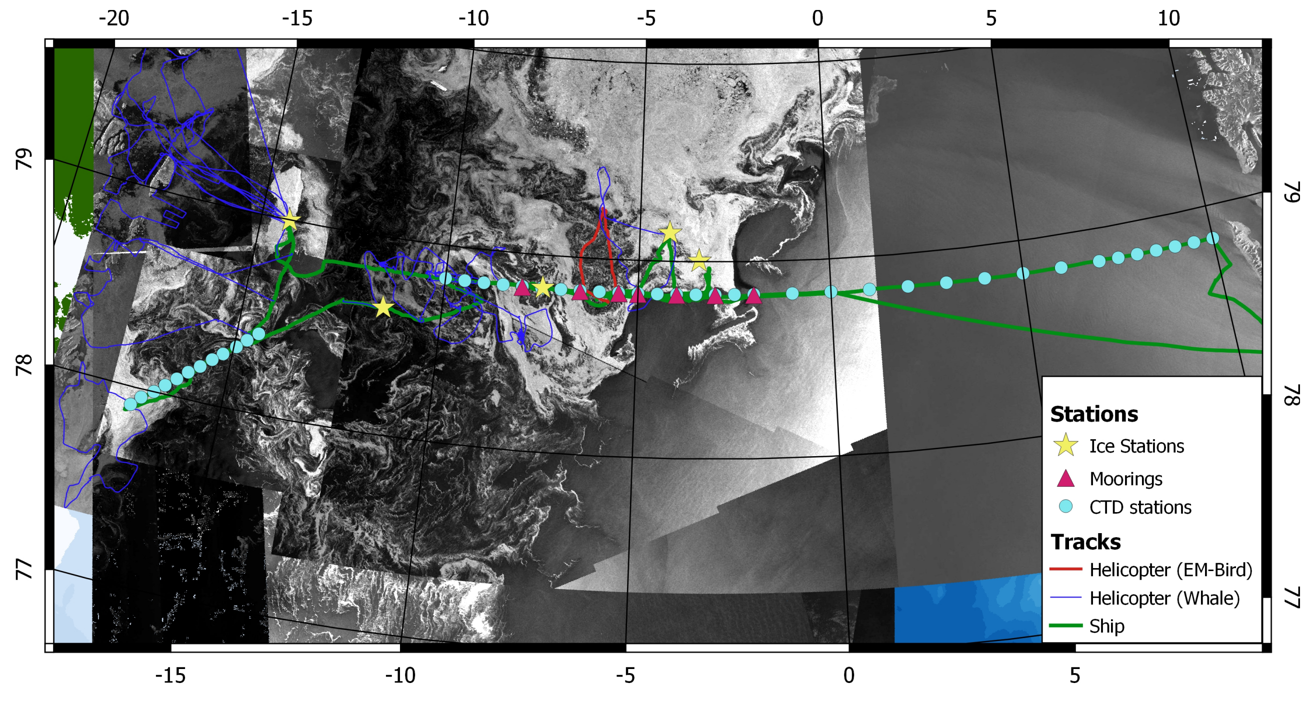
Fram Strait Cruise Report

1 – 16 September 2019

Cruise no. 2019707



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1. Cruise Overview

The objective of the annual cruise of the Norwegian Polar Institute to Fram Strait is to service the Arctic Outflow Observatory in the western Fram Strait. The purpose of this observing system is to monitor the properties of the Arctic freshwater, sea ice, and returning Atlantic water, as well as the state of ocean acidification, CDOM and nutrients in the East Greenland Current.

The main priority was to recover and redeploy seven NPI moorings across the East Greenland Current at 78°50' N, and to carry out the CTD/LADCP section including extensive water sampling for various tracers across the whole Fram Strait along the 78°50'N line. In addition, one CTD/LADCP section (Isle de France section) across the Belgica-Norske-Westwind trough on the east Greenland shelf, was carried out. D

Rather limited sea ice physics work was carried out across the East Greenland Current. This included in-situ work on some selected sea ice floes as well as on land-fast ice as far west as we could go on 78°50'N, and one helicopter flight with EM-bird. A new component to the sea ice work this year, was sampling for microplastics in sea ice. There was very little sea ice in the EGC and on the shelf this year, and it was hard to find floes from which to work on for sea ice and microplastic. The land-fast ice region on Belgica bank was very small relative to earlier years and it broke up just after we visited it.

Similar to 2018, there was a whale research programme deploying satellite transmitters on large whales, mainly bowhead whales, and tracking their movements in the following year, as well as collecting skin biopsies for genetic analyses. In ice covered water these tasks were conducted from a helicopter (Ecureuil 350) based on KPH.

Surface drifters across the shelfbreak East Greenland Current were deployed as part of a collaborative project with NIOZ, the Netherlands, to investigate the exchange of freshwater between the East Greenland Current and the interior basins. The drifters were typically deployed right after mooring recoveries or CTD stations.

The cruise hosted freelance journalist Cheryl Katz who covered the research in popular science articles for several magazines. In addition, Lawrence Hislop (REVocean) documented the cruise through photography and film as a collaboration with NPI.

Prioritization and timing of mooring operations, CTDs and flights were guided by sea ice images (Sentinel) send to the ship by the data management group at NPI.

2. Participants

Organisation
1. Laura de Steur (NPI, Cruise leader)
2. Paul A. Dodd (NPI, Cruise deputy)

Sea ice lead
3. Dima Divine (NPI)
4. Jean Negrel (NPI)

Microplastic sea ice:
5. Ingeborg Hallanger (NPI)
6. Vegard Sturzinger (NPI)

CTD/tracer/water sampling and analysis:
7. Colin Stedmon (DTU, Denmark)
8. Rafael Gonçalves-Araujo (DTU, Denmark)
9. Mischa Johannes Maria Saes (DTU, Denmark)
10. Thodoris Karpouzoglou (NPI)
11. Margot Debyser (University of Edinburgh)
12. Anne-Marie Wefing (ETH Zurich)
13. Flora Desmet (ETH Zurich)

Drifters:
14. Femke de Jong (NIOZ, Netherlands)
15. Elodie Duyck (NIOZ, Netherlands)

Whale research:
16. Christian Lydersen (NPI)
17. Kit Kovacs (NPI)
18. Martin Haupt (AWT, S. Africa)
19. Ola Rugland (helicopter pilot Airlift)
20. Harold Ederson (helicopter technician Airlift)

Technical Support:
21. Kristen Fossan (NPI, ocean moorings)
22. Jan Are Jacobsen (NPI, ocean moorings, sea ice)

Outreach:
23. Cheryl Katz (freelance journalist)
24. Lawrence Hislop (photography/film)

3. Sailing log

Thurs 29/09/2019	Arrival of most participants in LYB
Fri 30/09/2019	Clothing and gear from OLA-LYB. Survival suit course for 4p in morning, polar bear safety for non-NPI participants at NPI-LYB (not the full riffle course), and riffle + flare gun training for 6p (NPI mostly)
Sat 31/8/2019	Waiting for KPH to come in at 4pm. Last loading of pallets from OLA-LYB, and some unpacking after 4pm
Sun 01/09/2019	Checking in at 8:30. Unpack and install. Attempt to calibrate ADCP on land failed. Ready on board at 11:00. Departure at 13:20 (local time). Steaming all night to 0°W, 78°50'N for first CTD on main section.
Mon 02/09/2019	Arrival at 0°W, 78·50'N for first CTD at ~ 1000 (local time). CTD at 1°W. Mooring F10 recovery at 18:30 local time. Released but not in sight, takes ± half hour to spot it, no ice but quite some waves and foggy, visibility about 1 nm. Continue with CTDs overnight at 2°, 2.5°W and 3.5°W. Start drifter deployments at 2°W and at each half degree onward.
Tue 03/09/2019	Arrival at 3°W / F11 at 7 am. Started with CTD here first. Recovery of F11 postponed because of bad weather, same for F12. Continue with CTDs on section 4°W, 4.5°W (first little bit of ice here), 5°W. Recover F13 first instead. at 16:40 local. Little sea ice here damps the waves. No sea ice work. Too bad weather for flight. CTD at 5°W and 6°W. Night: steam back to F11.
Wed 04/09/2019	Recovery of F11 (morning), F12 (afternoon), and F13 (after midnight). Couple of CTDs in between and EM-bird flight in the evening. Steam to F17 overnight
Thurs 05/09/2019	Arrival at F17 at 8 am. No mooring there. Communication with the release shows it was dragged by an iceberg ~1100 m to the east-southeast. Found the location with triangulation (78° 50.100'N, 8°7.782'W) and MB and EK showed that only release and some floats are there, no mooring instruments anymore. Do not start dredging since no time for it. May do so later in the cruise or else next year. Afternoon: flight for whale research and MOB operation to collect thin ice for microplastic. Continue with CTDs on the section from 8W to ~ 13.5 or 14°W until after midnight.
Fri 06/09/2019	7 am not quite done with CTDs, last one was at 13°W, then a lot of broken up land fast ice spread out. Detour a bit to the south first to continue north at 14°7'W to find land-fast ice, toke one final CTD at 14°7W on the section. Lots of fast ice has been broken up last days after the strong northerly winds causing swell. Cannot find proper land-fast ice to work on until 2pm. Get 3 groups out on ice. Stay here the rest of the day. Flights for whales: morning, afternoon and evening. ADCP calibrations did not go well, needed to change out ADCPs, batteries and still no success. At 11pm call for polar bear at 1000m distance, we are called back to ship. Wait here until next day to finish ADCPs (ship is moored to the anchored ice)
Sat 07/09/2019	Continue 3 ADCP calibrations on the fast ice 8am. Still no success. Need to have a double set of ADCPs for ALL moorings. Flight for whales. Pick up at 11:30 am.

	Steam to the start (NE) of the Isle de France section. Start there at 21:30 local time.
Sun 08/09/2019	All morning and afternoon CTDs on Isle de France. We cannot make it all the way through since lots of very heavy old broken up fast ice on the SW end of the section, had to give up the last 4 stations. Return around 5pm local time. Steam to ~78°50'N, 11°W. Looking for thin ice to do MOB operation for thin ice, but polar bear occurred twice, postponed to next morning.
Mon 09/09/2019	After 8am, look for thin ice, about 1 hr of sampling from 9-10 am local time. Steam straight east at 78°38'N to deploy drifters since there is too much ice in the north, then head north again to the main section. Flight for whales in afternoon. Do not reach F17 in good time (not until 11pm) so decided to take 4 more CTDs around 10-9W to fill in gaps during the night. This is where we see a jet on the shelf typically. CTD cable in main hangar got damaged, had to stop with moon pool CTDs, continued with 2CTDs with small rosette from CTD hangar
Tues 10/09/2019	Arrival at F17 at 7am,check ice and drift conditions. Deploy F17 after 8am, followed by a CTD. Decide to steam to F14 since there is a lot of ice and it may take several hrs. Deploy F14 at 4am. Continue to 5.5W to try to recover F13B in the evening. Followed by CTD at 5.5W. Night, one more CTD over 800 m isobath
Wed 11/09/2019	Third attempt to recover F13B, better visibility and ice conditions ok. Recover at 6:30 am UTC. Too much swell to do ice work, cancelled, postponed to afternoon. Prep for F13B deployment at 08:45 UTC. Deployment goes quick and easy. After lunch, still too much swell for ice work. Prep for F13 deployment after 13:30 pm UTC. Deployed at ~15:33 UTC, easy once the ship was positioned such to keep the fast drifting ice away from the back deck. After dinner: head to the north-northeast into more heavy pack ice to get rid of the big swell that comes from the southeast. Sea ice station (7p) on one floe, 2 small boat trips, quiet weather, no swell, in the evening. Move further northeast to find another floe for Thurs morning at 7am.
Thurs 12/09/2019	Ice station from 8:30-11:30 am north of F12 at approx. 79°10N and 4°W. Steam south to F12 mooring site. Take a calibration CTD (#238) before dinner and deploy the mooring F12 after dinner at 16:31 UTC. Prep wire for last two moorings to go out Friday. Steam to ~10nm north of F11 to try an ice station early Friday morning.
Fri 13/09/2019	Ice station cancelled because of fog despite the presence of lots of good floes. Too risky, polar bear danger with no visibility. Steam to F11 mooring site (78°50'N, 3W), take a calibration CTD and deploy F11 at13:48 UTC. Steam to F10 but slightly south of the section in order to avoid ice, deploy 3 more drifters before getting to F10 at ~2W. Deploy F10 finally at 19:34 UTC (21:34 local time). Continue eastward along the main CTD section to continue with the CTD work again at 1°E. Start there around mid-night.
Sat 14/09/2019	CTDs along the section to the east. Calm weather, flat seas. Start packing up (mooring gear) and cleaning. Writing reports!
Sun 15/09/2019	Finished the CTD section already at 8 am (local time). Very smooth sailing and calm weather. Spend time on the shelf break for the whale team while the CTD water sampling analysis is being done during the day (~12 hrs). No options to fly anymore, no whale sightings, sailing around Foraustlanded. Evening start steaming to LYB. Request from ship was to get in on Monday 8 am so that the CTD (moon pool) cable can be terminated and fixed.
Mon 16/09/19	Arrival in LYB very early am. Packing and cleaning.

