Fram Strait 2016 Cruise report

25 Aug – 13 Sep 2016

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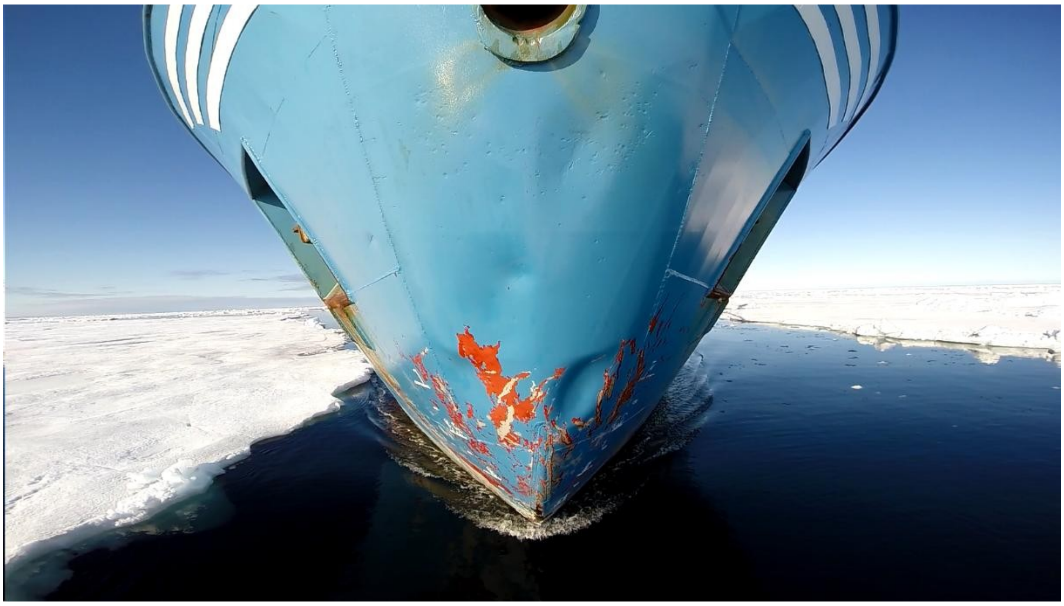

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Cruise Overview

NPI has maintained an array of oceanographic moorings in the East Greenland Current in Fram Strait since the early 1990s. This array has provided a long time series of observations with which to monitor the outflow from the Arctic Ocean. The main priority of the 2016 cruise was to recover and redeploy the NPI moorings across the East Greenland Current (EGC) at 78° 50 N.

NPI has carried out annual sections of CTD and conservative tracer measurements along 78°50'N since 1997. During the 2016 cruise CTD/LADCP sections included extensive water sampling for various tracers and chemical parameters and optical measurements across Fram Strait along the 78° 55” N section. Work on sea ice was also carried out on a number of ice stations and by helicopter.

This year was subject to quite heavy ice conditions along the mooring array, but despite this, and loss of couple of cruise days to an unexpected return to Longyearbyen early in the cruise, moorings were recovered quite timely and re-deployed on schedule. Time in between recovery and re-deployment was shortened, but due to favourable ice conditions near the Greenland coast we managed to enter Dijmphna Sound, this was the second time Lance entered the fjord and thus we re-did observations from 2012. Ice conditions were also favourable along the Isle de France CTD section, and this section could also be repeated as in previous years.

Sea ice physics work was carried out across the EGC where ice exits the Arctic on a number of ice stations. This included in situ work on the ice (drillings, EM and ice coring). Helicopter based work included sea ice thickness measurements and aerial photography. A sea ice mass balance buoy (IMB) was deployed on the fast ice off the Greenland coast. Ship-mounted instruments were to study GNSS signal reflectometry for sea ice studies.

Satellite SAR images were be obtained regularly and transferred to Lance on a nearly daily basis from NPI in Tromsø (maps made by Jennifer King). These maps aided in the planning and navigation of Lance. More specific satellite acquisitions were done by the UiT (CIRFA) group.

Sailing Log

Date (times are in UTC)	Main Activities
Thu 25/8	• **Lance departed Longyearbyen at 1300** • Start sailing towards 78 50’N 000° 00’W
Fri 26/8	• CTD and IOP at 78° 55' N, 0°W • Abort mission - return to Longyearbyen to drop off one crew member
Sat 27/8	• Arrive Longyearbyen – Depart Longyearbyen (1120am) • Steam to mooring site F11
Sun 28/8	• Arrival at mooring site F11 • Recover F11-17 (10:53) • CTD at F11 • Sea ice station (zodiac 6 pax) • CTD at 78° 55' N, 1°W • CTD and IOP at 78° 55' N, 2°W
Mon 29/8	• CTD, IOP and C-OPS at 78° 55' N, 3°W • CTD, IOP and C-OPS at 78° 55' N, 3.5°W • Sea ice station (zodiac 6 pax) • CTD, IOP and C-OPS at 78° 55' N, 4°W • Helicopter flight • CTD at 78° 55' N, 4.5°W
Tue 30/8	• Recover F12-17 (07:43) • CTD at F12 • Recover F13-17 (17:03) • CTD at F13 • CTD, IOP and C-OPS at 78° 55' N, 5°W
Wed 31/8	• CTD at 78° 55' N, 5.5°W • Recover F13B-2 (08:05) • Helicopter flight • CTD at F13B • Recover F14 (13:28) • CTD, IOP and C-OPS at F14 • Sea ice station (MOB boat 1+6 pax) • CTD, IOP and C-OPS at 78° 55' N, 6°W • CTD at 78° 55' N, 6.5°W • CTD, IOP at 78° 55' N, 7°W
Thu 1/9	• CTD, IOP at 78° 55' N, 8°W • Recover F17 (06:51) • Recover F18 (07:50) • 0805-0845CTD, IOP and C-OPS at F17/F18 • Sea ice station (MOB boat. 6+1 pax) • CTD, IOP and C-OPS at 78° 55' N, 9°W • CTD, IOP and C-OPS at 78° 55' N, 10°W • CTD, IOP and C-OPS at 78° 55' N, 11°W • CTD, IOP and C-OPS at 78° 55' N, 12°W • CTD, IOP and C-OPS at 78° 55' N, 13°W
Fri 2/9	• Moored to fast ice at 79° 19’N, 13° 29 W (6:47) • Sea ice station (11 pax) • Helicopter flight EM & camera

	• 1353-1958 Helicopter flights and IMB deployment on fast ice (4 pax on ice) • IMB deployed at 79°19'N, 13°54'W by Sea Ice Team • CTD, IOP and C-OPS from ship when moored to fast ice (1635-1725)
Sat 3/9	• Move to new location on fast ice • Moored to fast ice (79 19.007 N, 13 28.596W) • Sea ice station (7 pax) • MOB boat thin ice sampling (1+4pax) • Helicopter EM & camera flight • Steaming to Dijmphna Sound • CTD, IOP in Dijmphna Sound (on way in) • CTD, IOP in Dijmphna Sound (on way in)
Sun 4/9	• CTD, IOP in Dijmphna Sound (on way in) • CTD, IOP in Dijmphna Sound (on way in) • CTD, IOP in Dijmphna Sound (on way in) • CTD, IOP in Dijmphna Sound (on way in) • CTD, IOP in Dijmphna Sound (on way in) • CTD, IOP in Dijmphna Sound (on way in) • Net tow at station neasrest glacier toongue • Redo two CTD station on way due to malfunction in LADCP on way in • 3 CTD stations outside Dijmphna Sound • Steam towards Isle de France (IdF)section
Mon 5/9	• 0850-0902 CTD IdF • 0932-1005 CTD, IOP & C-OPS IdF • 1043-1054 CTD IdF • 1124-1140 CTD IdF • 1210-1235 CTD IdF • 1304-1325 CTD IdF • 1355-1417 CTD IdF • 1444-1540 CTD, IOP and C-OPS IdF • 1610-1637 CTD IdF • 1713-1815 CTD, IOP and C-OPS IdF • 1853-1915 CTD IdF • 1945-2008 CTD IdF • 2030-2120 CTD, IOP and C-OPS IdF • 2135-2155 CTD IdF • Steaming to Yo-Yo station
Tue 6/9	• 0110 Start 13 hr yo-yo station (hourly CTD) • Sea ice station (MOB 1+5 pax) • 0820-0855 C-OPS and IOP • 1310 end of yo-yo • Net tow • Steam towards F17
Wed 7/9	• Arrival at mooring site F17 at 0600 am • **Deployed F17** (0907) • Steam to F14 • **Deployed F14** (1323) • 1410-1542 Sea ice station (1+9 pax), incl. thin ice sampling • Stop engines for night, very thick fog
Thu 8/9	• Steam towards F13B • **Deployed F13B** (0906) • 1103-1240 Sea ice station (5 pax + 1 PG on Lance) • Steam to F13 in heavy ice • **Deployed F13** (1718)

	• 1940-2030 Helicopter EM & camera flight
Fri 9/9	• Drifted far south during night, making way through ice towards F12 • **Deploy F12** (1328) • 1650-1820 Sea ice station (5 pax, anchored to floe) • 1840-2020 Extra CTD for calibrations • Move to F11 site
Sat 10/9	• Arrival at mooring site F11 at 0500 • **Deployed F11** (0920) • 1100-1310 Sea ice station (6 pax) • Lots of sediment in the sea ice • 1415-1530 Helicopter flight EM and camera • Evening off
Sun 11/9	• 0645-0900 Sea ice station (5 pax) • 1310-1349 extra CTD for calibrations • CTD at 78°55'N, 1°E (heavy swell, and 1 kn drift) • CTD and IOP at 78°55'N, 2°E (heavy swell, and 1 kn drift)
Mon 12/9	• CTD at 78°55'N, 3°E (heavy swell, and 1 kn drift) • Abort CTD due to heavy seas, steaming east • CTD at 78°55'N, 6.5°E • CTD, IOP and C-OPS at 78°55'N, 6°E • CTD, IOP and C-OPS at 78°55'N, 7°E • CTD at 78°55'N, 7.5°E
Tue 13/9	• CTD, IOP at 78°55'N, 8°E • CTD at 78°55'N, 8.5°E • CTD, IOP at 78°55'N, 9°E • Steam towards Isfjorden to avoid gale force storm • CTD at entrance to Adventfjorden • **Lance docked at Kullkaia in Longyearbyen**
Wed14/9	• Arrival and disembarking in Longyearbyen • Offloading ship and packing gear

Moorings recovered during FS2016

Mooring	Position	Depth (m)	Date and time (UTC)	Instrument	Serial #	Instrument depth (m)
F11-17	N 78° 48.992' W 03°01.508'	2450	Deployed: 9 Sept 2015, 08:32 Recovered: 28 Aug 2016, 10:55	**IPS** **SBE37** ADCP **SBE37** RCM9 **SBE37** RCM11 **SBE37** RCM Seaguard AR861	**51062** **7054** 17461 **3996** 1049 **7061** 538 **8226** **834** **449**	**49** **51** 55 **270** 273 **1532** 1535 **2437** 2440 2443
F12-17	N 78° 49.148' W 04° 00.900'	1830	Deployed: 8 Sept 2015, 12:17 Recovered: 30 Aug 2016, 07:43	**IPS** **SBE37** ADCP **SBE37** RCM9 **SBE37** RCM11 **SBE37** RCM11 AR861	**51127** **7055** 17462 **3994** 836 **10294** 556 **8227** 117 500	**47** **49** 53 **272** 269 **1468** 1471 **1817** 1820 1825
F13-17	N 78° 50.164' W 05° 00.086'	1010	Deployed: 7 Sept 2015, 10:26 Recovered: 30 Aug 2016, 17:03	**IPS** ADCP **SBE16** RCM9 AURAL **SBE37** **SBE37** RCM9 **SBE37** RCM Seaguard AR861	**51064** 16831 **7253** 1175 - **3995** **7060** 1326 **13504** 345 743	**49** 55 **56** 57 74 **146** **244** 247 **997** 1000 1003
F13B-2	N 78° 50.182'N W 05° 30'.886'	520	Deployed: 6 Sept 2015, 10:59 Recovered: 31 Aug 2016, 08:05	**SBE37-IM** ADCP ICEBOX **SBE37-IM** **SBE37** RCM Seaguard **SBE37** AR661	**13506** 727 N/A **13507** **7059** 883 **13505** 410	**30** 60 60 **62** **102** ?104 **202** 516
F14-17	N 78° 48.866' W 006° 30.033'	271	Deployed: 5 Sept 2015, 14:03 Recovered: 31 Aug 2016, 13:07	**IPS** **SBE37** ADCP **SBE37** RCM9 AR861	**51127** **7058** 16876 **7057** 1325 568	**58** **62** 67 **258** 261 265
F17-12	N 78° 50.167' W 08° 05.010'	225	Deployed: 5 Sept 2015, 07:05 Recovered: 1 Sept 2016, 06:23	**SBE16** ADCP **SBE16** AR661	**7212** 7636 **7339** 501	**45** 98 **100** 210
F18-10	N 78° 49.290', W 08° 04.722'	218	Deployed: 5 Sept 2015, 08:25 Recovered: 1 Sept 2016, 07:25	Seaguard string AR861	1593 553	70-120 211

Table 1: *Moorings recovered during FS2016.*

NOTES on recovered instruments:

- SBE37 Microcats & SBE16 Seacats: ALL GOOD
- SBE37 IM IceCat: SN 13506: Drift in P? Check again in 2017. If we retrieve it consider to calibrate it against CTD.
- ADCPs: Good at first sight. Need to be investigated in detail to see if compass did not have an offset. ADCPs never been calibrated properly on board.
- AADI RCMs: All .dsu files downloaded OK and appeared of reasonable size (i.e. all RCMs had started). The AADI .cdb calibration files were not brought on board, hence they could not be exported to .Asc by the 5059 Data Reading Program. That will be done asap on return at NPI.
- AADI Seaguard CM: SN 345 at F13 did **not** perform well, bad U,V data. The two others at F13B and F11 are GOOD.
- AADI Seaguard string: GOOD
- IPS: The IPS (SN 51127) on F12 did **not** start recording. It will be exchanged with an older type IPS4 instrument. This IPS5 will need to be send to ASL for servicing.

