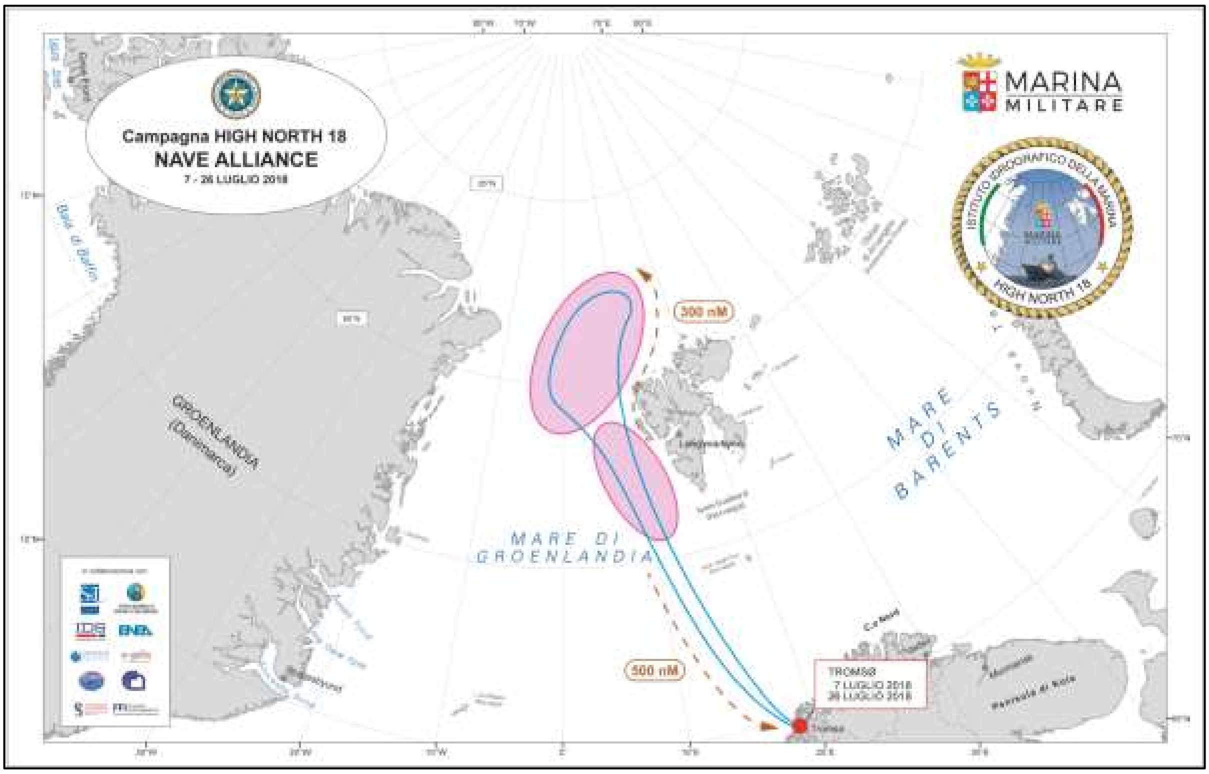
High North 18
Arctic Marine Geophysical Campaign

7 – 26 July 2018

Italian Navy

IIM CMRE CNR ENEA ERI IDS OGS UNI-SORBONNE



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SUMMARY

High North 18 Campaign was carried out onboard the Italian R/V Alliance between 7 and 26 July 2018. The main goal of the campaign was to investigate the marine geophysical, oceanographic, and geological conditions in 5 different areas: INBIS Channel, South Western Svalbard and Storfjorden, Kongsfjorden and Yermak Plateau. The ship moved northwards up to 81° 50.27' N close to the sea ice edge to investigate the characteristics of the sea ice, water masses and sediment dynamics.

The cruise was characterized by 76 stations (hydrological, sedimentological, geophysical measurements) with 553 km^2 area surveyed by MBES (MultiBeam Echo Sounder) with the purpose of mapping the bottom morphology, seabed nature and water column. A new high resolution seabed mapping was obtained for all investigated sites according to the IHO hydrographic standards (International Hydrographic Organization). Data acquired through the CTD (Conductivity-Temperature-Depth, 33 vertical profiles and Scanfish surveys) probe will be used to define physical characteristics of the water column. A glider mission, consisting of 4 gliders flying at the same time along the West Spitsbergen Current (WSC), was performed. Water and sediment samples have been also collected. A specific activity to observe and sample plastic pollution at sea surface was conducted during the cruise using a manta trawl. Finally, 4 oceanographic moorings have been deployed on the slope of Western Spitsbergen in order to obtain short a long term observations of water masses and sediment dynamics.

The most important part of the acoustic activity was conducted on the Yermak Plateau. The target was to obtain a morphobathymetric chart of this unsurveyed area, in order to improve the World's database, validated by seafloor sediment samples. In the Kongsfjorden area is conducted a MBES survey and an oceanographic mooring (named KGF) has been deployed. A 3D mapping of the water column and bottom, is obtained to better understand the flow paths of the water masses and the seabed morphodynamics. In particular the acoustic backscatter data was used to characterize the nature of the seabed using sediment samples referring to the depositional features and hydrological aspects.

Another important goal of the cruise was to investigate the bottom structures and hydrological properties in the South Svalbard region measuring potential temperature, salinity, density, oxygen, and turbidity throughout the water column and close to the seabed. In the Storfjorden, the surface layer was clearly influenced by fresh water deriving from ice melting and intrusions of Atlantic water constrain by the seabed morphology. Data collected in this region can provide useful information on the main properties of the dense waters formed during winter 2017-2018. Offshore Kongsfjord, CTD casts highlighted the presence of water intrusions likely coming from the shelf and fjord areas with the development of eddies and bottom sediment processes.

Data collected in the northernmost part of Svalbard Archipelago, and in particular along the transect on the Yermak Plateau, show signals of Atlantic water moving towards the Arctic Ocean confined in the layer between 100 m and 500-600 m depth on a complex seabed.

These preliminary results are an important starting point for our developing research over this area and for future collaborations.

R/V Alliance, Tromsø July 26th 2018

Chief Scientist	Project Manager
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HIGH NORTH 18 TEAM.

CONTENTS

1. Scientific Background and Goals

Mapping the seafloor has resulted in some major breakthroughs in our understanding of earth system processes. Different approaches, equipment and processing affect such mapping everywhere, but particularly in the Arctic Ocean. Few hydrographic data are available and the main product is the GEBCO-IBCAO (International Bathymetric Chart of the Arctic Ocean) database with the nautical charts (Figure 1).

Figure 1 A Planning Chart for the Arctic Region, 1:7.500.000, 4006.

In particular, the NW Barents Sea continental margin has been the target of several surveys in the last decade: SVAIS (R/V Hesperides) in 2007, EGLACOM (R/V OGS Explora) in 2008, GLACIBAR (R/V Jan Mayen) in 2009, CORIBAR (R/V Maria S. Merian) in 2013, PREPARED (R/V G.O. Sars) in 2014, EDIPO-DEGLABAR (R/V OGS Explora) in 2015, and HN17 (R/V Alliance) in 2017.

The High North 18 cruise gave us the opportunity to collect new multibeam echosounder data, in order to cover some areas along the continental margin that had not been covered before and to improve seabed mapping in some key areas from the morphological and sedimentological point of view. In order to characterize the water masses and relevant circulation, the literature needs data from moorings and physical parameter measuring along transects or profiles using CTD, glider, Scanfish. High North 18 was supported by 'several and good' measuring stations, and the new bathymetric data will be used for GEBCO-IBCAO or to reconstruct the dynamic of the cold deep water or particular habitats or environments in the past. This is crucial to try and understand the future.

2. Cruise Narrative

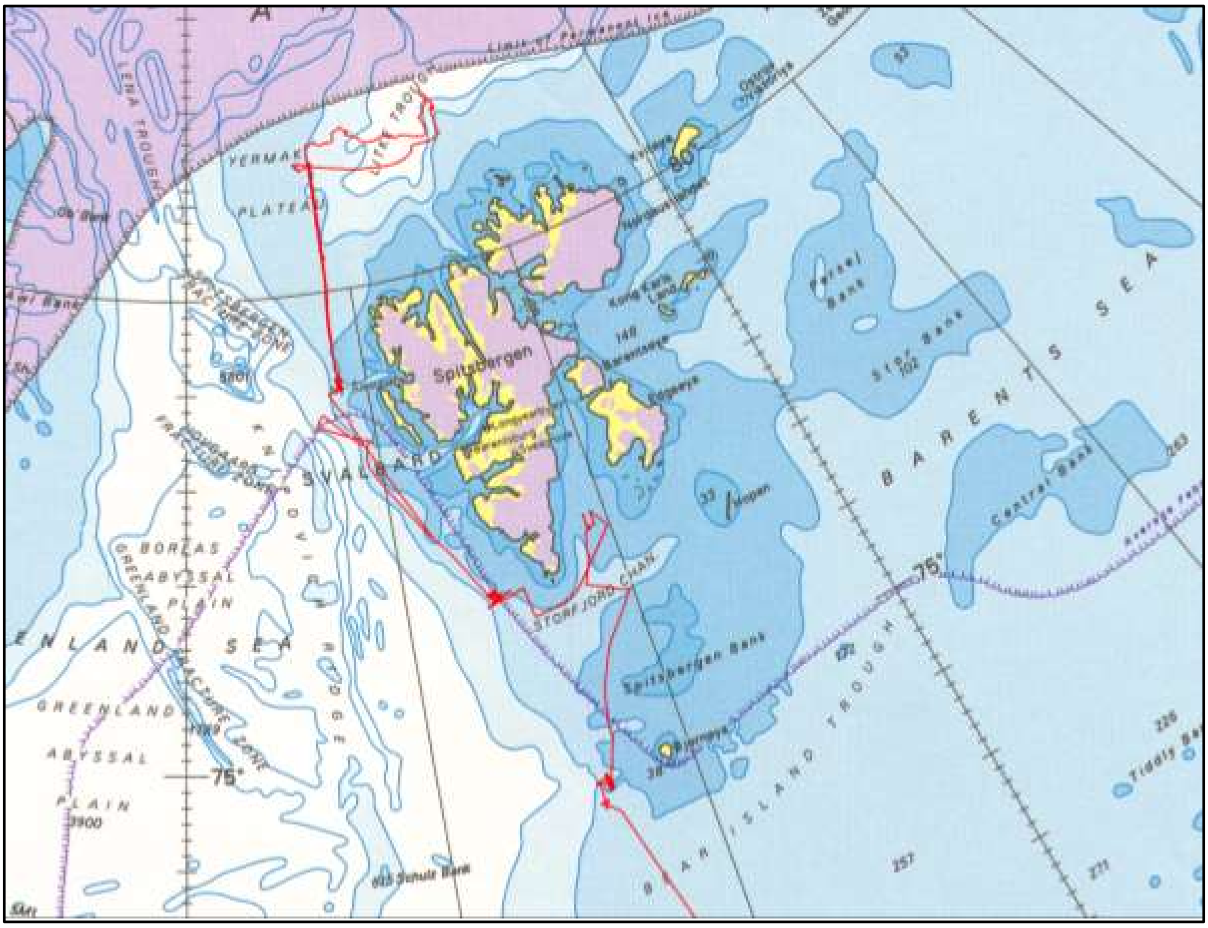


Figure 2 High North 18 cruise – Track lines in red

July 8th, 2018, Sunday (sunny in the morning, cloudy in the afternoon, 1.5 m long wave in open sea)

R/V Alliance left the port of Tromsø (Norway) in the morning of July, 8th, 2018.

July 9th, 2018, Monday (cloudy, moderate wind 20 kts, 1.5m wave)

One day was needed to reach the first working area in the INBIS Channel. We had a safe navigation and we arrived on July 9th, 2018 at ca. 10 AM in working area close to Bjørnøya.

We deployed 2 lagrangian drifters and an oceanographic mooring (INBIS), we recovered a glider (DORA), we collected 2 CTD casts and deployed a MANTA trawl for microplastics pollution investigation. This day we also collected MBES profiles according to the international hydrographic standards in order to detect a minimum depth area represented on nautical charts.

July 10th, 2018, Tuesday (cloudy, windy, progressively rough sea, 2.5m wave)

The activities were stopped and involved to the transfer route to the Storfjord caused by a storm and bad weather condition.

July 11th, 2018, Wednesday (2m wave, windy, cloudy/rainy)

We continued to move to the Storfjorden where we arrived on July, 11th. There, we surveyed the seafloor and water column by MBES and acquired data from the water column with 3 CTD casts and 2 scanfish deployment, together with a bottom sediment samples using a box corer complete with GoPro images.

July 12th, 2018, Thursday (2m wave, windy, cloudy/rainy)

July 12th we moved to S1 mooring site after 8 CTD stations in the Ornsund Banken. The S1 was maintained, than deployed on July 13th. In the area of mooring MBES data were collected and 2 drifters and a MANTA deployed.

July 13th, 2018, Friday (windy, 1.5m wave, cloudy)

We deployed the S1 mooring and moved to the North sector.

July 14th, 2018, Saturday (1m wave, calm wind, cloudy/rainy/sunny)

In a cloudy and rainy day, on July 14th we arrived to Forland Banken where we deployed 4 gliders (MARIA, DORA, NOA and ARTURITA); unfortunately NOA had a problem so we decided to immediately recover her. In the same area we made 2 MANTA sampling and the first DRONE flight to check its performances in this extreme and particular environment. Then, after a help request from “Laboratoire d’Océanographie et du Climat” of Pierre and Marie Curie University (Paris), we moved 30NM West to recover also TINTIN glider that was facing hardware problems.

July 15th, 2018, Sunday (partly cloudy, calm sea and light wind)

July 15th, we continued with cloudy sky our measurements of seafloor water column by MBES, CTD stations in Kongsfjord and we collected sediment samples using box corer. We also deployed an oceanographic mooring (KGF). After this activity we moved toward north direction along the 8° 30’ E Meridian looking for the limit of marginal ice zone, acquiring MBES data of the almost unexplored area of the Yermak Plateau, and collecting several CTD casts during the route because of the fast change of sound speed velocity.

July 16th, 2018, Monday (cloudy, 0.5m wave)

On July 16th, at 21:21 UTC we finally arrived to see the ice at 81° 32' N, 008° 31' E, following the sea ice boundary with MBES free survey and sound velocity cast.

July 17th, 2018, Tuesday (cloudy/foggy; Light to moderate wind, 0.5m wave)

From July 17th to 19th, we continued the marginal ice zone characterization with collecting MBES, CTDs, gliders, scanfish, boxcorer, MANTA, and DRONE data.

July 18th, 2018, Wednesday (cloudy, very calm sea)

During these days we reached the highest latitude of the campaign at 81°50.27' N 019° E. During the day we conducted an integrated experiment using different platforms: acoustic glider, aerial drone with ortophotocamera and infrared camera supported by ground truths such as visual detections of the ice.

July 19th, 2018, Thursday (cloudy, rainy, 0.5m wave, light to moderate wind)

we transferred to the western sector of Yermak Plateau where we acquired MBES data on a bank and along the track line between 81°20' N to 80°10'N and 008°40'E and we collected on boxcorer sediment sample.

July 20th, 2018, Friday (1.5m wave, moderate wind, cloudy/rainy)

We moved South to the Kongsfjord Area where we collected 4 CTDs and we recovered 2 gliders (DORA and ARTURITA) and the KGF mooring on July 20th, a rainy and windy day. We continued the MBES acquisition.

July 21th, 2018, Saturday (2m wave in the morning, 1.5m wave in the late afternoon, partly cloudy, sunny)

July 21th, we recovered MARIA and we deployed another mooring (ID2) in the Isfjord Slope, where we also made the last CTD to calibrate the mooring.

July 22th, 2018, Sunday (0.5 m wave, cloudy, light to moderate wind)

Then we moved to the last working area, INBIS Channel, in order to recover INBIS mooring.

July 23th, 2018, Monday (1.5m wave, 20-30kts wind)

This day is dedicated to move to Tromsø

July 24th, 2018, Tuesday (1.5 - 1m wave, 10-20kts wind)

R/V Alliance arrived in Tromsø.