Tues 17/09/19	Offloading the vessel in the morning. Departure from participants from LYB

4. Mooring operations during FS2019

The moorings (F11, F12, F13, F13B, F14) from the Fram Strait Arctic Outflow Observatory were recovered and redeployed. Unfortunately, F17 on the shelf (8°W) was lost, likely dragged by an iceberg since we triangulated the release to be 1 km west from the position.

F10 was recovered and serviced after two years, which is an attempt to continue the time series in the recirculation area and abandoned by AWI in 2016. The extra mooring F13B at 5.5°W for enhanced near-surface measurements (IceCAT in EGC core) was recovered and deployed again as well.

There were two IceCATs deployed (F13B and F17), both were lost. No data from F17 since while mooring was gone. Good data from F13B until Dec 2018 only. Likely it got hit by an iceberg since also the ADCP stopped working then. 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.

4.1 Moorings recovered during FS2019

Mooring	Position	Depth (m)	Date and time (UTC)	Instrument	Serial #	Instrument depth (m)
F10-14	N 78° 49.624' W 01° 57'.048	2657	Deployed: 8 Sept 2017, 12:23 UTC. Recovered: 2 Sept 2019, 16:43 UTC	ADCP RCM7 **SBE37** **SBE37** RCM Seaguard **SBE37** RCM8 AR861	16831 1175 **13253** **14100** 1846 **8227** 12733 1424	65 67 **69** **239** 253 **2649** 2651 2654
F11-20	N 78° 49.161' W 03° 3.248'	2474 m (EK80) vs 2488 m (MB)	Deployed: 9 Sept 2018, 09:34 UTC Recovered: 4 Sept 2019, 07:28 UTC	IPS **SBE37** ADCP **SBE37** RCM9 **SBE37** RCM11 **SBE37** RCM8 AR861	**51062** **3490** 18070 **4702** 1324 **3552** 494 **8821** 10071 287	**53** **56** 61 **269** 272 **1537** 1539 **2452** 2455 2460
F12-20	N 78° 49.270' W 04° 1.327'	1864	Deployed: 8 Sept 2018, 09:25 UTC Recovered: 4 Sept 2019, 10:59 UTC	**IPS5** **SBE37** ADCP **SBE37** **SBE37** RCM Seaguard **SBE37** RCM11 **SBE37** RCM11 AR861	**51167** **3489** 24385 **7074** **4837** 884 **3554** 235 **8822** 228 182	**59** **61** 65 132 **281** 288 **1491** 1493 **1834** 1836 1839

F13-20	N 78° 50.392' W 04° 59.485'	1045 (too deep, mooring length off...? ADCP at 50m. MB ok with 2017 data. EK80 off?)	Deployed: 7 Sept 2018, 10:44 UTC Recovered: 3 Sept 2019, 14:40 UTC	**IPS** **SBE37** ADCP AURAL **SBE37 (extra...)** **SBE37** **SBE37** RCM9 **SBE37** RCM11 AR861	**51064** **7056** 16876 NA **12234** **12232** **3993** 1327 **3551** 561 053	**47** **55** 60 82 **112** **162** **264** 267 **1020** 1022 1027
F13B-5	N 78° 50.261' W 05° 30.848'	530 m	Deployed: 6 Sept 2018, 12:53 UTC Recovered: 11 Sept 2019, 06:38 UTC	**SBE37-IM weak link** ADCP ICEBOX **SBE37** RCM7 **SBE37** AR661	**13506** 727 N/A **12233** 7718 **10295** 291	**15 (62!)** 60 58 **N/A** **no data** 100 **149** 504
F14-20	N 78° 48.870' W 06° 30.055'	272	Deployed: 6 Sept 2018, 08:35 UTC Recovered: 4 Sept 2019, 22:35 UTC	**IPS** **SBE37** ADCP **SBE37** **SBE56** **SBE56** **SBE37** RCM9 AR861	**51138** **14097** 20021 **14098** **3943** **3944** **3992** 1046 506	**50** **54** 60 **101** **204** **229** **256** 258 262
F17-15	N 78° 50.175' W 08° 4.879'	226	Deployed: 5 Sept 2018, 14:03 UTC **Lost: taken by an iceberg :(**	**SBE37-IM (no DL)** **SBE16** **SBE37** ADCP **SBE16** **SBE56** **SBE37** AR661	**15910** **6693** 2962 7636 **6694** **3944** **7062** 110	

Table 4.1: Moorings recovered during FS2019. See mooring diagrams at the end of the cruise report.

Notes:

- F10 recovered in good shape after two years.
- The IceCAT on F13B was lost, good data until Dec 2018 at 15m, after that, it fell down to 65m. It completely stopped in March. Likely it was hit by an iceberg in March since then the ACDP also stopped working... The Microcat at 100m depth SN 12333 stopped after 10 days, leakage in battery pack. Send to Seabird but it was indeed flooded and they could not retrieve data.
- Data from SBE37 SN 7056 from F13 could not be downloaded, need to send to Seabird to have it checked. There they could extract the data, we got it in xml format / plain text.
- F17 was lost; release was dragged ~1000 m west, likely by an iceberg. No instruments anymore, release was located, see log, and perhaps dredge for release later or next year.

4.2 Moorings deployed during FS2019

Mooring	Position	Depth (m)	Date and time (UTC)	Instrument	Serial #	Instrument depth (m)
F10-15	N 78° 49.623' W 01° 57.036'	2663 m (EK80 likely 10 m off, top is 50 m below surface)	Deployed: 13 Sept 2019, 19:34 UTC	ADCP RCM9 **SBE37** RCM7 **SBE37** **SBE37** Nortek Aquadopp* AR861	18070 (dir only) 1175 **7059** 9464 **14099** **8226** 930 506	50 52 **54** 180 **222** **2634** 2639 2640
F11-21	N 78° 49.121' W 03° 3.072'	2454 m added 10 m kevlar (EK80 likely 10 m off, IPS is just 43 m under surface)	Deployed: 13 Sept 2019, 13:48 UTC	**IPS5** **SBE37** ADCP **SBE37** RCM9 **SBE37** RCM11 **SBE37 (re-used)** RCM Seaguard AR861	**51062** **3492** 17462 **3996** 1049 **7061** 538 **8821** 834 499	**44** **46** 50 **273** 276 **1526** 1529 **2439** 2442 2445
F12-21	N 78° 49.274' W 04° 1.332'	1830 m (EK 1850 m?) (EK80 is likely 12 m off, top is ~ 64 m below surface)	Deployed: 12 Sept 2019, 16:31 UTC	**IPS5** **SBE37** ADCP **SBE37** RCM9 **SBE37** RCM11 **SBE37** RCM11 AR861	**51167** **7055** 20021 **3994** 836 **13505** 556 **10294** 117 500	**60** **62** 66 **278** 282 **1482** 1486 **1816** 1819 1820
F13-21	N 78° 50.346' W 04° 59.959'	1012 m	Deployed: 11 Sept 2019, 15:33 UTC	**IPS** ADCP **SBE16** AURAL **SBE37** **SBE37** RCM9 **SBE37** RCM Seaguard AR861	**51140** 18151 **7253** n/a **3995** **7060** 1326 **13504** 345 743	**50** 56 **59** 72 **147** **245** 248 **996** 1000 1002
F13B-6	N 78° 50.213' W 05° 30.149'	524 m	Deployed: 11 Sept 2019, 09:40 UTC	**SBE37-IM weak link** ICEBOX RCM Seaguard **SBE37** **SBE37**	**21029** n/a 883 **9853** **9852**	**34** 60 65 **67** **106**

				AR661	410	519
F14-21	N 78° 48.884' W 06° 30.001'	269 m	Deployed: 10 Sept 2019, 14:34 UTC	**IPS** **SBE37** ADCP **SBE37 (re-used)** **SBE56** **SBE37** RCM9 AR861	**51138** **7058** 17461 **7054** **3943** **7057** 1325 568	**46** **52** 56 **100** **207** **257** 260 261
F17-16	N 78° 50.180' W 08° 4.798'	226	Deployed: 10 Sept 2019, 07:06 UTC	**SBE37-IM weak link** **SBE16** **SBE37** ADCP **SBE16** **SBE56** **SBE37 (re-used)** AR661	**21024** **7212** **13525** 24518 **7339** **3942** **14098** 501	**24** **54** **105** 105 **108** **180** **214** 216

Table 4.2: Moorings deployed during FS2019. (Full SN of Nortek Aquadopp: 42836-1-930)*
See mooring diagrams at the end of the cruise report.

Notes:

SBE37 recovered in 2019 and redeployed again:
--> Redeployed SN 14098 (from F14-20) on F17-16
--> Redeployed SN 7054 (from F12-20) on F14-21
--> Redeployed SN 8821 (from F11-20) on F10-15

Send 2 SBE37for repairs in Sept:
--> SN 12233 had leakage in battery pack, stopped after 10 days. No useful data.
--> SN 7056 the data could not be uploaded, Seabird did so and send as xml plain text. OK

Calibration cast on CTD down to 1820 m were done for:
--> SN 8227 (F10 bottom)
--> SN 8821 (F11 bottom)
--> SN 8822 (F12 bottom)

4.3 ADCP calibrations FS2019

The calibrations of ADCPs on land-fast ice (6-7/9/2019) did not go at all for three ADCPs. In addition, the ADCP deployed on F10 could not finalize a 360° compass calibration and an RCM9 was added underneath it to obtain direction. This resulted in that we did not have a sufficient amount of well-calibrated ADCPs to deploy one on F13B. See details below.

- ! 3 ADCPs were calibrated in Tromsø (2/7/2019)
- ! We tried to calibrate one new one (SN 24518) in LYB (1/9/2019). This failed. Comm error. Exchange memory card and try on ice. After several attempts it remained with a large error.