Moorings deployed during FS2016

Mooring	Position	Depth (m)	Date and time (UTC)	Instrument	Serial #	Instrument depth (m)
F11-18	N 78° 48.998' W 03° 01.559'	2465	Deployed: 10 Sept 2016, 09:20	IPS	**51062**	55
				SBE37	**3490**	**57**
				ADCP	17461	59
				SBE37	**4702**	**270**
				RCM9	1324	273
				SBE37	**3552**	**1551**
				RCM11	494	1554
				SBE37	**8821**	**2454**
				RCM8	10071	2455
				AR861	287	2458
F12-18	N 78° 49.156' W 04° 00.427	1849	Deployed: 9 Sept 2016, 13:29	**IPS4**	**1047**	**60**
				SBE37	**3489**	**62**
				ADCP	17462	66
				SBE37 (new)	**14097**	**~150**
				SBE37	**4837**	**280**
				RCM9	884	283
				SBE37	**3554**	**1488**
				RCM11	235	1490
				SBE37	**8822**	**1832**
				RCM11	228	1835
				AR861	182	1839
F13-18	N 78° 50.283' W 04°59.191'	1036 (too deep)	Deployed: 8 Sept 2016, 17:20	**IPS**	**51064**	**65**
				SBE37	**7056**	**70**
				ADCP	16831	75
				AURAL	n/a	100
				SBE37	**12232**	**172**
				SBE37	**3993**	**272**
				RCM9	1327	252
				SBE37	**3551**	**1024**
				RCM11	561	1026
				AR861	053	1030
F13B-3	N 78° 50.266' W 05° 30.873'	526	Deployed: 8 Sept 2016, 09:06	**SBE37-IM** weak link	**13506**	**26**
				ICEBOX	11435	58
				ADCP	727	60
				SBE37	**12234**	**63**
				SBE37	**12333**	**102**
				RCM7	9464	104
				SBE37	**10295**	**154**
				AR661	291	519
F14-18	N 78° 48.861' W 06° 30.074'	271	Deployed: 7 Sept 2016 13:23	**IPS**	**51127**	**58**
				SBE37	**3492**	**62**
				ADCP	16876	66
				SBE37 (new)	**14098**	**102**
				SBE56 (new)	**3943**	**197**
				SBE56 (new)	**3942**	**227**
				SBE37	**3992**	**257**
				RCM9	1046	261
				AR861	506	265
F17-13	N 78° 50.179' W 08° 04.913'	225	Deployed: 7 Sept. 2016 09:08	**SBE37-IM** weak link	**13507**	**25**
				SBE16	**6693**	**55**
				SBE37	**2962**	**75**
				ADCP	7636	106
				ICEBOX	n/a	108
				SBE16	**6694**	**110**
				SBE56 (new)	**3944**	**190**
				SBE37	**7062**	**210**
				AR661	110	218

Table 2: *Moorings deployed during FS2016.*

Notes:

* 3 SBE56 thermistors have been put out on F17 (190 m) and F14 (230 and 200 m) to measure Atlantic Water temperature above the bottom.

* ICECATs: Two were deployed in 2016. We used 3 weak links per deployment: two to each SBE37 IM and one to the top float. Two data loggers with newly (home-made) batteries were deployed; one data logger is in storage (requires new battery if put out in 2017)

CTD Measurements

The CTD used as an SBE911+ unit. 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.

A paper log sheet was completed at each CTD station. Log sheets list the depths at which bottles were fired and the samples taken from each bottle. Times 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 logged time and position data.

CTD Package Configuration

- Primary temperature sensor serial number **2400** was used for the entire cruise
- Secondary temperature sensor serial number **5299** was used for the entire cruise

- Primary conductivity sensor serial number **2056** was used for the entire cruise
- Secondary conductivity sensor serial number **3742** was used for the entire cruise

- Digiquartz pressure sensor serial number **0972** was used for the entire cruise

- Oxygen sensor sensor serial number **1740** was used for the entire cruise

CTD sections

Drift ice conditions on the East Greenland Shelf allowed Lance to move along three sections during the cruise:

1. **Main Fram Strait Section** (Figure 1)**:** An east-west section along the Fram Strait mooring array line at 78º 50 N, which is repeated annually. During Fram Strait 2016, stations were completed between 009 E and 012 W. Station spacing was 20 km for most of the transect and 10 km in the cores of the inflow and outflow. However large swell prevented sampling between 003 E and 006 E. Figure 1 shows the data collected along the Main Fram Strait Section.

2. **Isle de France Section** (Figure 2)**:** A high-resolution (6.5 km spacing) 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 section was completed in August 2013, August 2014, August 2015 as well as during FS2016. Figure 2 shows the data collected along the Norske Trough section During FS2016 the CTD was continually re-deployed at 1-hour intervals for 13 hours at one location along the Isle de France section in an attempt to record the variability associated with the tidal cycle.
3. **Dijmphna Sound Section** (Figure 3)**:** A high-resolution (4.5 km spacing) section along the length of Dijmphna sound, repeating an earlier section from 2011. Figure 3 shows the data collected along the Dijmphna Sound section.

Salinity Sensor Calibration

Water samples for laboratory salinity measurement were collected at most CTD stations. At stations where tracer samples were collected, salinity samples were collected at standard depths of 5, 15, 25, 50, 75, 100, 150, 200, 250 and 300 dbar, plus two samples from the bottom of the water column. At stations where tracer samples were not collected, samples for salinity measurement were collected from deep parts of the water column where the salinity gradient was shallow (usually below 500 m). Deep regions provide the best data for conductivity sensor calibration as the water trapped in the Niskin bottles is most similar to that sampled by the CTD.

Salinity samples were analysed on broad Lance using a Guildline Portasal portable salinometer which was standardised after every 24 measurements using IAPSO P-series standard seawater.

Comparison of laboratory salinity measurements and CTD-salinity measurements revealed an offset of < 0.002 practical salinity units for the primary sensor group (Figure 4). The mean offset between the primary sensor group and the laboratory measurements is, smaller then the precision of laboratory salinity measurements (+/- 0.003) and no correction is made here.

Comparison of laboratory salinity measurements and CTD-salinity measurements revealed an offset of around < 0.001 practical salinity units for the secondary sensor group (Figure 4). The mean offset between the primary sensor group and the laboratory measurements is, smaller then the precision of laboratory salinity measurements (+/- 0.003) and no correction is made here.

Both sets of CTD sensors performed exceptionally well during the cruise. The offsets determined relative to the laboratory salinity measurements are two of the smallest offsets ever determined during a Fram Strait cruise.

Dissolved Oxygen Sensor Calibration

The dissolved oxygen sensor attached to the CTD did not collect any usable measurements during the cruise. The sensor showed a large and variable pressure-dependant offset relative to laboratory oxygen (Winkler) samples. The offset could not be removed by regression against laboratory measurements. Inspection of the sensor during the later part of the cruise suggested that the membrane separating the electrolyte from the seawater environment had become perforated. A perforated membrane is the mostly likely explanation for the poor performance of the sensor. In future, the oxygen sensor membrane should be inspected as soon as anomalous dissolved oxygen profiles are collected and the sensor should be replaced if necessary.

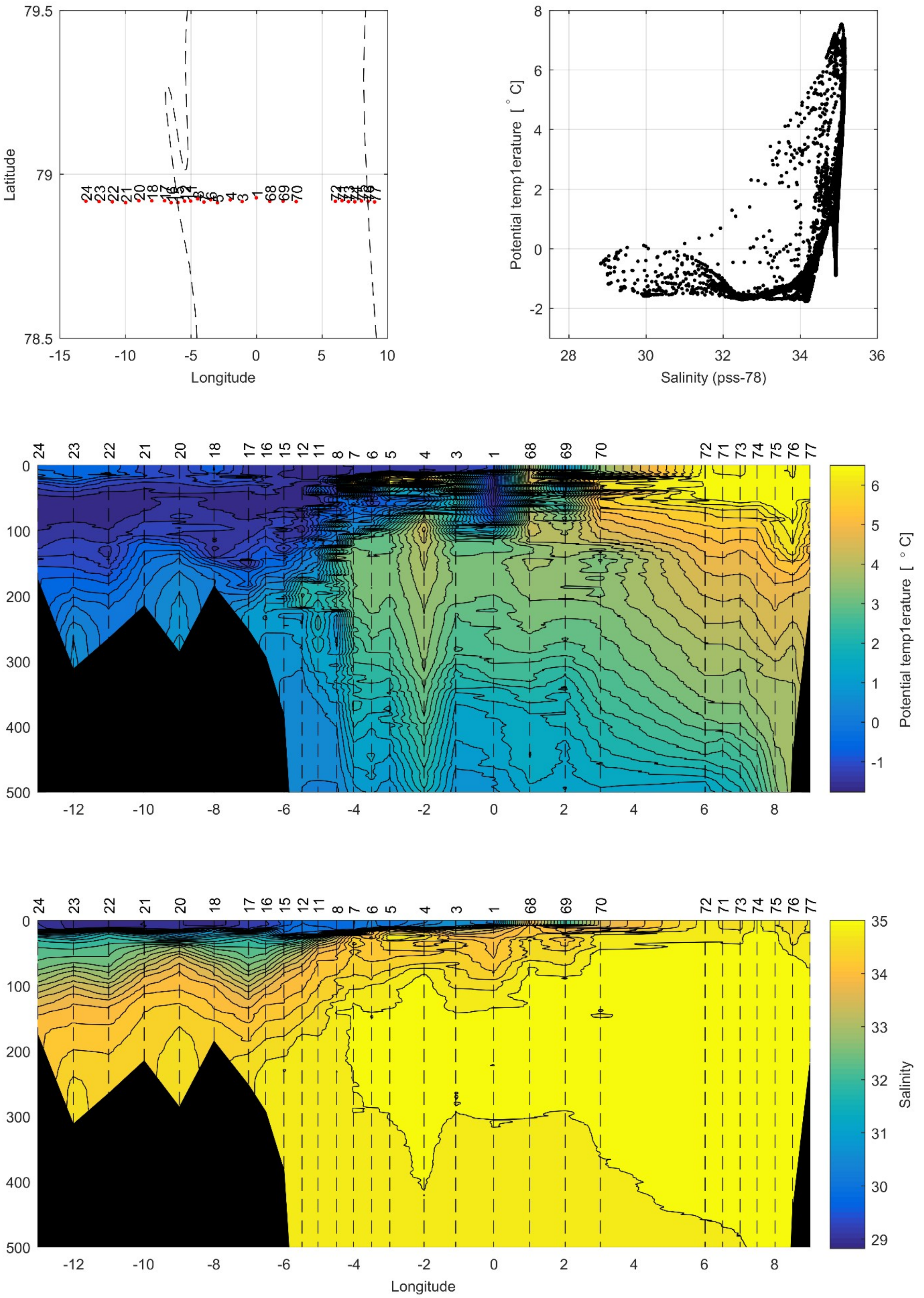


Figure 1: Map showing the locations of CTD stations along the **Main Fram Strait Section** (top left panel); Measurements from the primary temperature and salinity sensors in θ-S space (top right panel); and sections of potential temperature and salinity (lower 2 panels). Station numbers are indicated above sections.

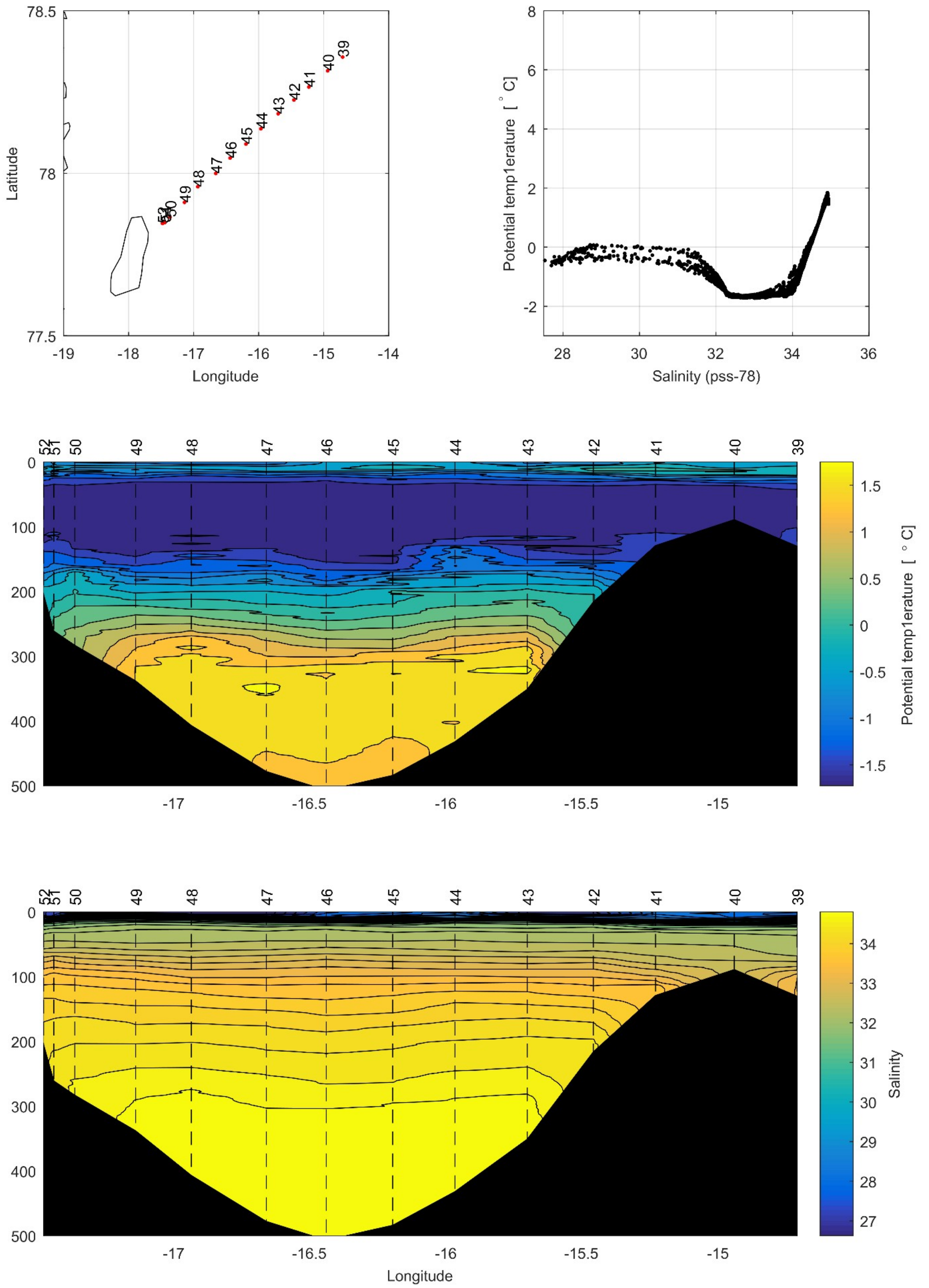


Figure 2: Map showing the location of CTD stations along the **Îsle de France Section** (top left panel); (top left panel); Measurements from the primary temperature and salinity sensors in θ-S space (top right panel); and sections of potential temperature and salinity (lower 2 panels). Station numbers are indicated above sections.

