (Figure 4.4): A high-resolution section across the northern part of the Belgica-Norske Trough on the East Greenland continental shelf. This section is in a

similar location to sections completed in 2011, 2015 and 2017 Heavy ice in the region prevented an exact repeat in 2017.

4. Nioghalvfjerds section (Figure 4.5): A high-resolution east-west section across the Belgica-Norske Trough in front of Nioghalvfjerdsbreen (79N Glacier). This section was permitted by exceptionally open ice conditions in 2018.

4.3 Salinity Sensor Validation

Water samples for laboratory salinity measurement were collected along the main Fram Strait stations and at selected stations along the Îsle de France and Nioghalvfjerdsbreen sections. At stations where tracer samples were collected, salinity samples were collected at standard depths of 1, 5, 15, 25, 50, 75, 100, 150, 200, 250 and 400 dbar, plus one sample from the bottom of the water column.

Salinity samples were analysed on broad using Guildline Portasal portable salinometer (serial number 70177), which was standardised after every 24 measurements using IAPSO P-series standard seawater from batch 160.

Comparison of laboratory salinity measurements and CTD-salinity measurements revealed an offset of -0.004 practical salinity units for the primary sensor group and an offset of -0.03 practical salinity units for the secondary sensor group (Figure 4.6). The mean offset between the primary sensor group and the laboratory measurements is, equal to the precision of laboratory salinity measurements (+/- 0.003) and no correction is made here. The mean offset between the secondary sensor group and the laboratory measurements is, only marginally larger than the precision of laboratory salinity measurements (+/- 0.003) and no correction is made here.

Both sets of CTD sensors performed well during the cruise. The offsets determined relative to the laboratory salinity measurements are close to the significant level assuming an accuracy of +/- 0.003 for the laboratory salinometer. The fact that the sensor – laboratory difference is normally distributed and similar for both sensors gives confidence that both the sensors are performing well, however the magnitude of the offset is approaching a level at which the profile data would need adjustment. If the sensors are not returned to seabird for calibration soon, post calibration of cruise data may be necessary on subsequent cruises. For comparison freshly calibrated primary and secondary sensor sets deployed during the 2017 Fram Strait cruise had mean offsets of +0.0007 and +0.0008 practical salinity units.

An Optimare laboratory salinometer (serial number 18) was tested during Fram Strait 2018 but did not give useful measurements. A log file describing the operation of this unit is tabulated in Appendix 1

Dissolved Oxygen Sensor Validation (Fransson, Chierici)
For the oxygen sensor validation, we used triplicates seawater samples and analyzed them regarding dissolved oxygen using Winkler titration. We did not find any consistent offset between sensor and analyzed oxygen concentration.

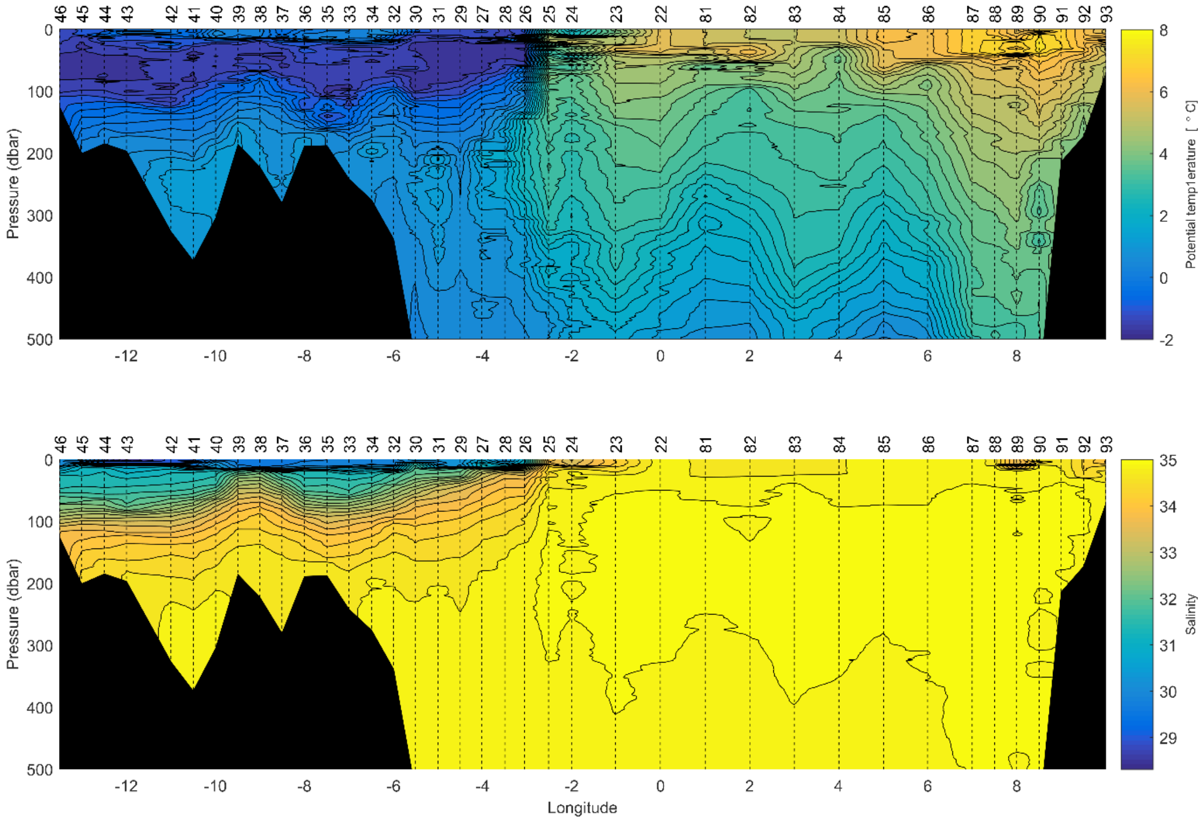


Figure 4.2: CTD measurements along the Main Fram Strait Section; Measurements from the primary temperature (top panel) and salinity (bottom panel) sensors. Station numbers are indicated above sections.

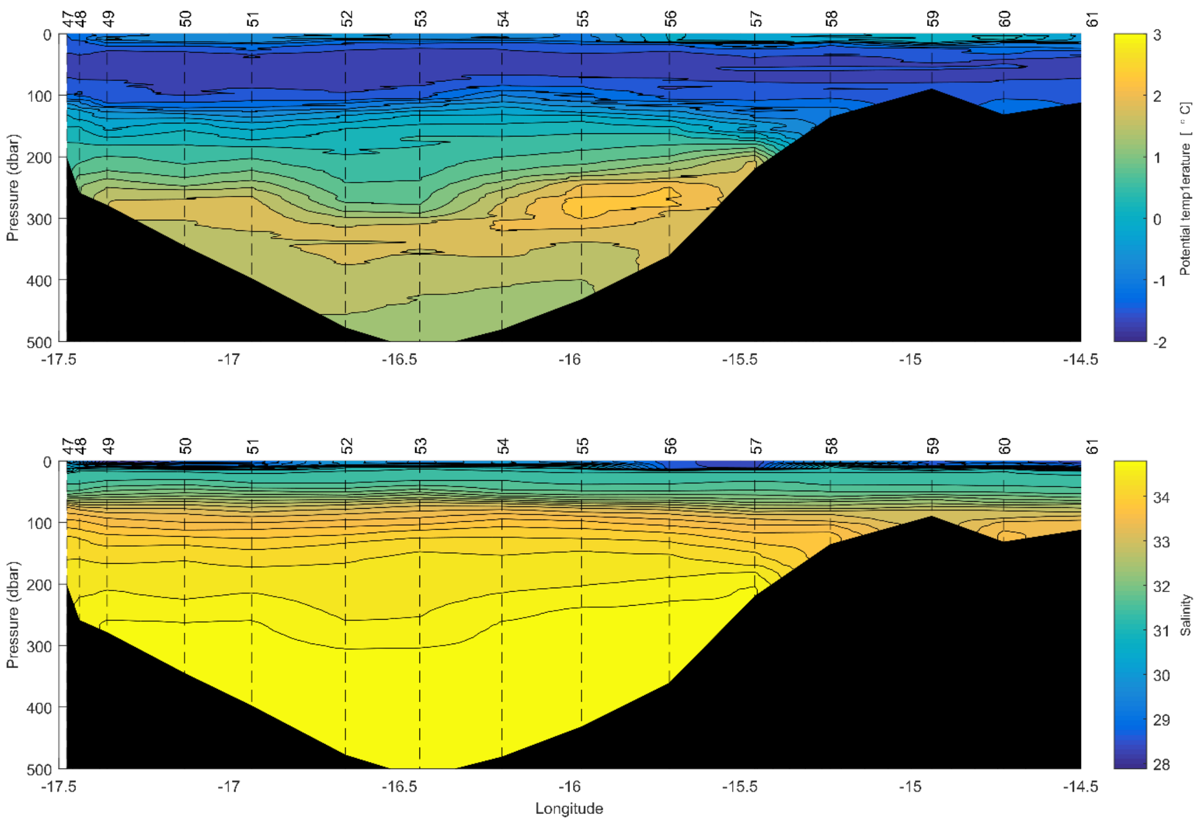


Figure 4.3: CTD measurements along the Îsle de France Section; Measurements from the primary temperature (top panel) and salinity (bottom panel) sensors. Station numbers are indicated above sections.