F17	F14	F13B	F13	F12	F11	F10 deploy for 2 years
Attempt in LYB: bad memory card. Exchanged with another one and calibrated on fast ice. Use look-up table for post-cal.	Calibrated in Tromsø	No calibrated ADCP to deploy. Only RCM here.	Calibrated in Tromsø	Calibrated on fast ice	Calibrated in Tromsø	Attempt to calibrated on ice failed, deploy with an RCM
Error after cal: 12.8°	Error after cal: 1.4°	--	Error after cal: 1.0°	Error after cal: 2.8°	Error after cal: 2.4°	No calibr. Error in dir, speed only!
Lithium	Lithium	--	3 alkaline	3 alkaline	Lithium	3 alkaline
BTM track	ICE track	--	BTM track	BTM track	ICE track	BTM track
SN 24518 (=new)	SN 17461	--	SN 18151	SN 20021	SN 17462	SN 18070

Table 4.3: ADCP deployment plan 2019.

5. CTD Measurements

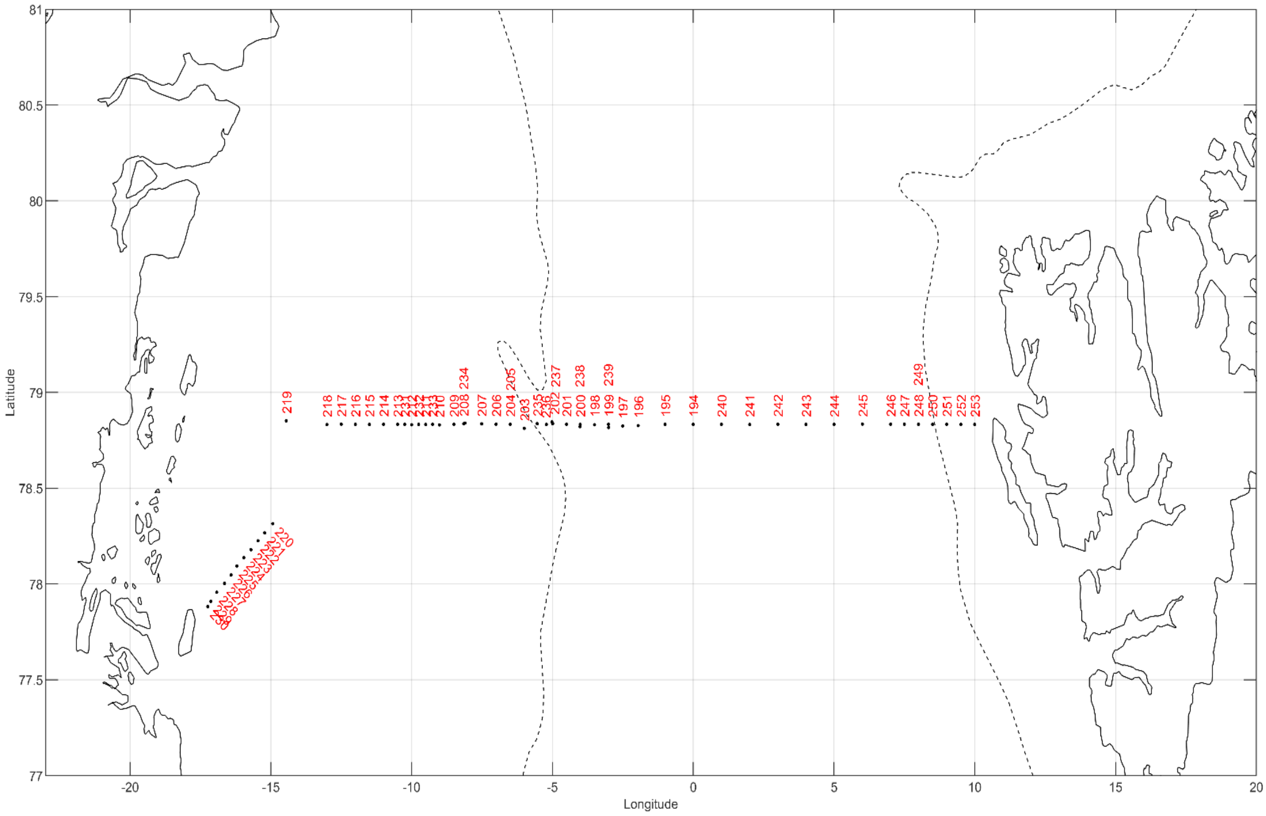


Figure 5.1. CTD stations completed during FS2019. Where two stations occur at the same location, the number of the second station is offset for readability.

5.1 General Approach

The CTD used was an SBE911+ unit. The T, S and O_2 ducts was flushed with Triton-X and freshwater between stations, and then rinsed with seawater just before deployment, to avoid problems with icing. At the beginning of stations the CTD was lowered to 10 dbar and allowed to soak until the pump started and sensors stabilised. The CTD was then brought to the surface and then lowered to within 10 m of seabed as determined using the altimeter. The CTD and deck unit were powered on ca. 10 minutes before the beginning of each cast to allow the lamp in the ISUS nitrate fluorometer to warm up and stabilise. Data acquisition was generally initiated just before deployment 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 Isle de France section the CTD was lowered though a 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. Note that on some stations only odd-numbered bottles were used. NMEA time and position information was fed to the acquisition computer and added to each scan line of the data files. Cast positions and starting times were also automatically added to the header of all data files. Note that the first station completed during Fram Strait 2019 has the number 194 and not 001. The vessel operators specify numbers assigned to CTD stations. The first cast each year has the number 1 and subsequently casts are numbered sequentially.

5.2 CTD Package Configuration

Channel	Sensor	Serial Number	Last Calibration
Frequency	Temperature 1	4534	19-May-2019
Frequency	Conductivity 2	2860	09-May-2019
Frequency	Pressure	12162	19-Dec-2017
Frequency	Temperature 2	5884	21-May-2019
Frequency	Conductivity 2	4386	09-May-2019
A/D Voltage 0	SBE43 Oxygen 1	3636 (Stns. 194-194) 3785 (Stns. 195-end)	05-Dec-2017 04-Dec-2018
A/D Voltage 1	Altimeter	73084	24-Dec-2017
A/D Voltage 2	SBE43 Oxygen 2	3115	05-Jun-2019
A/D Voltage 3	CDOM Flourometer	FLCDRTD-1930*	25-Jul-2019
A/D Voltage 4	Transmissometer	CST-1839DB	14-Dec-2017
A/D Voltage 5	Chl. Flourometer	FLRTD-1547 (Stns. 194-203)	01-Apr-2016
A/D Voltage 6	I S U S V 3 NO_3 Flourometer	232 (Stns. 204-237)	User Polynomial
A/D Voltage 7	Free	N/A	N/A

Table 5.1: CTD package configuration during FS2019. Primary Oxygen sensor SBE43 3636 was replaced with SBE43 3785 after station 194. CDOM fluorometer FLRCTD1930 has an internal gain setting (AsV) which can be varied between 1, 2 and 4. AsV was set to 1 during FS2019 (maximum gain, smallest range). On previous Fram Strait cruises the AsV was probably set to 2. The ISUS V3 was only deployed at stations shallower than 1000 m over the East Greenland Shelf (203-237) due to operating limits.

5.3 CTD Sections

Very open drift ice conditions on the East Greenland Shelf allowed the vessel to move along two sections during the cruise (Figure 5.1). Station times and the types of samples collected are summarized in Table 5.3:

1. Main Fram Strait Section (Figure 5.2): An east-west section along the Fram Strait mooring array line at 78º50'N, which is repeated annually. During Fram Strait 2019, stations were completed between 010°E and 013.5°W. Station spacing was 1°longitude (~20 km) for most of the section and 0.5°longitude (~10 km) in the cores of the inflow and outflow and over the East Greenland Shelf.

2. Isle de France Section (Figure 5.3): 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 northwestern 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.

5.4 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 section. 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 163.

Comparison of laboratory salinity measurements and CTD-salinity measurements revealed an offsets of 0.001 practical salinity units for both the primary and secondary sensor groups (Figure 5.4). The mean difference between both the primary and secondary sensor group and the laboratory measurements was, smaller than the precision of laboratory salinity measurements (+/- 0.003) so no correction is made here.

Both sets of CTD sensors performed well during the cruise. The small offsets determined relative to the laboratory salinity measurements and excellent agreement between primary and secondary sensor groups reflects the very recent calibration of the conductivity sensors. Freshly calibrated primary and secondary sensor sets deployed during the 2017 Fram Strait cruise showed similar mean offsets of +0.0007 and +0.0008 practical salinity units. Sensors deployed during the 2018 Fram Strait Cruise, which had been used for more than 8 months without calibration showed larger offsets of 0.003 and 0.004, and approached the level where post-calibration would be necessary.

5.5 Dissolved Oxygen Sensor Validation

Water samples for laboratory oxygen measurement were collected at standard depths of 400, 1000 and 2000 dbar and at the bottom of the cast at stations along the main and Îsle de France sections. Samples were collected in triplicate in volume-calibrated glass bottles, with an angled glass stopper. A silicon tube was attached to the spigots of the Niskin bottles and inserted to the bottom of the sampling bottles, which were filled slowly to minimise exposure to the atmosphere. Winkler re-agents 1 and 2 were added to the samples immediately after sampling and samples were then stored under water, and allowed to reach room temperature to allow volumetric consistency with reagents added during analysis.

Analysis followed standard protocol using a Metrohm Ti-Touch potentiometric titrator, with a 2 ml dosing unit filled with 0.1M thiosulphate. Samples were run in 7 batches of 3 to 30 samples. Sets of 4 blanks were run before and after each batch of samples and 4 measurements of an internal iodate standard (0.01M, prepared at NPI in Tromsø on 19-June-2019) were run before each batch of samples.

Comparison of laboratory oxygen measurements and CTD-oxygen measurements revealed an offset of 4.16 µmol l^{-1} for the primary sensor and an offset of 0.62 µmol l^{-1} for the secondary sensor (Figure 5.4). The primary sensor had not been serviced / calibrated for more than 8 months before the cruise and this may be the reason for the large difference with laboratory measurements and the abnormal shape of the sensor/laboratory histogram.

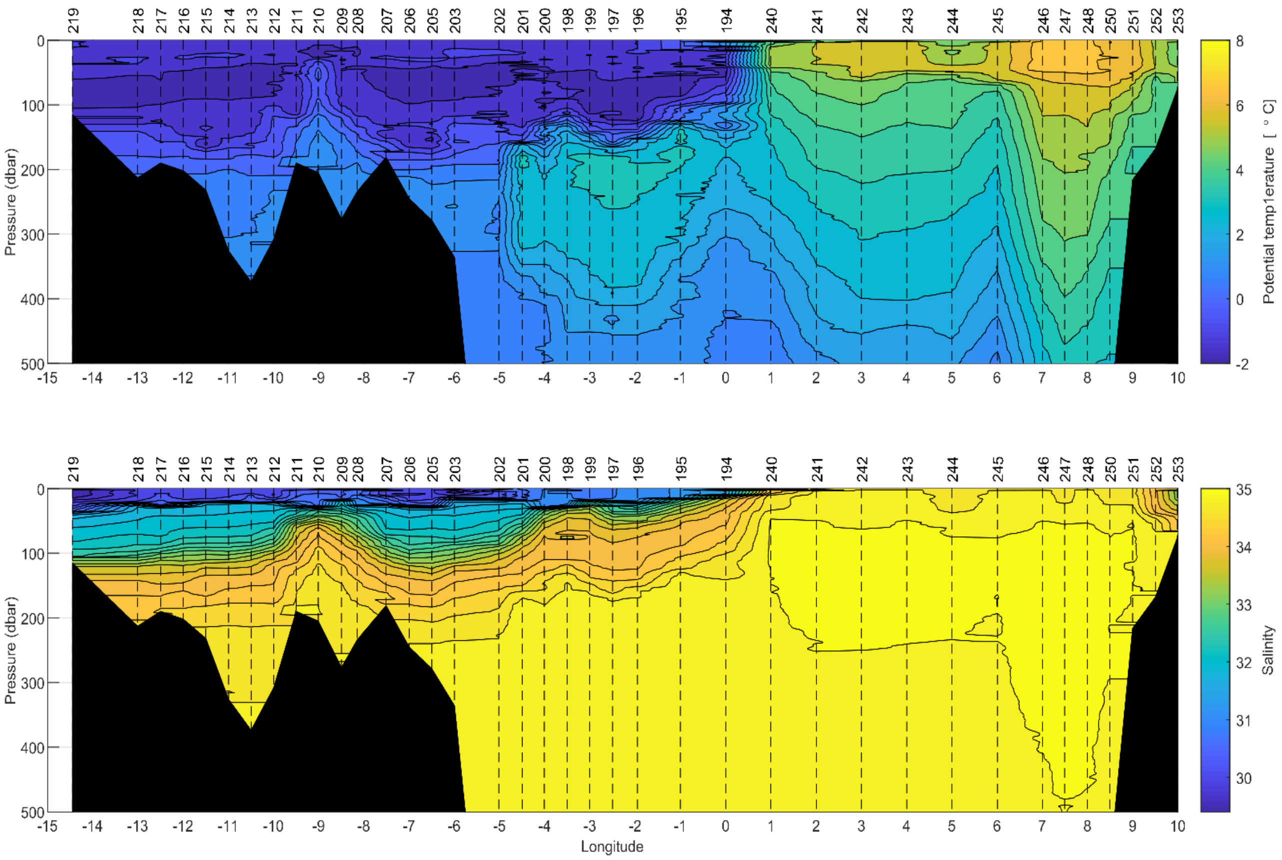


Figure 5.2: CTD measurements along the Main Fram Strait Section; Measurements from the primary temperature (top panel) and salinity (bottom panel) sensors. Station numbers are indicated above sections.