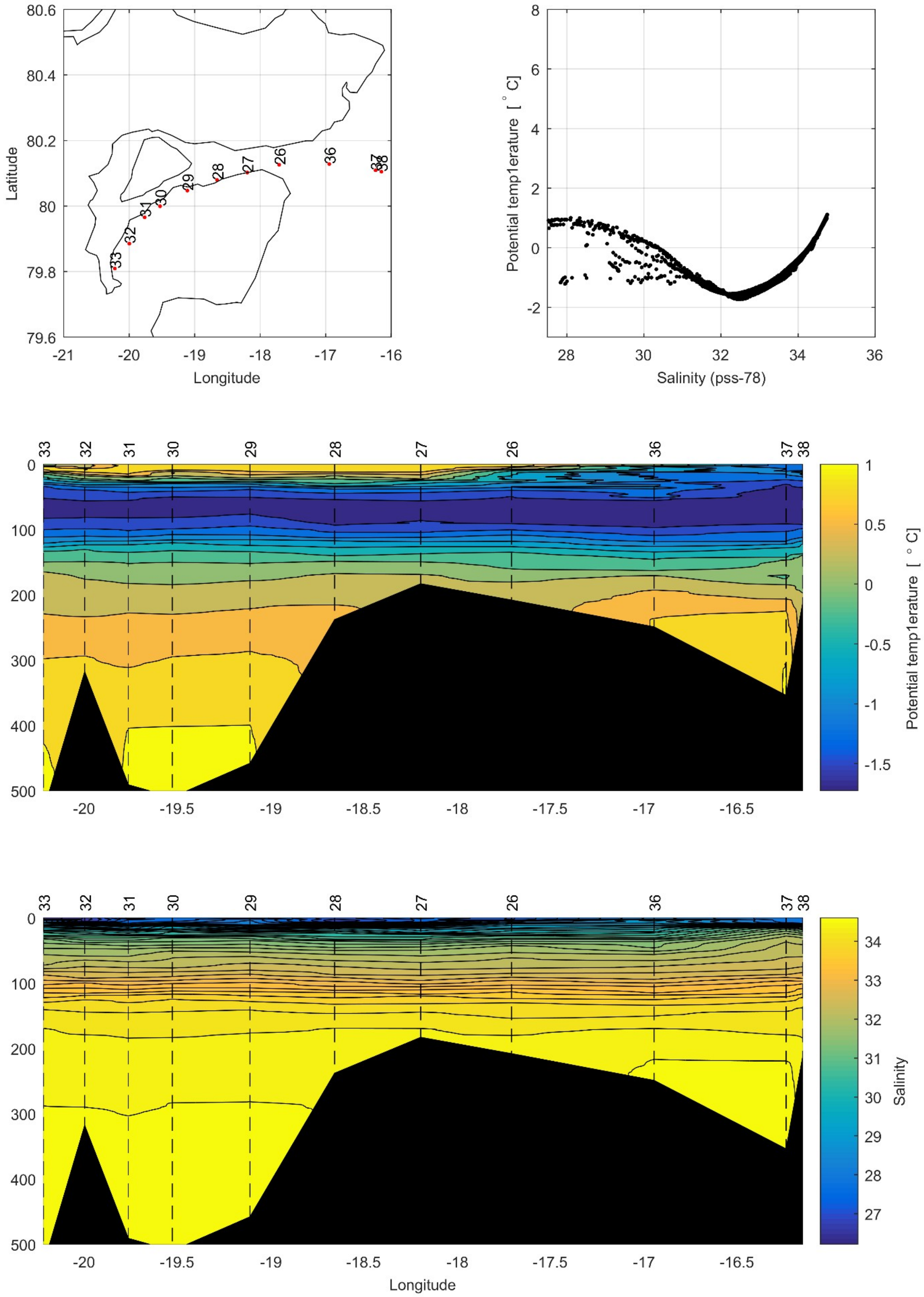


Figure 3: Map showing the location of CTD stations along the **Dijmphna Sound Section** (top left panel); Measurements from the primary temperature and salinity sensors in θ-S space (top right panel); and sections of potential temperature and salinity (lower 2 panels). Station numbers are indicated above sections.

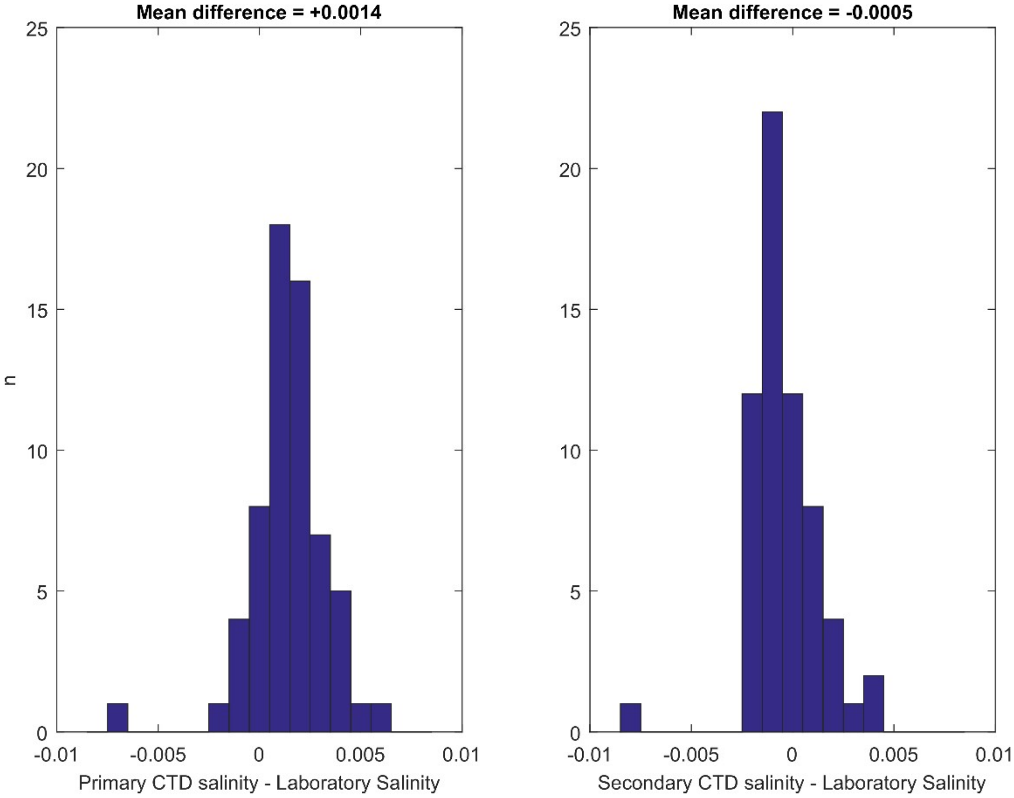


Figure 4: Histograms showing the difference between the primary (left hand panels) and secondary (right hand panels) sensor groups on the CTD and laboratory salinity measurements. Only points deeper than 400 m are considered, due to step salinity gradients close to the surface.

Tracer (biogeochemical) sampling during FS2016

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 Dijmphna Sound and Îsle de France sections.

Samples were collected in the following order:

1. Dissolved oxygen
2. DIC & Total alkalinity
3. CDOM (Filtered)
4. $\delta^{15}N$
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 $\delta^{18}O$ isotope ratio analysis and dissolved nutrient analysis were always collected when Total Alkalinity and Dissolved Inorganic Carbon samples were collected.

Coloured dissolved organic matter (CDOM): Samples for $\delta^{18}O$ isotope ratio analysis and dissolved nutrient analysis were always collected when CDOM samples were collected.

$\delta^{15}N$: Samples were collected at selected locations.

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.

Niskin bottle operations: The rubber bands which hold the Niskin bottles closed were in fair condition at the beginning on the cruise and required little attention during the cruise. The rubber o-rings retaining the taps of several Niskin bottles remained in good working order throughout the cruise.

Tracer samples of sea ice: Ice cores for tracer analysis were collected at most sea ice stations (See also the section about specific sea ice work in this cruise report). Cores were collected in triplicate so as to allow some assessment of the variability of properties at each site sampled. Loose surface snow was removed before coring. Complete cores were stored in air-tight buckets 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. Figure 5 shows the location of sites where ice cores for tracer analysis were collected.

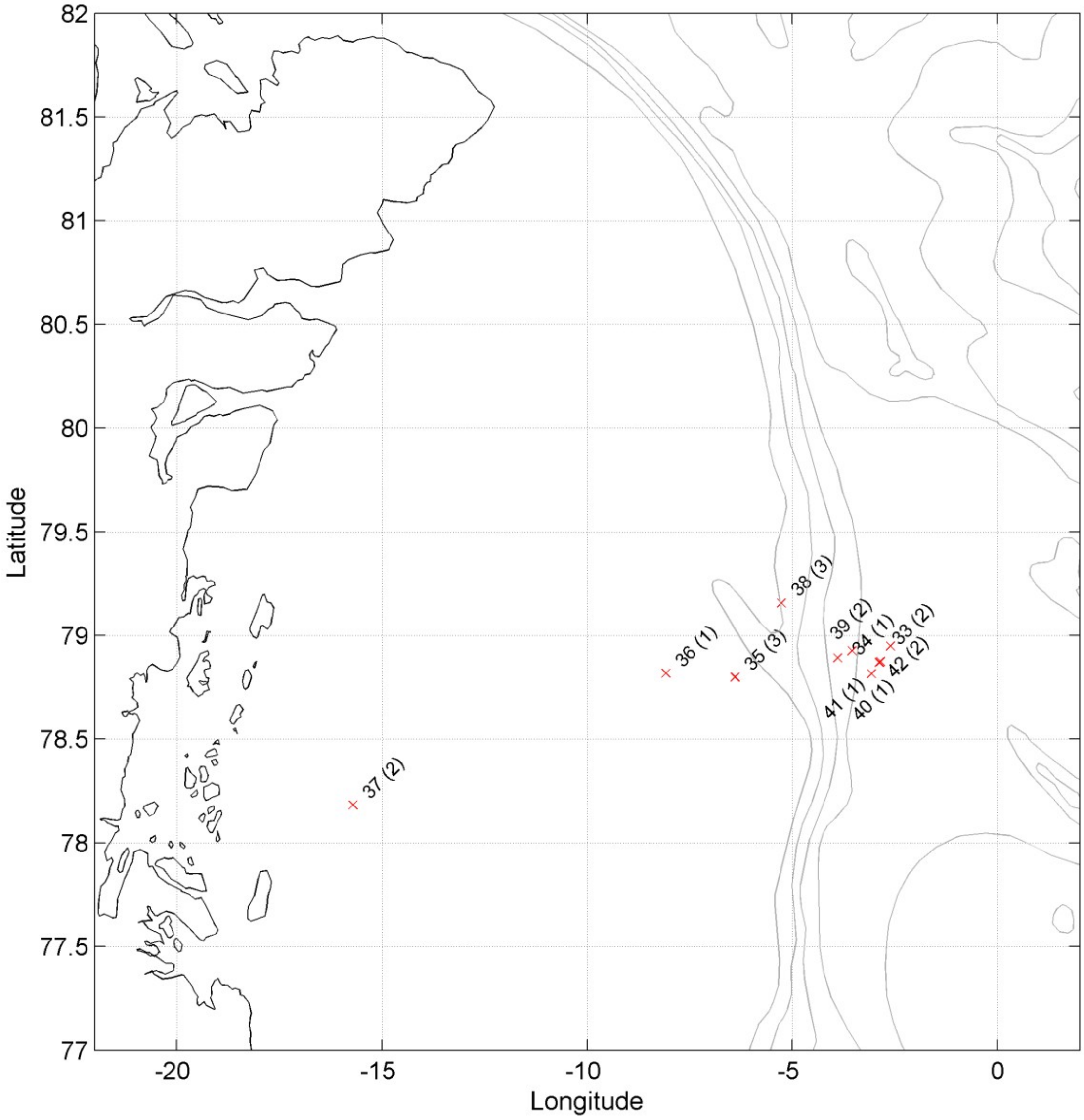


Figure 5: Locations of sea ice floes where cores were collected for tracer analysis. The first number is a serial number assigned to ice floes from which tracer measurements have been collected. i.e.: tracer measurements have been collected from 42 ice floes in Fram Strait since sampling began in 2013. Numbers in brackets indicate the number of cores collected from each floe.

Sea ice work during FS2016

General

The sea ice work on Fram Strait 2016 cruise was coordinated by Anja Rösel (NPI), team members were Jean Negrel (NPI), Dmitry Divine (NPI), Johannes Loose (UiT), Maximilian Semmling (GFZ).
Additionally, Helicopter operations were conducted, mainly for Helicopter based electromagnetic measurements (HEM) and Stereo Camera flights. Marius Bratrein (NPI), Jean Negrel, Dmitry Divine, and Anja Rösel were involved in the helicopter surveys.

Figure 6: Last sea ice station S17 on 11.9.2016

Altogether we had 17 sea ice stations and 6 HEM flights (Table 3 and Figure 12). On 02.09.16 we deployed a seasonal IMB on the fastice area close to the coast of Greenland at N 79 13 and W 13 54.

Thin ice sampling

The thin ice samples were mainly collected from the "Man overboard-boat ", or, where possible from the edge of an ice floe. Temperatures, salinity, thickness, and visual information were collected. Frost-flowers were sampled where available, and analyzed. Altogether we had 4 thin ice sampling spots, new ice formation was only observed on some days between 3.9. and 8.9.16.

Sea ice stations

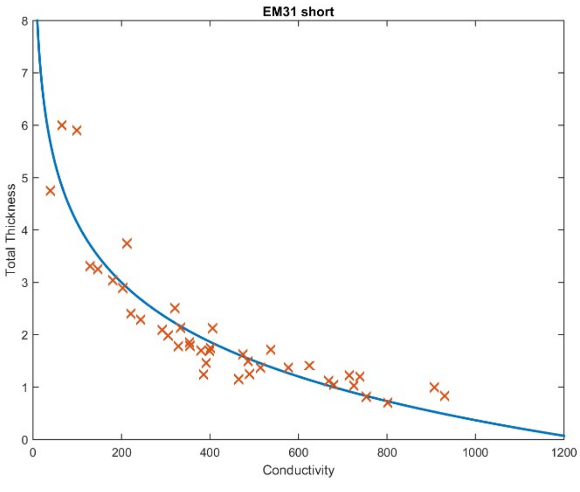


Figure 7. EM31SH calibration curve from drill holes made during FS2016

On the 12 main sea ice stations (Table 3) we collected ice cores for salinity and temperature analysis and for archive storage and later analysis of the microstructure. On every full sea ice station, 1 to 3 tracer cores were collected by Paul Dodd (see above). In addition, 11 core bottoms were collected for sea ice biomarker IP25 in a collaborative pilot 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, and after a snowfall event on 31.8.2015 we only had this thin fresh snow layer of 2-3 cm on the ice. On 10. and 11. 9.16 we had melting conditions with air temperatures above the freezing point, and rain (on 11.09.16). In general, the ice was very rotten, the bottom irregular, on some station false bottoms were observed. On 10.9.16 we were surrounded by many sediment covered ice floes, 3 sediment samples were taken for the geochemical analysis in order to find out the origin of the sediments and a likely area of sea ice formation.

The ice thickness of the ice floe was surveyed directly by thickness drilling and indirectly using a Geonics EM31-MK2 short. 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 ArcherII 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). In total, 14 profiles were collected to characterize the ice thickness of the station floe. The results of all thickness measurements with the em31 instrument are shown in Figure 8. The very broad distribution shows the variety of ice classes covered during this cruise. The mode around 6m represents a heavily ridged areas of fast ice at the edge.

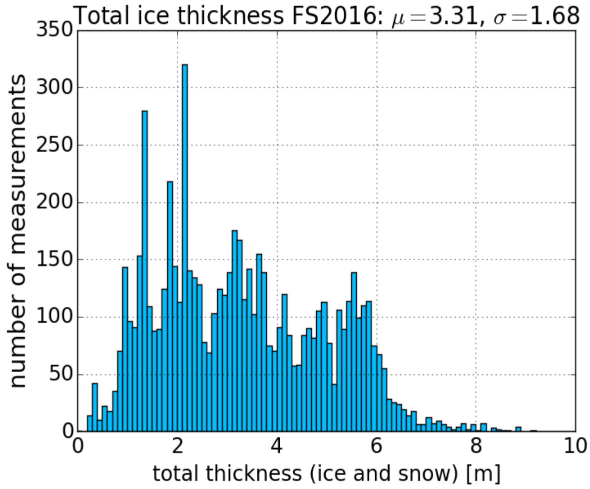


Figure 8. Total snow and ice thickness distribution from all EM31SH transects on Fram Strait 2016.