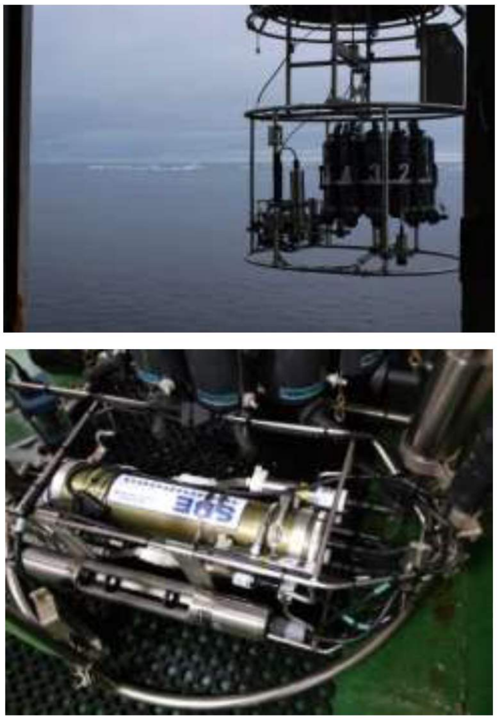
3. Operations and Preliminary Results

3.1 Water Column CTD-Profiling and Rosette (Bensi M., Guideri M., Armanino E., Mansutti P., Ampolo Rella M., Sanna M.)

During HN18, hydrographic vertical profiles were recorded through a Conductivity-Temperature-Depth probe (CTD, mod. SeaBird SBE911plus, Figure. 3) from the surface down to the bottom, within ~ 8–10 m of the seabed. The CTD probe was equipped with a double couple of TC, oxygen (SBE43), fluorescence, turbidimeters sensors, one transmissometer, and one altimeter.

Data were pre-processed on board through the SBE-DataProcessing toolbox and visualized with OceanDataView (Schlitzer R., 2002[1]) to perform a preliminary analysis and output of the collected data, and check the quality of the data collected during the campaign. Additionally, CTD casts were performed on demand during multibeam surveys to calibrate the echosounder with corrected sound velocities.

Potential temperature (θ, °C), salinity (S, p.s.u), and potential density (σ_{θ}, kg m^{-3}) were calculated from original in-situ data. Data were averaged every 1 dbar with overall accuracies within ±0.002°C for temperature, ±0.005 for salinity, and 2% of saturation for dissolved oxygen. For salinity quality check purposes, water samples were regularly taken from Niskin bottles to perform high quality measurements at the OGS calibration centre facility by means of an Autosal Salinometer model Guildline 8400B. Laboratory salinometer will be standardised using IAPSO Standard Sea Water. Water samples were collected on board in flint glass bottles with screw caps equipped with poly-seal cones to prevent leakages and evaporation. Samples procedures followed the international standard.



Main sensors: T- C - OxygenSBE43 primary and secondary (CMRE);
Auxiliary sensors: Transmissometer mod. Chelsea; Fluorimeter mod. Chelsea Aqua3 (CMRE); two Fluorimeter/Turbidimeter mod. WetLabs (CMRE & OGS); Altimeter
Rosette water sampler equipped with n°12 Niskin Bottles 5L capacity.

Figure 3 *Water sampler device (Rosette) equipped with 12 Niskin bottles (5L capacity) and CTD probe. The table on the right reports the configuration of the CTD 9 11plus used during HN18 cruise.*

[1] Schlitzer R., 2002. Ocean Data View, ⟨http://www.awi-bremerhaven.de/GEO/ODV⟩.

A total of 33 CTD profiles have been collected during the HN18 campaign. Figure 4. shows the distribution of the hydrological stations. Main study areas were: INBIS channel (Barents Sea), south west Svalbard and Storfjorden, offshore area in front of Kongsfjorden, and Yermak Plateau north of Svalbard up to the ice edge. One CTD cast was also carried out in front of Isfjorden were mooring ID2 were deployed.

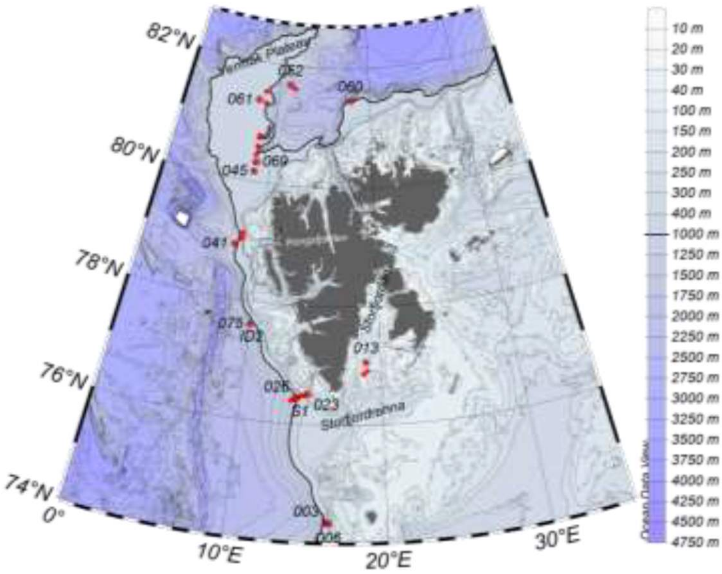


Figure 4 Hydrological stations collected during the HN18 cruise (left). Numbers refer to station names.

Preliminary results from CTD casts show that:

- **In the south Svalbard region** the CTD survey was carried out to investigate hydrological properties along the zonal (West-Est) transect in the surrounding of S1 mooring (~1000 m deep), from offshore towards the continental shelf (Figure 5). Additionally, three (3) CTD casts have been collected also in the shallower part of the Storfjorden measuring potential temperature, salinity, and density of -1,71°C, 34.78, and 28 kg m^{-3} close to the bottom (120 m depth, not shown). There, the surface layer was clearly influenced by fresh water deriving from ice melting. Storfjorden is a key region of the Svalbard Archipelago where very cold and dense waters form during winter seasons due to sea ice formation. Data collected in this region can provide useful information on the main properties of the dense waters formed during winter 2017-2018. After their formation, such waters partly remain trapped within depressions in the fjord and partly outflow through Storfjordrenna and move north-westward geostrophically balanced following bathymetric constraints (Skogseth et al., 2005[2]). Overall, by comparing preliminary CTD data collected during HN18 cruise with those collected during HN17 cruise at S1 and in the surrounding area, we noted a slight temperature and salinity decrease in 2018 with respect to the previous year, in the layer 200-800 m depth. In the deep layer, at depths > 1000 m, instead, temperature appeared slightly higher (+0.02 °C), while salinity lower (-0.01) than in 2017

[2] Skogseth R., P.M. Haugan, M. Jakobsson, 2005. Watermass transformations in Storfjorden. Continental Shelf Research 25 (2005) 667–695.

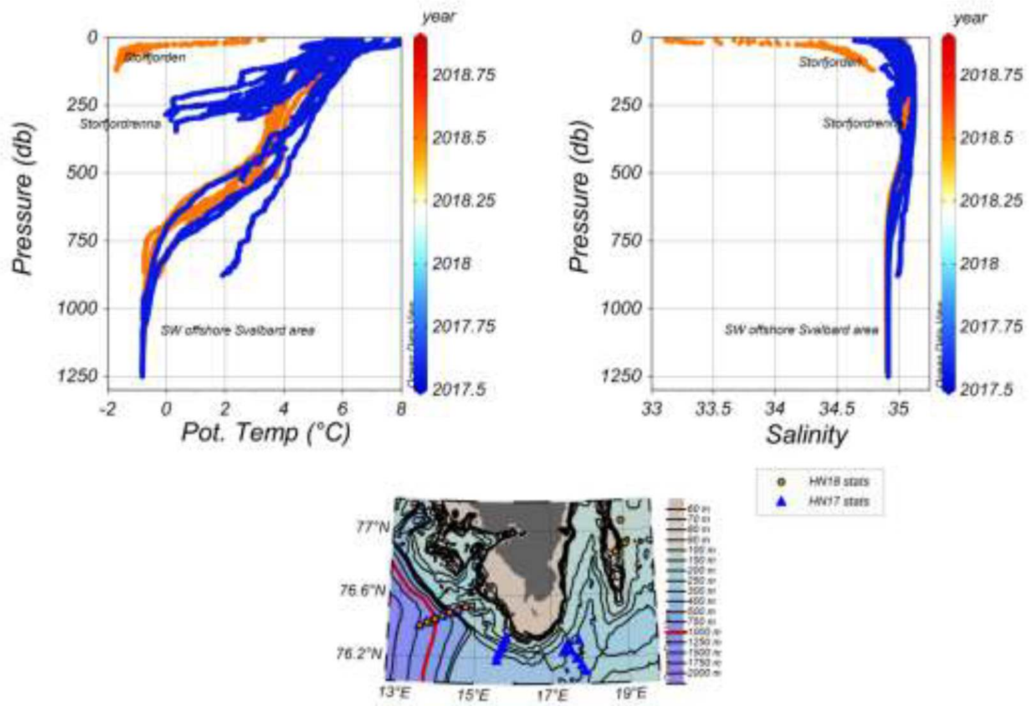


Figure 5 Vertical profiles of potential temperature (°C) and salinity collected in the south Svalbard.
A comparison between data collected during HN17 and HN18 is shown
(Blue lines and triangles refer to HN17, orange lines and dots refer to HN18 data).

- **Offshore Kongsfjorden,** CTD casts highlighted the presence of water intrusions likely coming from the shelf and fjord areas (Figure 6). Indeed, in two profiles (stats. 070 and 044), at depths of 180 m and 550 m respectively, we found a signature of fresher, colder, and more oxygenated water intruding the layer occupied by Atlantic Water. Turbidity also increased within those signatures, revealing a larger sediment content.

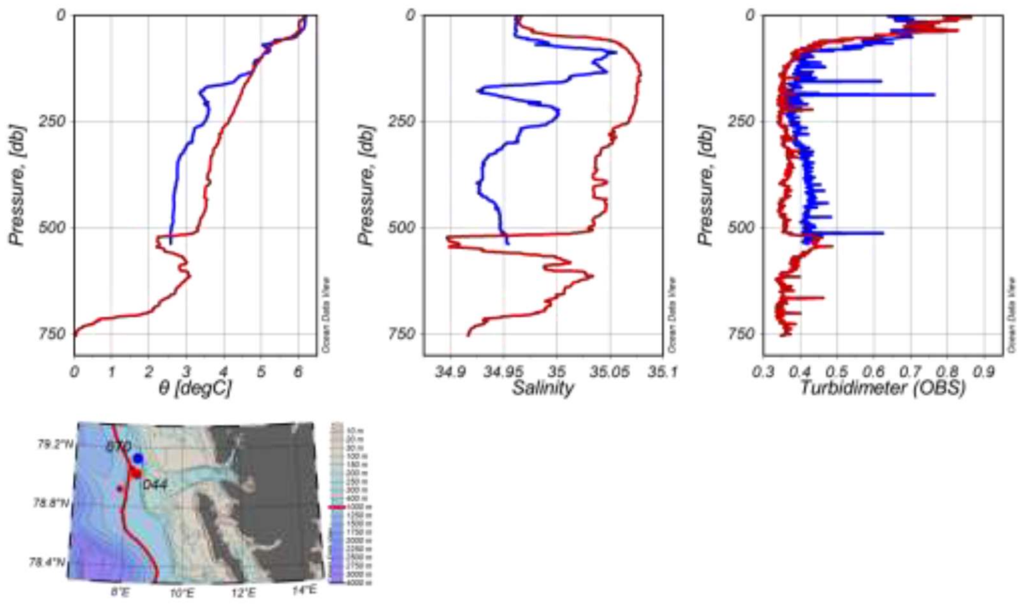


Figure 6 CTD casts (potential temperature, salinity, and turbidity) collected in the offshore area in front of Kongsfjorden.

Data collected in the northernmost part of Svalbard Archipelago, and in particular along the meridional transect on the Yermak Plateau (Figure 7), show signals of Atlantic water moving towards the Arctic Ocean confined in the layer between 100 m and 500-600 m depth. Underneath this layer there is water with temperature below 0°C and salinity > 34.9, being the latter increasing with depth. Surface and sub-surface layer was occupied by water progressively becoming fresher (down to 32) and colder (down to 0°C) in the northernmost part of the study region. Alternated patches of fresher and saltier waters at surface may indicate the presence of mesoscale structures north of Svalbard, where Atlantic water moves eastward contributing to maintain free of ice this portion of Arctic Ocean.

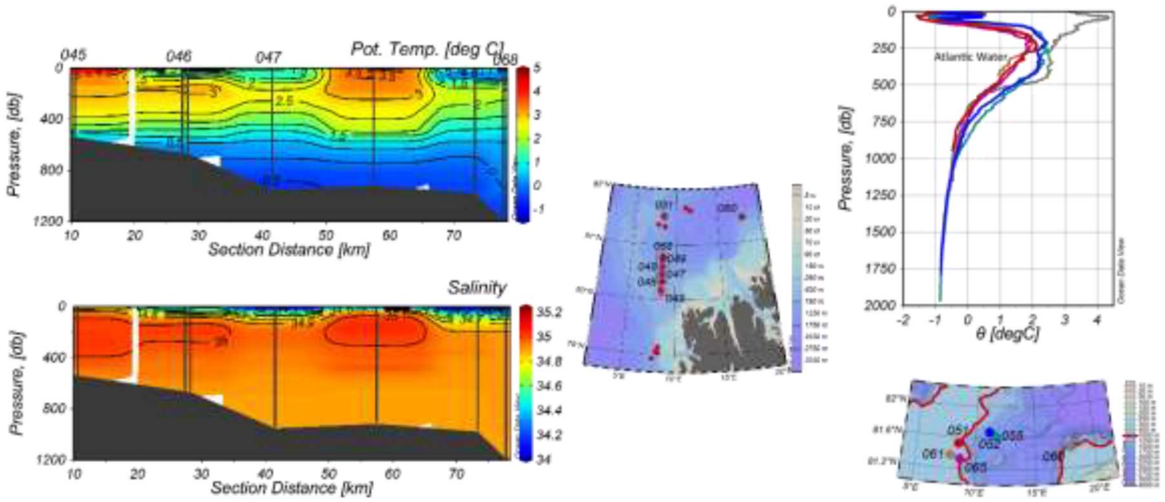


Figure 7 CTD meridional section collected along the Yermak Plateau (potential temperature and salinity).The plot on the right shows potential temperature profiles in the northernmost area reached during HN18

3.2 Vessel-mounted Acoustic Doppler Current Profiler – VMADCP (Ampolo-Rella M., Garau B., Russo A.)

Vertical profiles of sea current were acquired continuously by means of 2 Teledyne–RDI Ocean Surveyor ADCPs at 75 kHz and 300 kHz mounted in the hull of NRV Alliance. The observed current velocities were corrected considering the ship navigation and inertial movement acquired from the bridge Seapath and embedded in the ADCP data. Data were collected using Narrow Band settings in order to account for low density of scattering particles in the water column. The 75 kHz ADCP has a vertical range around 400 m, cell spacing has been set at 8 m and 8 m blanking was applied. The 300 kHz has a vertical range around 100 m, cell spacing has been set at 4 m with 5 m blanking.

An example of data collected by the 75kHz ADCP is showed in Fig. 8.

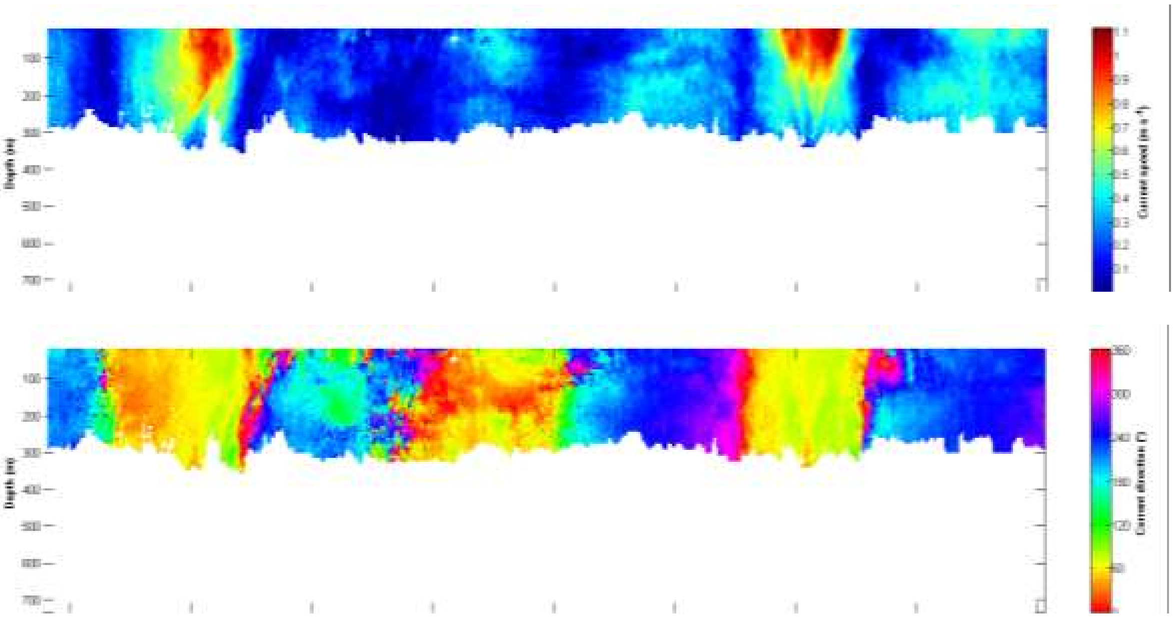


Figure 8 Time series of vertical current profiles acquired along 9 days by the TRDI Ocean Surveyor 75 kHz ADCP. Upper panel: current speed (color scale from 0 to 1.1 m s-1); lower panel current direction (color scale from 0 to 360°)

3.3 EIVA Scanfish III® (Ampolo Rella M., Brogini A., Garau B., Russo A.)

The EIVA ScanFish III (Figure 9) is a towed, undulating vehicle having a depth range up to around 200 m (at low speed and with dedicated winch); at 5 knots, the dives can extend from few meter below the sea surface up to about 120 m depth.