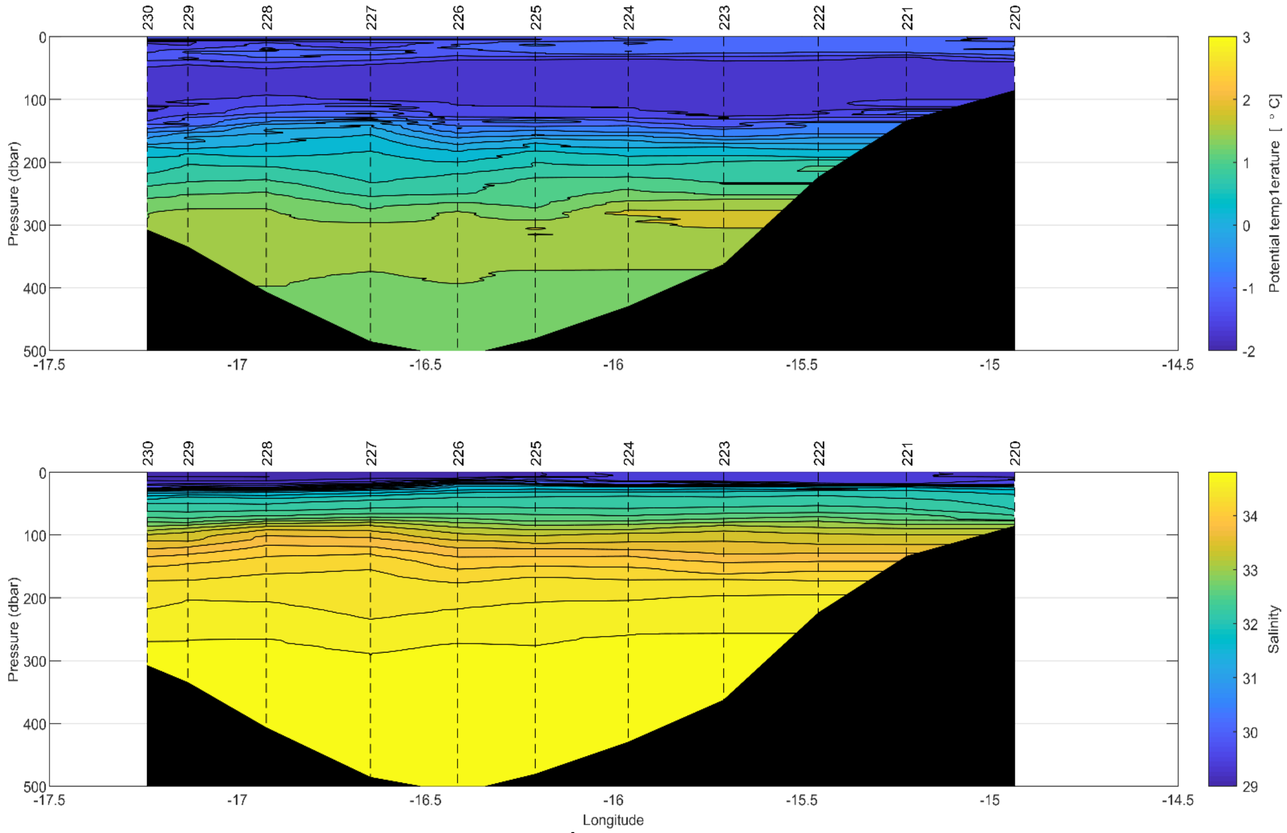


Figure 5.3: CTD measurements along the Îsle de France Section Measurements from the primary temperature (top panel) and salinity (bottom panel) sensors. Station numbers are indicated above sections.

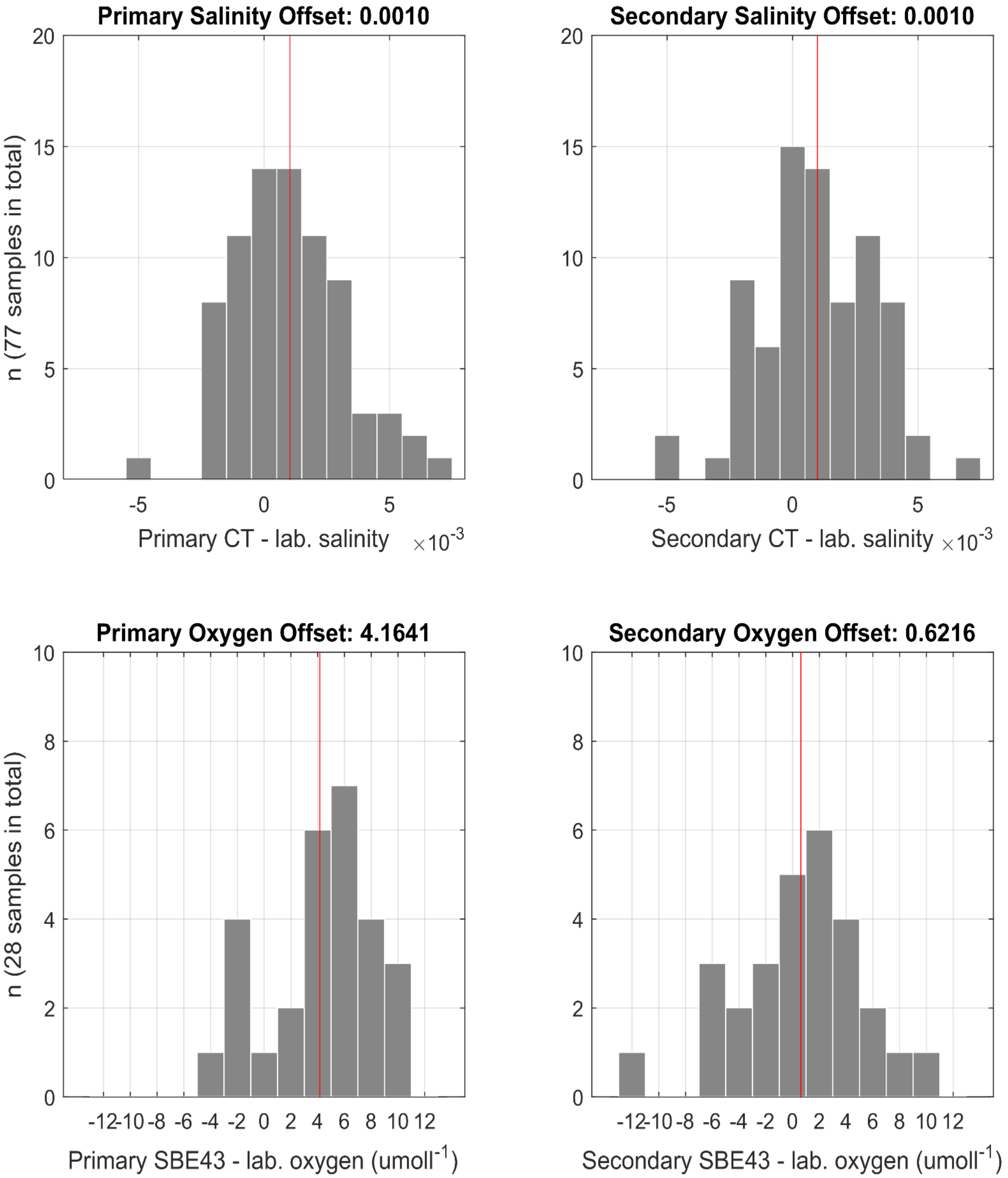


Figure 5.4: Histograms showing the difference between the primary (left hand panels) and secondary (right hand panels) sensor groups on the CTD and laboratory salinity and dissolved oxygen measurements. Only points deeper than 400 m are considered for salinity validation, due to step salinity gradients close to the surface.

6. Biogeochemical Program

Table 6.1 lists sample types that were collected from Niskin bottles and melted sea ice cores. Samples marked with an asterisk were analysed onboard, other samples will be analysed ashore.

Variable	Description
Laboratory Salinity*	Used to validate and (if necessary) calibrate conductivity sensors on the CTD. Required to obtain representative salinity values for Niskin bottles closed in steep salinity gradients, where CTD salinity values are unsuitable.
Dissolved Oxygen*	Used to validate and (if necessary) calibrate dissolved oxygen sensors on the CTD. Dissolved oxygen is a basic parameter, which can be used to estimate water mass ages, interpret how non-conservative parameters have been affected by biological interactions and to trace Pacific water in combination with dissolved nitrate measurements.
Dissolved Inorganic Carbon (DIC) & Total Alkalinity (A_T)	Used to investigate the carbonate system, including estimation of carbon fluxes and monitoring of the ocean acidification state.
Dissolved Organic Carbon (DOC)	Used to investigate the carbonate system, including estimation of carbon fluxes. NB: Measured from nutrient bottle samples.
Nitrate, Nitrite, Phosphate & Silicate*	Used to investigate nutrient cycling in Arctic Ocean, to trace Pacific Water and to calibrate the ISUS nitrate fluorometer deployed on the CTD, which measures continuous profiles of dissolved nitrate. NB: Duplicate sampling planned in case of problems with onboard measurements.
Coloured Dissolved Organic Matter (CDOM)*	Used to trace fresh water masses in the Arctic Ocean, to investigate the optical properties of the water column and to help interpret carbonate system measurements. CDOM samples are used to calibrate the CDOM fluorometer on the CTD, which measures continuous profiles of CDOM, which responds to a single excitation wavelength.
Stable Nitrogen & Silicon Isotopes	Used to map the isoscape in Fram Strait – the isoscape is used to interpret isotope ratio measurements in organisms from the perspective of describing food webs. Also used to validate nutrient and nutrient-oxygen ratios employed to trace Pacific and Shelf waters, which are affected by nitrifying and de-nitrifying organisms.
Stable Oxygen Isotopes ($\delta^{18}O$)	Used to separate sea ice meltwater from river input & precipitation. Combined with CDOM and/or total alkalinity measurements $\delta^{18}O$ is also be used to identify freshwater from precipitation.
^{129}I	Used to trace Atlantic-derived water masses circulating in the Arctic Ocean basin. Also used to study the fate of anthropogenic radionuclides released by fuel reprocessing.