ICE stereocamera system

During the cruise there were 6 flights made with the ICE stereocamera system onboard AS350. In total some 1.2 Tb of data were collected, comprising approximately 40000 images. During the ice station on fast ice the thickness drill locations were spray painted before the over flight with the ICE camera. The spray marked points registered on the images will later be used as calibration Z-points for the photogrammetric reconstruction of the fast ice surface topography.

Helicopter-borne sea ice thickness measurements (HEM-surveys)
pilot: Mats Olsen, helicopter: LN-OMB; Airlift AS

Large-scale sea ice thickness was observed using a helicopter-borne electromagnetic instrument (HEM). In total, 6 flights were undertaken simultaneously with stereographic imaging with the ICE camera system. An overview of the flights is given in Table 1 and the tracks are shown in Fig. xx. For additional information about the overflown ice cover, a GoPro Hero camera was mounted downward looking on the helicopter, taking photographs every 2 seconds. We tried to coordinate the HEM flights with satellite acquisitions for UiT (arranged by Malin Johansen and Martine Espeseth), but either ice or weather conditions made a successful coordination difficult.

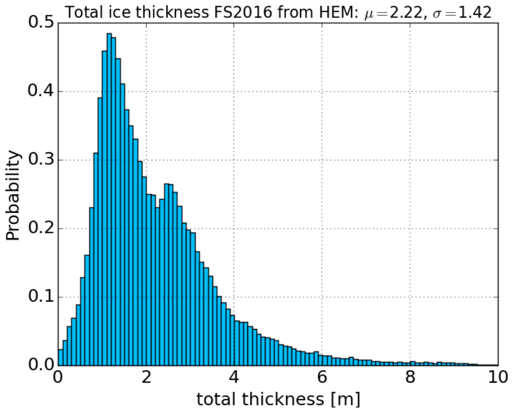


Figure 9: Total ice thickness distribution from all HEM surveys.

The mean ice thickness from EM31 is 3.3 m, while the mean ice thickness from HEM is 2.2 m. The pdf of all HEM flights shows a bimodal distribution, the first peak at 1.3 m, the second peak at 2.5 m (Fig. 9).
The observed size of the floes especially in the eastern parts of Fram Strait was very small (20-100m) with a significant contribution of brash ice in between the floes. This situation most likely causes a bias towards a thinner ice thickness. The Flights F3 and F4 have a clear mode of ice thickness around 2-2.5 m, which represents the solid fast ice cover (Fig. 10).

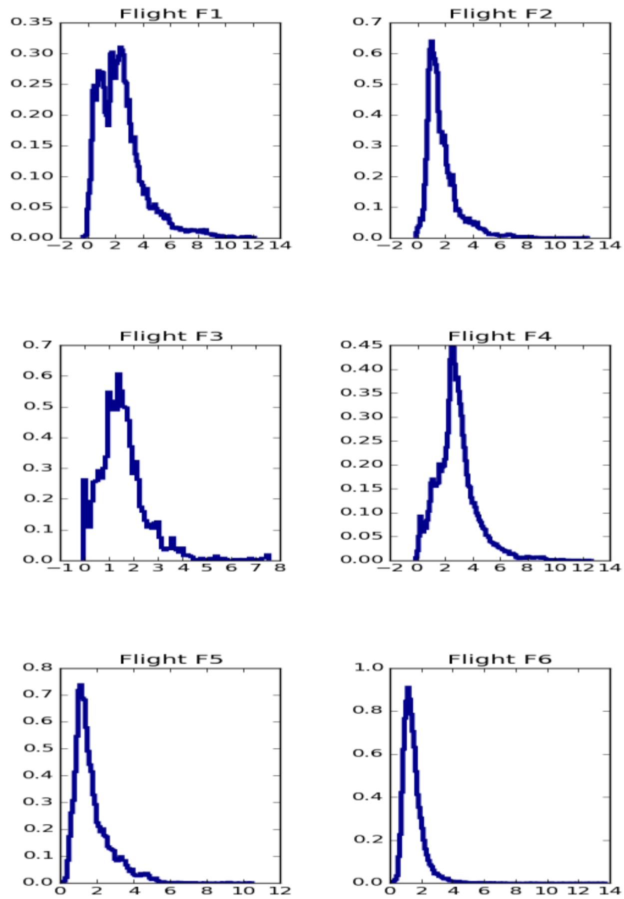


Figure 10: Total ice thickness distribution from single HEM surveys.

Ice observations from the bridge (ASSIST)

Sea ice conditions were observed every three hours from the bridge of RV Lance while moving, and twice a day during the drift station. 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 addition, the IceCam, an automated system installed onboard Lance, recorded a series of five images from port to starboard every 30 minutes with parallel logging of position.

Ice berg observation from the bridge.

In total we registered the positions of 26 ice bergs, mainly in the vicinity along the Greenland coast. These observations will be used as validation for satellite based ice berg detection approaches.

Reflectometry Experiment (Max Semmling)

Earth-reflected Global Navigation Satellite System (GNSS) signals offer a wide range of remote sensing applications. The most frequently studied geophysical parameters are: sea surface wind speed and distribution, sea surface height, snow depth, soil moisture and land vegetation cover. Attempts were also made to study sea-ice parameter, in particular the ice concentration, the ice classification and its thickness. It has been shown that the sensitivity of GNSS reflection (GNSS-R) to ice surface roughness allows to classify the ice. The increase of ice concentration on the developed sea can be detected by the decrease of surface roughness. In particular altimetric retrievals based on GNSS-R to estimate the ice thickness are challenging. The signal penetration into the ice, dependent on the ice permittivity and the signal's incidence angle, is crucial for altimetric retrievals. The experiment performed during this cruise potentially contributes to a better understanding of GNSS-R signal penetration into ice.

Setup and Preliminary Results

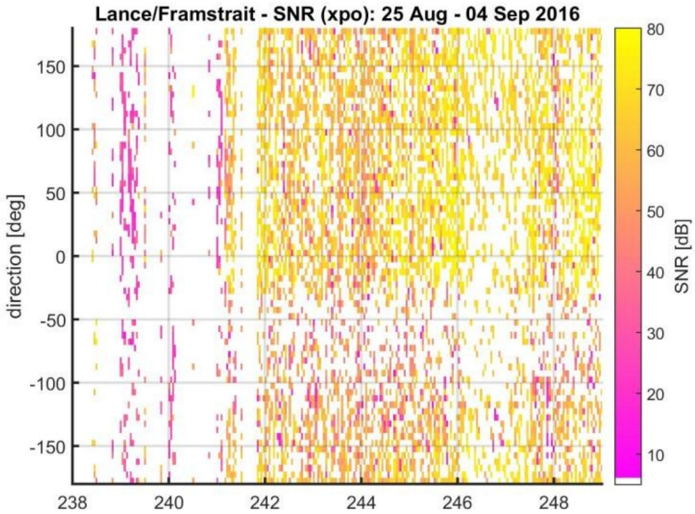


Figure 11: example SNR plot for first half of the cruise.

A GORS (GNSS Occultation, Reflectometry, Scatterometry) type receiver with three antenna links has been set up on the ship's crow's nest. Another standard geodetic type receiver with one antenna link has been set up on the ship's bow. Both setups run during the entire campaign (25 Aug – 14 Sep). A signal-to-noise ratio (SNR) is retrieved from the signal spectrum. Fig. 11 shows the SNR classified with respect to the observation's direction over the first half of the cruise (25 Aug to 4 Sep, i.e. 238 to 241 day of year 2016).

The SNR is calculated for 5min sections of GNSS-R data and is classified to the respective direction angle in the ship's body frame (0° ahead, +90°/-90° starboard/port-side and +/-180° astern). Except for the gaps during the first four days of the campaign, acquisition was almost continuously. Despite the restricted field of view observations occur almost omni-directional with significant reduction only in port-side direction. A major difference in both SNR plots is detected between the period of developed open-ocean (DoY 239) with low values (< 30dB) and drift-ice/fast-ice period (DoY 242-245/246-247) with considerable higher values (up to 80dB). This crucial difference can be explained by the different types of surface roughness encountered for developed ocean and sea-ice surfaces.

Data Comparison and Next Steps

The campaign offers a variety of ancillary data that can potentially be used to analyse the reflectometry experiment with respect to the research GNSS-R sea-ice application. First of all continuous sea-ice observations have been conducted from the ship every 3 hours between 26 Aug and 10 Sep. These observations include parameters, e.g. ice concentration, ice type and ice topography (level ice or ridges), which may influence GNSS-R observations. Sea-ice station were established at dedicated locations to gain additional in-situ data on ice thickness, temperature, salinity and snow cover. Furthermore a ship-based helicopter equipped with a EM-bird instrument measured sea-ice thickness along designated flight transects during the cruise. Especially the first two data sets have overlap with the GNSS-R observations and are most promising for comparison.

Date	Day	#	time (UTC)	lat (start)	lon (start)	Task	weather/conditions
25.08.2016	1		13:00			departure LYR	overcast, windy
26.08.2016	2		09:15	78 45	1 22	Transit - Instrument maintenance	windy, rough sea, 30 knts
27.08.2016	3		11:00			LYR - afterwards Transit	
28.08.2016	4					Transit to F11, EMB preps,	overcast, 15 knts wind
28.08.2016	4	S1	14:28	78 48	-3 04	Coring, Thickness Drilling	overcast, 15 knts wind
29.08.2016	5	F1	17:34			Flight W, then N, than back to 1st Pos (Triangle)	
29.08.2016	5	S2	09:53	78 55	-3 22	Coring, Thickness Drilling	drizzle, ice cover 70%, thick MYI, intense melt
30.08.2016	6					no ice station - salinity measurements, maintenance	
31.08.2016	7	F2	08:52			Flight W, then N, then E, then S (rectangle)	sun, clear sky, 3/8 Ci, 2/8 As in E, fog N
31.08.2016	7	S3	15:54	78 49	-6 26	Coring, Thickness Drilling, EM31	snow in the beginning, clearing up in the end
01.09.2016	8	S4	09:17	78 49	-8 05	Coring, Thickness Drilling, EM31	overcast, 10 knts wind - 2deg
02.09.2016	9	S5	08:09	79 19	-13 18	Fastice: coring, EM31, thickness drill, marking points for stereo cam	sunny, -2deg
02.09.2016	9	F3	08:30			Flight over fastice	fog in the morning, then sunny
02.09.2016	9	S6	14:10	79 13	-13 54	Fastice: Buoy deployment, Sal/T coring, EM31	sunny, -5deg
03.09.2016	10	S7	06:47	79 19	-13 29	Fastice: coring, EM31, thickness drill, massive ridge close by	sunny, -5deg
03.09.2016	10	S8a, S8b	07:26	79 18	-13 28	thin ice sampling from MOB	sunny, -5deg
03.09.2016	10	F4	09:17			Flight over fastice, buoy, and S5	fog in the morning, then sunny
04.09.2016	11		19:42			CTD transect in Dijmphna sound	
05.09.2016	12					office/lab work, maintenance	
06.09.2016	13	S9	07:53	78 11	-15 46	coring, EM31, calibr.	Sunny
06.09.2016	13	S10	09:02	78 10	-15 43	thin ice	Sunny
07.09.2016	14	S11	14:21	78 49	-6 28	coring, EM31, calibr., polar bear warning, station aborted	fog
07.09.2016	14	S12	15:36	78 49	-6 27	thin ice	Fog
08.09.2016	15	S13	11:07	78 49	-5 16	coring, EM31, calibr.	Overcast
08.09.2016	15	S13B	11:07	78 49	-5 16	thin ice	Overcast
08.09.2016	15	F5				short flight W-E and up North	
09.09.2016	16	S14	18:15	78 53	-3 53	coring incl. 2 outreach cores, EM31	small floes, overcast, fog - no flying conditions
10.09.2016	17	S15	11:12	78 53	-2 53	coring, em31, small floe with sediments	Overcast
10.09.2016	17	S16	12:31	78 52	-2 51	coring, em31, small floe with sediments nearby S15	overcast
10.09.2016	17	F6				flight towards N and W	overcast
11.09.2016	18	S17	07:01	78 57	-2 37	Coring, EM31, calib. drilling	Rainy
12.09.2016	19					Maintenance, packing, office (data processing/backup)	

Table 3: An overview of all visited ice stations and flights, including tasks.

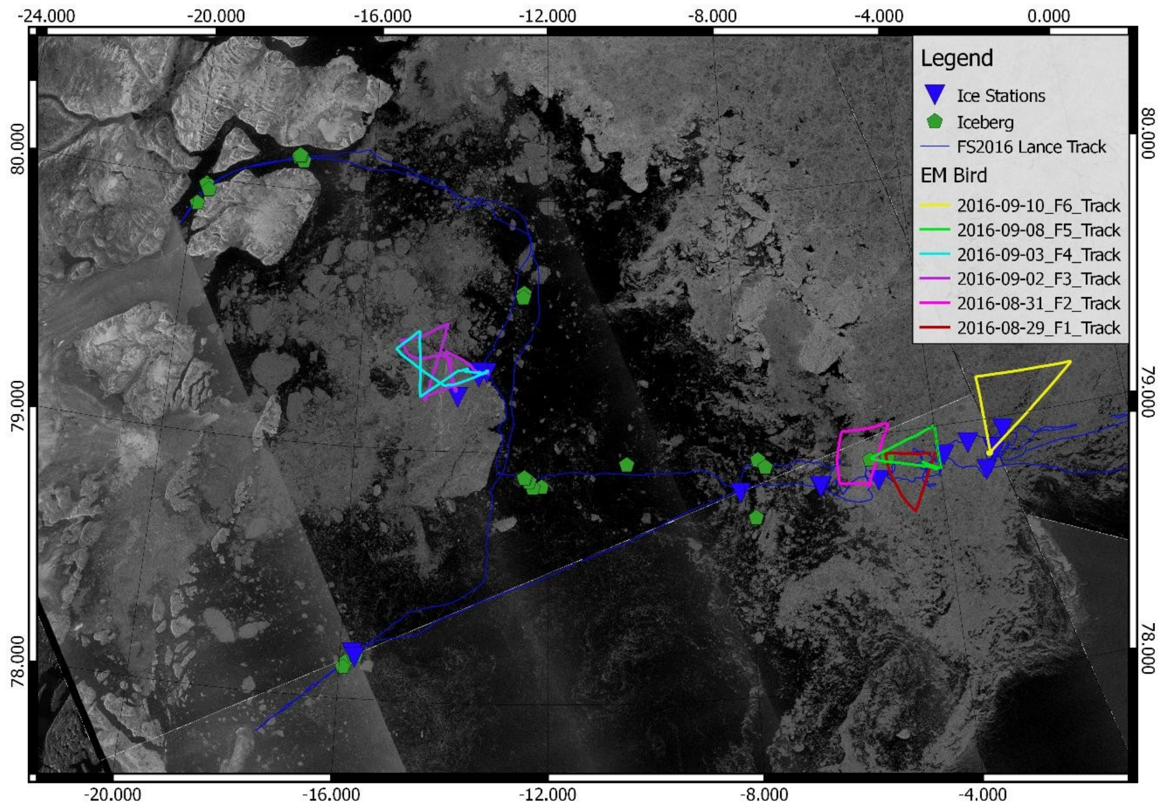


Figure 12: Overview of sea ice stations, flight tracks, and Lance's track on FS2016

Satellite data acquisitions

The remote sensing group at University of Tromsø, in addition to near-daily Sentinel-1 radar images we used for operations, required higher resolution images for work on sea ice remote sensing (Figure 13 and Table 4). Linked to this are either helicopter borne work to map the sea ice in a scene, ship-based observations of the ice pack or on-ice work for surface condition mapping during satellite acquisition or ice measurement and sampling.