Figure 9 The EIVA ScanFish III being recovered onbard R/V Alliance.

The ScanFish has been equipped with two Seabird Electronics SBE 49 CTDs (measuring temperature, conductivity and pressure), a SBE 43 dissolved oxygen sensor and a Wetlab BB2FL (measuring fluorescence, CDOM and backscatter).

ScanFish has been towed on 4 occasions (reported in Table 1), reaching a total of over 17 hours of acquisition.

Table 1. Date, time and position of the ScanFish operations

Station	NR	Date	Time UTC	Latitude (degree N)	Longitude (degree E)	
HN18_011	1	11/07/2018	13:02	76.92480	18.92200	deployment
HN18_012	1	11/07/2018	14:49	77.06893	18.92217	recovery
HN18_015	2	11/07/2018	16:40	77.15883	18.93382	deployment
HN18_016	3	11/07/2018	23:46	76.89133	19.30867	recovery
HN18_050A	3	16/07/2018	16:27	81.24200	8.49900	deployment
HN18_050B	3	16/07/2018	19:50	81.51000	8.49300	recovery
HN18_066	4	19/07/2018	13:15	81.24006	8.42856	deployment
HN18_067	4	19/07/2018	16:49	81.24940	8.44940	recovery

The data will be processed ashore.

3.4 Glider operations

A glider mission consisting of 4 gliders flying at the same time along the Western Spitsbergen Current (WSC) was planned for the High North 18 campaign. The main goal of this mission was to catch cold eddies in the water column. The trajectories followed by the 4 gliders are showed in Figure 10.; the next paragraph describes the SeaExplorer glider mission, the following paragraph reports the Slocum gliders missions (including a fifth glider equipped with hydrophone and deployed in the marginal sea ice zone).

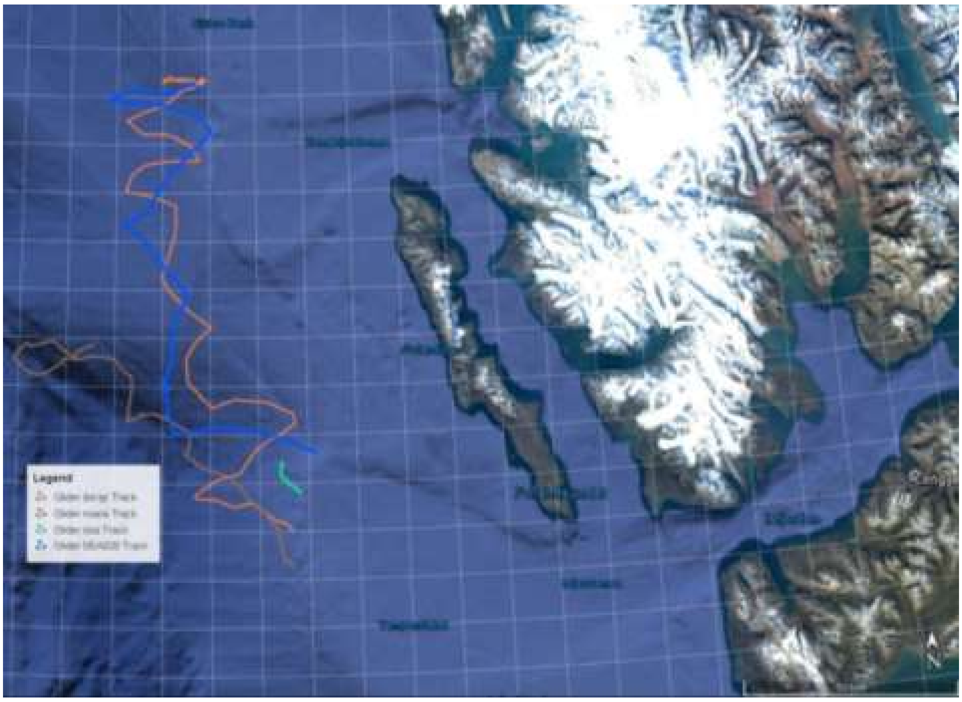


Figure 10 Trajectories followed by the 4 gliders participating to the WSC mission; the glider were deployed in the Isfjorden offshore area, spaced about 5 nautical miles each other.

Data collected in the Kongsfjorden area by the SeaExplorer SEA028 (blue line in Figure 10) and the Slocum Dorajr (orange line in Figure 10) during the final part of their missions are showed in the Section 3.4.1.

3.4.1 SeaExplorer Glider 028 (Artana C.)

The SeaExplorer 028 (Figure 11) was one of the four gliders used during the WSC mission. The glider was deployed at 78°21.927' N and 9° 31.892' E the 14/07/2018 at 11:10 and recovered on the 20/07/18 at 16:30 at 79° 7.274 N 8°25.802 E. The SeaExplorer 028 sampled along 5 days a part of the WSC between Isfjord and Kongsfjord.

Before the glider deployments some basic test were carried out on board of the ship. The pressure and the temperature inside the glider were monitored during a few days and as well as the functionality of all the constituents of the glider (ballast, angular, linear, flash, etc). For this mission the drop weight was sacrificed due to its low battery. Due to the strong currents in the regions, the planned track of the SeaExplorer 028 (red segments in Figure 12) was slightly modified between 78°26.59 N and 78°45.449. The SeaExplorer 028 was then able to accomplish the rest of the mission without any particular trouble (Figure 12).

Figure 11. Sea Explorer 028

The SeaExplorer028 provides measurement of water temperature, conductivity, pressure, dissolved oxygen, chlorophyll and CDOM. Its position was transmitted every 3 hours by iridium and was permanently monitored. We obtained 88 profiles between the surface and 700 m depth. The profiles recorded by the Sea Explorer are shown in Figure 13. Cold eddies do not seem to be present in the data. Instead, a plume of cold and fresh water extended between 600 and 400 m seems to be detected by the SeaExplorer028 between the 19 and 20 July.

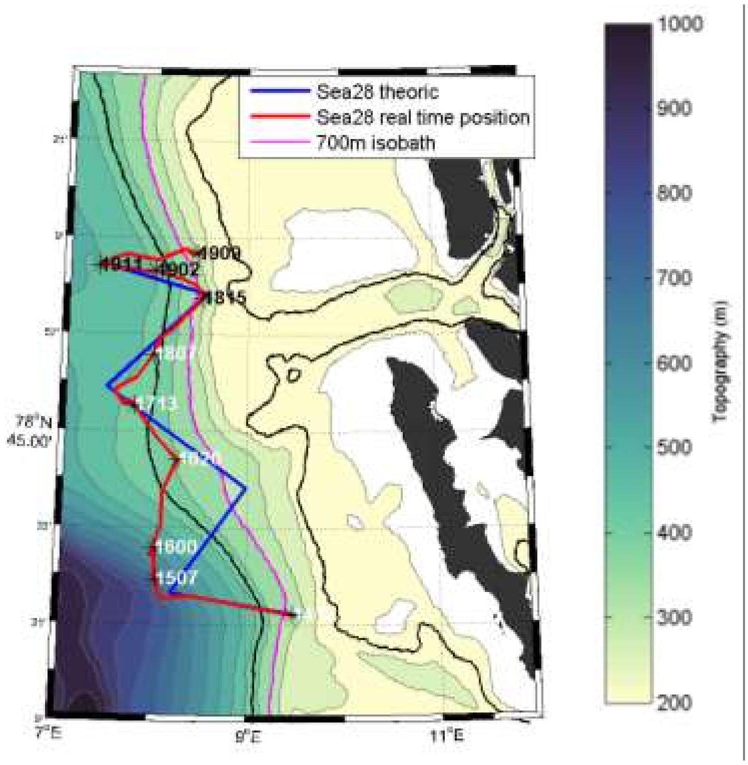


Figure 12. SeaExplorer 028 trajectory (blue: planned; red: real) and bottom topography

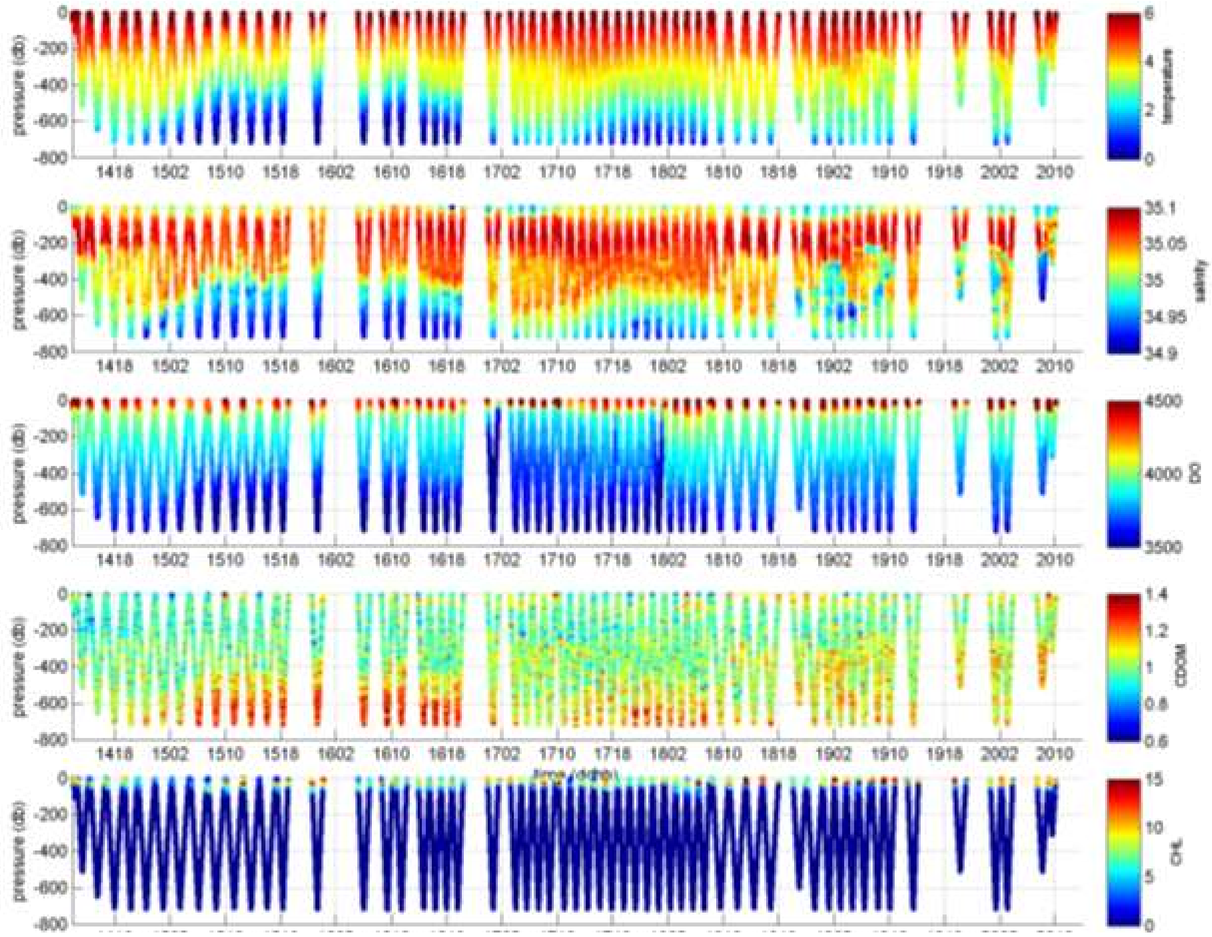


Figure 13. Profiles from Sea Explorer 028 sub-sampled real-time data; from top to bottom: Temperature (°C), salinity, Dissolved Oxygen, Colored Dissolved Organic Matter, Chlorophyll (mg m-3)

3.4.2 Slocum Gliders Dorajr, Maria, Noa and Sophie (Ampolo Rella M., Garau B., Russo A.)

Dorajr and Maria are G2 (with propeller) deep (rated up to 1000m) Slocum gliders equipped with a pumped Seabird electronics SBE 41 CTD (measuring temperature, conductivity and pressure) and a WetLabs BB@FL (measuring backscattering, chlorophyll and CDOM).

Noa is a G1 deep Slocum Glider and Sophie a G1 shallow (rated up to 200m) Slocum Glider, both equipped with unpumped Seabird 41 CTD.

Figure 14. Gliders Maria (right) and Noa (left). The larger size of Maria (G2 with extended batteries) compared to Noa (G1 with standard batteries) can be noted.

Sophie also mounted a hydrophone for recording ambient noise and an accelerometer for measuring wave height.

The glider activities started on the 9 July at 9:55 with the recovery of Dorajr (deployed during the NREP18 sea trial)west of Bear Island. Later on, three Slocum gliders (Dorajr, Maria and Noa) have been deployed on the 14 July for the WSC experiment as reported in Table 2. Because of leakage, Noa had to be recovered on the same day of her deployment.

Table 2. Times and positions of the 3 Slocum gliders deployed on the 14 July 2018.

Glider name	Operation	Station name	Date	Time	Latitude (degree Nord)	Longitude (degree Est)
Dorajr	Recovery	HN18_002	9/07/2018	9:55	74.13620	16.30135
Dorajr	Deployment	HN18_030	14/07/2018	6:52	78.13222	9.30687
Maria	Deployment	HN18_031	14/07/2018	8:22	78.20333	9.31787
Noa	Deployment	HN18_032	14/07/2018	10:16	78.27803	9.42483
Noa	Recovery	HN18_040	14/07/2018	21:54	78.33807	9.23821
Dorajr	Recovery	HN18_070A	20/07/2018	16:10	79.09262	8.31227
Maria	Recovery	HN18_073	21/07/2018	11:55	78.40946	7.40219

The graphs in Figures. 15 and 16 show the CTD data collected by Maria and Dorajr, respectively, and derive from low vertical resolution data transmitted in near real time every 3 hours.