^{236}U	Combined with ^{129}I, ^{236}U provides more information about the age and pathways followed by Atlantic-derived water masses.
^{233}U	Combined with ^{129}I, ^{233}U provides more information about the age and pathways followed by Atlantic-derived water masses.
^{13}C	Used to estimate the age of various water masses.

Table 6.1 – Variables measured from water samples collected during FS2019

Samples collected from the water column

Table 6.2 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.

Station	Salinity	Winkler	$\delta^{18}O$	Nutrients	A_T-C_T	$\delta^{15}N$	δSi	^{129}I	^{233}U	^{236}U
194	20		12	12	12	12	10	11		11
195	12	9	12	12	12	12				
196	15	9	12	12	12	12		10		10
197	16		12	12						
198	16	9	12	12						
199	15		12	12	12	12	9	11		11
200	14		11	11	11	11		11		11
201	15		12	12						
202	12		12	12	12	12	9	8		8
203	11		11	11	11	11		7		7
204										
205	10	3	10	10						
206	10	3	10	10	10	10	8	6		6
207										
208	10		10	10	10	10		5	12	6
209	0									
210	9		9	9	9	9		6		
211										
212	10	3	10	10	10	10	8	5	10	5
213										
214	11	3	11	11	11	11		6		
215										
216	9	3	9	9	9	9	8	6	12	6
217			0							
218	9		9	9						
219	8		8	8						
220	6	3	6	6	6	6	5			
221										

222										
223										
224	12	3	12	12	12	12	10			
225										
226	12		12	12	12	12		8		8
227										
228	10	3	10	10	10	10	8			
229										
230	10	3	10	10	10	10	8			
231		3								
232		6								
233		3								
Station	**Salinity**	**Winkler**	**$\delta^{18}O$**	**Nutrients**	**A_T-C_T**	**$\delta^{15}N$**	**δSi**	**^{129}I**	**^{233}U**	**^{236}U**
234										
235	11	6	11	11						
236	12	9	12	12						
237		3								
238										
239		3								
240	12	3	12	12	12	12				
241	12		10	10	10	10		9		9
242	12		12	12						
243	12		12	12	12	12	9			
244	12	6	12	12						
245	12		12	12	12	12				
246	12		12	12	12	12	9			
247	12	3	12	12						
248	12		12	12	12	12	8	9		
249									12	
250	12		12	12						
251	10		10	10	10	10		6		6
252	9		9	9						
253	6		6	6	6	6	5			

Table 6.2 Number of each type of water sample collected at each CTD station.

Samples collected from melted sea ice cores

Sea ice cores for biogeochemical analysis were collected from sea ice at the locations shown in Figure 6.1. Whole cores were melted onboard in a single container and meltwater samples were collected for the following analyses:

- Laboratory Salinity
- Stable Oxygen Isotopes ($\delta^{18}O$)
- Nitrate, Nitrite, Phosphate & Silicate
- Coloured Dissolved Organic Matter (CDOM)
- Total Alkalinity (A_T)
- ^{236}U

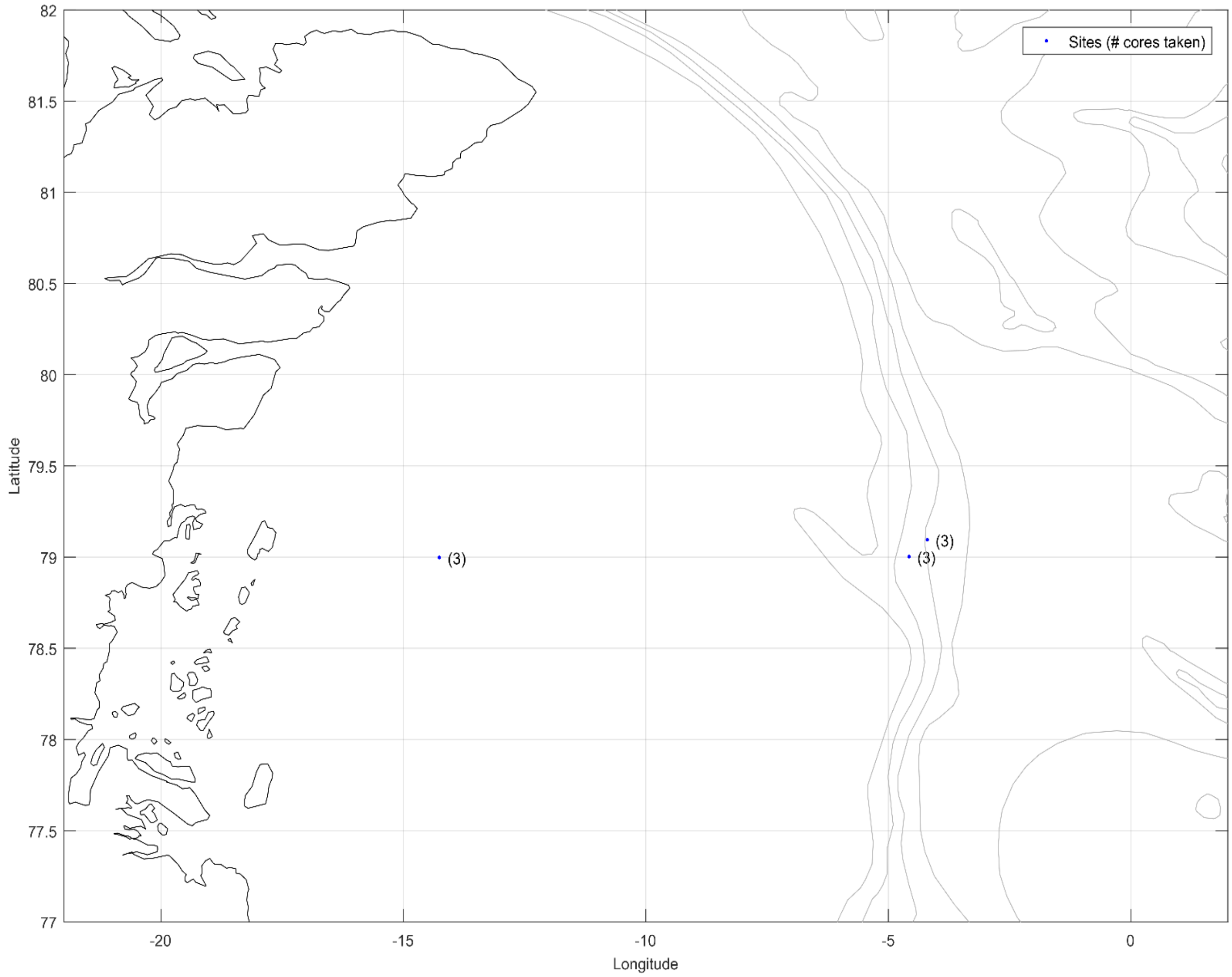


Figure 6.1 Locations where sea ice cores were collected for biogeochemical sampling.

7. Sea ice work on Fram Strait 2019 cruise

7.1 General

The sea ice work on Fram Strait 2019 cruise was coordinated by Dmitry V. Divine (NPI), with a support from Jean Negrel (NPI), Paul Dodd (NPI), Microplastic group of Ingeborg Hallanger (NPI) and Vegard Sturzinger (NPI), and the CTD team members during stations on the ice.

As in the previous two years, 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 in the core of the ECG and open water almost all the way to 12°W. Sea ice work was further hampered by a relative shortness of the cruise this year and unfavorable weather conditions: twice sea ice stations had to be canceled due to safety reasons such as swell and fog.

Altogether we made 5 sea ice stations (see Table 7.1) which include three regular ice stations on drift ice and two thin ice sampling. A 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 covered waters.

7.2 Helicopter-borne sea ice thickness measurements (HEM-surveys) of ice thickness in the East Greenland Current

Via collaboration with a group on whale research (Lydersen and Kovacs) we conducted an aerial regional scale sea ice survey in the area of the core of the East Greenland current. During a 1 hour and 25-minute-long flight some 120 km of sea ice covered area along the flight track was studied using a helicopter-borne electromagnetic instrument EM-bird (Figure 6.1)

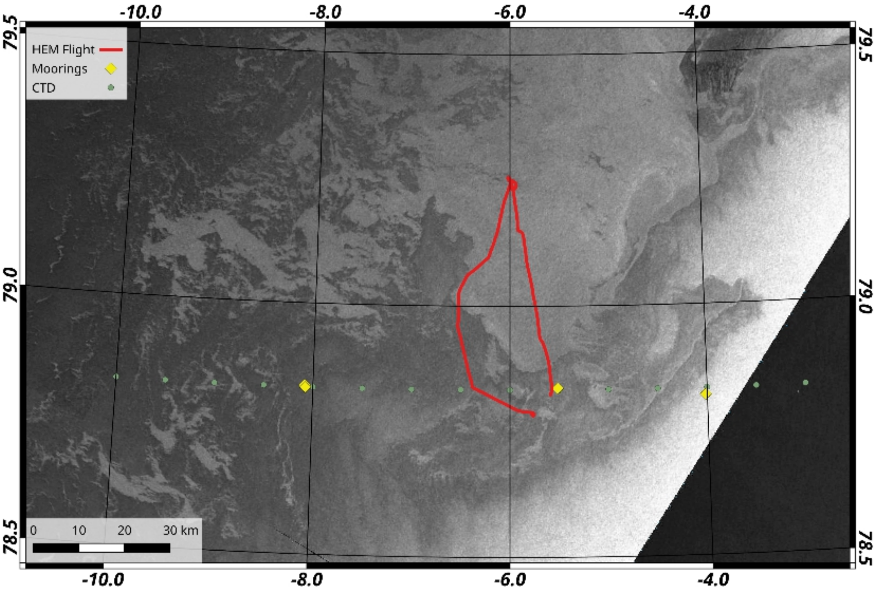


Figure 7.1. HEM-survey flight track. Note that the sea ice image was acquired some 2 days prior to the flight and do not exactly corresponds the real ice situation during the flight. Interpretation of the derived data including a conversion to the actual sea ice thickness will follow.

7.3 Sea ice stations

On three main sea ice stations (S2, S4, S5) we collected ice cores for salinity and temperature analysis, chemical analyses, micro-plastic particles (collaboration with ocean microplastic group) and for archive storage and later analysis of the microstructure. Stations 1 and 3 were stations on thin ice. On every full sea ice station, 1 to 3 tracer cores were additionally collected by Paul Dodd (NPI) and his team. Stations positions are found in Table 7.1, and also shown in the main map for the cruise.

On a longer station on fast ice, sea ice thickness of the floe was additionally surveyed directly by thickness drilling and indirectly using a Geonics EM31-MK2 short (EM31SH). 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. The data acquired will be analysed later.

All three main stations featured rather think (2-3 m) and fresh ice according to salinity measurements; suggesting the ice floes surveyed were Second- or Multiyear ice.

Figure 7.2: Edge of multiyear fast ice east of Greenland. Note a relatively high melt pond fraction (some 30-40%) and a highly variable surface topography. Photo Lawrence Hislop.

Due to limited snow cover (0-2 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.

7.4 Thin ice sampling

The thin ice samples on Sea ice stations 1 and 3 were collected from the small boat. In addition we sampled thin ice from the Sea ice station 5 ice floe edge. Temperatures, salinity, thickness, and visual information were collected. Altogether, we had three thin ice sampling spots for each station. New ice formation whenever observed, was also registered in ASSIST.

Figure 7.3: Sea ice station 5; thin ice sampling procedure from the floe edge, 12.09.2019

7.5 Ice observations from the bridge (ASSIST)

Sea ice conditions were observed every one to three hours, except for the night time between midnight and 6:30, from the observation deck of RV KPH. 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 some 60 observations were made during the cruise while RV KPH was in the ice zone.