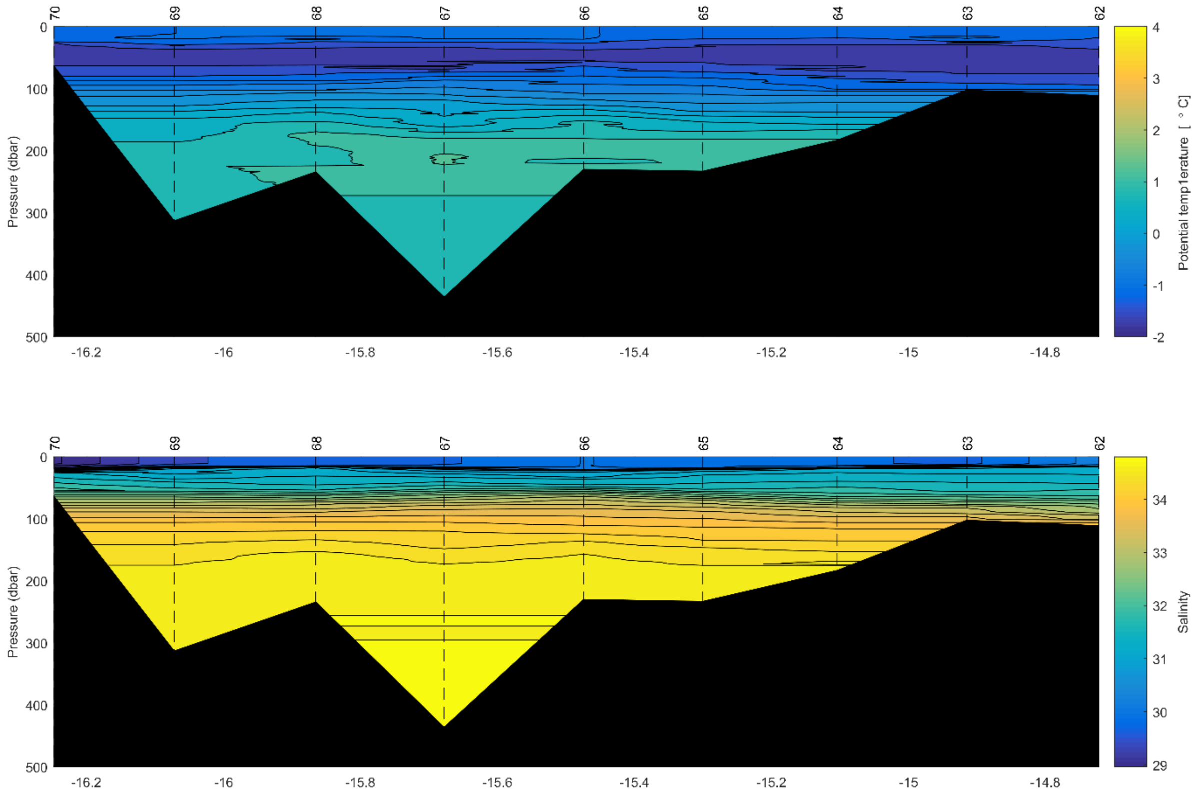


Figure 4.4: CTD measurements along the Westwind Section; Measurements from the primary temperature (top panel) and salinity (bottom panel) sensors. Station numbers are indicated above sections.

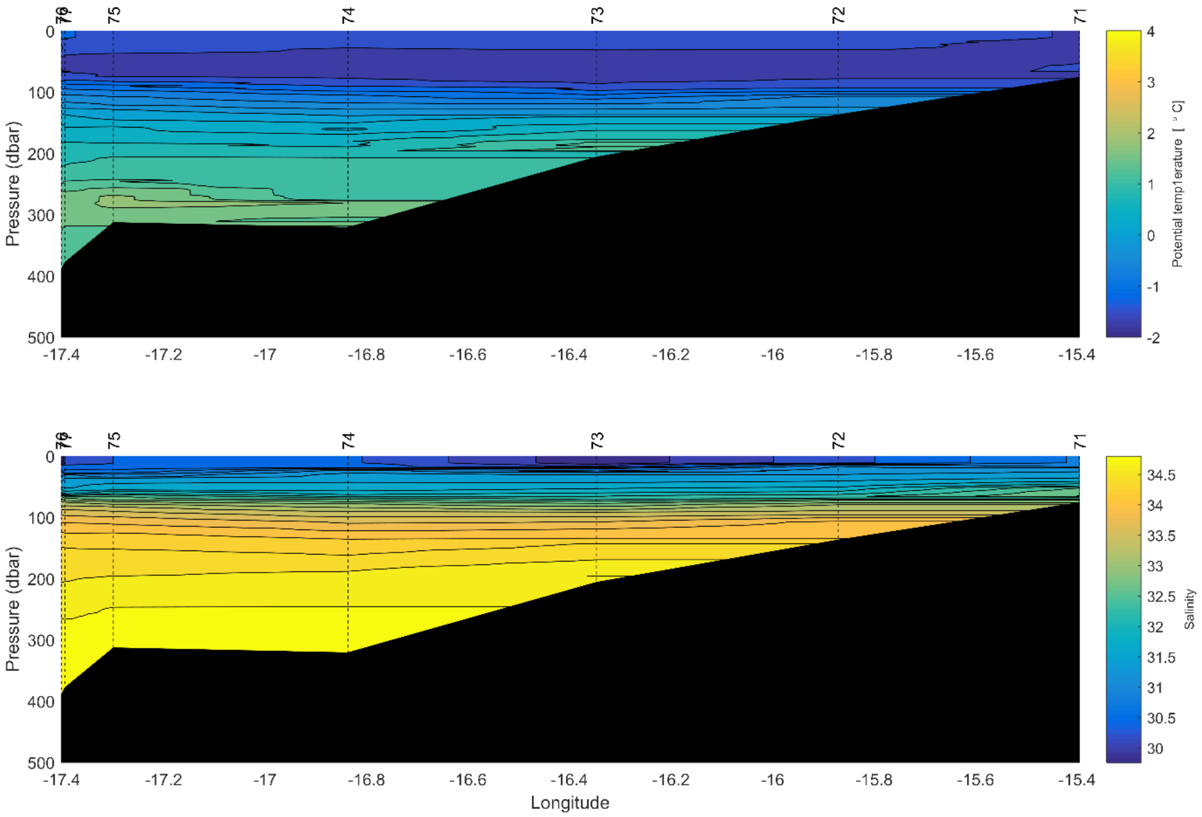


Figure 4.5: CTD measurements along the Nioghalfjerdsbreen Section; Measurements from the primary temperature (top panel) and salinity (bottom panel) sensors. Station numbers are indicated above sections.

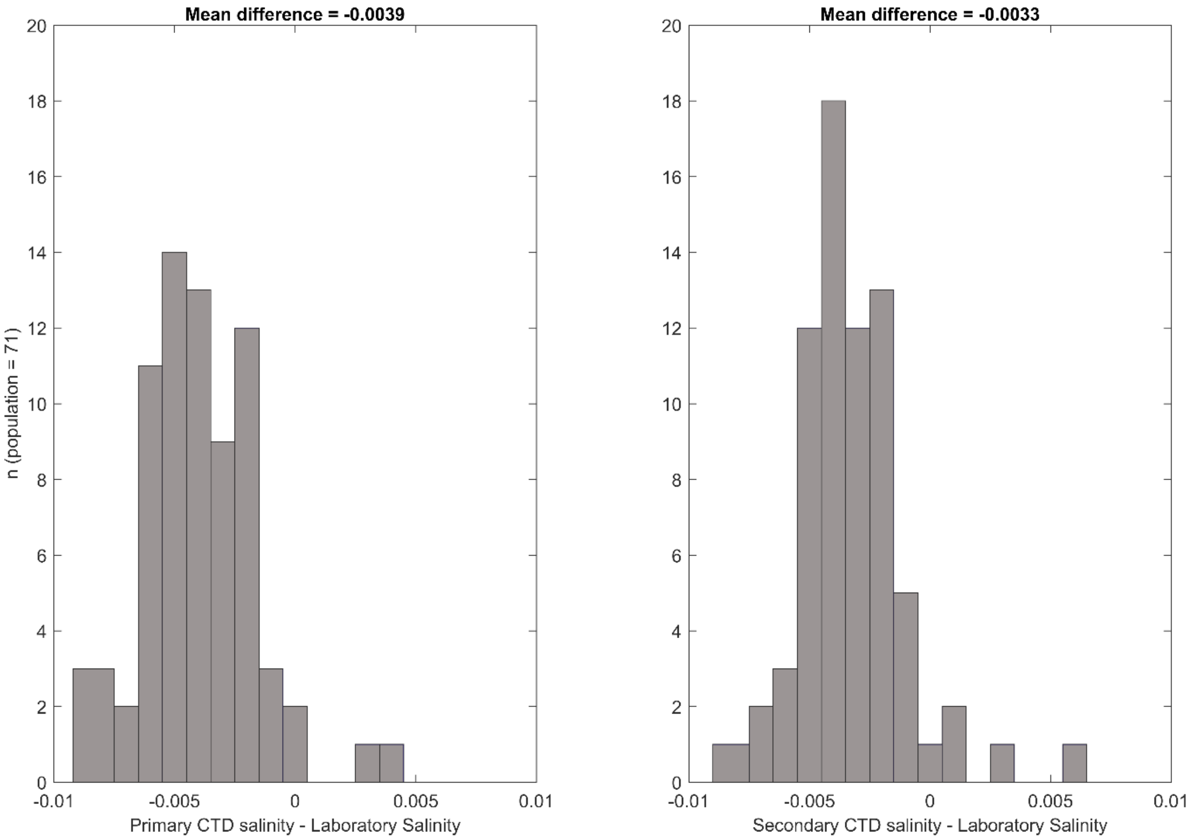


Figure 4.6: Histograms showing the difference between the primary (left hand panels) and secondary (right hand panels) sensor groups on the CTD and laboratory salinity measurements. Only points deeper than 400 m are considered, due to step salinity gradients close to the surface.