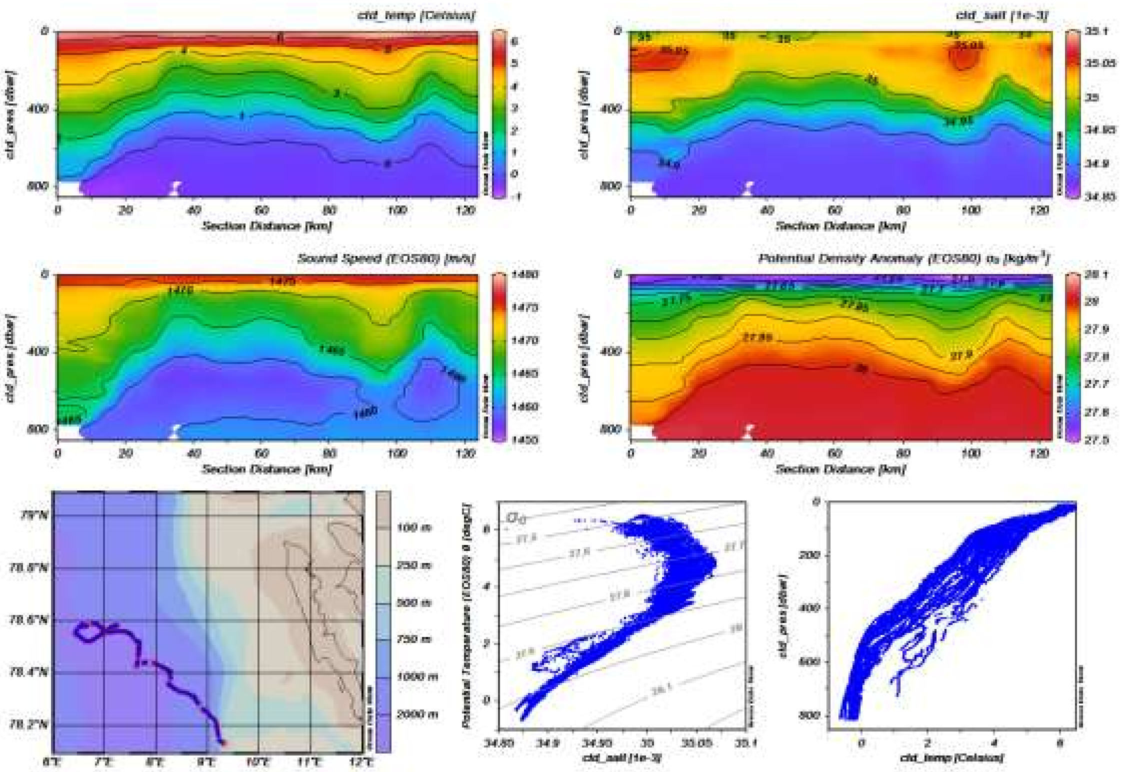


Figure 15. Data collected by Maria during the WSC mission from 14 to 21 July 2018. Panels from left to right and from up to down report: vertical transects of temperature (°C), salinity, sound speed (m s^{-1}) and potential density anomaly (kg m^{-3}), map of the area with the glider track, cumulative potential temperature-salinity diagram, cumulative vertical profiles of temperature.

Maria was unable to follow the planned trajectory because of compass failure. She remained at sea until the recovery on 21 July. The data collected and transmitted in near-real time are showed in Figure 15.

Dorajr accomplished regularly her mission and was recovered on 20 July (together with the glider SeaExplorer 028); the data collected and transmitted in near-real time are showed in Figure 16.

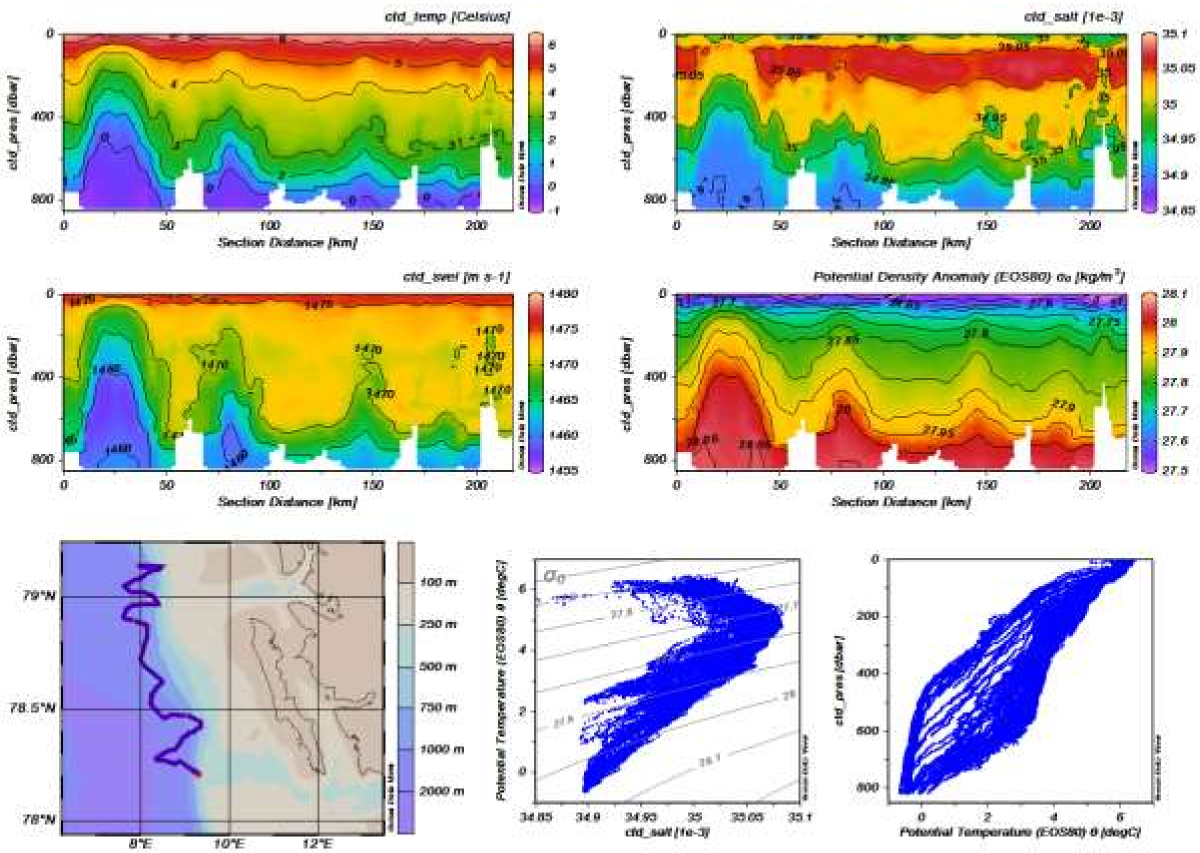


Figure 16. Data collected by Dorajr during the WSC mission from 14 to 20 July 2018. Panels from left to right and from up to down report: vertical transects of temperature (°C), salinity, sound speed (m s^{-1}) and potential density anomaly (kg m^{-3}), map of the area with the glider track, cumulative potential temperature-salinity diagram, cumulative vertical profiles of temperature.

The glider Sophie was dedicated to test capabilities for investigating ambient noise and wave height in the vicinity of the sea ice edge.

A first deployment was attempted on 17 July at 13:10 at about 2 nautical miles (nm) from the sea ice edge (position 81° 35.874'N 11° 29.978'E) but had to be interrupted at 13:40 because of heavy fog blocking visual contact with the workboat.

The second deployment was done on 18 July at around 6:30 (position 81° 35.874'N 18° 4.4 E) with the sea ice edge at about 1 nm to NW. Sophie was sent toward east and after the first dive (target depth 100m) emerged slight west of the starting position, while sea ice moved toward east. The second dive (again with target depth at 100m depth) was directed toward SE with sea ice at about 0.5 nm. The following dive had target depth at 150m with route toward south. Sophie did not communicate when the end of the dive was expected; she sent her position after a second dive and resulted around the sea ice, behind (or inside) a fragmented ice tongue. On the next dive, started with the workboat onboard and hence in quiet conditions, Sophie did not communicate on the expected end of the first dive; she sent her position after almost 2 hours and when NRV Alliance tried to reach her, she resulted to be about 900m inside a relatively compact sea ice area. So it was sent toward SE. Again she did not communicate on the expected end of the first dive; meanwhile NRV Alliance and sea ice were drifting relatively fast (much faster than Sophie) toward SE. When Sophie finally sent her position, she resulted to be very close to her last position; but now sea ice was more fragmented and she was on the edge of a quite large pond surrounded by sea ice. NRV Alliance slowly moved toward her, crossing a belt of sea ice fragments; the workboat was deployed nearby Sophie for the recovery, completed by 16:30. Figure 17 shows Sophie being approached by the workboat for recovery.

From preliminary analysis of the navigation data, during emersions for 4 times Sophie resulted to be blocked by the sea ice; on the last two dives, when she practically did not move from her starting position, the rudder was blocked so she dived spiraling without advancing horizontally.

The collected acoustic data are of good quality. It has been a good lesson about the complexity of glider operations in presence of sea ice: propeller and ad-hoc sensors and software are needed, as well as reliable forecasts of sea ice drift.

Figure 17. The recovery of the Slocum glider Sophie with R/V Alliance

3.5 Acoustic survey (Demarte M., Salvatore R., De Salvo G. Marro M.)

Objectives

The NW Barents Sea continental margin has been the target of several surveys in the last decade: SVAIS (R/V Hesperides) in 2007, EGLACOM (R/V OGS Explora) in 2008, GLACIBAR (R/V Jan Mayen) in 2009, CORIBAR (R/V Maria S. Merian) in 2013, PREPARED (R/V G.O. Sars) in 2014, EDIPO-DEGLABAR (R/V OGS Explora) in 2015 and High North17 in 2017 (NR/V ALLIANCE).

These cruises allowed the acquisition of a wealth of morphobathymetric data that are now jointly processed at OGS and Italian Hydrographic Institute.

The High North18 cruise gave us the opportunity to collect new Multibeam data, in order to complete some areas along the continental margin that haven't been completely covered previously. Moreover it was possible to improve the morphobathymetric charts in some key areas, like the Yermak Plateau (NW Svalbard).

This acoustic survey focused in particular on the following five areas:

I. The Yermak Plateau. This is the most important part of the acoustic activity during the entire cruise. The target was to obtain a morphobathymetric chart of this not completely covered area, in order to improve the world's database, validated by a seafloor sediment sampling.

II. The Kongsfjorden area where the KFG mooring has been deployed, in order to characterize the 3D mapping of the water column and bottom, to better understand the flow paths of the water masses and the morphodynamics in the Kongsfjorden. In particular the acoustic backscatter data was used to characterize the nature of the seabed using sediment samples and to investigate this area from a sedimentological point of view referring to the depositional features and hydrological aspects.

III. The Hornsund area where the S1 mooring, has been deployed, in order to characterise the bathymetry as well as the seabed characteristics, in order to better define the influence of the water masses cascading along the slope and bottom features.

IV. The INBIS Channel System (Southwestern Bjornoya Island) is surveyed to collect new data in this area and to detect the shape of the minimum depth (62 m.).

V. A limited area of the Storfjorden Channel has been investigated with the MBES. Also in this case the acoustic survey was also used to locate the sediment sampling and characterize this site from a sedimentological point of view.

Acquisition

Over 1500 square kilometres of bathymetry, Backscatter and Water Column data were collected in order to describe the seabed morphology and to add useful information for navigation.

The main instrument used is the MBES Kongsberg EM 302 keel mounted. Positioning is delivered by the integrated system Kongsberg Seapath 330 receiving STARFIX L1 differential corrections decoded by the FUGRO SEASTAR 3610 decoder.

Sound Velocity profiles applied to data during the survey were collected by means of the SEABIRD SE 911 CTD probe. Pressure, Temperature and Salinity data were converted by the “SBE Dataprocessing” software using the Chen-Millero algorithm and loaded within the acquisition software (SIS (Seafloor Information System) versione 4.3.0,) each time they were available.

Data validation was achieved by means of the software CARIS "Hips & Sips" version 10.4.

A DTM (30m cell) and a Backscatter mosaic (30m cell) were produced.

Preliminary results

I. On the Yermak Plateau, the total investigated area is around 760 km^2 (Figure 18) from 80° 09’ N, 008° 32’ E to 81° 30’ N, 008° 30’ E, covering a bathymetric range between 400 m and 1300 m depth.

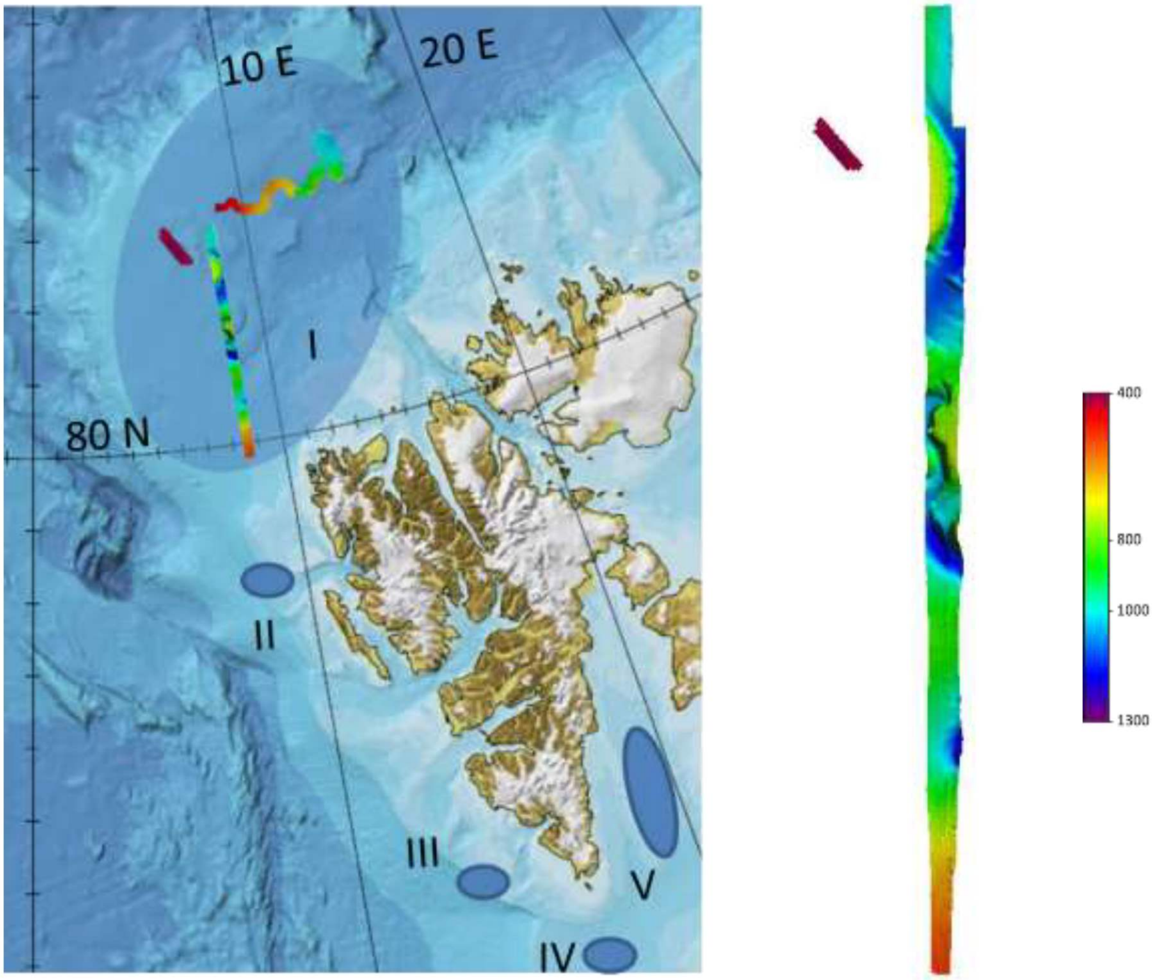


Figure 18. MBES survey sectors: I Yermak Plateau and blue areas II Kongsfjord, III Hornsund, IV INBIS, V Stofjorden

In the southern part of the investigated area on the Yermak Plateau, it is possible to distinguish some channels, mainly orientated N-S (Figure 19 A). The intra-channels ridges show a regular smoother morphology.

In the central and northern part, we found an interesting morphology where the shelf edge is affected by iceberg-keel grounding that produces a seafloor vertical roughness. The flanks of the deeper incised canyons are affected by erosive gullies (Figure 19 B and C).

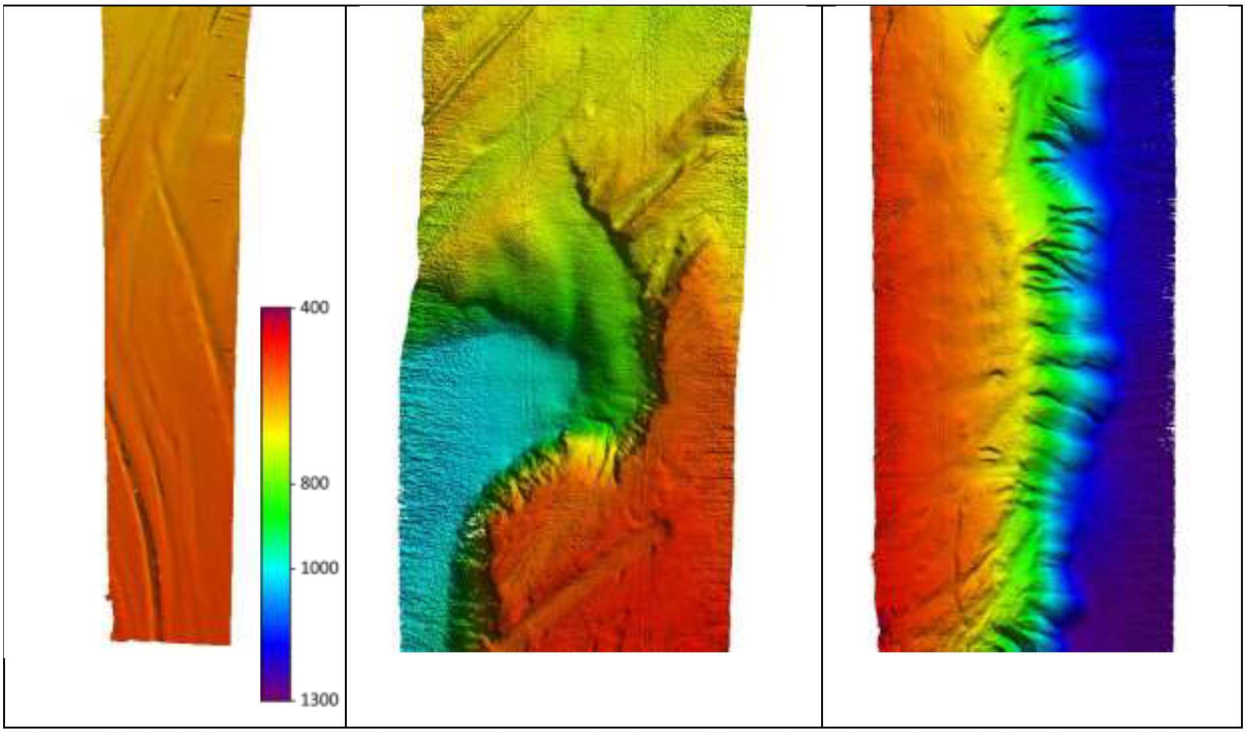


Figure 19. A, B, C: southern, central and northern part of the multibeam investigated area in the Yermak Plateau.