For the Tandem-X images, topography measurements are of particular importance. Tandem-X scenes are ordered almost every day over the same area.

For the RISAT images, measurements of thin ice are of particular importance.

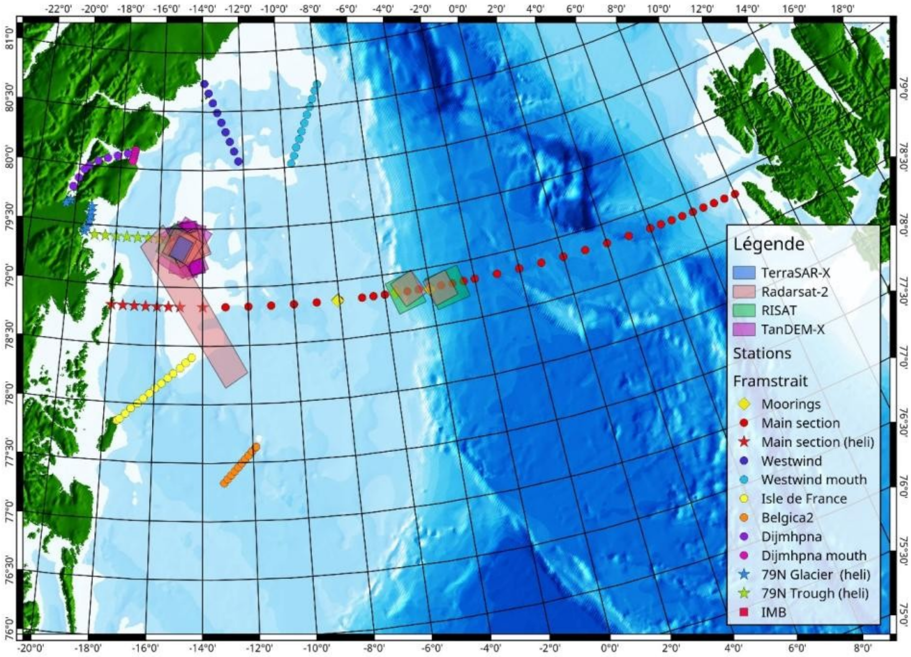


Figure 13. Location of planned acquisitions of specific satellite scenes during the FS2016

Table 4: Planned satellite acquisitions. RS2=Radarsat-2, TDMX=Tandem-X and TSX=TerraSAR-X.

Golden days	Date	Time	Sensor	Comments	Area
	25-Aug	18:10	RS2	Ridges	East of 79N glacier
		18:17	TDMX		
	27-Aug	17:11	RS2	Thin ice observations	F11
		17:27	Risat		
	28-Aug	16:42	RS2	Thin ice observations	F13-F14
		17:19	Risat		
X	30-Aug	9:06	RS2	Ridges	East of 79N glacier
		17:24	RS2		
		7:27	TDMX		
		9:01	TDMX		
		16:51	TDMX		
		18:25	TDMX		
X	31-Aug	8:36	RS2	Thin ice observations	East of 79N glacier
		8:44	TSX		
		9:04	Risat		
		16:55	RS2	Met.no scener	East of 79N glacier
	1-Sep	18:06	RS2	Ridges	East of 79N glacier
		17:51	TDMX		
	2-Sep	17:37	RS2	Ridges	East of 79N glacier
		17:34	TDMX		
	3-Sep	17:08	RS2	Ridges	East of 79N glacier
		17:16	TDMX		
	6-Sep	17:20	RS2	Ridges	East of 79N glacier
		17:59	TDMX		

CDOM-Heat Optics work

The objective of the work of CDOM-Heat project during the Fram Strait 2016 R/V Lance cruise was to collect IOP (Inherent Optical Properties) and radiometric data profiles across the strait. In addition in collaboration with the CTD and tracer sampling program onboard Lance to collect water samples for characterization of optical properties of the seawater, namely dissolved (CDOM) and particulate absorption as well as concentration of chlorophyll a.

Four CDOM-Heat project participants took part in the cruise, M. Darecki (IOPAS), A. Raczkowska (IOPAS, ISP-KNOW), M. Konik (IOPAS) and M. Granskog (NPI – Cruise Leader). Polish team were responsible for operating the IOP instruments and collecting water samples for dissolved and particulate absorption as well as concentration of chlorophyll a. In total, measurements on 35 stations were undertaken (Table 5).

Water sampling

Water samples were collected at three depths 5, 15 and 25 m for particulate absorption and at several depths as other tracers down to 400 m for CDOM absorption. Samples for CDOM (Chromophoric Dissolved Organic Matter) absorption were collected using gravity filtration directly from the Niskin bottle tab with use of the Millipore Optical XL filter cartridge with a pore size of 0.2 microns. Filter cartridge was rinsed with MilliQ water prior to first use, and extensively flushed with sample water during sampling. Samples were collected into 40 ml amber glass vials (EPA type). Samples were stored at +4C in dark until analysis onshore.

Particulate absorption samples (Table 5) and chlorophyll-a samples were collected from the same casts in 10L plastic carboys. Each carboy were filled with water from the specific Niskin bottle from the ship’s CTD rosette. Water was filtered onto Whatmann GF/F glassfibre filters using low vacuum (Fig. 14). Samples were stored directly at -80 °C, and transferred in a dryshipper with liquid nitrogen after the cruise to the homelab.

Table 5. List of IOP profiles, particulate absorption, dissolved absorption, Chl a and radiometric measurements carried out during the Fram Strait 2016 Cruise

Station No.	Date	Time	Latitude	Longitude	IOP	Particle Abs	Dissolved Abs	Chl a	Radio-metry	ice cover %/info
1	26.08.2016	12:29	78 55.71 N	00 01.58 W	□□	□□	□□	□□	□□	10
4	28.08.2016	23.34	78 55.37 N	02 00.49 W	□□	□□	□□	□□	□□	60
5	29.08.2016	04:23	78 54.81 N	02 50.02 W	□□	□□	□□	□□	□□	70
6	29.08.2016	09:13	78 55.00 N	03 30.00 W	□□				□□	70
7	29.08.2016	13.31	78 54.92 N	04 01.10 W	□□	□□	□□	□□	□□	80
11	30.08.2016	23.09	78 55.10 N	05 01.92 W	□□	□□	□□	□□	□□	90
14	31.08.2016	13.51	78 48.92 N	06 30.15 W	□□	□□	□□	□□	□□	40
15	31.08.2016	19.17	78 54.67 N	06 04.18 W	□□	□□	□□	□□	□□	-
17	31.08.2016	22.44	78 55.12 N	07 00.83 W	□□	□□	□□	□□	□□	50
18	01.09.2016	0.53	78 55.16 N	07 59.74 W	□□	□□	□□	□□	□□	30
19	01.09.2016	08:09	78 50.16 N	08 04.58 W	□□	□□	□□	□□	□□	80
20	01.09.2016	12:59	78 55.18 N	08 58.95 W	□□	□□	□□	□□	□□	35
21	01.09.2016	15:12	78 54.87 N	09 59.46 W	□□	□□	□□	□□	□□	5

22	01.09.2016	18:00	78 54.97 N	10 59.99 W	□□	□□	□□	□□	□□	<10
23	01.09.2016	20:21	78 55.01 N	12 00.56 W	□□	□□	□□	□□	□□	-
24	01.09.2016	22:41	78 55.08 N	13 01.24 W	□□	□□	□□	□□	□□	5
25	02.09.2016	16:43	79 19.28 N	13 18.18 W	□□	□□	□□	□□	□□	fast ice Greenland
26	03.09.2016	22:26	80 07.58 N	17 42.21 W	□□	□□	□□	□□	□□	Dijmphna Sund fjord
27	03.09.2016	23:40	80 06.12 N	18 11.88 W	□□	□□	□□	□□	□□	Dijmphna Sund fjord
28	04.09.2016	00:46	80 04.88 N	18 40.22 W	□□	□□	□□	□□	□□	Dijmphna Sund fjord
29	04.09.2016	02:08	80 02.86 N	19 06.94 W	□□	□□	□□		□	Dijmphna Sund fjord
30	04.09.2016	03:20	79 59.96 N	19 31.61 W	□□	□□	□□	□□	□□	Dijmphna Sund fjord
31	04.09.2016	04:37	79 57.96 N	19 45.82 W	□□	□□	□□	□□	□□	Dijmphna Sund fjord
32	04.09.2016	06:24	19 59.86 N	12 45.91 W	□□	□□	□□	□□	□□	Dijmphna Sund fjord
33	04.09.2016	07:51	79 48.55 N	20 13.07 W	□□	□□	□□	□□	□□	Dijmphna Sund fjord
40	05.09.2016	09:40	79 18.61 N	14 56.38 W	□□	□□	□□	□□	□□	20/ Isle de France
46	05.09.2016	14:50	78 02.84 N	16 26.74 W	□□	□□	□□	□□	□□	20/ Isle de France
48	05.09.2016	17:22	77 57.49 N	16 56.12 W	□□	□□	□□	□□	□□	40/ Isle de France
51	05.09.2016	20:33	77 50.93 N	17 26.47 W	□□	□□	□□	□□	□	30/ Isle de France
60	06.09.2016	08:13	78 10.92 N	15 41.88 W	□□	□□	□□	□□	□	10/ 12h of CTD
69	11.09.2016	23:41	78 55.07 N	02 01.39 E	□□	□□	□□	□□	□□	10
72	12.09.2016	15:41	78 55.07 N	06 0.31 E	□□				□	-
73	12.09.2016	19:57	78 55.01 N	07 0.16 E	□□	□□	□□	□□	□□	0
75	12.09.2016	23:59	78 55.08 N	07 59.95 E	□□	□□	□□	□□	□□	0
77	13.09.2016	03:04	78 54.96 N	78 54.96 E	□□	□□	□□	□□	□□	0

Figure 14: Filtration equipment for water samples in the laboratory onboard.

In situ measurements

The IOP measurements

At all stations (Table 5) inherent optical properties (IOP) were measured *in situ* with the use of three instruments connected together: ‘AC9 package’, LISST and a-sphere (Fig. 16).

‘AC9 package’ consisted of an ac-9*plus* attenuation and absorption meter (WET Labs Inc., USA), the WetStar 3 channel CDOM fluorometer (WET Labs Inc., USA), the MicroFlu-Chl chlorophyll fluorometer (TrioS GmbH, Germany), and a Seabird SBE 49 FastCAT Conductivity-Temperature-Depth probe (Seabird Electronics, USA.). The data streamed from all the instruments were merged with DH4 sensor interface module (WET Labs Inc.) and transferred in real-time to the deck unit. Then, they were uploaded to the PC after each cast.

The ac-9*plus* measures the absorption (*a*) and beam attenuation (*c*) coefficients at nine wavelengths (412, 440, 488, 510, 532, 555, 650, 676 and 715 nm). Scattering (*b*) was determined by subtraction of absorption signal from attenuation values. CDOM fluorescence was measured with a MicroFlu-CDOM fluorometer (TRIOS GmbH,Germany) and WETStar fluorometer (WET Labs inc.), which are suitable for in situ measurements without any prior filtration of the water. The maximum of the excitation light spectrum is 370 nm and maximum emission of the light detector is set at 460 nm. The TRIOS MicroFlu-Chla fluorometer had the same functional features as the one for CDOM measurements, except for the different excitation (470 nm) and emission (685 nm) wavelengths.

The LISST 100X instrument for in-situ observations of particle size distribution and volume concentration (Sequoia Instruments, Inc., USA) was deployed along with the Integrated Optical-Hydrological probe. The key elements of the LISST 100X self-contained instrument are a solid-state laser diode operating at 670 nm wavelength and a specially designed 32-ring-photodiode detector. Ring detector records scattering at 32 angles. The rings cover an angular range from 0.0017 to 0.34 radians, which corresponds to size ranges from 1.2 to 250 microns respectively.

The Hyperspectral Spherical-Cavity Absorption Meter (a-Sphere, HOBI Labs) extended data package of spectral absorption measurements in the range 355-750 nm with 1 nm resolution. It consisted of a solid-state LED light source, an integrating sphere that was made of solid plastic, which was characterised by high diffuse reflectivity, and was shielded against external light by an opaque housing. Moreover, a sensitive CCD spectrometer that measured radiance inside the sphere with spectral resolution of about 0.3 nm from 200 to 850 nm. The results were provided in transferable units of inverse meters (m^{-1}) and hardly any scattering from suspended particles affected the measurement due to the novel technique of the measurement developed by HOBI Labs.

The AOP measurements

The Apparent Optical Properties (AOP) were measured using a set of radiometers called C-OPS (the Compact Optical Profiling System). It consisted of 2 in-water radiometers that measured downward irradiance and upwelling radiance in the water column. They were deployed on a free-fall frame, up to 200m max depth depends on light conditions in the water column. The profiling system was supported by a reference radiometer for the comparison with the above-surface downwelling irradiance and an additional shadow-band system that was used for the measurements of diffuse and direct components of the Sun light. The C-OPS set operated in 19 narrow wavebands (305,340,380,412,443,465,490,510,532,555,565,589,625,665,683,710,765,875nm and PAR sensor)

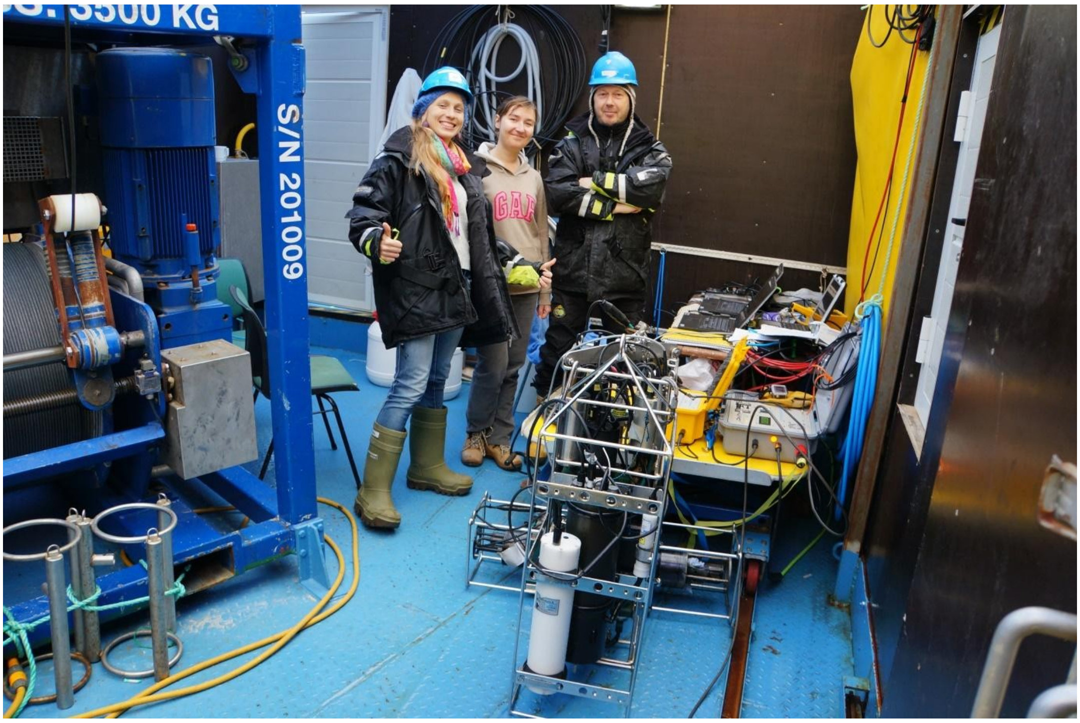


Figure 15; IOP team and the equipment and computer lab.