Stn	Date (UTC)	Time (UTC)	Depth	S	^{18}O	Nuts	AT-CT	CDOM	O_2	^{129}I	^{236}U	N	Si
22	26-Aug-2018	17:03	2629 m	16	12	12	16	12	--	10	10	12	12
23	26-Aug-2018	20:51	2513 m	12	12	12	12	12	--	--	--	--	--
24	27-Aug-2018	00:17	2703 m	19	14	14	19	14	--	11	11	14	--
25	27-Aug-2018	03:36	2626 m	12	12	12	--	--	--	--	--	--	--
26	27-Aug-2018	10:27	2508 m	19	12	12	17	12	4	11	11	12	12
27	27-Aug-2018	17:27	1887 m	15	12	12	12	12	--	11	11	12	--
28	27-Aug-2018	21:36	2297 m	12	12	12	--	--	--	--	--	--	--
29	28-Aug-2018	02:04	1492 m	12	12	12	--	--	--	--	--	--	--
30	28-Aug-2018	07:38	531 m	12	12	12	--	--	--	--	--	--	--
31	28-Aug-2018	13:06	1034 m	12	12	12	16	12	--	8	8	12	12
32	28-Aug-2018	21:20	343 m	11	11	11	11	11	--	7	7	--	--
33	28-Aug-2018	23:58	243 m	10	10	10	10	10	--	6	6	10	10
34	29-Aug-2018	07:35	276 m	10	10	10	--	--	--	--	--	--	--
35	29-Aug-2018	10:45	188 m	--	--	--	--	--	--	--	--	--	--
36	29-Aug-2018	15:04	189 m	9	9	9	9	9	--	6	6	--	--
37	29-Aug-2018	16:53	285 m	--	--	--	--	--	--	--	--	--	--
38	29-Aug-2018	18:27	214 m	9	9	9	9	9	--	6	--	9	--
39	29-Aug-2018	20:11	188 m	--	--	--	--	--	--	--	--	--	--
40	29-Aug-2018	21:46	305 m	10	10	10	10	10	--	6	6	10	24

41	29-Aug-2018	23:39	374 m	--	--	--	--	--	--	--	--	--	--
42	30-Aug-2018	01:40	327 m	10	10	10	10	10	--	6	--	--	--
43	30-Aug-2018	04:47	199 m	9	9	9	9	9	--	6	6	9	9
44	30-Aug-2018	06:44	193 m	--	--	--	--	--	--	--	--	--	--
45	30-Aug-2018	08:58	202 m	9	9	9	9	9	--	7	7	--	--
46	30-Aug-2018	11:49	124 m	--	--	--	--	--	--	--	--	--	--
47	01-Sep-2018	10:19	202 m	--	--	--	--	--	--	--	--	--	--
48	01-Sep-2018	10:51	258 m	--	--	--	--	--	--	--	--	--	--
49	01-Sep-2018	11:54	278 m	10	10	10	10	10	--	--	--	10	--
50	01-Sep-2018	13:11	342 m	--	--	--	--	--	--	--	--	--	--
51	01-Sep-2018	14:30	400 m	11	11	11	11	11	--	--	--	--	--
52	01-Sep-2018	15:46	479 m	--	--	--	--	--	--	--	--	--	--
53	01-Sep-2018	18:20	515 m	12	12	12	12	12	--	7	7	12	7
54	01-Sep-2018	20:01	482 m	--	--	--	--	--	--	--	--	--	--
55	01-Sep-2018	21:38	432 m	12	12	12	12	12	--	--	--	--	--
56	01-Sep-2018	23:09	362 m	--	--	--	--	--	--	--	--	--	--
57	02-Sep-2018	00:36	223 m	9	9	9	--	9	--	--	--	--	--
58	02-Sep-2018	02:16	138 m	--	--	--	--	--	--	--	--	--	--
59	02-Sep-2018	03:33	87 m	6	6	6	6	6	--	--	--	--	--
60	02-Sep-2018	04:49	128 m	--	--	--	--	--	--	--	--	--	--
61	02-Sep-2018	06:26	109 m	7	7	7	7	7	--	--	--	--	--
62	03-Sep-2018	01:43	111 m	--	--	--	--	--	--	--	--	--	--
63	03-Sep-2018	02:41	98 m	--	--	--	--	--	--	--	--	--	--
64	03-Sep-2018	03:38	183 m	--	--	--	--	--	--	--	--	--	--
65	03-Sep-2018	04:53	233 m	--	--	--	--	--	--	--	--	--	--
66	03-Sep-2018	05:52	229 m	--	--	--	5	--	--	--	--	--	--
67	03-Sep-2018	08:56	429 m	--	--	--	--	--	--	--	--	--	--
68	03-Sep-2018	11:06	237 m	--	--	--	--	--	--	--	--	--	--
69	03-Sep-2018	14:27	314 m	--	--	--	--	--	--	--	--	--	--
Stn	**Date (UTC)**	**Time (UTC)**	**Depth**	**S**	**^{18}O**	**Nuts**	**AT-CT**	**CDOM**	**O_2**	**^{129}I**	**^{236}U**	**N**	**Si**
70	03-Sep-2018	16:30	64 m	--	--	--	--	--	--	--	--	--	--
71	04-Sep-2018	05:18	76 m	--	--	--	--	--	--	--	--	--	--
72	04-Sep-2018	10:47	137 m	--	--	--	--	--	--	--	--	--	--
73	04-Sep-2018	12:19	206 m	--	--	--	7	--	3	--	--	--	--
74	04-Sep-2018	14:53	320 m	--	--	--	--	--	--	--	--	--	--
75	04-Sep-2018	16:28	313 m	9	9	9	10	9	3	--	--	--	--
76	04-Sep-2018	17:59	389 m	--	--	--	12	--	--	--	--	--	--
77	04-Sep-2018	19:00	382 m	10	10	10	--	10	--	--	--	--	--
78	06-Sep-2018	21:49	561 m	--	--	--	--	--	--	--	--	--	--
79	08-Sep-2018	00:29	1879 m	--	--	--	--	--	--	--	--	--	--
80	08-Sep-2018	22:56	2492 m	--	--	--	--	--	--	--	--	--	--
81	09-Sep-2018	15:33	2472 m	14	12	14	--	12	3	--	--	--	--
82	09-Sep-2018	18:43	2538 m	18	12	12	13	12	4	10	8	--	--
83	09-Sep-2018	22:07	2447 m	14	12	12	--	--	4	--	--	--	--
84	10-Sep-2018	01:05	2329 m	14	12	12	12	--	4	--	--	--	--
85	10-Sep-2018	04:00	2692 m	14	12	12	--	--	4	--	--	--	--

86	10-Sep-2018	07:17	2458 m	14	12	12	12	--	4	--	--	--	--
87	10-Sep-2018	10:20	1447 m	12	12	12	--	--	3	--	--	12	12
88	10-Sep-2018	12:10	1157 m	12	12	12	--	--	--	--	--	--	--
89	10-Sep-2018	16:22	1017 m	12	11	11	12	4	--	9	8	11	12
90	10-Sep-2018	20:01	577 m	12	12	12	--	--	--	7	--	--	--
91	10-Sep-2018	21:24	211 m	9	9	9	--	--	--	--	--	9	--
92	10-Sep-2018	22:33	171 m	--	--	--	--	--	--	--	--	--	--
93	10-Sep-2018	23:33	72 m	6	6	6	--	--	--	--	--	6	--

Table 4.2 Number of each type of water sample collected at each CTD station. Midway Westwind 1 (from CTD 65-70) and 79.5N section (71-77) we used the Moonpool system! I.e. Bad or no data in upper 10 m!

5. Biogeochemical Sampling

Water samples were collected at standard pressures of 5, 15, 25, 50, 75, 100, 150, 200, 250, 400 dbar and at the bottom of each cast along the main Fram Strait section and at selected stations along the Îsle de France and Westwind Trough sections. The samples collected at each CTD station are listed in table 4.2. Samples were collected in the following order:

1. Dissolved oxygen (see section 6)
2. DIC & Total alkalinity (see section 6)
3. CDOM (Filtered)
4. $\delta^{15}N$ and $\delta^{x}Si$ (Filtered)
5. $\delta^{18}O$
6. Nutrients
7. Salinity
8. ^{129}I

Dissolved Oxygen: Winkler samples were collected at selected stations to calibrate the SBE 43 dissolved oxygen sensor on the CTD. Samples were always collected in triplicate so that the precision of analysis could be evaluated.

Total alkalinity and dissolved inorganic carbon (A_T & DIC): Samples for Total Alkalinity and Dissolved Inorganic Carbon samples were collected (Table 4.2) and analysed onboard the ship.

$\delta^{18}O$ isotope ratio analysis and dissolved nutrients: Samples for $\delta^{18}O$ isotope ratio analysis and dissolved nutrient analysis were always collected when Total Alkalinity and Dissolved Inorganic Carbon samples were collected.

$\delta^{15}N$ & $\delta^{x}Si$: Samples were collected at selected locations targeting polar and shelf watermasses.

Oxygen isotope ratio analysis and dissolved nutrient analysis: Samples for $\delta^{18}O$ isotope ratio analysis and dissolved nutrient analysis were always collected concurrently.

Laboratory salinity analysis: Samples for laboratory salinity analysis were collected from all Niskin bottles. When the surface of the water column is strongly stratified, the salinity of water trapped in Niskin bottles can be significantly different from that measured by the conductivity sensor at the bottom of the CTD package, which is approximately 1 meter deeper then the top of the Niskin bottles. Independent laboratory salinity measurements give salinity measurements which correspond exactly to the other tracer measurements made from Niskin bottles. Laboratory measurements were made with a Guildline Portasal 8400b salinometer, which was standardized every 24 samples using P-series seawater supplied by OSIL.

^{129}I: samples were collected at selected locations targeting Atlantic and re-circulating Atlantic water

Tracer samples of sea ice: Ice cores for tracer analysis were collected at most sea ice stations. Cores were collected in duplicate or triplicate so as to allow some assessment of the variability of properties at each site sampled. Loose surface snow was removed before coring. Cores were stored in evacuated air-tight bags and melted within 48 hours of collection, after which the melt water was sub-sampled. Cores were handled with latex or nitrile gloves and an all-plastic syringe was used to extract water from buckets for CDOM sampling.

6 Carbonate chemistry, climate gases, and ocean acidification

PI's: Agneta Fransson (NPI) and Melissa Chierici (IMR)

This study is partly supported by the OA^{state} project in the Fram Centre OA-Flagship program

Main objectives:

1) Study trends in carbonate chemistry and ocean acidification state in Arctic outflow waters;
2) Effect of meltwater and sea ice on interannual variability in carbonate chemistry and air-sea CO_2 uptake.