A preliminary sediment classification based on both morphology and backscatter data were produced by means of CARIS "Hips & Sips" (see chapter 3.7) on the NW part of the survey. Acoustic backscatter data are validated by one seafloor sampling (Figure 20).

II. In the Kongsfjorden area, swath data were acquired together with the KGF mooring, CTD, glider and a seafloor sediment.

For more details on the integrated experiment and preliminary results, see paragraph 3.8.

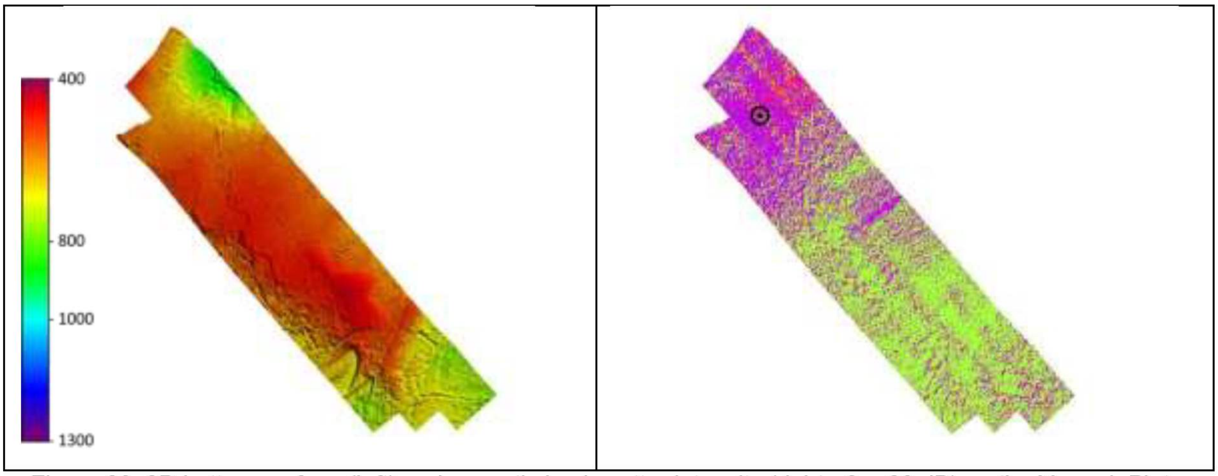


Figure 20. 2D bottom surface (left) and acoustic backscatter intensity (right, -8 - -20 dB) on the Yermak Plateau. The black circle indicates the seafloor sampling site (box-core HN18_BCO_062_003).

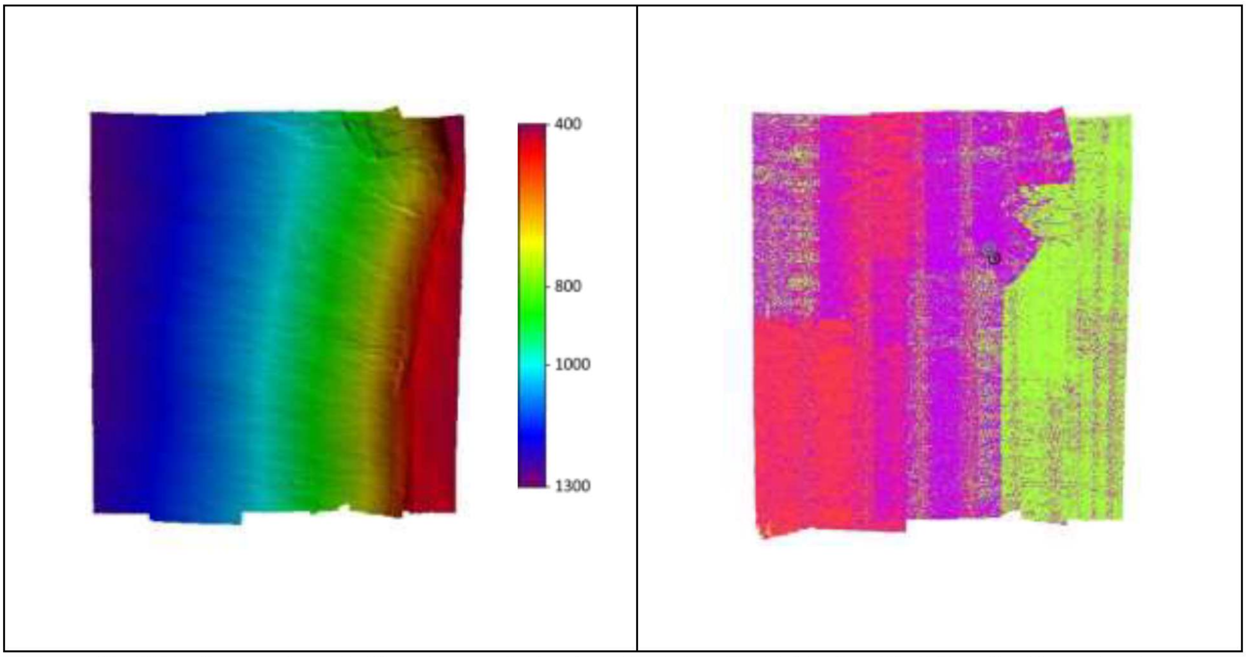


Figure 21. 2D bottom surface (left) and acoustic backscatter intensity (right, -8 - -20 dB) on the Kongsfjorden. The green circle indicates the box-core HN18_BCO_042_002 and the black one the KGF mooring site.

III. In the Hornsund area, where the mooring S1 has been deployed, the swath data have been acquired, ranging from around 200 m to 1200 m depth, covering an area equal to 192 km^2.

The continental shelf is characterized by several glacial scars and incisions while the shelf break and the deeper area show a smooth morphology, with no hydrological channels or gullies, or gravitative mass movements.

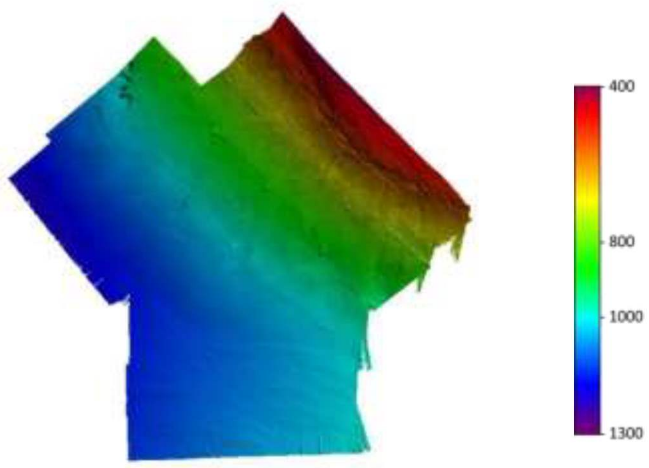


Figure 22. Swath bathymetry in the Hornsund area.

IV. In the INBIS Channel, swath data have been acquired. The research of the minimum sounding permitted to extend the surveyed area collected during the HN17 and define the bathymetry of the minimum depth (62 m) represented on the existing nautical charts. The whole area is characterized by a regular bathymetry around 270 m depth with no anomalies with the surrounding seafloor (Figure 23 A and B).

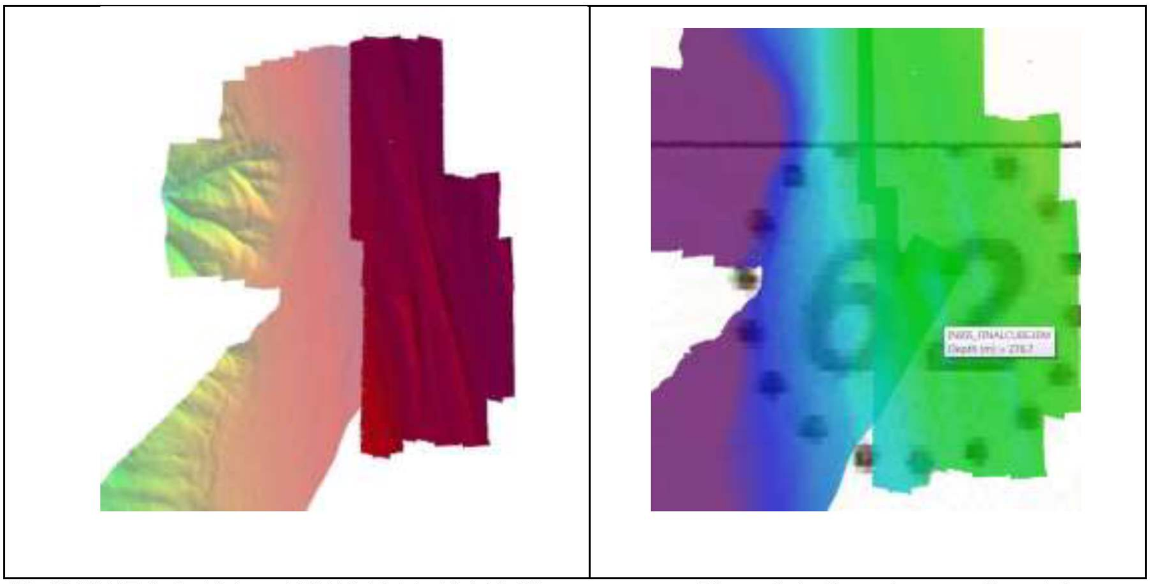


Figure 23. A) HN17 (left side) and HN18 (right side) Multibeam surveys; B) swath bathymetry over the minimum represented sounding of 62 m.

V. The swath data acquired in the Storfjorden are shown in Figure 24

In this area we performed a Multibeam survey and a preliminary sediment classification based on both morphology and backscatter data.

To confirm this analysis, a box corer sampling of the bottom and sub-bottom has been made in the northernmost part of the surveyed line where backscatter evidences indicated softer sediments.

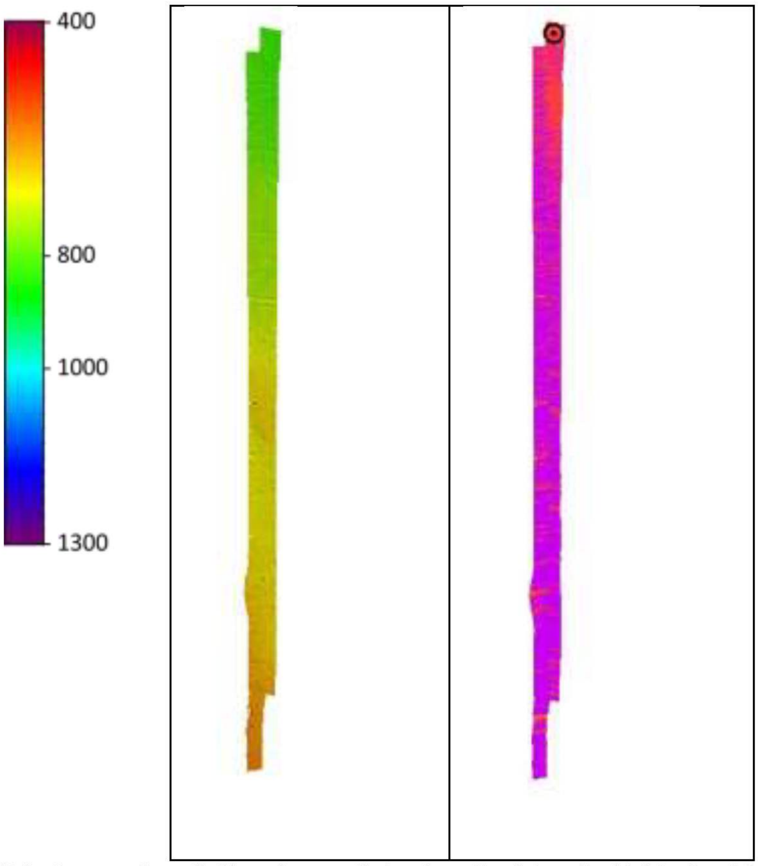


Figure 24. 2D bottom surface (left) and acoustic backscatter intensity (right, -8 - -20 dB) on the Storfjorden. The green circle indicates the box-core HN18_BCO_014_001.

Finally, a free Multibeam acquisition has been carried out at the ice edge, from the Northern part of Yermak Plateau survey at around 81° 31'N, 008° 26' E (~ 900 m depth) towards East for more than 100 NM, reaching maximum depths of ~ 3200 m at around 81° 50'N, 17° 37' (Figure 25).

Figure 25. Free Multibeam survey following the ice edge.

3.6 Seafloor sediment (Delbono I., Ferrero V., Sanna M., Demarte M.)

<u>Material and methods</u>

Seafloor sediments were sampled through the ENEA box-corer, with a stainless box sized 30x20x50 cm, working with 125 kg weighted head (Figure 26).

A GoPro camera and two spotlights were placed on the box-corer (Figure 27) in order to take videos from the deploy until the recovery phase and catch photos of the seafloor.

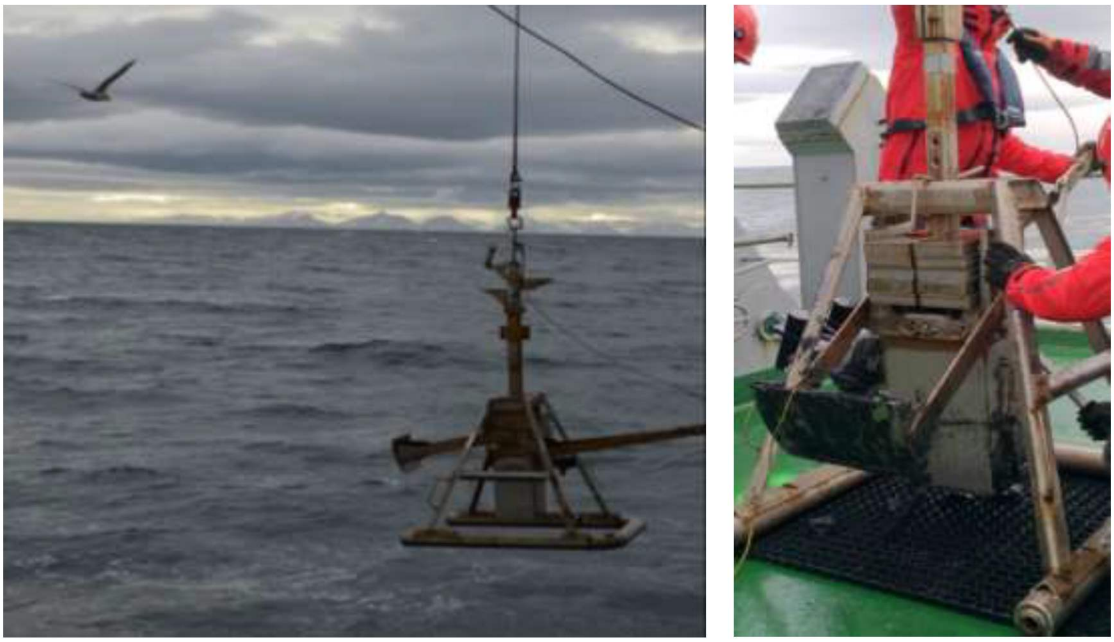


Figure 26. Box-corer used in High North 18: deploy and recovery phases in the Arctic Sea.