7.6 Ice service for the cruise

In order to ensure efficient implementation of the cruise plan during operation/steaming in ice covered waters, sea ice group was responsible for providing satellite-based sea ice charts. The ice charts for the cruise were made on a regular, daily to twice-daily basis depending on the planned activities and the focus area. In total 18 ice charts were compiled, example is shown in Figure 7.4.

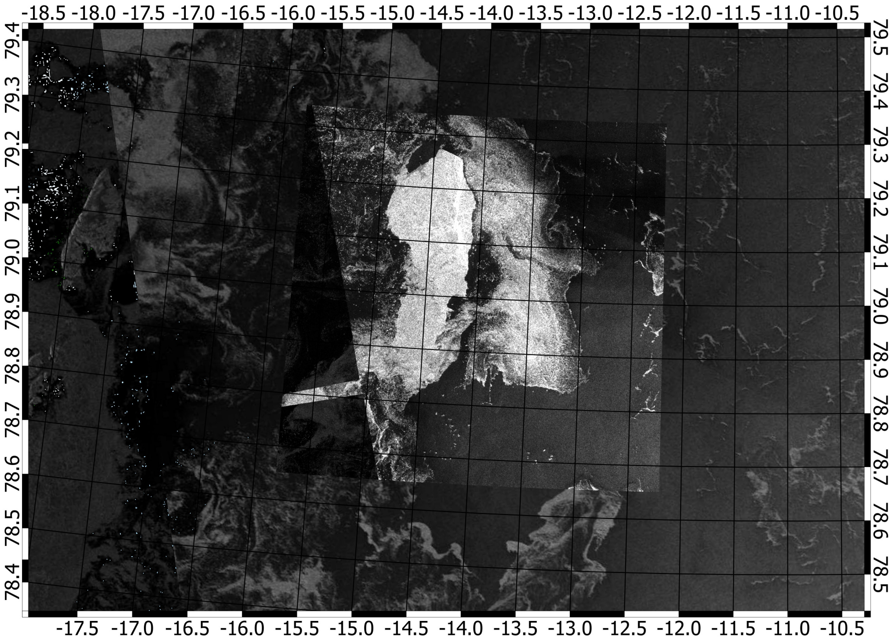


Figure 7.4: Ice chart from 06.09.2019 showing the breaking-up fast ice east of Greenland shore. The chart was used to navigate around the broken off piece to fast ice edge and sea ice station 2 site. Radar image Sentinel-1

7.7 Daily activities during the cruise

A detailed description of sea 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 FS2019 daily activities related to the sea ice work.

Date	Day	Stn #	Time (UTC)	Latitude (start)	Longitude (start)	Task/activities
01.09.2019	1		10:00			departure LYR; assembling EM-bird
02.09.2019	2					Transit - Instrument maintenance; testing EM-bird
03.09.2019	3					Data work, ASSIST observations
04.09.2019	4		18:45	78° 51.1'	-4° 59.1'	EM-bird flight
05.09.2019	5					Ice free area, data logging and analysis; working with

						ice charts and navigation towards fast ice
06.09.2019	6	S2	14:10	78.99	-14.26	Station on fast ice. Coring, Thickness drilling, EM31 surveys
07.09.2019	7	S3	08:10	78° 40.3’	-14° 28.9'	Bear guarding for ADCP calibration, data logging, and packing/analyzing collected samples from ice stations 1 and 2
08.09.2019	8					Office work, sea ice observations.
09.09.2019	9	S3	07:23	78° 38’	-12°30'	Thin ice station 3, data work
10.09.2019	10					Data analysis and processing; on stand by for sea ice station between 8 and 6 W. Moving slowly due to very thick pack ice in 4-6 miles wide strips.
11.09.2019	11	S4	19:40	79.0	-4°34'	Station on drift ice. Ice Coring, Thickness Drilling
12.09.2019	12	S5	07:00	79.144	-4.202	Station on drift ice. Ice Coring, Thickness Drilling
13.09.2019	13					Station on drift ice cancelled due to weather conditions.
14.09.2019	14					Packing EM-bird, report writing
15.09.2019	15					equipment maintenance and packing, report writing
16.09.2019	16					Arrival LYR; unloading KPH

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

8. Microplastic in sea ice, thin ice and sea water

Microplastic has been found everywhere in the Arctic. The highest levels of microplastic ever recorded are within sea ice with 38-20 000 microplastic particles per litre of sea ice. As a comparison, there are 0.00034 microplastic particles in a litre of seawater. The difference in number of microplastic between seawater and sea ice is huge and raise the question if sea ice has other sources for microplastic. Atmospheric transport of microplastic is possible and needs to be investigated.

This project will measure the amount of microplastic in sea ice cores, seawater from under the ice, a transect of sea water samples across the Fram strait and thin ice to answer how microplastic behaves in this environment. This will be used to identify sources of microplastic to sea ice, such as atmospheric transport or uptake through sea water. This project will also give us information on the exposure of microplastic to sea ice associated organisms. This knowledge can be used in modelling to explain how microplastic is incorporated into ice, and how microplastic can affect organisms.

Sea ice and sea water under ice

At ice station 2 in the Greenland fast ice, three sea ice cores were drilled for microplastic analyses. Through the core holes sea water was pumped up through filters. A total of 4 sea water samples were collected with volumes from 1.08 to 1.88 m^3.

Onboard sea water filtration for microplastic

The sea water inlet at 4 meters depth was used to sample high volume samples during the cruise. Water was collected before the filters for the onboard sea water system.

Thin ice sampling for microplastic

Samples of thin ice were collected from 5 locations during the cruise. Sample were collected by hand from the workboat (1-4) or from the side of an ice flow (5). At each location triplicates with approximately 3.5 litres of thin ice, and a blank sample, was collected.

Location	Date	Latitude N	Longitude W
1	05-09-2019	78° 50.106'	8° 31.95'
2	05-09-2019	78° 50.15'	8° 33.27'
3	05-09-2019	78° 50.23'	8° 35.009'
4	09-09-2019	78° 38.38'	12° 30.48'
5	12-09-2019	79° 14.411'	4° 20.238'

Table 8.1: Overview of thin ice sampling stations for microplastic

9. Whale program

The Fram Strait phase of the ICE-whales project in 2019 is nearly at an end. Weather conditions were largely conducive to searching, but ice conditions in the Greenland coastal polynya system were heavy (vast amounts of glacier ice in particular) and there were no bowheads sighted anywhere on the shelf. We only encountered four bowheads on the entire expedition, all in the mid-strait drift ice. One individual was tagged (sat, limpet) and biopsied. Narwhal were more numerous both coastally and in the drift ice, and we have done novel collections of biopsies from this population, which has never before been sampled. These samples will produce exciting scientific results when compared with the neighbouring population to the west on a variety of fronts (genetics, isotopic analyses of diet etc).

10. Drifter deployments

Surface drifters were deployed as part of the EGC DrIFT (East Greenland Current Drifter Investigation of Freshwater Transport) study. This project is funded by NWO (Netherlands Science Organisation) and is a collaboration with the ongoing freshwater monitoring in Fram Strait by the Norwegian Polar Institute. The aim of this project is to investigate the exchange of freshwater between the east Greenland shelf and the open ocean and to determine the impact of these freshwater fluxes on deep water formation regions. The drifters will highlight areas of exchange and will give insight into the mechanisms, for example wind-driven versus eddy-driven exchange. They will also show much mixing with surrounding waters occurs once the freshwater is off the shelf. This will be important to determine the impact on stratification in the convective regions. The first batch of 30 drifters in EGC DrIFT was deployed off Kulusuk, southeast Greenland in between 10 and 16 August 2019 and will cover the region between Kulusuk and Cape Farewell. The batch deployed on this cruise is aimed to cover the region between Fram Strait and Iceland.

The batch of 30 drifters deployed here consists of three types. The CARTHE drifters are small, relative inexpensive, biodegradable drifters (manufactured by Pacific Gyre) which transmit GPS position only. Their top consists of a donut shaped buoyancy body with a GPS unit in the center. They have cross-shaped fins with a depth of about 50 cm as sea-anchors. The SVP-I-XDGS drifters (manufactured by MetOcean) measure Sea Surface Temperature (SST) as well as position. They are based on the NOAA Surface Velocity Program (SVP) drifters, with a ~40 cm buoyant plastic sphere which also contains the GSP, iridium and sensors units and a holey sock sea anchors that extents 15 m below the sea surface. The SVP-BSC drifters (manufactured by NKE) measure SST, Sea Surface Salinity (conductivity), atmospheric pressure and position. They are similarly shaped as the SVP-I-XDGS drifters, but additionally have a short mast on top that contains the barometer.

At each position a CARTHE drifters is deployed together with a SVP drifters, to allow comparison in behaviour which may differ to due the different sea anchors. The drifter deployment positions are documented in Table 10.1. The first six deployments were made on the way west and are located on the east Greenland shelf slope near the main EGC core. West of 5°W ice coverage was too high for deployments, which may result in early loss of the anchor. Four deployments are located around 11°W, where a second southward core has been observed in earlier Fram Strait sections. The remaining five deployments were made on the way back east, near the EGC core and east of the drift ice.

#	Longitude West	Latitude North	Date Time UTC	CARTHE SN	SVP-I-XDGS IMEI	SVP-BSC IMEI
1	1° 34.39’	78° 29.76’	02-09-19 21:00	0-2677830	300234067057580	
2	2° 30.34’	78° 49.48’	03-09-19 00:30	0-2679725		300234068803170
3	3° 30.29’	78° 49.91’	03-09-19 03:55	0-2679547	300234067059930	
4	4° 00.61’	78° 49.94’	03-09-19 10:45	0-2679463		300234068603290
5	4° 30.04’	78° 49.99’	03-09-19 13:15	0-2679470	300234067055540	
6	4° 05.05’	78° 47.73’	04-09-19 12:20	0-2679032		300234068708270
7	10° 59.98’	78° 50.00’	05-09-19 22:50	0-2679528	300234067945770	
8	11° 30.03’	78° 49.97’	06-09-19 00:13	0-2679713		300234068602310
9	10° 59.69’	78° 37.30’	09-09-19 12:00	0-2679716	300234067056900	
10	10° 39.54’	78° 36.61’	09-09-19 12:40	0-2679720		300234068604400
11	4° 04.02’	78° 49.16’	12-09-19 18:00	0-2679858	300234067052580	
12	3° 39.76’	78° 48.02’	12-09-19 20:42	0-2679714		300234068501770
13	3° 14.55’	78° 49.53’	12-09-19 21:55	0-2679471	300234067055970	
14	2° 44.40’	78° 47.89’	13-09-19 14:58	0-2679723		300234068609530
15	2° 26.98’	78° 48.39’	13-09-19 15:32	0-2679865	300234067949780	

Table 10.1. Drifter deployment information.

10. 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 going through sea ice.

Lowered Acoustic Doppler Current Profiler (LADCP) data were collected at nearly 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 in the beginning from CTD 194 to 231. After that, the CTD work had to be continued with the small rosette and hence just a single-head LADCP was used on CTD # 236 to # 253.
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 A.

11. Outreach

This year we had a dedicated team for outreach on board. Freelance journalist Cheryl Katz interviewed scientists and students and wrote three stories based on the work done and its context during FS2019 cruise. She published two stories in National Geographic Online on the freshwater and AMOC and microplastic, and one at yale.edu on ocean acidification:

https://www.nationalgeographic.com/science/2019/12/why-ocean-current-critical-to-world-weather-losing-steam-arctic/

https://www.nationalgeographic.com/science/2019/10/remote-arctic-contains-more-plastic-than-most-places-on-earth/

https://e360.yale.edu/features/why-rising-acidification-poses-a-special-peril-for-warming-arctic-waters

Photo and film material was taken by former NPI colleague Lawrence Hislop. His photos accompanied the pieces Cheryl wrote and provided plenty of material to be used at NPI webpages, facebook, presentations, and further use in outreach illustrating the practical work done within the Arctic Outflow Observing system.