Secondary objective:

Sample calcifiers to study coupling between environmental variables and shell condition in planktonic calcifiers (shelled pteropods and foraminifera)

Total analyses onboard in 2018 in seawater and sea ice: 1277 chemical analyses at a total of 376 samples (26th to 6th Sept)

Carbonate chemistry and ocean acidification have been part of the Fram Strait observatory since 2011 and sea ice chemistry since 2012. In 2018, we continued this time-series in seawater and sea ice to observe an integrated change in the chemistry of the Arctic Ocean. Our focus is to investigate carbonate chemistry and the effects of meltwater and sea ice change on the CO_2 fluxes and ocean acidification. We sampled the water column and sea ice and performed instrument analyses onboard for the determination of the carbonate chemistry (total alkalinity (AT), total inorganic carbon (DIC), and pH). In addition, we performed Winkler titrations to estimate the dissolved oxygen (DO) concentration in seawater at selective stations, particularly near Greenland. During the cruise, an automated instrument recorded surface water pCO_2, oxygen, salinity and temperature from the ship water intake at 4 m.

For the studies of biological effects of ocean acidification on presumed vulnerable species, we performed four WP2 net casts with mesh size 64µm from variable depths along the NE Greenland coast (also in the NEW polynya) for studies of foraminifera and calcifying pteropods (*Limacina helicina* and *Limacina retroversa*). These samples were preserved in buffered ethanol and kept cool and dark and will be sorted and analysed at UiT (Norway) and JAMSTEC (Japan).

6.1 Water column

We sampled the water column from Niskin bottles mounted onto a CTD-Rosette (24-bottle) at the same depths as the other parameters were sampled (refer to CTD-team chapter), from a total of 32 stations. Most samples were analysed onboard (28 stations, 317 seawater samples for each parameter, 951 analyses) for carbonate chemistry. The samples for carbonate chemistry were sampled first or directly after dissolved oxygen (DO) samples and analysed within 24-hours directly onboard for the determination of total alkalinity (AT), total inorganic carbon (DIC), and pH (spectrophotometric on total scale). Sampling and analysis of carbonate chemistry followed Dickson et al., 2007. Four stations (2°E, 4°E, 6°E and 8°E) were only sampled and samples were preserved and stored cool and dark to post-cruise analysis at IMR in Tromsø. At some stations in Westwind 1 and 79,30°N cross-section, we sampled for nutrients and O18, which were stored for post-cruise analysis.

Summary of stations and sections analysed onboard: 317 obtained from 28 CTD-Rosette stations (14 stations on main section from 0 and every degree west until 13°W, east of 0: 2, 4, 6, and 8 were sampled; 7 stations on Isle de France section; 3 stations on Westwind 1 section; and 4 stations at 79°30'N cross-section).

Oxygen winkler titration were performed on 3 stations (1 triplicates at 4 depths, 2 full water column) a total of 37 analyses, teaching O_2 titration (Winkler) to CTD team students.

Table 6.1. Summary of stations where water samples were collected and analysed for carbonate chemistry onboard. In addition, seawater was sampled on 2, 4, 6, 8°E on main section which will be analysed after the cruise.

Stations	Date	Time	Latitude °N	Longitude °E	Bottom depth (m)
22	08/26/2018	17:00	78.83	0.01	2577
23	08/26/2018	20:51	78.83	-1.02	2484
24	08/27/2018	0:17	78.83	-2.00	2660
26	08/27/2018	10:27	78.82	-3.05	2476
27	08/27/2018	17:27	78.82	-4.02	1862
31	08/28/2018	13:06	78.84	-5.00	1028
32	08/28/2018	21:20	78.83	-6.00	342
33	08/28/2018	23:58	78.83	-7.00	243
36	08/29/2018	15:04	78.83	-8.00	191
38	08/29/2018	18:27	78.83	-9.00	221
40	08/29/2018	21:46	78.83	-9.99	278
42	08/30/2018	1:41	78.83	-11.00	330
43	08/30/2018	4:48	78.83	-12.00	202

45	08/30/2018	8:58	78.83	-13.01	213
49	09/01/2018	11:54	77.86	-17.36	278
51	09/01/2018	14:30	77.96	-16.93	400
53	09/01/2018	18:20	77.96	16.93	519
55	09/01/2018	21:38	78.14	-15.97	432
59	09/02/2018	0:33	78.32	-14.94	86
61	09/02/2018	6:26	78.40	-14.47	111
66	09/03/2018	5:52	80.04	-15.47	229
67	09/03/2018	8:56	80.09	-15.68	429
70	09/03/2018	16:30	80.24	-16.25	54
71	09/04/2018	5:18	79.50	-15.40	76
73	09/04/2018	12:19	79.50	-16.35	208
75	09/04/2018	16:28	79.50	-17.30	309
77	09/04/2018	19:00	79.48	-17.39	381

6.2 Sea ice chemistry

At sea ice stations, sea ice cores, and under ice water were sampled at all sea ice stations (see sea ice chapter for details on dates and locations). A total of 14 sea ice cores with a length from 4 cm to 300 cm spanning new, first and second year ice, as well as multi-year ice, were sampled. Three ice cores (from 1m to 1.8 m) were sliced into 10-cm pieces from the sea-ice top (snow-air interface to the ice-seawater interface) and melted in airtight bags and analysed for salinity, AT, DIC, pH directly onboard. In addition, we measured also four new ice samples (thin, 4 to 6 cm) and bucket samples (AT and S, integrated). For all stations, snow and ice thickness, freeboard, snow thickness, air, water, snow and sea-ice temperature were measured together with the sea-ice physics team. Several ice cores were stored in -20°C ice freeze lab for post-cruise processing and analysis.

6.3 Surface water measurements of pCO_2 and dissolved oxygen

Instrumentation installed at the seawater intake at 4 meters depth (side of hull) perform high frequency measurements (1-min averages) of partial pressure of CO_2 (pCO_2, General Oceanics) and oxygen (Aanderaa) in surface water and air were installed in the clean seawater laboratory before departure from Tromsø and measurements were performed during the whole cruise, except for when the ship was operating in heavy sea ice the system had to be turned off a few times due to limited or no water supply (pumps off).

6.4 Biological sampling for calcifiers (shelled pteropods and foraminifera)

We performed WP2 64 µm (mesh size) casts at 4 stations along the NE Greenland also in the Northeast water polynya (NEW). 1st impression by amateurs was increased biomass (algal) westward. Copepods were dominant, some fish larvae, and very few adult *Limacina helicina* (polar specie) and *Limacina retroversa* (sub-polar specie) were found, and likely juveniles as observed in microscope (lupe). The microscope showed large biodiversity in this size class (yet again, as for amateurs point-of-view)

7. Sea ice observations

7.1 General

The sea ice work on Fram Strait 2018 cruise was coordinated by Dmitry V. Divine (NPI), with a support from Marius Bratrein (NPI), Paul Dodd (NPI) and the CTD team during stations on the ice: Margot Debyser (University of Edinburgh), Anne-Marie Wefing (ETH Zürich), Charlotte Lautkötter (ETH Zürich), Alicia Lianne Hamar (DTU) and Christian M. Rhode Kiær (DTU).

As in 2017, the sea ice situation in Fram Strait at the transect latitude was not favorable for sea ice research, with very open pack ice (ice concentration 0.1-0.3) west of 2°W and no compact ice pack almost all the way to 12°W. As a result, the opportunities for doing sea ice stations were limited. Altogether we made 10 sea ice stations (see Table 7.1). The majority of sea ice observed outside fast ice area during the cruise was a thick second year/multiyear ice, often ridged and deformed with a thickness from visual observations exceeding 2 – 4 m. The floe sizes preferentially small in the range of 20-60 m. Fast ice area next to Greenland experienced a continuous swell triggered break up in the weeks preceding the cruise and during the cruise. We observed that drift ice in fast ice area might actually originate from this fast ice.

Regular sea ice observations using ASSIST protocol were also made by D.V. Divine while RV KPH was in the ice.

7.2 Sea ice stations

On 8 main sea ice stations (S1, S3, S4, S6, S7, S8, S9 and S10) we collected ice cores for salinity and temperature analysis, micro-plastic particles and for archive storage and later analysis of the microstructure. Station 2 had to be abandoned right after initial thickness drillings due to a swell break-up of the floe. Station 5 was a station on thin ice. On every full sea ice station, 1 to 3 tracer cores were collected by Paul Dodd (NPI). In addition, 7 core bottoms were collected for sea ice biomarker IP25 in a collaborative study with the GEO-section of NPI. The former snow layer from last winter and spring has been transformed to superimposed ice/snow ice on some/most spots, the samples of this layer were also analyzed onboard.

The ice thickness of the ice floe was surveyed directly by thickness drilling and indirectly using a Geonics EM31-MK2 short (EM31SH). For 3 ice stations extents of ice floes visited were sufficiently large to use EM31. The EM31 is placed on a sledge and pulled over the ice; the data including GPS position is logged at a frequency of 0.5 Hz to an Archer II field computer. Thickness drillings were done on selected spots for calibration and validation, and ice thickness and freeboard were measured with a Kovacs thickness gauge. Figure 7.2 present a calibration curve for EM31SH based on 16 calibration drillings made during the cruise.

In total, 4 profiles were collected to characterize the ice thicknesses of the station floes. The results of all thickness measurements with the EM31SH instrument (2 transects) made on Stations 3 and 4 on fast ice are shown below in Figures 7.2 and 7.3.