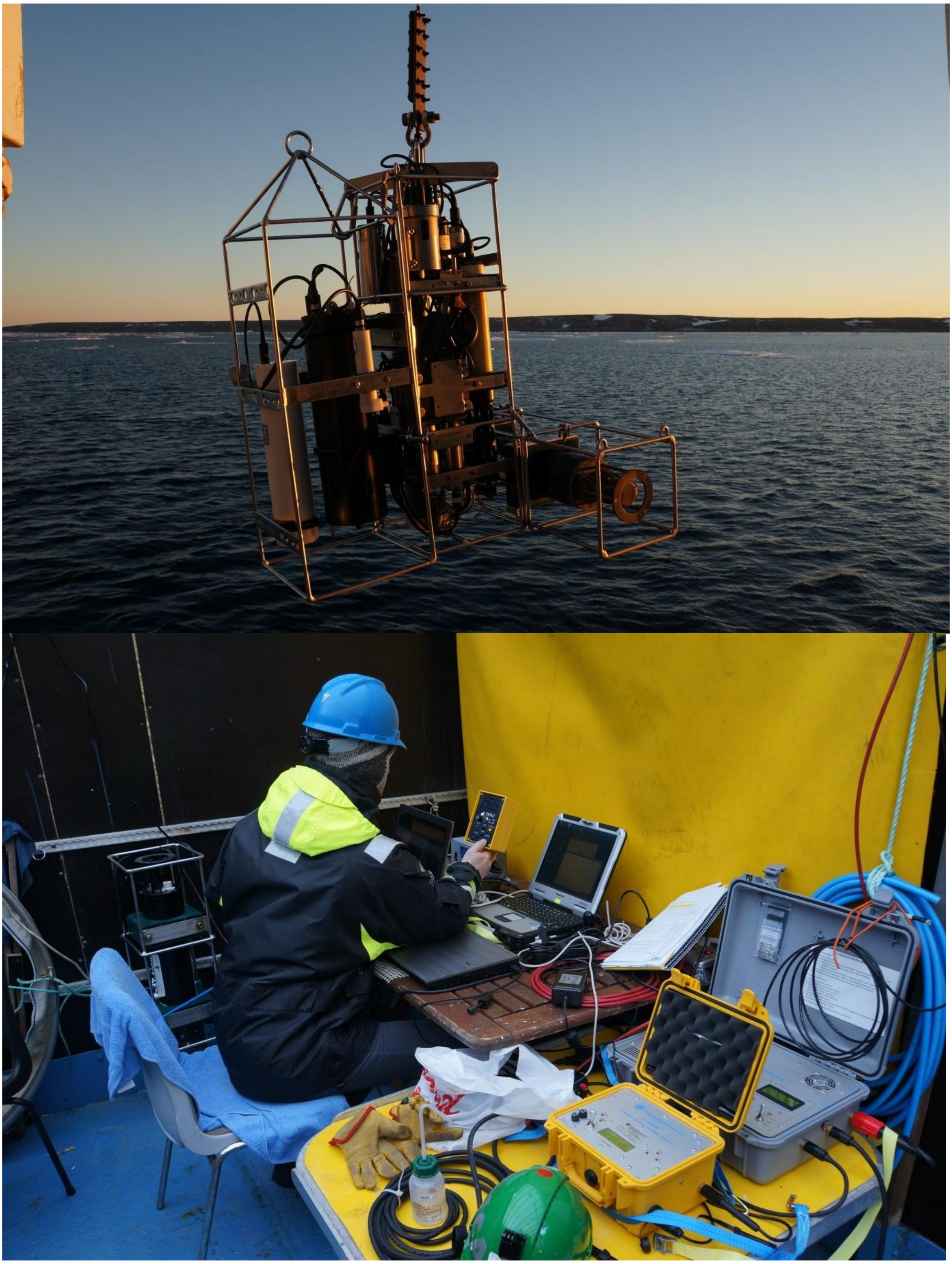
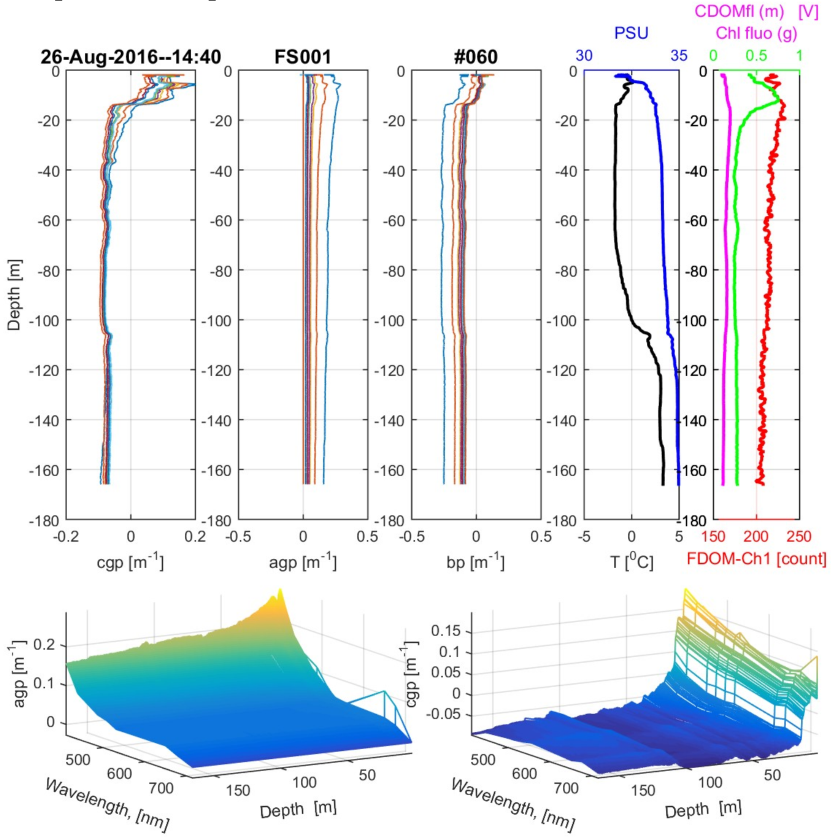
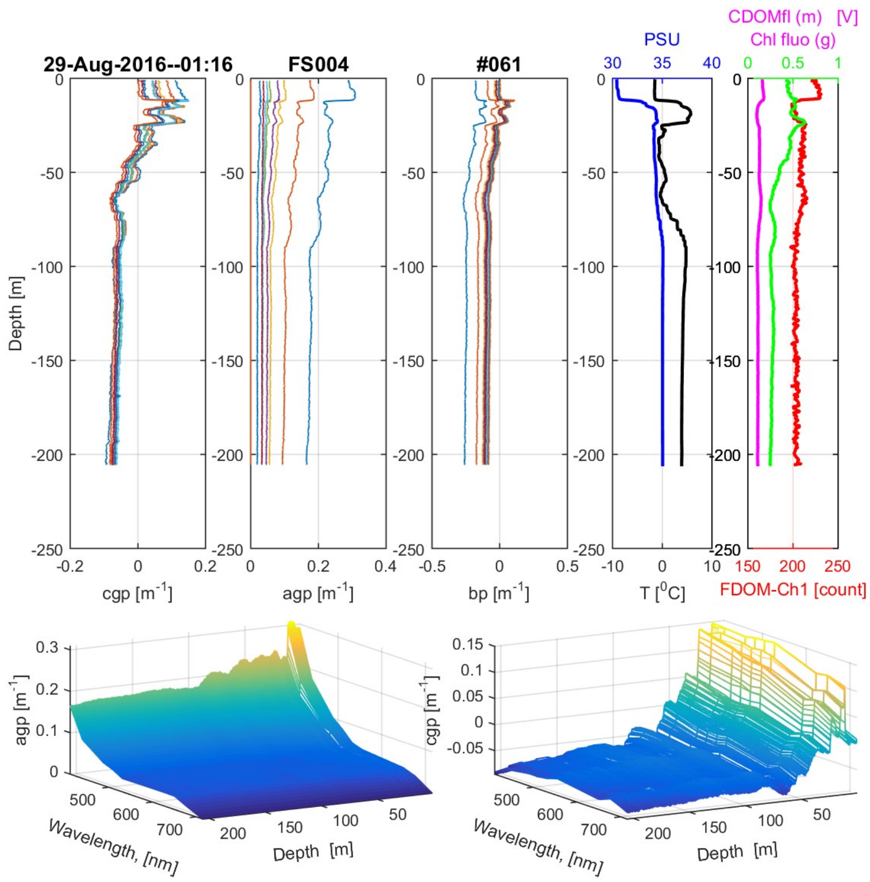
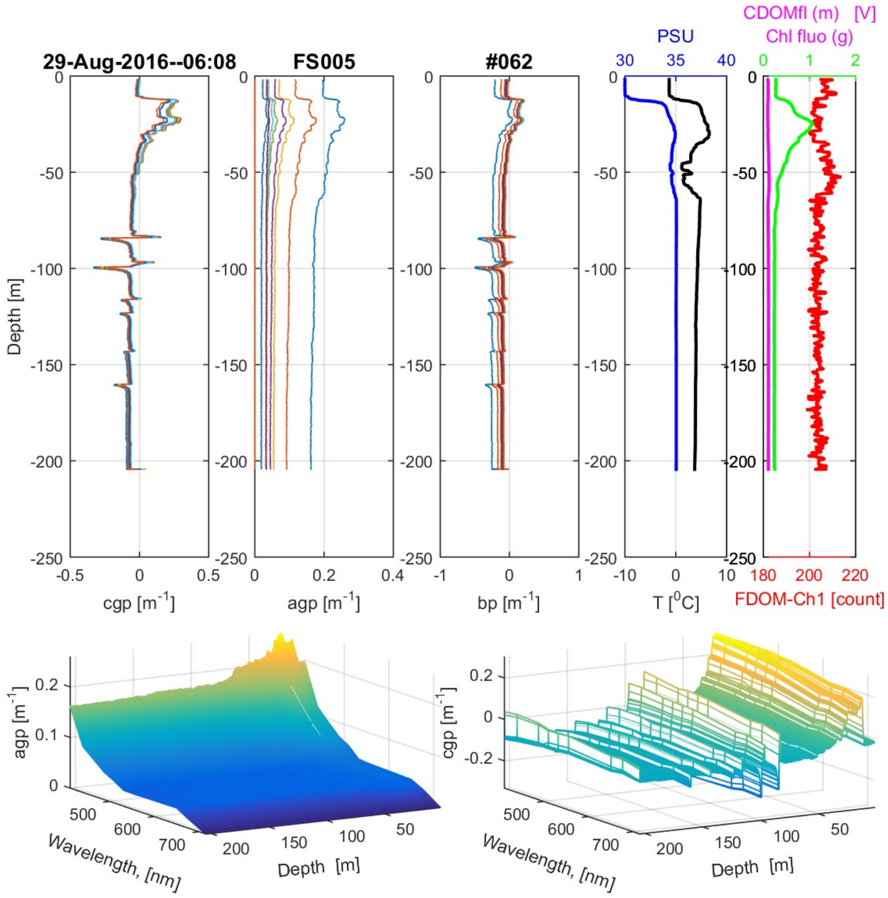


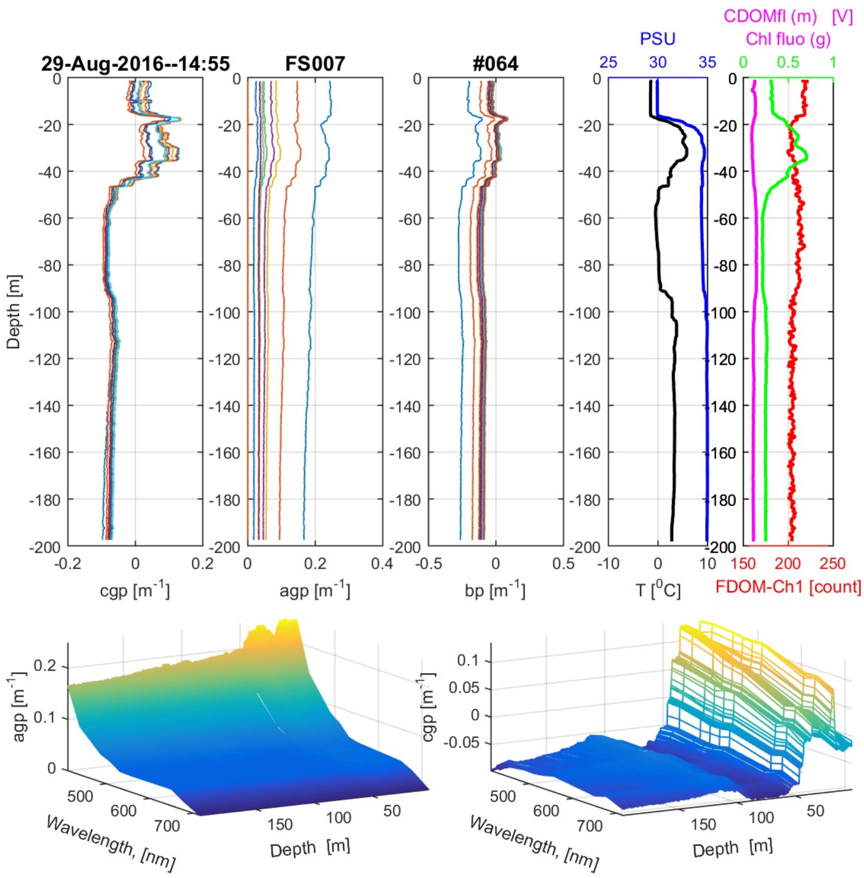
Figure 16: Top. Optical instruments for in situ measurements (from left to right: a-sphere, Ac-9 package, LISST). Bottom. Optical computer laboratory

Examples of IOP profiles measured in the cruise.