In addition, a short text and photos were send about twice a week by the science team to our home base at NPI to post on the oceanseaicenpi instagram account:
https://www.instagram.com/oceanseaicenpi/?hl=en

Appendix A: LADCP script files (Master, Slave and Single head)

```
; 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 M232_

; 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 S232_

$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

; Append command to the log file

$LC:\KH2019702\LADCP\ladcp_log.txt

$P

CR1

WM15

; !!! PRIOR TO EACH CAST MAKE SURE TO RENAME THE FILE NAME BELOW (L0xx_) TO MATCH THE CTD STATION NR !!!:

RN L116_

LZ030,220

CF11101

EA0

EB0

ED0

ES35

EX00111

EZ1111101

WB1

WD111100000

; blank after transmit [cm]

WF0176

; number of bins

WN015

; pings per ensemble

WP1
; bin length [cm]

WS0800

; ambiguity velocity [cm]

WV250

; SET AS MASTER ADCP

SM1

; TRANSMITS SYNCHRONIZING PULSE BEFORE EACH ENSEMBLE

SA001

; SYNCHRONIZING PULSE SENT ON EVERY PING

SI0

; WAIT .55 s after sending sync pulse

SW05500

; ensembles per burst

TC2

; time per burst

TB00:00:01.20

; time per ensemble

TE00:00:00.80

; time between pings

TP00:00.00

CK

; start Pinging

```
CS

; Delay 3 seconds

$D3

$p ********************************************************************************

$P Please disconnect the ADCP from the computer.

$P ********************************************************************************

; Close the log file

$L

;