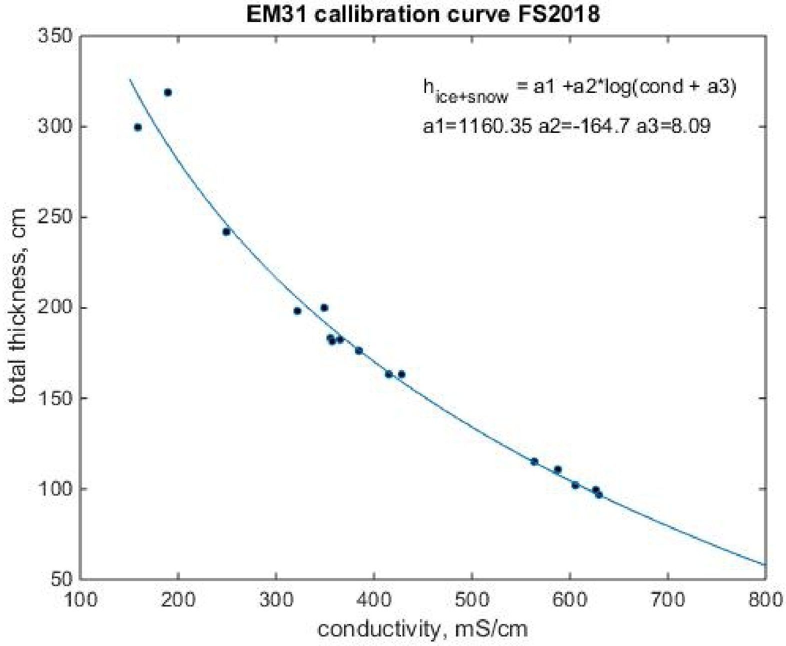


Figure 7.2: EM31SH calibration curve based on calibration thickness drillings.

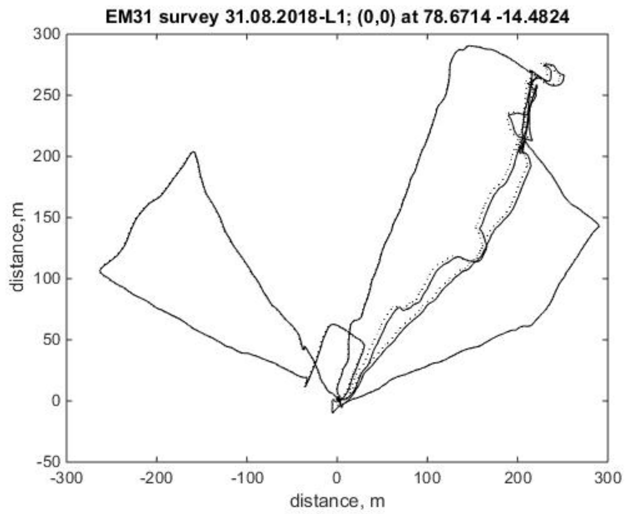


Figure 7.3: EM31 survey stations 3+4

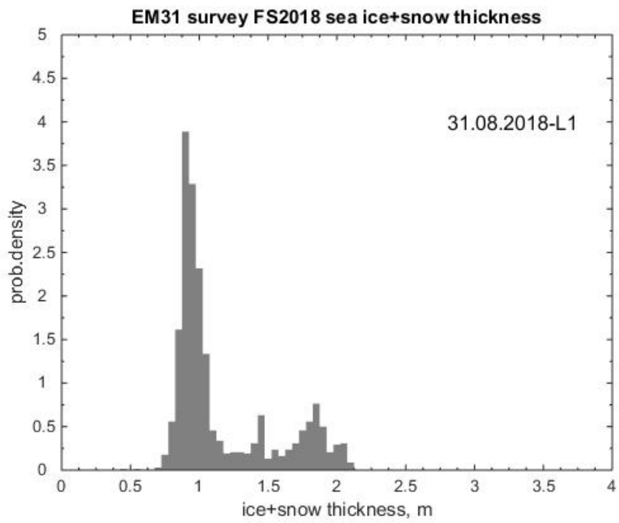


Figure 7.3: EM31 sea ice+snow thickness

Fast ice in the station area have shown spatially uniform properties with two types of ice surveyed and a clear bimodal thickness distribution with maxima at approximately 1 m and 1.8 m. This was also confirmed by visual in situ/ bridge based observations of the area (see Figure 7.4). Ice surface in the thinner ice area featured extensive melt pond coverage (up to 50%) in some areas that were partly refrozen with a 5 cm thick ice on the surface by the time of ice station.

Figure 7.4: KPH entering fast ice east of Greenland. Note the high melt pond fraction on the level ice around the icebreaker.

Due to limited snow cover (2-4 cm thick crust/scattering layer) and no significant precipitation events throughout the cruise, we did not use Magna Probe for measuring snow thickness. Instead, the scatter layer thickness was manually logged during the EM31SH transects/coring.

7.3 Thin ice sampling

The thin ice samples on Stations 5 and 7 were collected from the boat and ice floe edge, respectively- Temperatures, salinity, thickness, and visual information were collected. Altogether, we had four thin ice sampling spots, new ice formation was only observed on some days between 30.08 and 04.09.18 and registered in ASSIST.

Figure 7.5: Sea ice station 5 on thin ice, 01.09.2018

7.4 Ice observations from the bridge (ASSIST)

Sea ice conditions were observed every one to three hours, except for the night time between midnight and 06:30, from the observation deck of RV KPH and reported to Ice service at Met.no on a daily basis. Various sea ice parameters including sea ice types, floe sizes, snow cover, ridges, rafting etc. were recorded 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 total 107 observations were made during the cruise while RV KPH was in the ice zone.

7.5 Daily log of sea ice work during the cruise

Detailed description of ice station activities with station logs and photos is available in the cruise data collection, see folder "Sea Ice". Table 7.1 below shows a brief overview of FS2018 daily activities related to the sea ice work.

Table 7.1: An overview of all visited stations including tasks/activities.

Date	Day	#	time (UTC)	lat (start)	lon (start)	Task/activities
25.08.2018	1		13:00			Departure LYR
26.08.2018	2		09:15			Transit - Instrument maintenance
27.08.2018	3		11:00			Data work, ASSIST observations
28.08.2018	4	S1	17:20	78° 51.1’	-4° 59.1’	Ice Coring, Thickness Drilling
29.08.2018	5					Ice free area, data logging and analysis
30.08.2018	6	S2		78° 49.9’	-13° 41.8’	Attempt for ice station on fast ice, swell break up
31.08.2018	7	S3	08:10	78° 40.3’	-14° 28.9’	Station on fast ice. Coring, Thickness Drilling, EM31
31.08.2018	7	S4	11:30	78° 40.4’	-14°28.04’	Station on fast ice. Coring, Thickness Drilling, EM31
01.09.2018	8					Data analysis and processing
01.09.2018	8	S5	17:00	78° 01.5’	-16° 33.3’	Thin ice station 5
02.09.2018	9					Steaming to Westwind through, strong swell, small ice floes
09.03.2018	10	S6	18:30	80°10.9’	-16° 01.7’	Station on drift ice. Ice Coring, Thickness Drilling
09.04.2018	11	S7	06:40	79°30.6’	-15° 25.9’	Station on drift ice. Ice Coring, Thickness Drilling, EM31
09.05.2018	12					Office/lab work, processing, maintenance
09.06.2018	13					sample and data analysis/processing

09.07.2018	14	S8	17:10	79° 03.2’	-5° 09.3’	Station on drift ice. Ice Coring, Thickness Drilling
09.07.2018	14	S9	19:30	79° 02.2	-5° 09.6’	Station on drift ice. Ice Coring
09.08.2018	15					Sample and data analysis/processing
09.08.2018	15	S10	14:50	79° 04.7	-4° 13.9’	Station on drift ice. Ice Coring
09.09.2018	16					Sample and data analysis/processing
09.10.2018	17					Equipment maintenance and packing, report writing
09.11.2018	18					Equipment maintenance and packing, report writing

8. VMADCP and LADCP measurements

During the cruise, both hull-mounted and drop-keel mounted Vessel Mounted Acoustic Doppler Current Profilers (VMADCP) (38 kHz and 150 kHz) were used on the CTD transects across the Fram Strait and the shelf to provide continuous measurements of ocean velocity. The data collected was therefore a mix of these systems since the drop-keel VMADCPs are stopped and pulled up when sailing in sea ice.

Lowered Acoustic Doppler Current Profiler (LADCP) data were collected at all CTD stations. The set up consisted of a double-head LADCP system (one downward looking (master) and one upward looking (slave) ADCP) with external battery case on the large, 24-bottle CTD rosette. The data were processed using the LDEO processing package (Version IX.7 – IX.10) and detided with the barotropic tidal model (TMD2.03/DATA/Model_tpxo6.2). The script files to program and start the LADCP are given in Appendix C.

9. Whale project

The main purpose of the whale project was to deploy satellite transmitters into large whales, mainly bowhead whales, in order to track their movements the following year. If blue- or fin whales were observed we would also attempt to deploy satellite transmitters on these species. Since we mainly would operate in ice covered waters the deployment of the transmitters were to be done from a helicopter. This is a multi-year project and a co-operation between Norway, Greenland and Russia. The project team during the 2018 Framstrait cruise consisted of scientists from Norway and Russia in addition to the pilot and the mechanic (Figure 9.1).

Figure 9.1. The "whale team" in front of the Ecureuil 350 helicopter. From the left: Kit Kovacs, Olga Shpak, Christian Lydersen, Eirik Grønningsæter, Henning Hansen and Kenneth Buvik.

Weather permitting and in areas with reasonable ice conditions we flew a total of 29 h in search for bowhead whales. We deployed satellite transmitters (Figure 9.2) on 9 whales close to the Greenland coast during two days of good conditions, 4 on 31st August and 5 on 3rd September (Figure 9.3). In additions we collected biopsies for genetic studies from 2 bowhead whales on 31st August. During the last day of the cruise on 10 Sept we attempted to deploy satellite transmitters on whales observed in open water close to the shelf of Spitsbergen. This was a first time of operating under such conditions and turned out to be very successful. Five fin whales were tagged during the afternoon of that day (Figure 9.3). So a total of 14 satellite transmitters were deployed during this cruise and hopefully we will be able to track these individuals far into 2019.

Figure 9.2. A bowhead whale has just gotten a satellite transmitter attached to its back - deployed using a custom made air gun from a helicopter.