Figure 27. Box-corer used in High North 18 with the GoPro camera and two spolights placed on a side of the box-corer.

Sediment surface description and photographs have been carried out on the fresh sediment surface onboard prior the core sub-sampling. Textural and Munsell colour charts were used for comparison and placed next to the samples for photos.

Each box-core was sub-sampled as follows and as graphically described below (Figure 28):

- n. 1 core of 9 cm ø, for X-ray and physical properties analyses, stored at +4°C (IIM);
- n. 1 core of 9 cm ø, for grain size composition, core dating and micro-plastics, stored at +4°C (ENEA La Spezia);
- n. 1 pre-cut core of 9 cm ø, stored at +4°C (OGS);
- n. 2 cores of 4 cm ø, for micropaleontology, living foraminifera, meiofauna, stored at -20°C (UniPI);
- n. 1 stainless cylinder (F) of 7.5 cm^3, for the determination of the sediment density;
- n. 3 samples at 0-1 cm, 1-5 cm, 5-10 cm, for water content and preliminary textural analyses performed on board (IIM);
- n. 3 surface samples (upper 2 cm), for living foraminifera study, stored at -20°C (UniPI);
- n. 3 samples for macrofauna at 0-2 cm, 2-5 cm, 5-10 cm stored at -20°C (UnivPM).

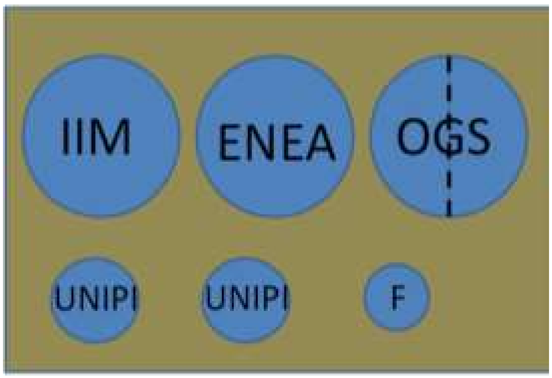


Figure 28. HN18 box core sub-sampling scheme.

Downcore sediment description was performed on a pre-cut liner: after the description, one half section was analysed for shear strength with a pocket penetrometer and sub-sampled; the second half section, untouched, was stored at +4°C.

Main results

A total of 3 box-cores was deployed during the cruise High North 18 (Table 3).

Table. 3. HN18 box-cores.

Core ID	Depth (m)	Sampling date	Lat. N	Long. E	Area	Recovery
HN18_014_BCO_01	127	11/07/2018	77° 03.832’	18°56.098’	Storfjorden	~ 27 cm
HN18_042_BCO_02	713	15/07/2018	79° 01.761’	08°24.490’	Kongsfjord	~ 15 cm
HN18_062_BCO_03	433	19/07/2018	81°21.300’	07°29.457’	Yermak Plateau	~ 11 cm

Results of each core are summarised in the Appendix: for each core, few photos are shown, together with lithology, Munsell colour, sediment structure, water content, pocket penetrometer data and a short description of lab observations.

Grain size analyses on top layers of the sediment cores were carried out onboard. The first box-core in Storfjorden (HN18_014_BCO_01) was characterised by very fine sediments and the top layer has a very low percentage of sand and gravel (sediment > 63 micron equal to 9%). Differently, the second box-core in Kongsfjord (HN18_042_BCO_02) was characterised by coarse sediments and IRD (Ice Rafted Detritus); the sediment fraction > 63 micron at the top core is equal to 84%. Finally, the third box-core at the Yermak Plateau (HN18_062_BCO_03) was characterised on top by coarse grained sand and black gravel. The sediment fraction greater than 63 micron at the top of this core was equal to 38%.

Field Vane Test analyses were carried out on all box-cores and results were always very close to zero.

Photos taken by the GoPro camera on the 3 box-cores on the seafloor are in Appendix.

3.7 Mooring

3.7.1 S1 maintenance (Langone L., Bensi E., Mansutti P.)

The Arctic region has gained a large interest because of climate changes and its effects on ice melting and global warming. Abrupt changes in the atmosphere are responsible for significant changes in the ocean water masses and in large-scale circulation patterns, which in turn affect again the global climate. The knowledge of the circulation and related processes along the southwest (SW) offshore Svalbard area and within Storfjorden (southern Svalbard Archipelago) is essential to describe the thermohaline circulation and the dense water formation (DWF) in the Arctic, and how they contribute to the global thermohaline circulation. DWF processes in this region depend on the rate of cooling and homogenisation of the Atlantic water along its northwards pathway, brine rejection, boundary convection on the Arctic Ocean shelves and slopes, and deep open-ocean convection in the central gyres of the Greenland and Iceland Seas. multiannual time-series in an area of potential interaction between the West Spitsbergen Current and the descending dense shelf plumes. In 2015, mooring S1 was serviced while mooring ID2 was recovered with the R/V Helmer Hansen. Mooring S1 was then serviced also in 2016 with the I/B Polarstern and in 2017 with R/V Alliance. Two short (~130m) moorings (S1 and I2) were deployed in 2014 during the RV G.O. Sars expedition 191 (Lucchi et al., 2014) in the SW offshore Svalbard at ~1000m depth, with the purpose of collecting

One of the activities foreseen by the cruise High North 18, was the maintenance of mooring S1 and the re-deployment of mooring ID2.

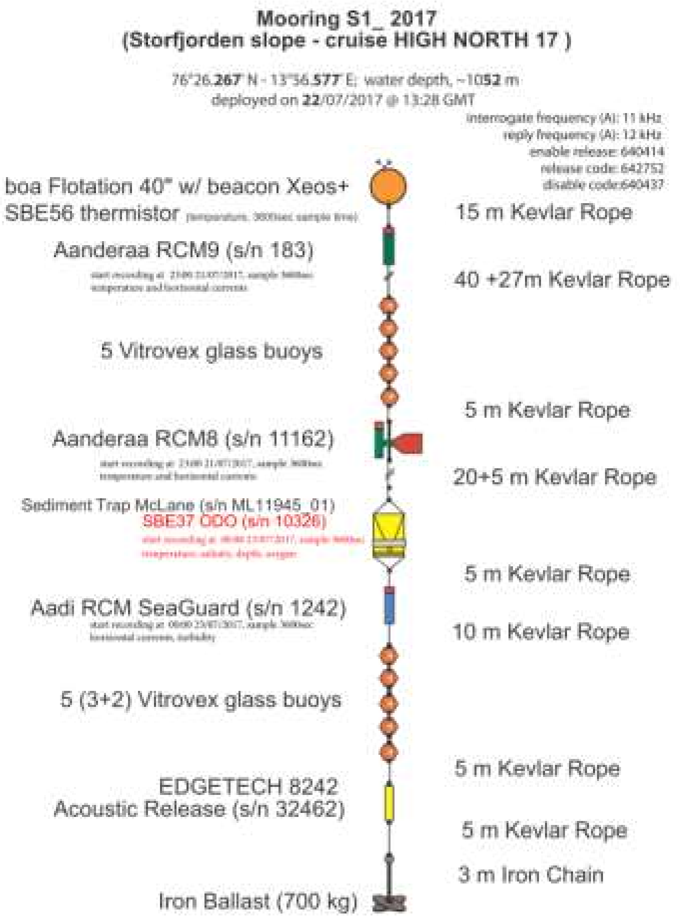


Figure 29. Configuration of mooring S1

S1 is 150m-long mooring, deployed nearby the Bellsund Sediment Drift at about 1040 m depth. During the last deployment it was equipped with 2 current meters, an automatic sediment trap, a temperature data logger, a recorder of temperature, conductivity, pressure and oxygen, and a radiobeacon. Turbidity data of the near-bottom water are also acquired by means of an optical backscatter sensor.

This activity is part of the project PNRA-DEFROST (DEep Flow Regime Off SpiTsbergen), which aims to investigate the temporal and spatial variability of the deep currents along the western margin of Svalbard in correspondence of recognized sediment drifts (Rebesco et al., 2013).

The choice of using a mooring is motivated by the fact that the most energetic processes occur in late winter and early spring, when surveys done by means of research vessels are hardly feasible due to the harsh environmental conditions in the area. Furthermore, long lasting measurements, extended to more than one year, by means of the moored sensors are unique tools to assess the year-to-year variability.

On July 13, mooring S1 was recovered (operations started at 8:40 UTC and finished at 10:03 UTC), maintained, and re-deployed during the same day (operations started at 16:45 UTC and finished at 17:48 UTC). CTD casts were performed before both the recovery and the deployment of mooring S1 (HN18_017_CTD_07 and HN18_026_CTD_14, respectively).

Data were downloaded from instruments. A preliminary data check pointed out the acquisition of complete annual time-series for all the instrumentation with the exception of the sediment trap, where the motor stopped to rotate after cup #4. Instruments were visually inspected and cleaned, the batteries were changed, the memories erased and the instruments re-programmed for a new year of measurements. Tests performed on the sediment trap indicated that the problem was caused by failure of an C-cell alkaline battery. The trap motor was tested with a complete rotation of the gear plate and then programmed for a new year of particle sampling.

The uppermost single-point current meter was changed with an ADCP current profiler in order to better define the vertical structure of currents near the sea bottom. The mooring line was enriched with an additional recorder of conductivity, temperature, depth and oxygen sensors just below the ADCP, and a second temperature data logger fasten to the near-bottom current meter. Finally, the acoustic release was substituted with a couple of XSEA Oceano 2500-S acoustic releases (s/n 2063 and 301, respectively.)

The new position and depth of the mooring S1 are: Latitude 76° 26.234’N; Longitude 13° 56.470’ E; water depth 1052 m.

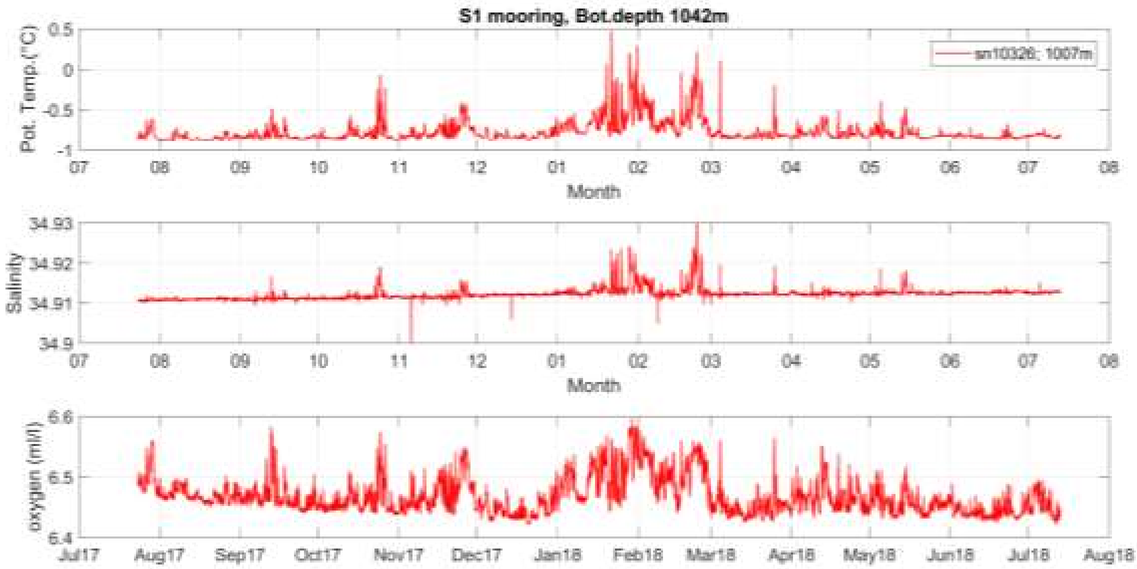


Figure 30. Time-series of thermohaline characteristics of water masses recorded at 1007 m water depth from July 2017 to July 2018.

Preliminary thermohaline and current meter data acquired at 1013 m of mooring S1 referred to the period 2017-2018 are shown in Figs. 30 and 31, respectively.

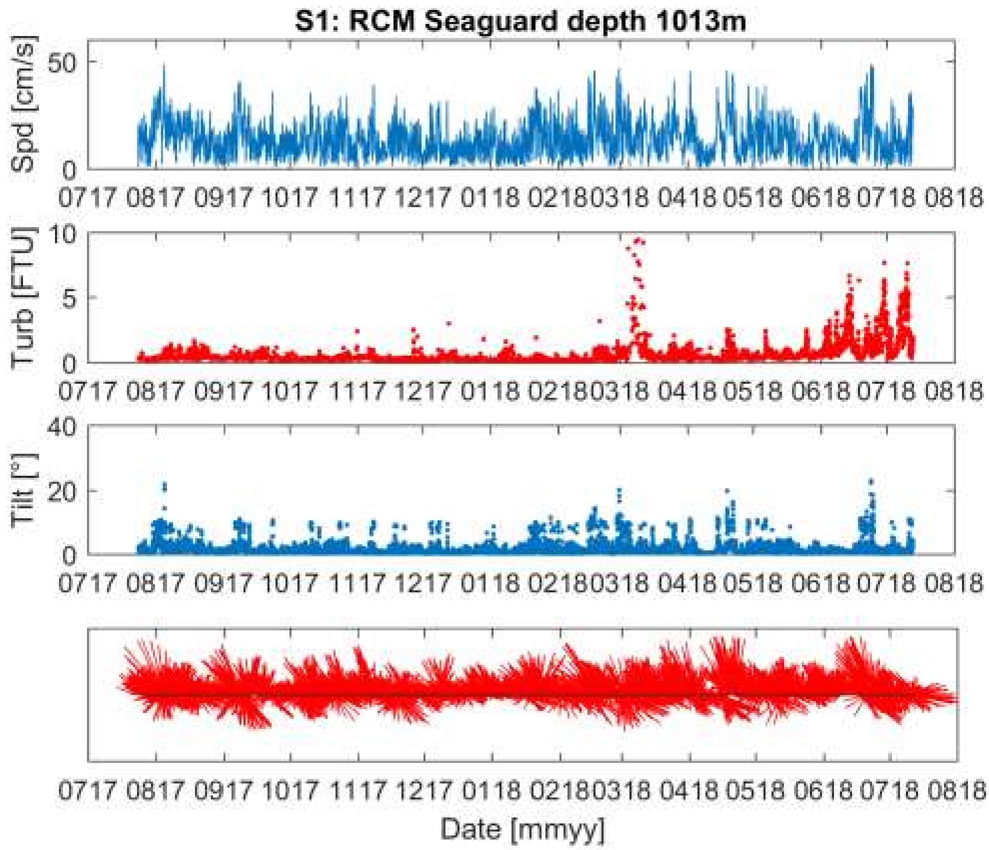


Figure 31. Time-series of current characteristics of water masses recorded at 1013 m water depth from July 2017 to July 2018.

An enhanced variability of thermohaline parameters was recorded in late October 2017 and from mid-Jan to early March 2018, with intrusions of warmer, saltier and more oxygenated waters. Minor oscillations occurred also in Sept and Nov 2017, and in May 2018. Time series of temperature measured at 4 levels (30 m to 145 m from the bottom), showed similar trends with lower amplitude oscillations in the deepest sensors (max temperature of 0.48 °C at 30 m above the sea bottom) with respect to level 130-145 m above the seabed (max temperature of 2.73 °C).

It is noteworthy that these pulsations are less dense than the ambient water, with enhanced dissolved oxygen concentrations. The higher oxygen content would suggest the incoming of a newly formed water mass, but it is intriguing that a less dense water can take place of denser waters. Turbidity peaked in March 2018 and from June 2018 until the end of time series. Its peaks do not seem always associated with the variability of temperature and salinity.

The NSDW (Norwegian Sea Deep Water) appears to be the stable signal (-0.9 °C; 34.91; 28.7 kg/m^3), while the intrusions of less dense waters may be referred to the effect of topographically-trapped waves excited and modulated by atmospheric forcing and by sporadic cascading of sediment-enriched shelf water plumes. These findings further confirm data acquired in the previous years (Sanchez-Vidal et al., 2015; Bensi et al., submitted).

Differently from past time-series, in 2017-2018 the intrusions of warmer and saltier water were reduced in amplitude suggesting that during the last year the drivers of these processes were less efficient.

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3.7.2 Oceanographic moorings (M. Ampolo-Rella, A. Brogini, A. Russo)

Two oceanographic moorings have been designed in support of scientific activities conducted during HN18.