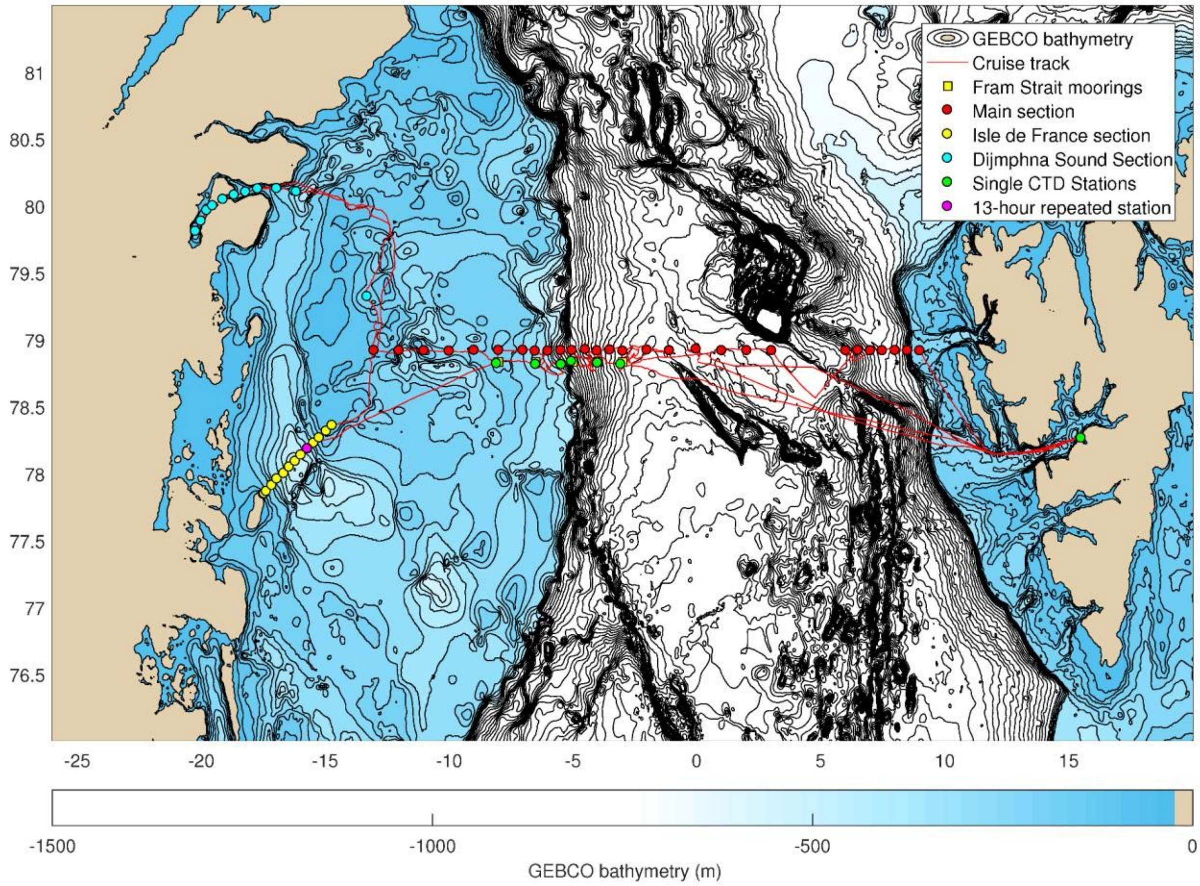





29-Aug-2016--06:08
FS005
#062
PSU
CDOMfl (m) [V]
Chl fluo (g)
Depth [m]
cgp [m-1]
agp [m-1]
bp [m-1]
T [0C]
FDOM-Ch1 [count]
agp [m-1]
cgp [m-1]
Wavelength, [nm]
Depth [m]


29-Aug-2016--14:55
FS007
#064
PSU
CDOMfl (m) [V]
Chl fluo (g)
Depth [m]
cgp [m-1]
agp [m-1]
bp [m-1]
T [0C]
FDOM-Ch1 [count]
agp [m-1]
cgp [m-1]
Wavelength, [nm]
Depth [m]

Appendix 1: Map of CTD stations

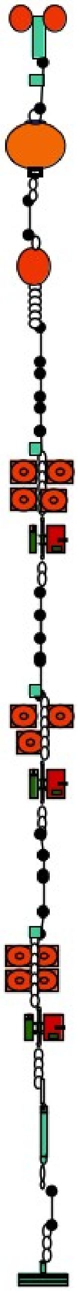


Appendix 2: Drawings of recovered moorings

Rigg F11-17 78 48,992N

Satt ut 9 SEP 2015 kl 08:35 003 01,508W

Tatt opp AUG kl



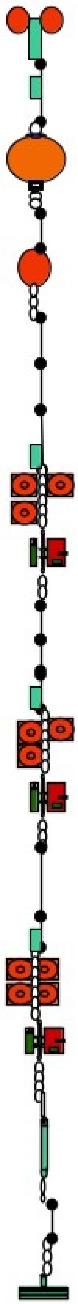
			Dyp:	Fra bunn:	Ut:
IPS	SNR. 51062		49	2401	08:30
SBE37 5 m Kevlar	SNR. 7054		51	2399	08:30
ADCP300	SNR: 17461		55	2395	08:30
1 m Kjetting galvanisert 10 m Kevlar					
Stålkule 37 McLane			67	2383	
1,0 m Kjetting galvanisert					
100 m Kevlar					
50 m Kevlar 50 m Kevlar					
SBE37	SNR. 3996		268	2182	08:16
4 Glasskuler (gule) 2 m Kjetting galvanisert					
RCM9	SNR.1049		269	2179	08:16
0,5 m Kjetting galv					
200(199) m Kevlar K 500(507) m Kevlar K 500(505) m Kevlar 40 m Kevlar					
SBE37 3 Glasskuler (2 oransje + 1 gul) 2 m Kjetting galvanisert	SNR. 7061		1532	928	07:46
RCM11	SNR.538		1535	925	07:46
0,5 m Kjetting galv 500(512) m Kevlar K 200 m Kevlar 200 m Kevlar					
SBE37 4 Glasskuler (gule) 2 m Kjetting galvanisert	SNR. 8226		2437	13	07:21
Seaguard	SNR.834		2440	10	07:21
0,5 m Kjetting rustfri Svivel					
AR861	SNR. 499	Pinger på: Pinger av: Release: Release m/ping:			
3,5 m Kevlar					
3 m Kjetting galvanisert					
ANKER 1230/(980) kg			2450	0	

Recovered mooring F11-17

Rigg F12-17 78 49,148N

Settes ut 8 SEP 2015 kl 12:19 004 00,900W

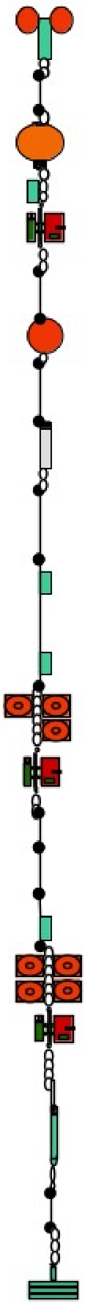
Tatt opp AUG 20 kl



			Dyp:	Fra bunn:	Ut:
IPS	SNR. 51167		47	1770	11:55
SBE37	SNR.7055		49	1772	11:55
5 m Kevlar					
ADCP300	SNR: 17462		53	1777	11:54
1,0 m Kjetting galvanisert					
10 m Kevlar					
Stålkule 37	SNR.		65	1765	
1,0 m Kjetting galvanisert					
200 m Kevlar					
SBE37	SNR.3994		272	1564	11:43
3 Glasskuler					
2 m Kjetting galvanisert					
RCM9	SNR. 836		269	1561	11:43
0,5 m Kjetting galv					
500(498) m Kevlar					
500(497) m Kevlar					
200(203) m Kevlar					
SBE37	SNR.10294		1468	362	11:15
3 Glasskuler					
2 m Kjetting galvanisert					
RCM11	SNR.556		1471	359	11:15
0,5 m Kjetting galv					
200(205) m Kevlar					
100(101) m Kevlar					
40 m Kevlar					
SBE37	SNR. 8227		1817	13	11:01
4 Glasskuler					
2 m Kjetting galvanisert					
RCM11	SNR.117		1820	10	11:01
0,5 m Kjetting rustfri					
Svivel					
AR861	SNR. 500	Pinger på: Pinger av: Release Release m/ping:			
3,5 m Kevlar					
3 m Kjetting galvanisert					
ANKER	1190/(960) kg		1830	0	

Recovered Mooring F12-17

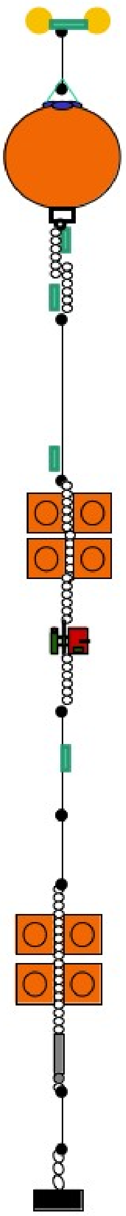
Rigg F13-17 78 50.164N
Settes ut 7 SEP 2015, kl 11:15 005 00.086W
Tatt opp AUG 201 kl :00



			Dyp:	Fra bunn:	Ned i vann:
IPS5	SNR. 51064		49	961	11:10
5 m Kevlar					
ADCP300	SNR: 16831		55	955	11:10
1,5 m Kjetting galv					
SBE16	SNR: 7253		56	954	11:10
RCM9	SNR. 1175		57	953	11:10
0,5 m Kjetting galv.					
10 m Kevlar					
Stålkule 37			69	941	
5 m Kevlar					
Hvallydopptaker			74	936	11:01
0,5 m Kjetting galv.					
20 m Kevlar					
50 m Kevlar					
SBE37	SNR. 3995		146	864	10:54
100 m Kevlar					
SBE37	SNR.7060		244	766	10:50
3 Glasskuler					
2 m Kjetting galv.					
RCM9	SNR.1326		247	763	10:50
0,5 m Kjetting galv					
500 m Kevlar K					
100 m Kevlar					
100 m Kevlar					
50 m Kevlar					
SBE37	SNR. 13504		997	13	10:32
4 Glasskuler					
2 m Kjetting galv.					
RCM11	SNR. 345		1000	10	10:30
0,5 m Kjetting rustfri					
Svivel					
AR861	SNR. 743	Ping på: Ping av: Release: Release m/ping:			
3,5 m Kevlar					
3 m Kjetting galvanisert					
ANKER 1100/(880) kg			1010	0	

Recovered mooring F13-17

Rigg F13B-2 78 50.182 N
Satt ut 6 SEP 2015 , kl 10 :59 005 30.886W

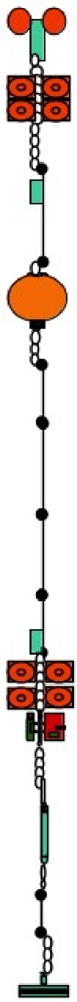


			Dyp:	Fra bunn:	Ut:
ICECat	SNR. 13506		30	486	10:57
30 m Wire weak link					
ADCP	SNR.727		60	456	10:57
IceCat Modem					
SBE37IM	SNR. 13507		62	454	10:57
40 m Kevlar					
SBE37SM	SNR. 7059		102	414	10:52
3 m Kjetting galv. 4 Glasskuler					
Seaguard	SNR. 883		204	312	10:52
SBE37SM	SNR. 13505		205	311	10:45
200 m Kevlar					
200(204) m Kevlar					
2 m Kjetting galv.					
4 GLASSKULER			506	10	10:36
AR661CS	SNR. 410	Ping on: Release: Arm:			
5 m Kevlar.					
2 m Kjetting galv.					
ANKER	770/(620)kg		516	0	

Recoverd mooring F13B-2

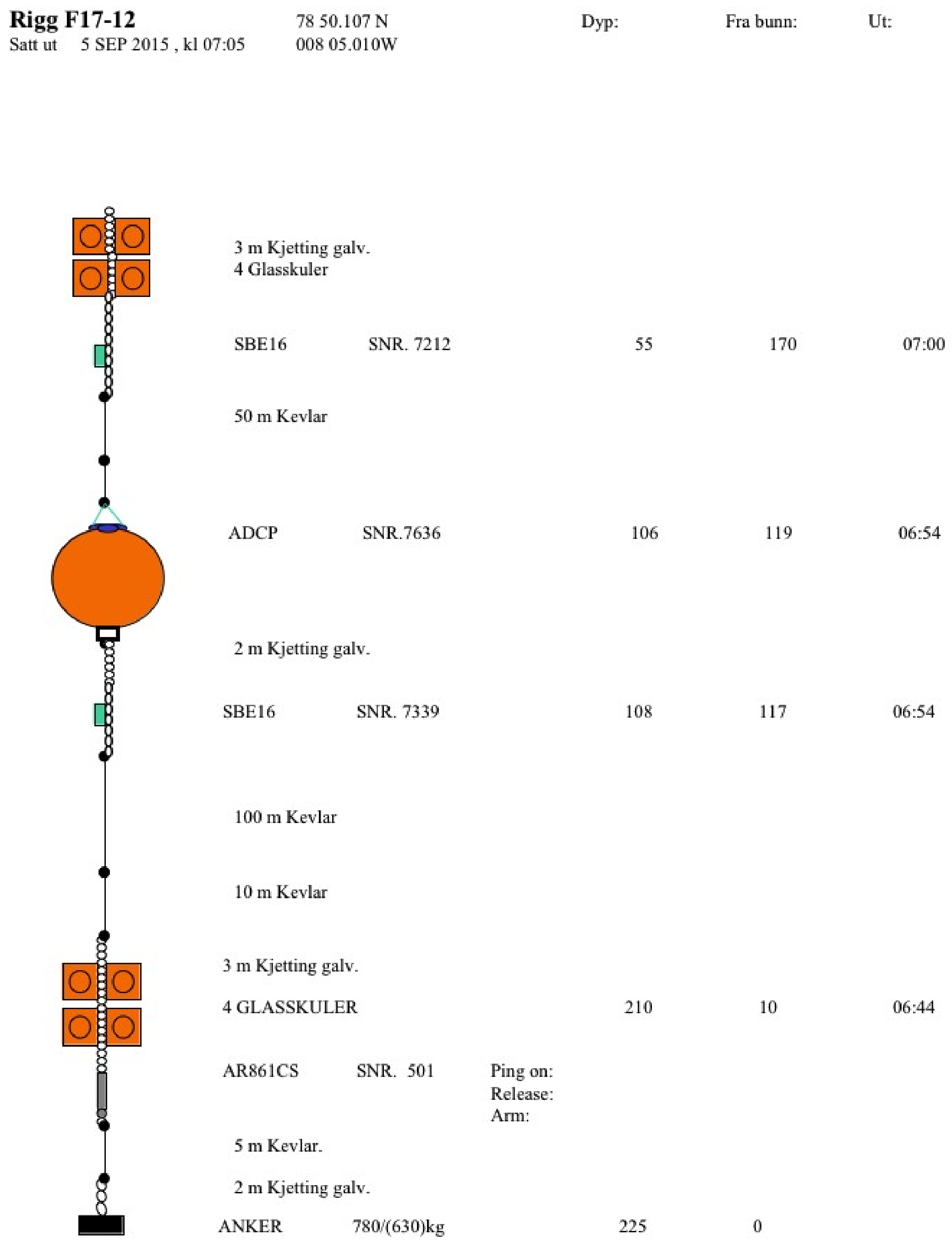
Rigg F14-17
Satt ut 5 SEP 2015 , kl 14:05