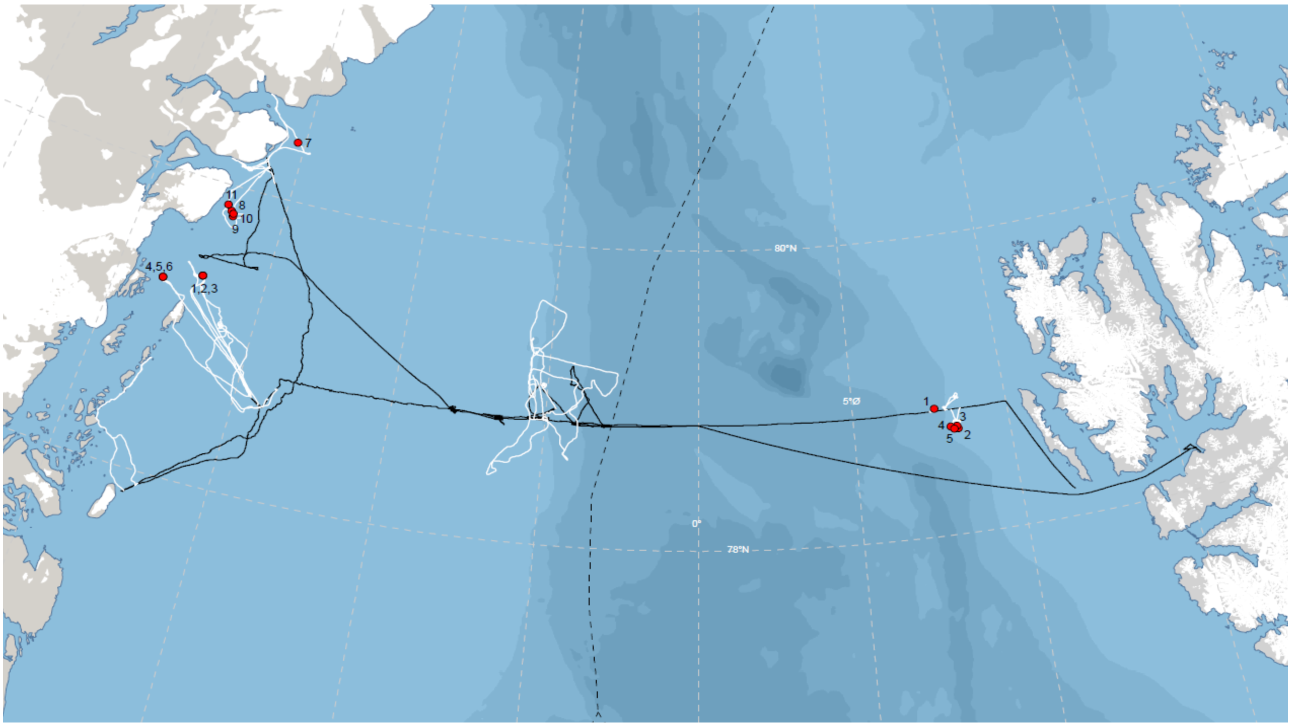
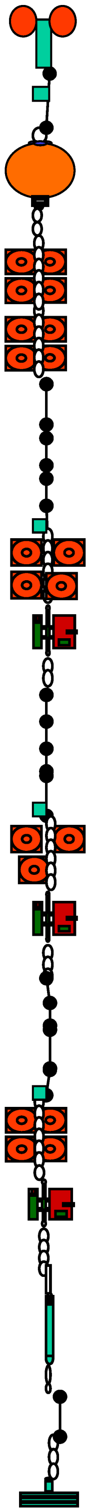


Figure 9.3. Map of sites where whales were encountered. Black line: ship tracks, white lines: helicopter tracks. Red points to the west of the map: locations of bowhead whales that were tagged (minus nrs.4 and 5 which are animals from which we took biopsies). Red points to the east of the map: locations where fin whales were tagged.

Appendix A: Diagrams of moorings recovered

Rigg F11-19 78 49,147N

Satt ut 9 Sep 2017 kl 18:42 : 003 03,189W

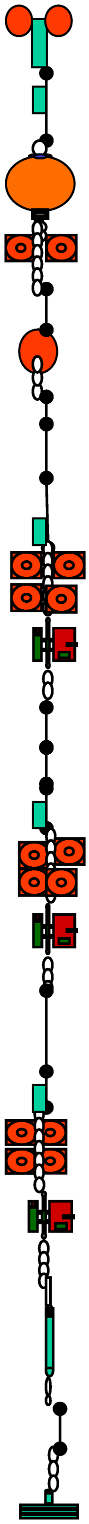


		Dyp:	Fra bunn:	Ut:
IPS	SNR. 51062	57	2396	18:35
SBE37	SNR. 3492	59	2394	18:35
5 m Kevlar				
ADCP300	SNR: 18070	63	2390	18:35
0,5 m Kjetting galvanisert				
8 Glasskuler (gule)		65	2388	
3 m Kjetting galvanisert				
100 m Kevlar				
50 m Kevlar				
50 m Kevlar				
SBE37	SNR. 3996	270	2183	14:39
4 Glasskuler (2 gule og 2 oransje)				
2 m Kjetting galvanisert				
RCM9	SNR.1049	274	2179	14:39
0,5 m Kjetting galv				
200(199) m Kevlar				
500(510) m Kevlar				
500(510) m Kevlar				
20 m Kevlar				
SBE37	SNR. 7061	1517	936	14:18
3 Glasskuler (gule)				
2 m Kjetting galvanisert				
RCM11	SNR.538	1520	933	14:18
0,5 m Kjetting galv				
500(511) m Kevlar				
200 m Kevlar				
200 m Kevlar				
SBE37	SNR. 8226	2440	13	13:58
4 Glasskuler (gule)				
2 m Kjetting galvanisert				
Seaguard	SNR.834	2442	11	13:58
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 499			
5 m Kevlar				
3 m Kjetting galvanisert				
ANKER	1230/(980) kg	2453	0	

Rigg F12-19

Satt ut 8 Sep 2017 kl 09:05 : 78 49,283N 004 01,373W

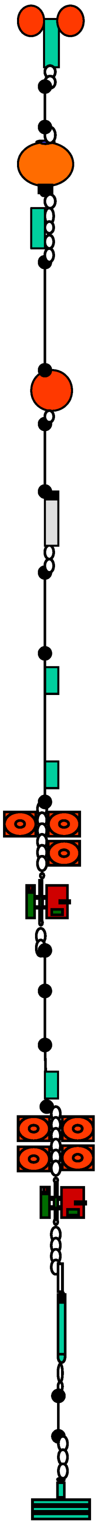
Tatt opp



		Dyp:	Fra bunn:	Ut:
IPS	SNR. 51167	59	1783	09:02
SBE37	SNR.7055	61	1781	09:02
5 m Kevlar				
ADCP300	SNR: 18151	65	1777	09:04
2 Glasskuler				
1,0 m Kjetting galvanisert				
0,5 m Kjetting galv				
10 m Kevlar				
Stålkule 37	SNR.	77	1765	
1,0 m Kjetting galvanisert				
0,5 m Kjetting galv				
200(199) m Kevlar				
SBE37	SNR.3994	278	1564	08:42
3 Glasskuler				
2 m Kjetting galvanisert				
RCM9	SNR. 836	281	1561	08:42
0,5 m Kjetting galv				
500(498) m Kevlar				
500(497) m Kevlar				
200(205) m Kevlar				
SBE37	SNR.13505	1494	348	08:22
3 Glasskuler				
2 m Kjetting galvanisert				
RCM11	SNR.556	1497	345	08:22
0,5 m Kjetting galv				
200(207) m Kevlar				
100(101) m Kevlar				
20 m Kevlar				
SBE37	SNR. 10294	1827	15	08:13
4 Glasskuler				
2 m Kjetting galvanisert				
RCM11	SNR.117	1830	12	08:13
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 500			
5 m Kevlar				
3 m Kjetting galvanisert				
ANKER	1190/(960) kg	1842	0	

Rigg F13-19

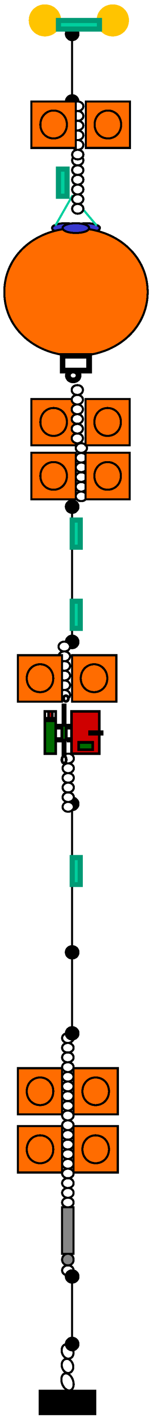
Satt ut 6 Sep 2017, kl 13:48 : 78 50.324N 005 00.146W



		Dyp:	Fra bunn:	Ned i vann:
IPS5	SNR. 51064	49	961	13:45
5 m Kevlar				
ADCP300	SNR: 20021	54	956	13:45
1,5 m Kjetting galv				
SEACAT SBE16	SNR. 7253	55	957	13:45
0,5 m Kjetting galv.				
10 m Kevlar				
Stålkule 37		65	947	
5 m Kevlar				
Hvallydopptaker		71	941	13:35
0,5 m Kjetting galv.				
20 m Kevlar				
50 m Kevlar				
SBE37	SNR. 3995	139	873	13:16
100 m Kevlar				
SBE37	SNR.7060	239	773	13:11
3 Glasskuler				
2 m Kjetting galv.				
RCM9	SNR.1326	242	770	13:11
0,5 m Kjetting galv				
500(497) m Kevlar				
100 m Kevlar				
100 m Kevlar				
50 m Kevlar				
SBE37	SNR. 13504	1007	15	12:56
4 Glasskuler				
2 m Kjetting galv.				
SEAGUARD	SNR. 345	1010	12	12:56
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 743			
5 m Kevlar				
3 m Kjetting galvanisert				
ANKER 1100/(880) kg		1022	0	