;Instrument       = Workhorse Sentinel

;Frequency        = 307200

;Water Profile    = YES

;Bottom Track     = NO

;High Res. Modes  = NO

;High Rate Pinging  = NO

;Shallow Bottom Mode= NO

;Wave Gauge       = NO
```

;Lowered ADCP = YES

;Ice Track = NO

;Surface Track = NO

;Beam angle = 20

;Temperature = 5.00

;Deployment hours = 12.00

;Battery packs = 1

;Automatic TP = YES

;Memory size [MB] = 256

;Saved Screen = 1

;

;Consequences generated by PlanADCP version 2.06:

;First cell range = 10.11 m

;Last cell range = 114.11 m

;Max range = 116.10 m

;Standard deviation = 1.73 cm/s

;Ensemble size = 521 bytes

;Storage required = 21.46 MB (22507200 bytes)

;Power usage = 43.18 Wh

;Battery usage < 0.1

;

; WARNINGS AND CAUTIONS:

; WM15 feature has to be installed has to be installed in Workhorse to use selected option.

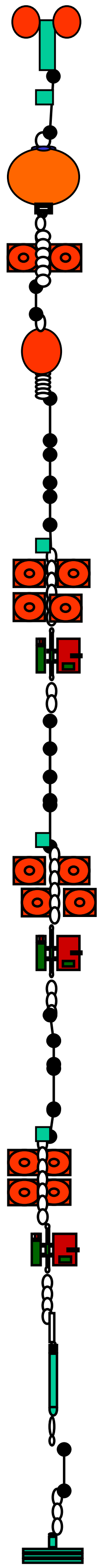
; Advanced settings have been changed.

Appendix B: Moorings recovered and deployed

Rigg F11-20

Satt ut 9 SEP 2018 kl 09:34 003 03,248W

Tatt opp AUG 201



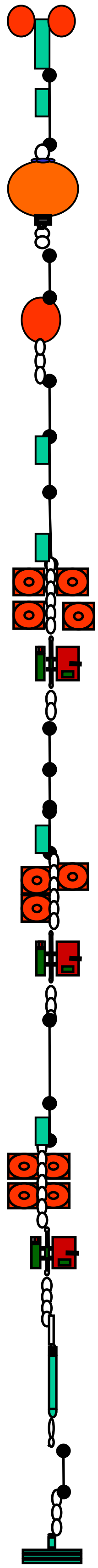
	78 49,161N	Dyp:	Fra bunn:	Ut:
IPS	SNR. 51062	51	2372	09:31
SBE37	SNR. 3490	53	2370	09:31
5 m Kevlar				
ADCP300	SNR: 18070	57	2366	09:31
2 Glasskuler				
1 m Kjetting galvanisert				
10 m Kevlar				
5 m Kevlar				
Stålkule 37 McLane		76	2347	
0,5 m Kjetting galvanisert				
100 m Kevlar				
20 + 10 m Kevlar				
50 m Kevlar				
5 m Kevlar				
SBE37	SNR. 4702	252	2171	09:13
4 Glasskuler (gule)				
2 m Kjetting galvanisert				
RCM9	SNR.1324	284	2139	09:13
0,5 m Kjetting galv				
200(204) m Kevlar				
500(496) m Kevlar				
500(498) m Kevlar				
50 m Kevlar				
SBE37	SNR. 3552	1504	919	07:46
4 Glasskuler				
2 m Kjetting galvanisert				
RCM11	SNR.491	1507	916	07:46
0,5 m Kjetting galv				
500(498) m Kevlar K				
200 (198)m Kevlar				
200 (205)m Kevlar				
SBE37	SNR. 8821	2408	15	07:23
4 Glasskuler (gule)				
2 m Kjetting galvanisert				
Seaguard	SNR.10071	2412	11	07:23
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 287			
5 m Kevlar				
2 m Kjetting galvanisert				
ANKER	1220/(980) kg	2423	0	

Rigg F12-20

78 49,270N

Settes ut 8 SEP 2018 kl 09:25 004 01.327W

Tatt opp AUG 20



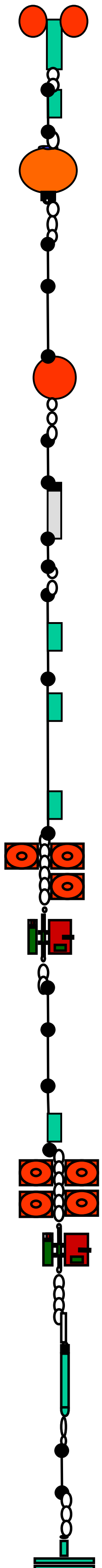
		Dyp:	Fra bunn:	Ut:
IPS	SNR. 51167	50	1778	09:22
SBE37	SNR.3489	52	1776	09:22
5 m Kevlar				
ADCP300	SNR: 24385	56	1772	09:22
0,5m Kjetting galvanisert				
10 m Kevlar				
Stålkule 37		68	1760	
0,5 m Kjetting galvanisert				
SBE37	SNR. 7074	120	1708	09:08
200 m Kevlar				
SBE37	SNR.4837	269	1559	09:03
4 Glasskuler				
2 m Kjetting galvanisert				
RCM9	SNR. 884	273	1558	09:03
0,5 m Kjetting galv				
497 m Kevlar				
500 m Kevlar				
199 m Kevlar				
SBE37	SNR.3554	1469	359	08:33
3 Glasskuler				
2 m Kjetting galvanisert				
RCM11	SNR.235	1473	355	08:33
0,5 m Kjetting galv				
199 m Kevlar				
100 m Kevlar				
40 m Kevlar				
SBE37	SNR. 8822	1813	15	08:17
4 Glasskuler				
2 m Kjetting galvanisert				
RCM11	SNR.228	1817	11	08:17
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 182			
3,5 m Kevlar				
3 m Kjetting galvanisert				
ANKER 1120/(940) kg		1828	0	

Rigg F13-20

78 50.392N

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

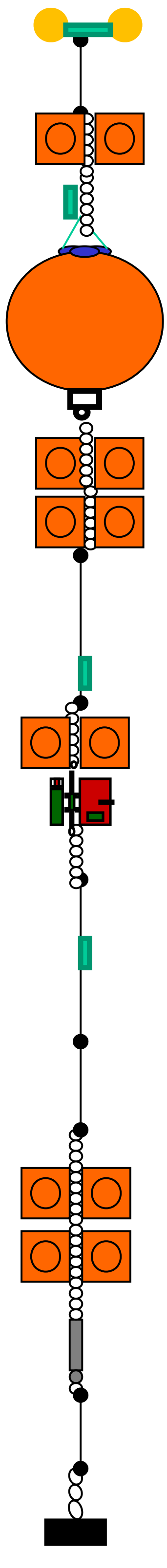
Tatt opp AUG 201



		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
Satt ut 5 SEP 2018, kl 12:53
Tatt opp Aug 201

78 50.261 N
005 30.848W



		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	

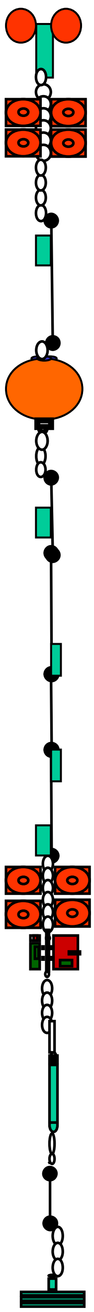
Rigg F14-20

Satt ut 6 SEP 2018 , kl 08:35

Tatt opp Aug 201

78 48,870N

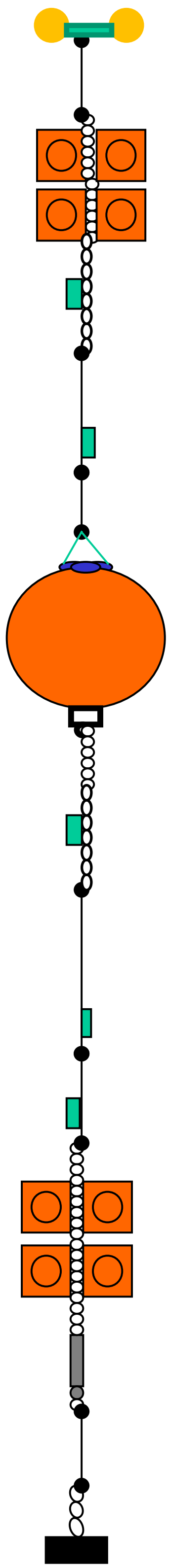
006 30,055W



			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	SNR.3992		253	14	08:03
4 Glasskuler 2 m Kjetting Galv.					
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

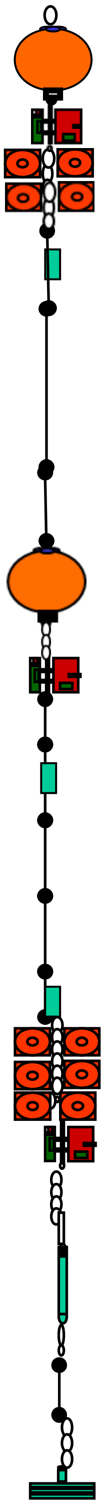
78 50. 175 N
008 04.879W



			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	

Rigg F10-15 78 49,623N

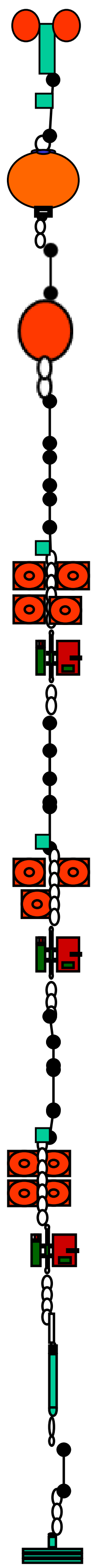
Satt ut 13 Sep 2019 , kl 19:34 001 57,036W



		Dyp:	Fra bunn:	Ned i vann:
ADCP/IPS-ram 300	SNR: 18070	50	2591	19:30
RCM9	SNR. 1175	52	2589	19:30
SBE37	SNR.7059	54	2585	19:30
100 (102) m Kevlar				
20 m Kevlar				
Stålkule Med svivel. 1 m Kjetting Galv.				
RCM 7	SNR. 9464	180	2414	18:24
0,5 m Kjetting Syrefast 0,5 m Kjetting Galv.				
SBE37	SNR. 14099	222	2417	18:24
4 x 500 (538,40,20,198,197,506,506) m Kevlar				
200(204) m Kevlar 100 (101 m Kevlar 100 (101) m Kevlar				
5 m Kevlar (totalt 2412)				
SBE37	SNR. 8226	2634	16	17:48
6 Glasskuler 3 m Kjetting Galv.				
Nortek	SNR. 42836-1-930	2639	11	17:48
Svivel				
AR861	SNR. 506			
5 m Kevlar				
3 m Kjetting				
ANKER	1200/(1000) kg	2650 (2663)	0	

Rigg F11-21

Satt ut 13 Sep 2019 kl 13:48 — 78 49,121N 003 03,072W

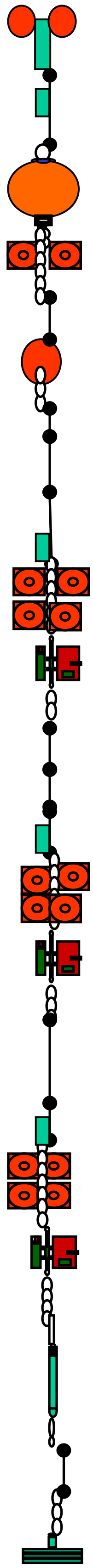


		Dyp:	Fra bunn:	Ut:
IPS	SNR. 51062	44	2409	13:42
SBE37	SNR. 3492	46	2407	13:42
5 m Kevlar				
ADCP300	SNR: 17462	50	2403	13:42
0,5 m Kjetting galvanisert				
10 m Kevlar				
Stålkule (gul)		72	2381	
Svivel				
1 m Kjetting galvanisert				
100 m Kevlar				
50 m Kevlar				
50 m Kevlar				
SBE37	SNR. 3996	273	2180	13:27
4 Glasskuler (2 gule og 2 oransje)				
2 m Kjetting galvanisert				
RCM9	SNR.1049	276	2177	13:27
0,5 m Kjetting galv				
200(199) m Kevlar				
500(510) m Kevlar				
500(510) m Kevlar				
20 m Kevlar				
10 m Kevlar				
SBE37	SNR. 7061	1526	927	13:08
3 Glasskuler (gule)				
2 m Kjetting galvanisert				
RCM11	SNR.538	1529	924	13:08
0,5 m Kjetting galv				
500(511) m Kevlar				
200 m Kevlar				
200 m Kevlar				
SBE37	SNR. 8821	2439	14	12:52
4 Glasskuler (gule)				
2 m Kjetting galvanisert				
Seaguard	SNR.834	2442	11	12:52
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 499			
5 m Kevlar				
3 m Kjetting galvanisert				
ANKER	1230/(980) kg	2453(2474?)	0	

Rigg F12-21

Satt ut 12/9-19 kl 17:25 — 78 49,274N, 004 01,332W

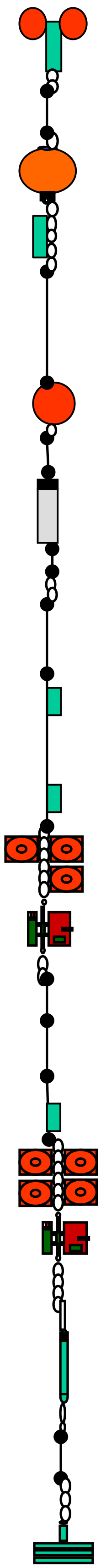
Tatt opp



		Dyp:	Fra bunn:	Ut:
IPS	SNR. 51167	60	1770	17:22
SBE37	SNR.7055	62	1768	17:22
5 m Kevlar				
ADCP300	SNR: 20021	66	1764	17:22
2 Glasskuler				
1,0 m Kjetting galvanisert				
0,5 m Kjetting galv				
10 m Kevlar				
Stålkule 37	SNR.	78	1752	
1,0 m Kjetting galvanisert				
0,5 m Kjetting galv				
200(199) m Kevlar				
SBE37	SNR.3994	278	1552	17:10
3 Glasskuler				
2 m Kjetting galvanisert				
RCM9	SNR. 836	282	1548	17:10
0,5 m Kjetting galv				
500(498) m Kevlar				
500(497) m Kevlar				
200(205) m Kevlar				
SBE37	SNR.13505	1482	348	16:53
3 Glasskuler				
2 m Kjetting galvanisert				
RCM11	SNR.556	1486	344	16:53
0,5 m Kjetting galv				
200(207) m Kevlar				
100(101) m Kevlar				
20 m Kevlar				
SBE37	SNR. 10294	1816	14	16:42
4 Glasskuler				
2 m Kjetting galvanisert				
RCM11	SNR.117	1819	11	16:42
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 500			
5 m Kevlar				
2 m Kjetting galvanisert				
ANKER	1190/(960) kg	1830 (1851)	0	

Rigg F13-21

Satt ut 11/9-19 kl 15:34 — 78 50.346N 004 59.959W

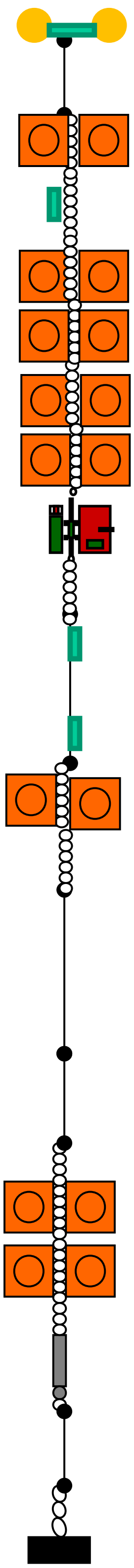


		Dyp:	Fra bunn:	Ned i vann:
IPS5	SNR. 51140	50	962	15:32
5 m Kevlar				
ADCP300	SNR: 18151	56	956	15:32
1,5 m Kjetting galv				
SEACAT SBE16	SNR. 7253	59	953	15:32
0,5 m Kjetting galv.				
10 m Kevlar				
Stålkule 37		69	943	
2 m Kevlar				
Hvallydopptaker		72	940	15:25
2 m Kevlar				
0,5 m Kjetting galv.				
20 m Kevlar				
Merke for instrument		95		
50 m Kevlar				
SBE37	SNR. 3995	147	865	15:18
100 m Kevlar				
SBE37	SNR.7060	245	767	15:16
3 Glasskuler				
2 m Kjetting galv.				
RCM9	SNR.1326	248	764	15:16
0,5 m Kjetting galv				
500(497) m Kevlar				
100 m Kevlar				
100 m Kevlar				
50 m Kevlar				
SBE37	SNR. 13504	996	16	15:02
4 Glasskuler				
2 m Kjetting galv.				
SEAGUARD	SNR. 345	1000	12	15:02
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 743			
5 m Kevlar				
3 m Kjetting galvanisert				
ANKER	1100/(880) kg	1012(1027)	0	

Rigg F13B-6

Satt ut 11/9-19 , kl 09:40

78 50.213 N
005 30.149W

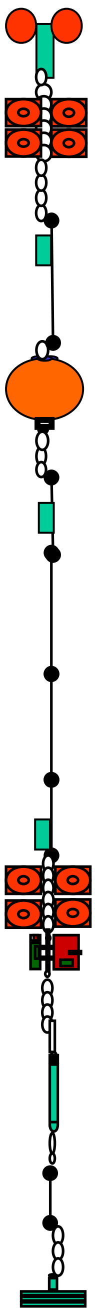


		Dyp:	Fra bunn:	Ut:
ICECat	SNR. 21029	34	490	09:40
25 m Wire				
Weak link				
1 m Kjetting galv.				
2 Glasskuler				
ICECAT modem				
4 m Kjetting galv.				
4 Glasskuler				
SEAGUARD	SNR. 883	65	459	09:35
0,5 m Kjetting galv.				
SBE37	SNR. 9853	67	457	09:30
41 m Kevlar				
SBE37	SNR. 9852	106	418	09:27
1 m Kjetting galv.				
2 Glasskuler				
0,5 m Kjetting galv.				
200(199) m Kevlar				
Merket 50 m ned		204		
205 m Kevlar				
Merket 100 m over kuler		413		
2 m Kjetting galv.				
4 GLASSKULER		513	11	09:20
AR661	SNR. 410			
5 m Kevlar.				
3 m Kjetting galv.				
ANKER	820/(640)kg	524(534)	0	

Rigg F14-21

Satt ut 10/9-19, kl 14: 33

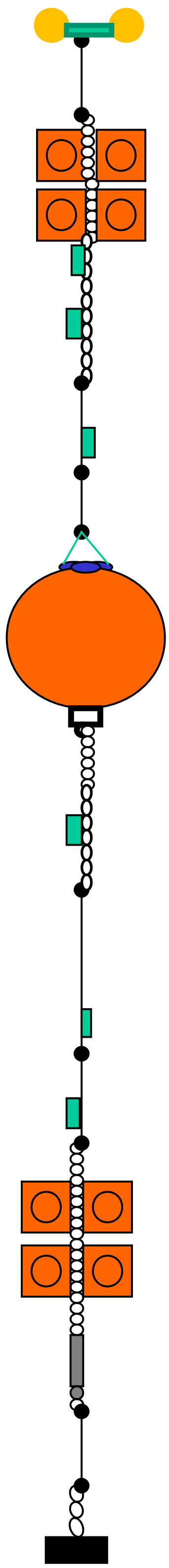
78 48,884N
006 30,001W



		Dyp:	Fra bunn:	Ned i vann:
IPS	SNR. 51138	46	224	14:30
4 Glasskuler				
2 m Kjetting galv.				
SBE37	SNR: 7058	52	218	14:28
5 m Kevlar				
ADCP 300	SNR: 17461	56	214	14:25
1 m Kjetting Galv.				
0,5 m Kjetting Galv.				
100 m Kevlar				
SBE37	SNR. 7054	100	170	14:18
50 m Kevlar				
SBE56	SNR: 3943	207	63	14:14
40 m Kevlar				
SBE37	SNR.7057	257	13	14:07
4 Glasskuler				
2 m Kjetting Galv.				
RCM9	SNR. 1325	260	10	14:07
Svivel				
AR861	SNR. 568			
3,5 m Kevlar				
2,5 m Kjetting				
ANKER	900/(740) kg	270 (269)	0	

Rigg F17-16
Satt ut 10/9-19 , kl 07:05

78 50. 180 N
008 04.798W



		Dyp:	Fra bunn:	Ut:
ICECAT	SNR.21024	25	201	07:05
3 m Kjetting galv. 4 Glasskuler		52	174	07:05
Datalogger				
SBE16	SNR.7212	54	172	07:05
0,5 m Kjetting 51 m Kevlar				
SBE37 Merket	SNR.13252	94	132	06:53
ADCP	SNR.24518	105	121	06:50
2 m Kjetting galv.				
SBE16	SNR.7339	108	118	06:50
0,5 m Kjetting				
99 m Kevlar				
SBE56	SNR.3942	180	36	06:44
5 m Kevlar				
SBE37	SNR.14098	214	12	06:42
2 m Kjetting galv.				
4 GLASSKULER		215	11	
AR861CS	SNR. 501			
5 m Kevlar.				
2 m Kjetting galv.				
ANKER	800/(700)kg	226	0	