The 2 moorings shared the same typology of instruments. Each one had one Acoustic Doppler Current Profiler (ADCP) TRDI Quartermaster 150 kHz (typical range 200m) and one ADCP TRDI Sentinel 300 kHz (typical range 100m), single point acoustic currentmeters Aanderaa RCM9, CTD recorders SBE 37 (measuring temperature, conductivity and pressure) and temperature-pressure recorders RBR.

Figure 32 shows the schematics of the mooring deployed at the INBIS Channel at position 74° 20.4755'N 16° 16.3748' E with bottom depth of 697 m. The position was inside a canyon that Multibeam analysis indicated as characterized by bottom currents arriving from the shelf. The 300 kHz ADCP monitored the upper 100 m layer aiming to detect dynamics related to semidiurnal tides nearby the critical latitude. The 150 kHz ADCP monitored the bottom 200 m layer aiming to observe the possible bottom currents from the shelf. The ballast has been released on the 9 July at 16:45, the recovery has been done on the 22 July at 23:30.

Figure 33 shows the schematics of the mooring deployed in the Kongsfjorden area at position 79° 1.53' N 8° 24.883' E with bottom depth of 708 m. The scope is described in the Section dedicated to the Kongsfjorden experiment. The two ADCPs were here positioned in order to monitor the water layer between 150 m (the max depth rating of the 300 kHz ADCP is 200 m) and 480 m, where cold, fresh eddies detached from the shelf were supposed to transit. A single point currentmeter monitored the bottom layer, where bottom currents from the shelf were also expected according to Multibeam analysis. Ballast has been released on the 15 July at 12:43, the recovery has been done on the 20 July at 19:49.

Preliminary analysis of the collected data indicates that all the instruments worked. A time series of the current magnitude collected by the 150kHz ADCP mounted on the KGF mooring is showed in the Section dedicated to the Kongsfjorden experiment (3.8).

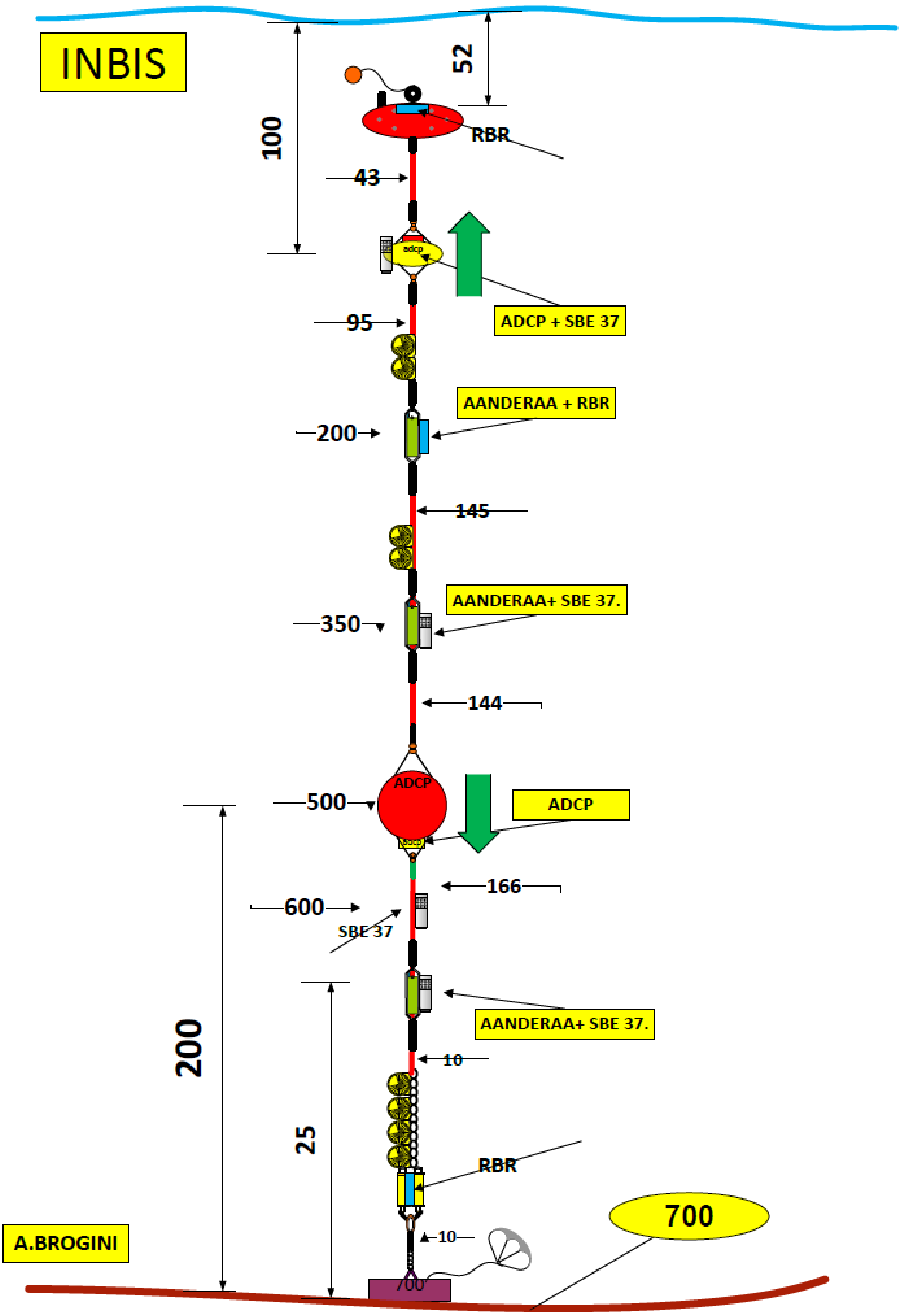

Figure 29. Schematics of the mooring INBIS deployed at the INBIS Channel. Real depths (m) could vary from nominal ones depending on real bottom depth (around 697 m), real length of ropes and their elasticity.

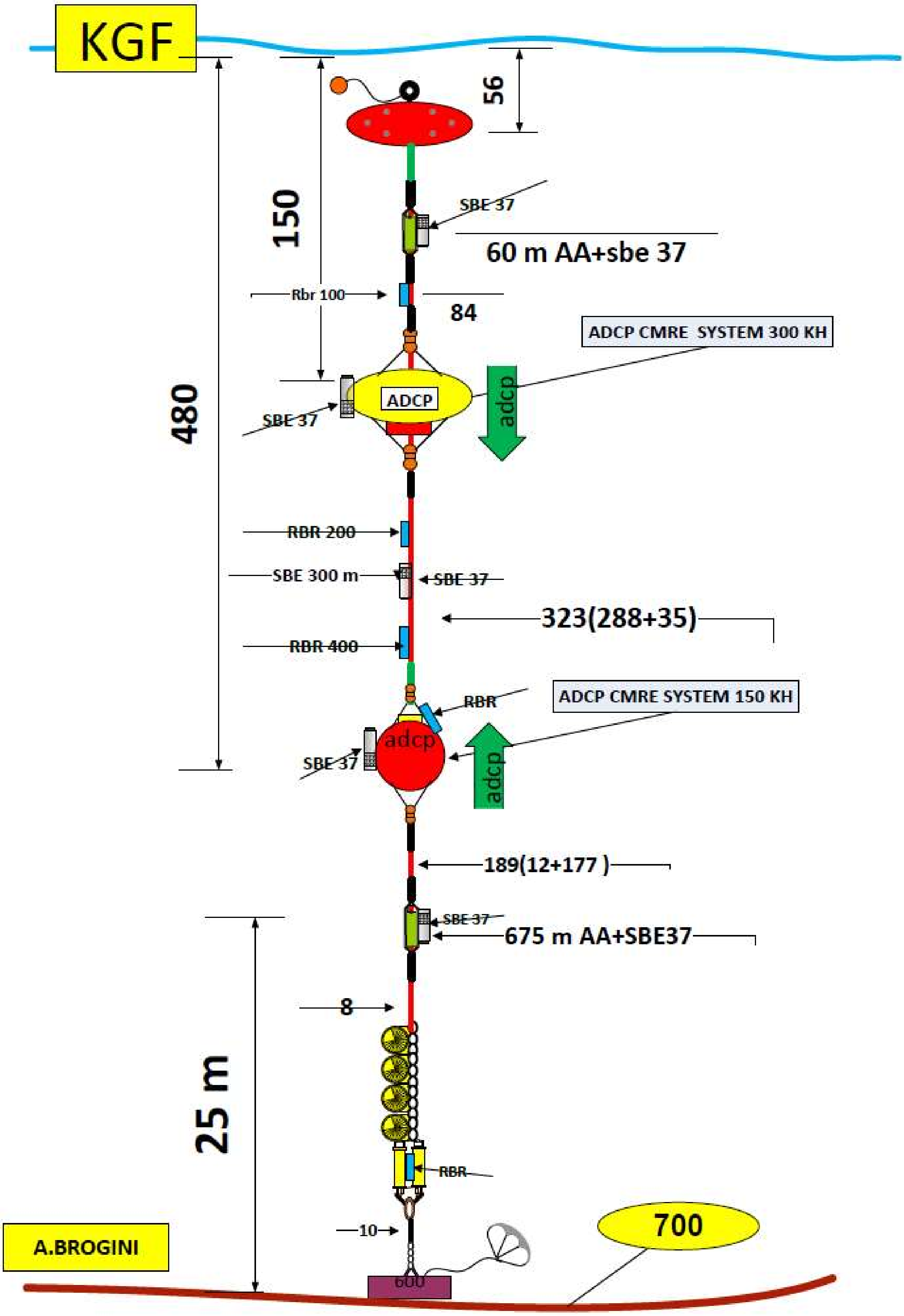

Figure 30. Schematics of the mooring KGF deployed at the Storfjorden. Real depths (m) could vary from nominal ones depending on real bottom depth (around 697 m), real length of ropes and their elasticity.

3.8 Preliminary results of the integrated experiment in the Kongsfjorden area (Artana C., Delbono I., Demarte M., Russo A.)

Multibeam survey, sediment sampling, glider missions, CTD casts and oceanographic mooring deployment have been conducted in the Kongfjorden area aiming to investigate possible interactions of cold, fresh waters coming from the fjord with the offshore waters.

The Multibeam survey covered the area (around 12.5x13.5 km2) reported in Figure 34 and revealed different seafloor structures in the Kongsfjorden area. On the shelf, typical glacial features deriving from melting ice shelf and iceberg scouring are evident (Figure 35). On the continental slope, 3 different areas can be identified: in the southern area there are more homogeneous conditions, not evidencing active bottom currents from the shelf; in the central area there are clear channels formed by active erosion generated by bottom water cascading from the shelf; in the northern area there is a more complex dynamics involving both hydrodynamics and gravitative movements (as slumps, slides, debris flows). The KGF mooring, described is Section x.x, has been deployed at bottom depth of 708 m in the central area inside an active channel (position showed in Fig. 1 and 2) with seafloor features shaped by cascading bottom currents and not showing evidences of gravitative mass movements.

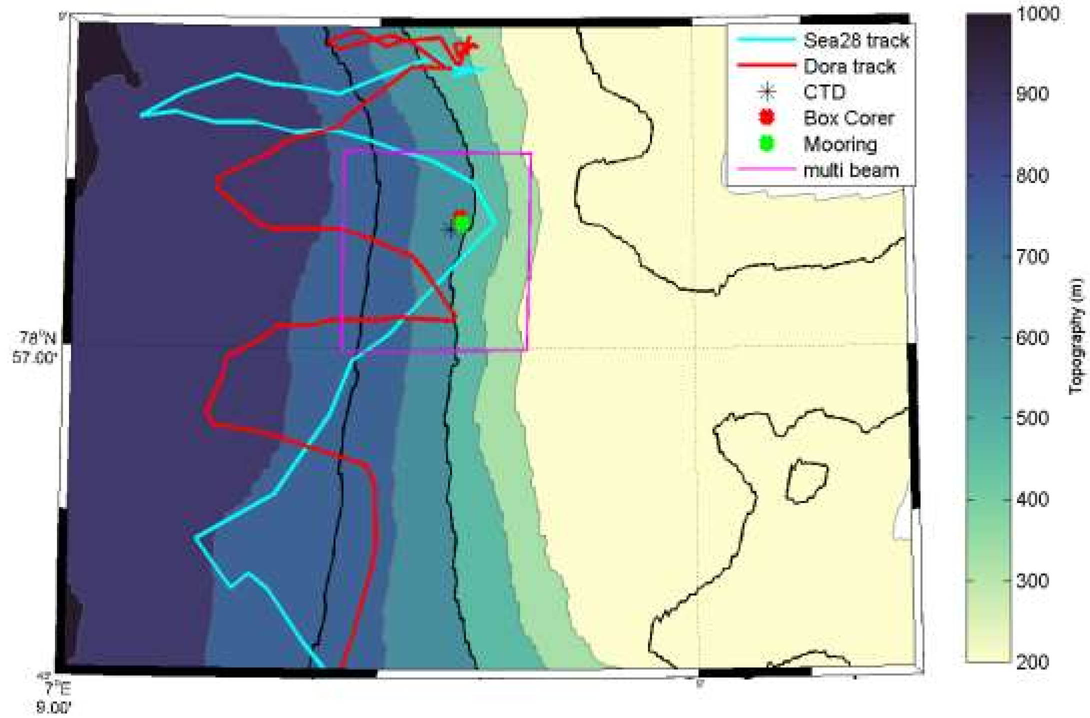

Figure 31. The area investigated at Storfjorden with bathymetric chart info. The purple square represents the area where Multibeam survey has been conducted. The red line is the trajectory followed by the glider Dorajr, the cyan line is the trajectory followed by the glider SEA028. The green symbol represents the position of the KGF mooring, almost on the same position where a sediment sample has been collected by means of box corer. The red symbol is the position of a CTD cast collected nearby the mooring KGF.

The acoustic backscatter intensity was characterized by high values, ranging between -7 and -20 db, over the whole Multibeam survey area. In particular the site of the mooring showed the class between -12 and -14 db, typical of mixed glacial marine sediments (diamicton). The box corer collected at 713 m depth nearby the KGF mooring (position showed in Figure 34 and 35) confirms the acoustic backscatter indications. Collected sediments are gravelly sand on top core over silty sand with very low water content in the top 10 cm (24-30%). Gravel and large cobbles are present in the upper 5 cm, cobbles and pebbles in the 7-12 cm layer.

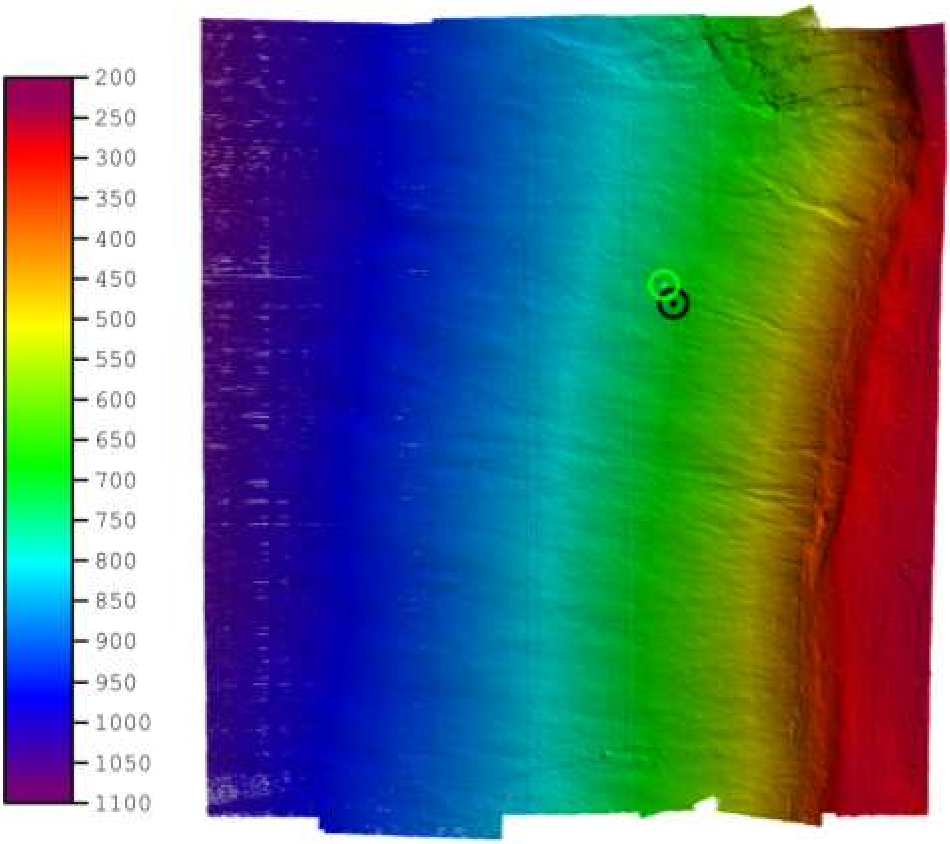

Figure 32. 2-D acoustic Multibeam seafloor view. The black circle indicates the KGF mooring position, the green circle the box corer position.