Rigg F13B-4 78 50.260 N

Satt ut 6 Sep 2017 , kl 09:43 : 005 30.926W

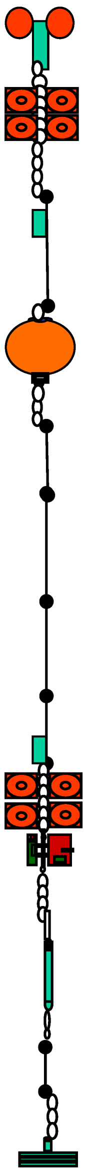


		Dyp:	Fra bunn:	Ut:
ICECat	SNR. 15910	30	494	09:40
25 m Wire				
Weak link				
1 m Kjetting galv.				
2 Glasskuler				
ICECAT modem				
ADCP	SNR.17462	57	467	09:35
2 m Kjetting galv.				
4 Glasskuler				
0,5 m Kjetting galv.				
SBE37	SNR. 9853	61	463	09:30
41 m Kevlar				
SBE37	SNR. 9852	101	423	09:27
1 m Kjetting galv.				
2 Glasskuler				
SEAGUARD	SNR. 883	103	421	09:27
0,5 m Kjetting galv.				
200(199) m Kevlar				
SBE37	SNR. 7059 Merket	154	370	09:15
205 m Kevlar				
2 m Kjetting galv.				
4 GLASSKULER		513	11	
AR661	SNR. 410			
5 m Kevlar.				
2 m Kjetting galv.				
ANKER	800/(620)kg	524	0	

Rigg F14-19

Satt ut 5 Sep 2017, kl 13:47 :

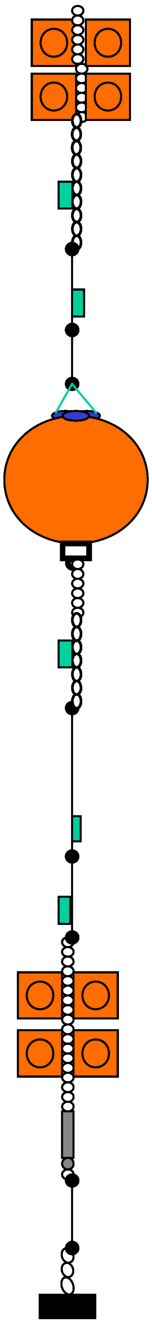
78 48,848N
006 30,058W



		Dyp:	Fra bunn:	Ned i vann:
IPS	SNR. 51127	54	219	13:45
4 Glasskuler				
2 m Kjetting galv.				
SBE37	SNR: 7058	60	213	13:45
5 m Kevlar				
ADCP 300	SNR: 24385	64	209	13:45
1 m Kjetting Galv.				
0,5 m Kjetting Galv.				
100 m Kevlar				
50 m Kevlar				
SBE56	SNR: 3943	210	63	13:35
40 m Kevlar				
SBE56	SNR: 3942	235	38	13:30
SBE37	SNR.7057	260	13	13:18
4 Glasskuler				
2 m Kjetting Galv.				
RCM9	SNR. 1325	263	10	13:18
Svivel				
AR861	SNR. 568			
3,5 m Kevlar				
2,5 m Kjetting				
ANKER	900/(740) kg	273	0	

Rigg F17-14 78 50. 186 N Dyp: Fra bunn: Ut:

Satt ut 5 Sep 2017 , kl 10:56 008 04.892W

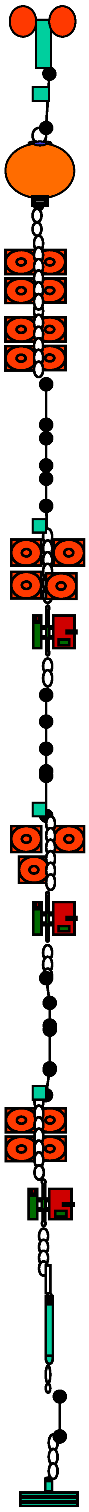


		Dyp	Fra bunn	Ut
3 m Kjetting galv. 4 Glasskuler		52	174	09:03
SBE16	SNR.7212	54	172	09:03
0,5 m Kjetting 51 m Kevlar				
SBE37	SNR. 13252	94	132	08:54
ADCP	SNR.17461	105	121	08:48
2 m Kjetting galv.				
SBE16	SNR.7339	108	118	08:48
0,5 m Kjetting				
99 m Kevlar				
SBE56	SNR.3944	188	38	08:38
5 m Kevlar				
SBE37	SNR.14099	214	12	08:34
2 m Kjetting galv.				
4 GLASSKULER		215	11	
AR861CS	SNR. 501			
5 m Kevlar.				
2 m Kjetting galv.				
ANKER	800/(700)kg	226	0	

Appendix B: Diagrams of moorings deployed

Rigg F11-19 78 49,147N

Satt ut 9 Sep 2017 kl 18:42 : 003 03,189W

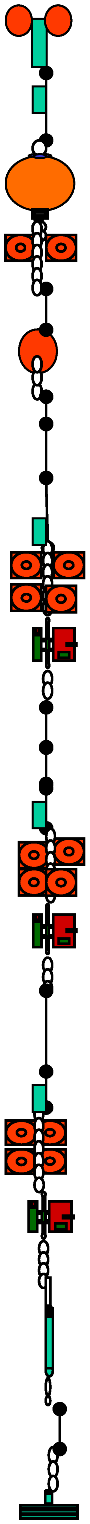


		Dyp:	Fra bunn:	Ut:
IPS	SNR. 51062	57	2396	18:35
SBE37	SNR. 3492	59	2394	18:35
5 m Kevlar				
ADCP300	SNR: 18070	63	2390	18:35
0,5 m Kjetting galvanisert				
8 Glasskuler (gule)		65	2388	
3 m Kjetting galvanisert				
100 m Kevlar				
50 m Kevlar				
50 m Kevlar				
SBE37	SNR. 3996	270	2183	14:39
4 Glasskuler (2 gule og 2 oransje)				
2 m Kjetting galvanisert				
RCM9	SNR.1049	274	2179	14:39
0,5 m Kjetting galv				
200(199) m Kevlar				
500(510) m Kevlar				
500(510) m Kevlar				
20 m Kevlar				
SBE37	SNR. 7061	1517	936	14:18
3 Glasskuler (gule)				
2 m Kjetting galvanisert				
RCM11	SNR.538	1520	933	14:18
0,5 m Kjetting galv				
500(511) m Kevlar				
200 m Kevlar				
200 m Kevlar				
SBE37	SNR. 8226	2440	13	13:58
4 Glasskuler (gule)				
2 m Kjetting galvanisert				
Seaguard	SNR.834	2442	11	13:58
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 499			
5 m Kevlar				
3 m Kjetting galvanisert				
ANKER	1230/(980) kg	2453	0	

Rigg F12-19

Satt ut 8 Sep 2017 kl 09:05 : 78 49,283N 004 01,373W

Tatt opp

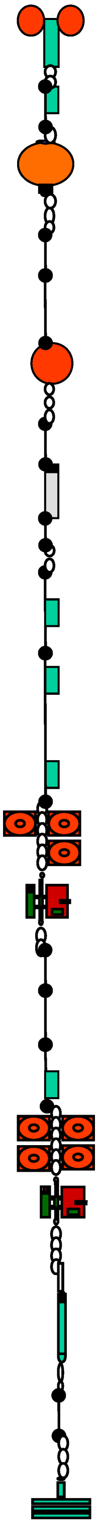


		Dyp:	Fra bunn:	Ut:
IPS	SNR. 51167	59	1783	09:02
SBE37	SNR.7055	61	1781	09:02
5 m Kevlar				
ADCP300	SNR: 18151	65	1777	09:04
2 Glasskuler				
1,0 m Kjetting galvanisert				
0,5 m Kjetting galv				
10 m Kevlar				
Stålkule 37	SNR.	77	1765	
1,0 m Kjetting galvanisert				
0,5 m Kjetting galv				
200(199) m Kevlar				
SBE37	SNR.3994	278	1564	08:42
3 Glasskuler				
2 m Kjetting galvanisert				
RCM9	SNR. 836	281	1561	08:42
0,5 m Kjetting galv				
500(498) m Kevlar				
500(497) m Kevlar				
200(205) m Kevlar				
SBE37	SNR.13505	1494	348	08:22
3 Glasskuler				
2 m Kjetting galvanisert				
RCM11	SNR.556	1497	345	08:22
0,5 m Kjetting galv				
200(207) m Kevlar				
100(101) m Kevlar				
20 m Kevlar				
SBE37	SNR. 10294	1827	15	08:13
4 Glasskuler				
2 m Kjetting galvanisert				
RCM11	SNR.117	1830	12	08:13
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 500			
5 m Kevlar				
3 m Kjetting galvanisert				
ANKER	1190/(960) kg	1842	0	

Rigg F13-20 78 50.392N

Settes ut 7 SEP 2018 , kl 10:44 004 59.485W

Tatt opp AUG 201

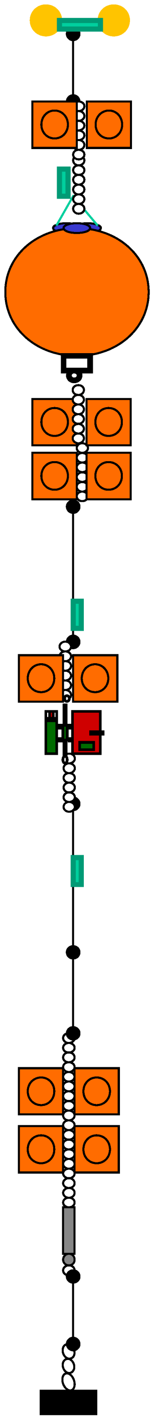


		Dyp:	Fra bunn:	Ned i vann:
IPS5	SNR. 51064	50	972	09:40
SBE37	SNR: 7056	52	970	09:40
5 m Kevlar				
ADCP300	SNR: 16876	56	966	09:40
1,5 m Kjetting galv				
5 m Kevlar				
10 m Kevlar				
Stålkule 37		73	949	
1,5 m Kjetting galv.				
5 m Kevlar				
Hvallydopptaker		81	941	09:25
2 m Kevlar				
0,5 m Kjetting galv.				
50 + 20 m Kevlar				
SBE37	SNR. 12234	104	918	09:18
SBE37	SNR. 12232	157	865	09:12
100 (103) m Kevlar				
SBE37	SNR.3993	258	764	08:45
3 Glasskuler				
2 m Kjetting galv.				
RCM9	SNR.1327	262	760	08:45
0,5 m Kjetting galv				
500 (498)m Kevlar K				
200 (198)m Kevlar				
50 m Kevlar				
SBE37	SNR.3551	1008	14	16:36
4 Glasskuler				
2 m Kjetting galv.				
RCM11	SNR. 561	1012	10	16:36
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 053			
3,5 m Kevlar				
3 m Kjetting galvanisert				
ANKER	1110/(880) kg	1022	0	