78 48,866N
006 30,033W

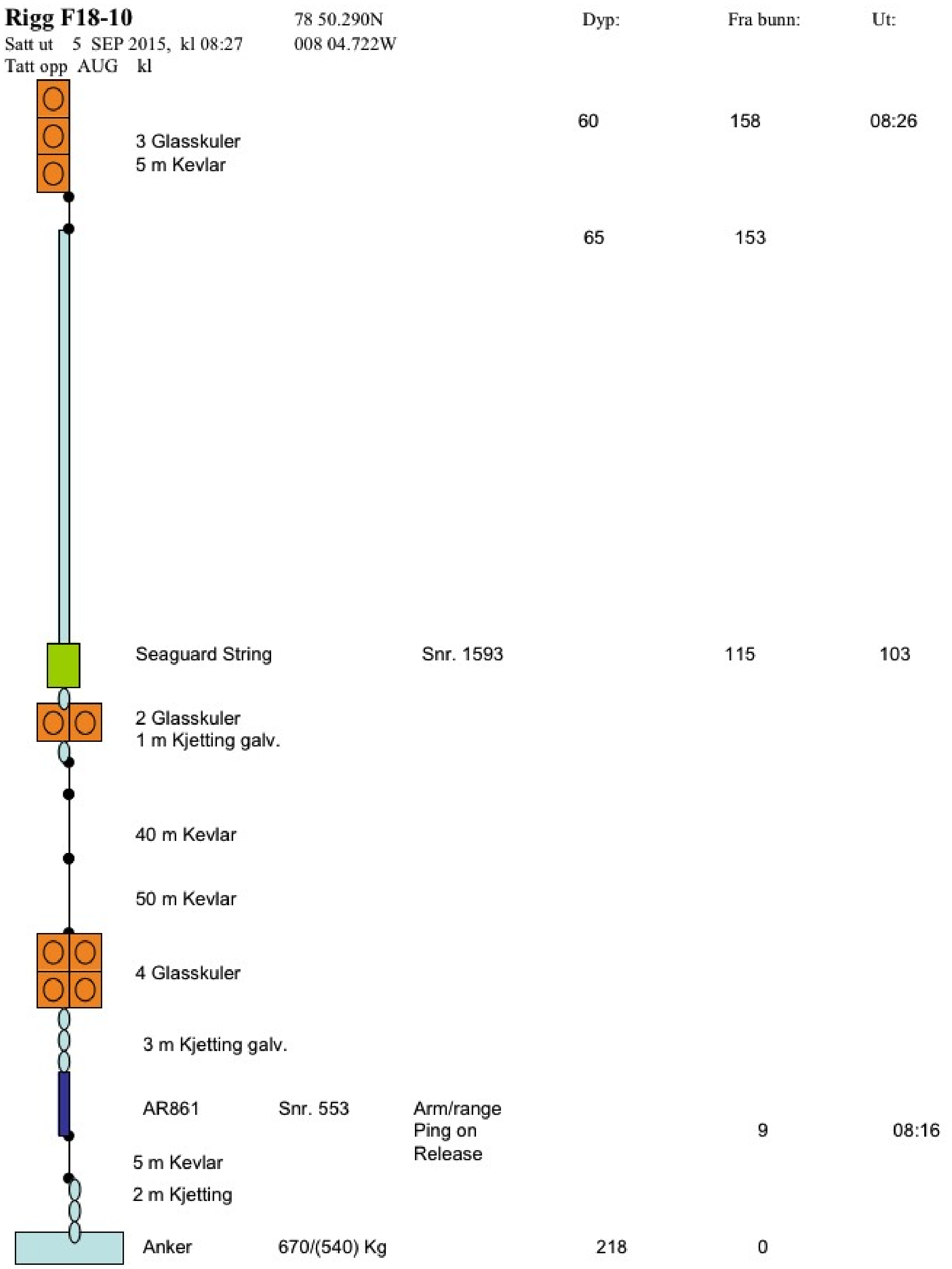


Komponent	SNR		Dyp:	Fra bunn:	Ned i vann:
IPS	SNR. 51127		58	213	11:04
4 Glasskuler 2 m Kjetting galv.					
SBE37	SNR: 7058		62	209	14:04
5 m Kevlar					
ADCP 300	SNR: 16876		67	204	14:03
1 m Kjetting Galv. 0,5 m Kjetting Galv.					
100 m Kevlar					
50 m Kevlar					
40 m Kevlar					
SBE37	SNR.7057		258	13	11:53
4 Glasskuler 2 m Kjetting Galv.					
RCM9	SNR. 1325		261	10	13:50
Svivel					
AR861	SNR. 568	Arm: Range: Ping on:			
3,5 m Kevlar					
2,5 m Kjetting					
ANKER 925/(740) kg			271	0	

Recovered mooring F14-17



Recovered mooring F17-12



Recovered mooring F18-10

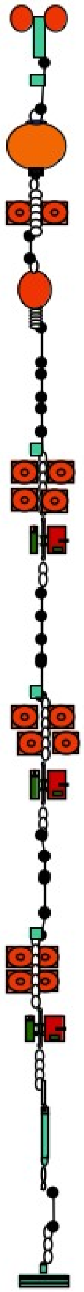
Appendix 3: Drawings of deployed moorings

Rigg F11-18

Satt ut 10 SEP 2016 kl 09:18 003 01,559W

Tatt opp AUG kl

78 48,998N



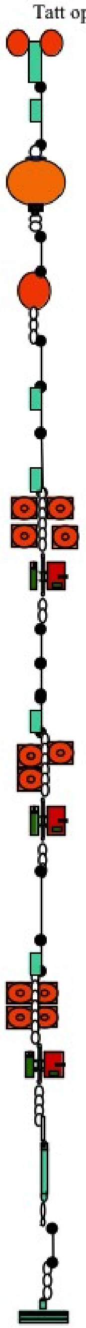
		Dyp:	Fra bunn:	Ut:
IPS	SNR. 51062	58	2390	09:09
SBE37	SNR. 3490	60	2388	09:09
5 m Kevlar				
ADCP300	SNR: 17461	64	2384	09:09
2 Glasskuler				
1 m Kjetting galvanisert				
10 m Kevlar				
Stålkule 37 McLane		76	2372	
1,0 m Kjetting galvanisert				
100 m Kevlar				
50 (49)m Kevlar				
50 m Kevlar				
5 m Kevlar				
SBE37	SNR. 4702	281	2167	08:54
4 Glasskuler (gule)				
2 m Kjetting galvanisert				
RCM9	SNR.1324	284	2164	08:54
0,5 m Kjetting galv				
200(204) m Kevlar K				
500(495) m Kevlar				
500(498) m Kevlar				
50 m Kevlar				
SBE37	SNR. 3552	1532	916	08:36
4 Glasskuler				
2 m Kjetting galvanisert				
RCM11	SNR.494	1535	913	08:36
0,5 m Kjetting galv				
500(498) m Kevlar K				
200 (198)m Kevlar				
200 (205)m Kevlar				
SBE37	SNR. 8821	2435	13	08:20
4 Glasskuler (gule)				
2 m Kjetting galvanisert				
Seaguard	SNR.10071	2438	10	08:20
0,5 m Kjetting rustfri				
Svivel				
AR861	SNR. 287 — Pinger på: Pinger av: Release: Release m/ping:			
3,5 m Kevlar				
3 m Kjetting galvanisert				
ANKER	1220/(980) kg	2448	0	

Deployed mooring F11-18

Rigg F12-18 78 49,156N

Settes ut 9 SEP 2016 kl 13:29 004 00,427W

Tatt opp AUG 20 kl



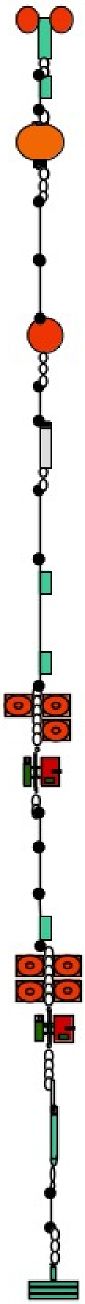
			Dyp:	Fra bunn:	Ut:
IPS	SNR. 1047		57	1778	11:55
SBE37	SNR.3489		59	1776	11:55
5 m Kevlar					
ADCP300	SNR: 17462		63	1772	11:27
0,5m Kjetting galvanisert					
2 x 10 m Kevlar					
Stålkule 37	SNR. 596		85	1750	
1,5 m Kjetting galvanisert					
SBE37	SNR. 14097		151	1684	11:57
200 m Kevlar					
SBE37	SNR.4837		276	1569	11:52
4 Glasskuler					
2 m Kjetting galvanisert					
RCM9	SNR. 884		279	1566	11:52
0,5 m Kjetting galv					
500 m Kevlar					
500 m Kevlar					
200 m Kevlar					
SBE37	SNR.3554		1479	366	11:25
3 Glasskuler					
2 m Kjetting galvanisert					
RCM11	SNR.235		1482	353	11:25
0,5 m Kjetting galv					
200 m Kevlar					
100 m Kevlar					
40 m Kevlar					
SBE37	SNR. 8822		1822	13	11:10
4 Glasskuler					
2 m Kjetting galvanisert					
RCM11	SNR.228		1825	10	11:13
0,5 m Kjetting rustfri					
Svivel					
AR861	SNR. 182	Pinger på: Pinger av: Release Release m/ping:			
3,5 m Kevlar					
3 m Kjetting galvanisert					
ANKER 1120/(940) kg			1835		

Deployed mooring F12-18

Rigg F13-18 78 50.283N

Settes ut 8 SEP 2016, kl 17:18 004 59.191W

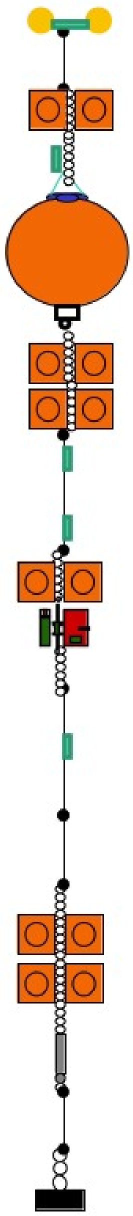
Tatt opp AUG 201 kl :00



			Dyp:	Fra bunn:	Ned i vann:
IPS4	SNR. 51064		54	964	17:15
SBE37	SNR: 7056		56	962	17:15
5 m Kevlar					
ADCP300	SNR: 16831		60	958	17:15
1,5 m Kjetting galv					
5 m Kevlar					
10 m Kevlar					
Stålkule 37			77	941	
1,5 m Kjetting galv.					
5 m Kevlar					
Hvallydopptaker			84	934	17:07
0,5 m Kjetting galv.					
50 + 20 m Kevlar					
SBE37	SNR. 12232		155	863	15:00
100 (103) m Kevlar					
SBE37	SNR.3993		256	762	16:57
3 Glasskuler					
2 m Kjetting galv.					
RCM9	SNR.1327		259	759	16:57
0,5 m Kjetting galv					
500 (498)m Kevlar K					
200 (198)m Kevlar					
50 m Kevlar					
SBE37	SNR.3551		1005	13	16:36
4 Glasskuler					
2 m Kjetting galv.					
RCM11	SNR. 561		1008	10	16:36
0,5 m Kjetting rustfri					
Svivel					
AR861	SNR. 053	Ping på: Ping av: Release: Release m/ping:			
3,5 m Kevlar					
3 m Kjetting galvanisert					
ANKER 1110/(880) kg			1018	0	

Deployed mooring F13-18

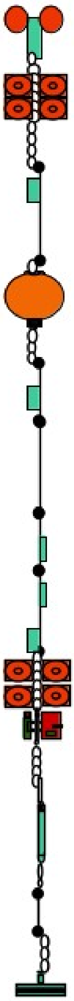
Rigg F13B-3 78 50.266 N Dyp: Fra bunn: Ut:
Satt ut 8 SEP 2016 , kl 09:08 005 30.873W



			Dyp	Fra bunn	Ut
ICECat	SNR. 13506		22	505	09:06
25 m Wire					
Weak link					
1 m Kjetting galv.					
2 Glasskuler					
ICECAT modem					
ADCP	SNR.727		60	467	09:05
3 m Kjetting galv.					
4 Glasskuler					
SBE37	SNR. 12234		65	462	08:33
50 m Kevlar					
SBE37	SNR. 12233		113	414	08:25
1 m Kjetting galv.					
2 Glasskuler					
RCM7	SNR. 9464		115	412	08:25
200 m Kevlar					
SBE37	SNR. 10295		166	361	08:16
200 m Kevlar					
2 m Kjetting galv.					
4 GLASSKULER			516	11	
AR661	SNR. 291	Range: Release:			
5 m Kevlar.					
2 m Kjetting galv.					
ANKER	800/(620)kg		527	0	

Deployed mooring F13B-3

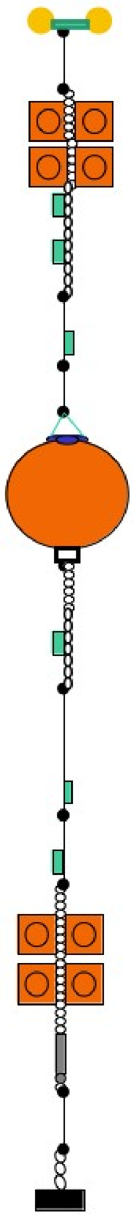
Rigg F14-18 78 48,861N
Satt ut 7 SEP 2016 , kl 13:23 006 30,09W



			Dyp:	Fra bunn:	Ned i vann:
IPS	SNR. 51127		57	215	13:07
4 Glasskuler 2 m Kjetting galv.					
SBE37	SNR: 3492		61	211	13:07
5 m Kevlar					
ADCP 300	SNR: 16876		65	207	13:07
1 m Kjetting Galv. 0,5 m Kjetting Galv. 40 m Kevlar					
SBE37	SNR: 14098		106	166	12:58
100 (102) m Kevlar					
50 (51) m Kevlar					
SBE56	SNR.3943		259	63	12:47
SBE56	SNR.3942		234	38	12:42
SBE37	SNR.3992		259	13	12:38
4 Glasskuler 2 m Kjetting Galv.					
RCM9	SNR. 1046		262	10	12:38
Svivel					
AR861	SNR. 506	Arm: Range: Ping on:			
3,5 m Kevlar					
2,5 m Kjetting					
ANKER 920/(740) kg			272	0	

Deployed mooring F14-18

Rigg F17-13 Satt ut 7 SEP 2016 , kl 09:08 — 78 50. 179 N 008 04.913W



Instrument	SNR		Dyp:	Fra bunn:	Ut:
ICECat	SNR. 13507		27	198	09:08
25 m Wire					
Weak link					
3 m Kjetting galv.					
4 Glasskuler					
ICECAT Modem					
SBE16	SNR.6693		55	170	09:03
40 m Kevlar					
SBE37	SNR.2962		75	130	08:54
10 m Kevlar					
ADCP	SNR.7636		106	119	08:48
2 m Kjetting galv.					
SBE16	SNR.6694		108	117	08:48
100 m Kevlar					
SBE56	SNR.3944		187	38	08:38
5 m Kevlar					
SBE37	SNR.7062		213	12	08:34
2 m Kjetting galv.					
4 GLASSKULER			214	11	
AR661	SNR. 110	Ping on: Release:			
5 m Kevlar.					
2 m Kjetting galv.					
ANKER	815/(700)kg		225	0	

Deployed mooring F17-13