Rigg F13B-5 78 50.261 N Dyp: Fra bunn: Ut:

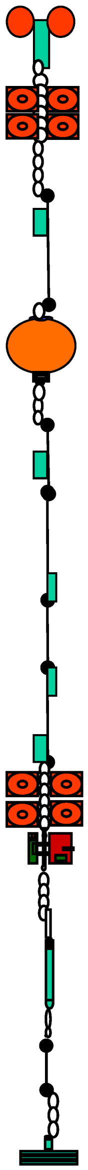
Satt ut 5 SEP 2018, kl 12:53 005 30.848W

Tatt opp Aug 201



		Dyp	Fra bunn	Ut
ICECat	SNR. 13506	17	510	12:47
25 m Wire				
Weak link				
1 m Kjetting galv.				
2 Glasskuler				
ICECAT modem				
ADCP	SNR.727	42	485	12:47
3 m Kjetting galv.				
4 Glasskuler				
51 m Kevlar				
SBE37	SNR. 12233	96	431	12:42
1 m Kjetting galv.				
2 Glasskuler				
RCM7	SNR. 7718	99	428	12:42
206 m Kevlar				
SBE37	SNR. 10295	150	377	12:30
(Merke på ca 50 m ned)				
206 m Kevlar				
(Merke på ca 101 m over kuler) - 105				
2 m Kjetting galv.				
4 GLASSKULER		515	12	
AR661	SNR. 291			
5 m Kevlar.				
2 m Kjetting galv.				
ANKER	800/(620)kg	527	0	

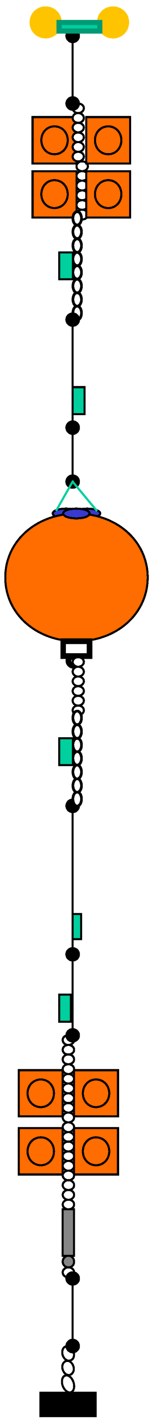
Rigg F14-20 78 48,870N
Satt ut 6 SEP 2018 , kl 08:35 006 30,055W
Tatt opp Aug 201



			Dyp:	Fra bunn:	Ned i vann:
IPS	SNR. 51138		50	217	08:31
4 Glasskuler 2 m Kjetting galv.					
SBE37	SNR: 14097		54	213	08:31
5 m Kevlar					
ADCP 300	SNR: 20021		58	209	08:30
1 m Kjetting Galv. 0,5 m Kjetting Galv. 40 m Kevlar					
SBE37	SNR: 14098		99	168	08:21
100 (103) m Kevlar					
SBE56	SNR.3943	(25 m over 56)	203	64	08:16
SBE56	SNR.3942	(25 m over 37)	228	39	08:12
50 (51) m Kevlar					
SBE37 4 Glasskuler 2 m Kjetting Galv.	SNR.3992		253	14	08:03
RCM9	SNR. 1046		257	10	08:01
Svivel					
AR861	SNR. 506				
3,5 m Kevlar					
2,5 m Kjetting					
ANKER 920/(740) kg			267	0	

Rigg F17-15
Satt ut 5 SEP 2018, kl 14:03
Tatt opp Aug 201

78 50. 175 N
008 04.879W



			Dyp:	Fra bunn:	Ut:
SBE37	SNR. 15910		32	196	14:02
20 m Kevlar					
Weak link o/u					
3 m Kjetting galv.					
4 Glasskuler					
SBE16	SNR.6693		56	172	14:02
0,5 m Kjetting galv.					
40 m Kevlar					
SBE37	SNR.2962		96	132	13:52
10 m Kevlar					
ADCP	SNR.7636		107	121	13:48
1,5 m Kjetting galv.					
SBE16	SNR.6694		109	119	13:48
0,5 m Kjetting galv.					
102 m Kevlar					
SBE56	SNR. 3944	(20 m over 37)	196	32	13:38
5 m Kevlar					
SBE37	SNR.7062		216	12	13:34
2 m Kjetting galv.					
4 GLASSKULER			217	11	
AR661	SNR. 110				
5 m Kevlar.					
2 m Kjetting galv.					
ANKER	815/(700)kg		228	0	

Appendix C: Script files for Master/Slave LADCP programming and starting

```
; Append command to the log file
$LC:\KH2018708\LADCP\Mladcp_log.txt
$P **************************************************************************
$P ************** LADCP Master. Looking down (firmware v16.3) *************
$P ************* Master and Slave will ping at the same time ***************
$P ************ staggered single-ping ensembles every 0.8/1.2 s *************
$P **************************************************************************
; Send ADCP a BREAK
$B
; Wait for command prompt (sent after each command)
$W62
; Display real time clock setting
tt?
$W62
; Set to factory defaults
CR1
$W62
; use WM15 for firmware 16.3
; activates LADCP mode (BT from WT pings)
WM15
$W62
; Rename data file prior to new CTD station and use CTD station nr
RN M022_
; Flow control (Record data internally):
; - automatic ensemble cycling (next ens when ready)
; - automatic ping cycling (ping when ready)
; - binary data output
; - disable serial output
; - enable data recorder
CF11101
$W62
; coordinate transformation:
; - radial beam coordinates (2 bits)
```

```
; - use pitch/roll (not used for beam coords?)
; - no 3-beam solutions
; - no bin mapping
EX00100
$W62
; Sensor source:
; - manual speed of sound (EC)
; - manual depth of transducer (ED = 0 [dm])
; - measured heading (EH)
; - measured pitch (EP)
; - measured roll (ER)
; - manual salinity (ES = 35 [psu])
; - measured temperature (ET)
EZ0011101
$W62
;
; - configure staggered ping-cycle
; ensembles per burst
TC2
$W62
; pings per ensemble
WP1
$W62
; time per burst
TB 00:00:01.20
$W62
; time per ensemble
TE 00:00:00.80
$W62
; time between pings
TP 00:00.00
$W62
;
; - configure no. of bins, length, blank
; number of bins
```

```
WN015
$W62
; bin length [cm]
WS0800
$W62
; blank after transmit [cm]
WF0000
$W62
; ambiguity velocity [cm]
WV250
$W62
; amplitude and correlation thresholds for bottom detection
LZ30,220
$W62
; Set ADCP to narrow bandwidth and extend range by 10%
LW1
$W62
;
; SET AS MASTER ADCP
SM1
$W62
; TRANSMITS SYNCHRONIZING PULSE BEFORE EACH ENSEMBLE
SA011
$W62
; WAIT .55 s after sending sync pulse
SW05500
$W62
; SYNCHRONIZING PULSE SENT ON EVERY PING
SI0
$W62
; keep params as user defaults (across power failures)
CK
$W62
; echo configuration
T?
```

$W62

W?

$W62

; start Pinging

CS

; Delay 3 seconds

$D3

$p ***

$P Please disconnect the ADCP from the computer.

$P ***

; Close the log file

$L

```
; Append command to the log file
$LC:\KH2018708\LADCP\Sladcp_log.txt
$P *************************************************************************
$P ************** LADCP SLAVE. Looking UP (firmware v16.30) *************
$P ************* Master and Slave will ping at the same time ***************
$P ************ staggered single-ping ensembles every 0.8/1.2 s ************
$P *************************************************************************
; Send ADCP a BREAK
$B
% Wait for the command prompt; BBTalk needs this before each command
$W62
; Display real time clock setting
tt?
$W62
; Set to factory defaults
CR1
$W62
; use WM15 for firmware 16.3
; activates LADCP mode (BT from WT pings)
WM15
$W62
; Rename data file prior to new CTD station and use CTD station nr
RN S022_
$W62
; Flow control (Record data internally):
; - automatic ensemble cycling (next ens when ready)
; - automatic ping cycling (ping when ready)
; - binary data output
; - disable serial output
; - enable data recorder
CF11101
$W62
; coordinate transformation:
; - radial beam coordinates (2 bits)
; - use pitch/roll (not used for beam coords?)
```

```
; - no 3-beam solutions
; - no bin mapping
EX00100
$W62
; Sensor source:
; - manual speed of sound (EC)
; - manual depth of transducer (ED = 0 [dm])
; - measured heading (EH)
; - measured pitch (EP)
; - measured roll (ER)
; - manual salinity (ES = 35 [psu])
; - measured temperature (ET)
EZ0011101
$W62
; - configure staggered ping-cycle
; ensembles per burst
TC2
$W62
; pings per ensemble
WP1
$W62
; time per burst
TB 00:00:01.20
$W62
; time per ensemble
TE 00:00:00.80
$W62
; time between pings
TP 00:00.00
$W62
;
; - configure no. of bins, length, blank
; number of bins
WN015
$W62
```

```
; bin length [cm]
WS0800
$W62
; blank after transmit [cm]
WF0000
$W62
; ambiguity velocity [cm]
WV250
$W62
; amplitude and correlation thresholds for bottom detection
LZ30,220
$W62
; Set ADCP to narrow bandwidth and extend range by 10%
LW1
$W62
;
; SET AS SLAVE ADCP
SM2
$W62
; TRANSMITS SYNCHRONIZING PULSE BEFORE EACH ENSEMBLE
SA011
$W62
; don't sleep
SS0
$W62
; WAIT UP TO 300 SECONDS FOR SYNCHRONIZING PULSE
ST0300
$W62
; keep params as user defaults (across power failures)
CK
$W62
; echo configuration
T?
$W62
W?
```

$W62

; start Pinging

CS

; Delay 3 seconds

$D3

$p ***

$P Please disconnect the ADCP from the computer.

$P ***

; Close the log file

$L