Two gliders, Dorajr and SEA028, sampled the Kongsfjorden area from the 17th July until the morning of the 20th July; their trajectories are reported in Figure 34. The collected real-time data reveal a wide "plume" of cold, fresh water. Figure 36 and 37 show glider transects surveyed between the 18 and 19 July, mapped from offshore toward the shelf. Turbidity data collected by SEA028 suggests that the plume has been in contact with a bottom turbid layer.

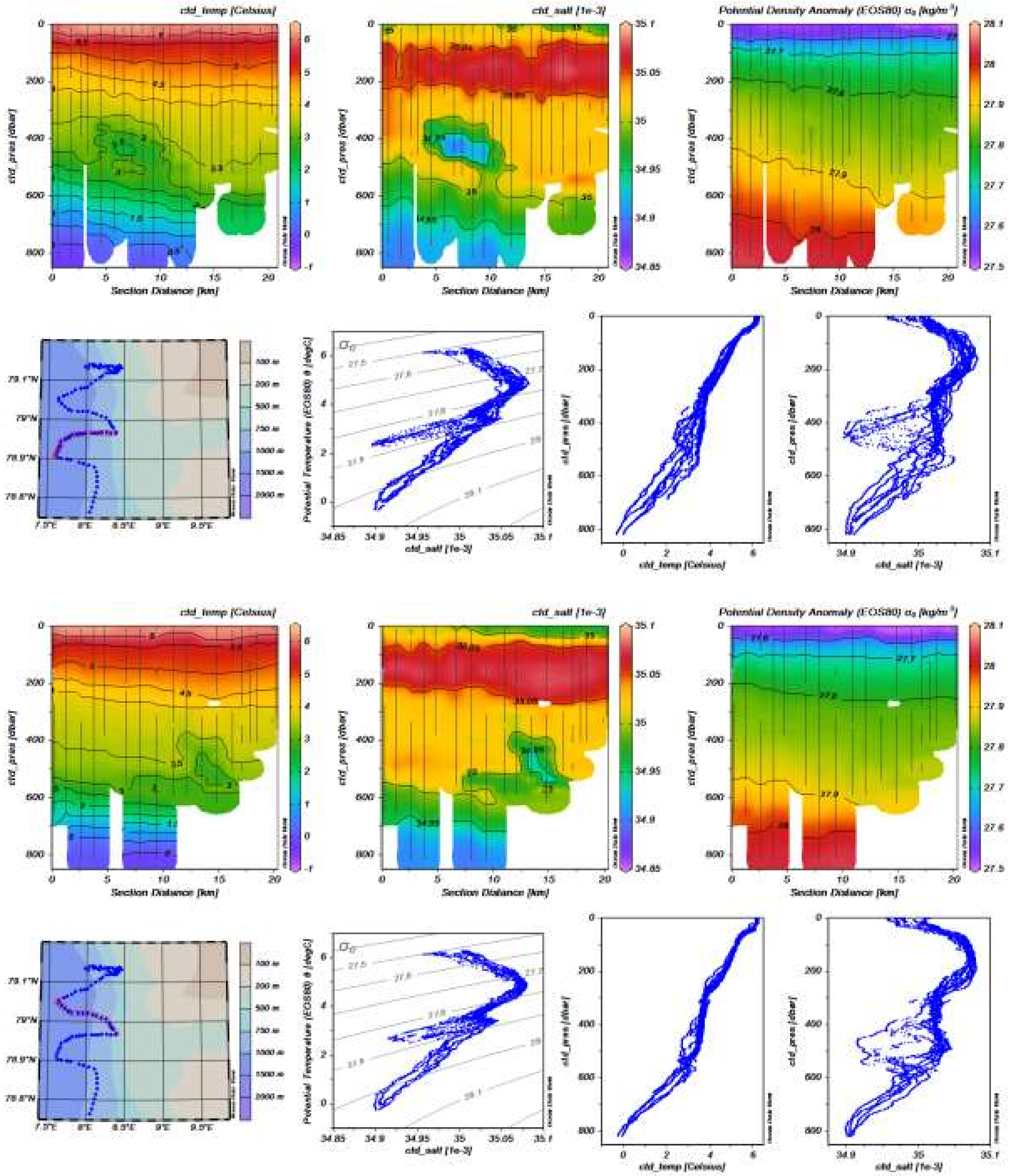

Figure 33. Vertical transects (evidenced in red on the maps) surveyed by glider Dorajr on the 18th July and on the 18th – 19th July. Upper panels from left to right report temperature (°C), salinity, and potential density anomaly (kg m-3); lower panels from left to right show the map of the area with the glider track, potential temperature-salinity diagram, vertical profiles of temperature and salinity.

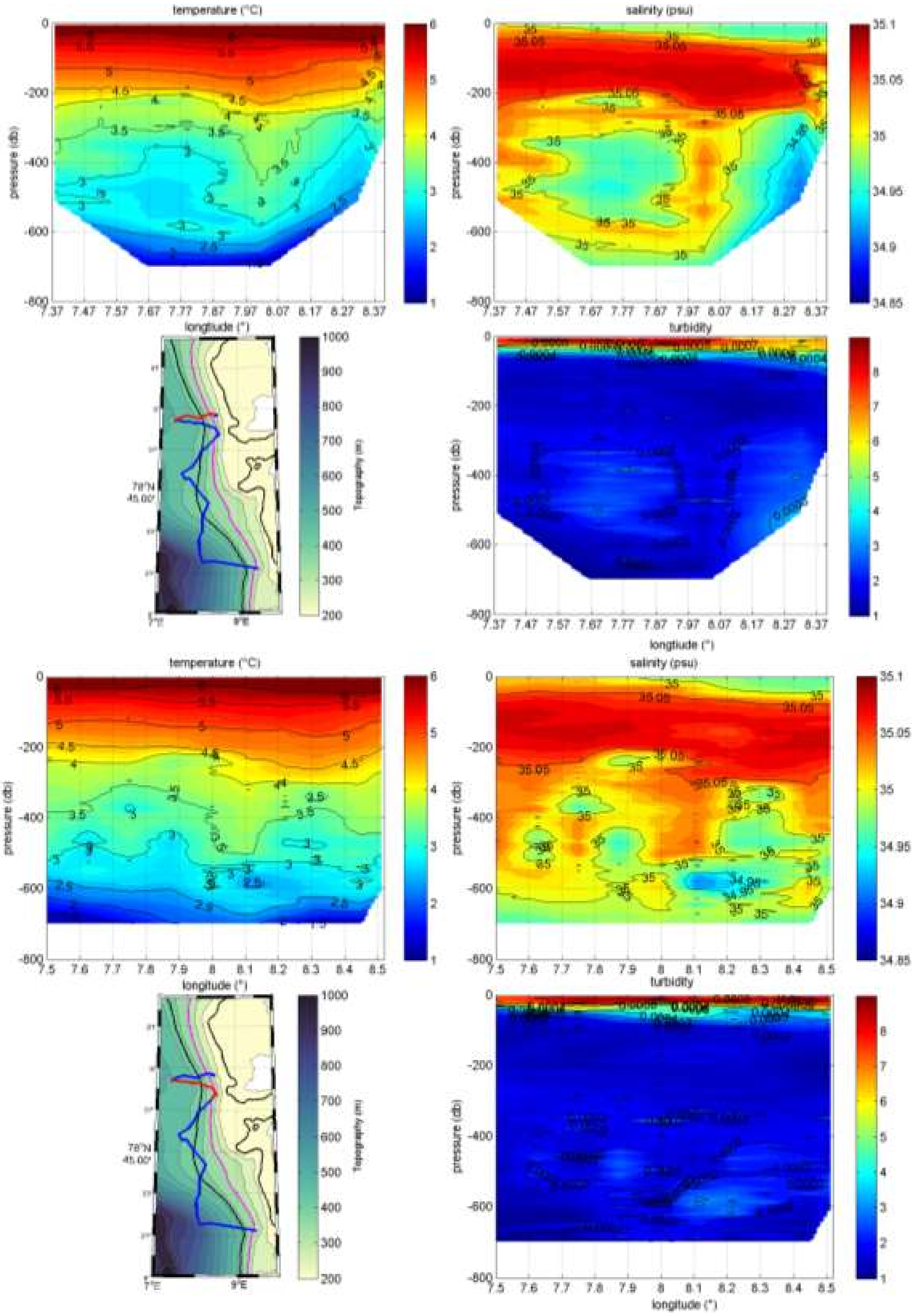

Figure 34. Vertical transects (evidenced in red on the maps) surveyed by glider SEA028 on the 18th – 19th July and on the 19th - 20th July. Upper panels from left to right report temperature (°C), and salinity; lower panels from left to right show the map of the area with the glider track and turbidity.

Four CTD casts were collected in the area. Particularly interesting resulted the cast collected on the 15 July (reported in red in Figure 34), very close to both the KGF mooring and to the glider tracks. As it can be seen in Fig. 38, collected data confirms the presence (between 500 and 600m depth) of a water mass with same characteristics of the one constituting the plume detected by the gliders. It also reveals that this water mass was unstable (both the double SBE911 CTs indicate a density inversion up to 0.015 kg m-3). The density inversion is probably generated by water cascading from the Kongsfjorden shelf along the continental slope, hypothesis supported by the associated higher turbidity (lower beam transmission and higher beam attenuation in Figure 38) indicating that it has been in the bottom layer. The density lower than surrounding waters generates the upward moving plume, more evident in the glider vertical sections showed in Figure 36.

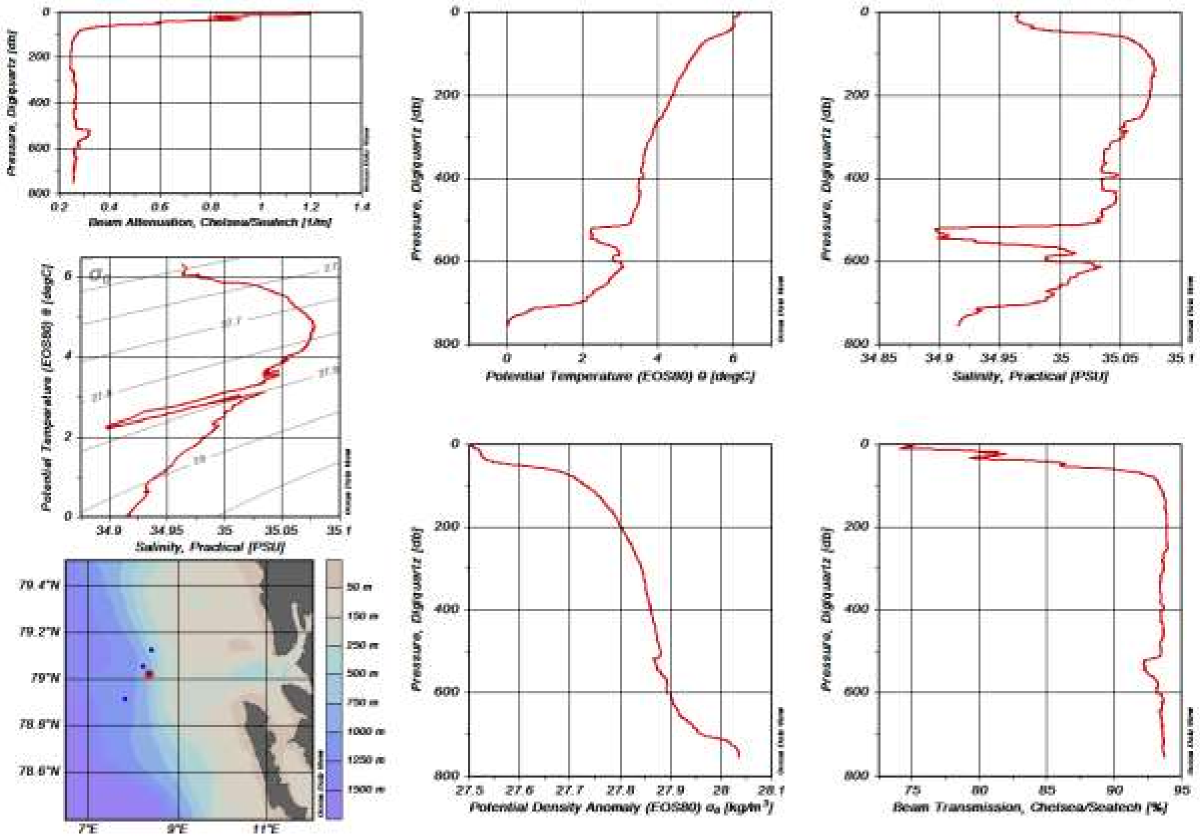

Figure 35. Vertical profiles of beam attenuation, temperature, salinity, potential density anomaly, beam transmission and the potential temperature-salinity diagram from the CTD cast collected close to the KGF mooring.

The KGF mooring deployed in the area (position reported in Figures 34 and 35) from the 15 to the 20 July is very close to the cited CTD cast. Moored instruments (see the schematics reported in Section x) were not observing the specific water layer (500-600m) individuated by the CTD cast shown in Fig. 5, but during the 5 days of deployment waters with similar characteristics were observed, especially on the last couple of days when current speed increased (Figure 39 reports current magnitude in mm/s and temperature - red line overimposed - in degree C multiplied by 10). The ADCP was at about 475 m depth, upward looking, each cell is 8m, the first cell is centered at 12.27 m from the head; hence the water column has been sampled from around 460 m up to 188 m depth every 5min during the 5 days of deployment. During periods with low water temperature (2.0-2.5 °C), high values of the current (up to over 0.4 m s-1) are present. The current remained substantially directed northward along the whole monitored period; a relevant (0.1 m s-1) westward component appears only at around sample 1200, on the 19th July, together with the minimum temperature.

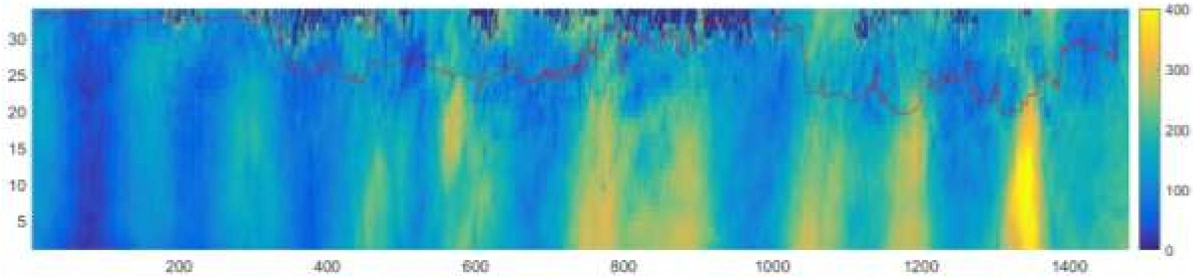

Figure 36. Magnitude of the current (mm/s) observed by the 150 kHz ADCP located at around 475 m depth on the mooring KGF and monitoring the water column from around 460 m (lower Y axis) up to 188 m (upper Y axis). The red line represents the sea temperature (values on the left axis have to be divided by 10) recorded by a sensor installed on the ADCP.

3.9 Marine Lidar (Nuvoli M.)

The aim of the campaign is to detect the presence and concentration of chlorophyll and organic substances present in the water column scanned by the lidar.

Lidar uses a short-lasting laser pulse to induce fluorescence following anelastic diffusion.

The emission induced by the laser is collected by an optical telescope, spectrally filtered and finally sent to the optical sensor, which provides for the conversion of the optical signal into an electrical signal. The heart of the device is a newly developed optical microsensor realized through the use of a silicon Avalanche PhotoDiode (APD) device with very high sensitivity of detection.

The marine lidar consists of a power supply and a laser head that sends pulses at 355nm on the surface from a height of about 14m.

The two elements are connected by an "umbilical cord" of about 2.5m.

In figure 40 you can see the complete instrument (left) and the optical window of the head (right).

Figure 37. The marine LIDAR

The Lidar acquired data in June 9-23 and 25-26, then had malfunctions until it wasturned off on June 27.

Later, some restarts were attempted, but it was necessary to transport it to the laboratory and to disassemble it for repair.

After the repair took place, on July 19 the instrument began to function again regularly.

The following plot shows the signals detected continuously on the four channels with different wavelengths.

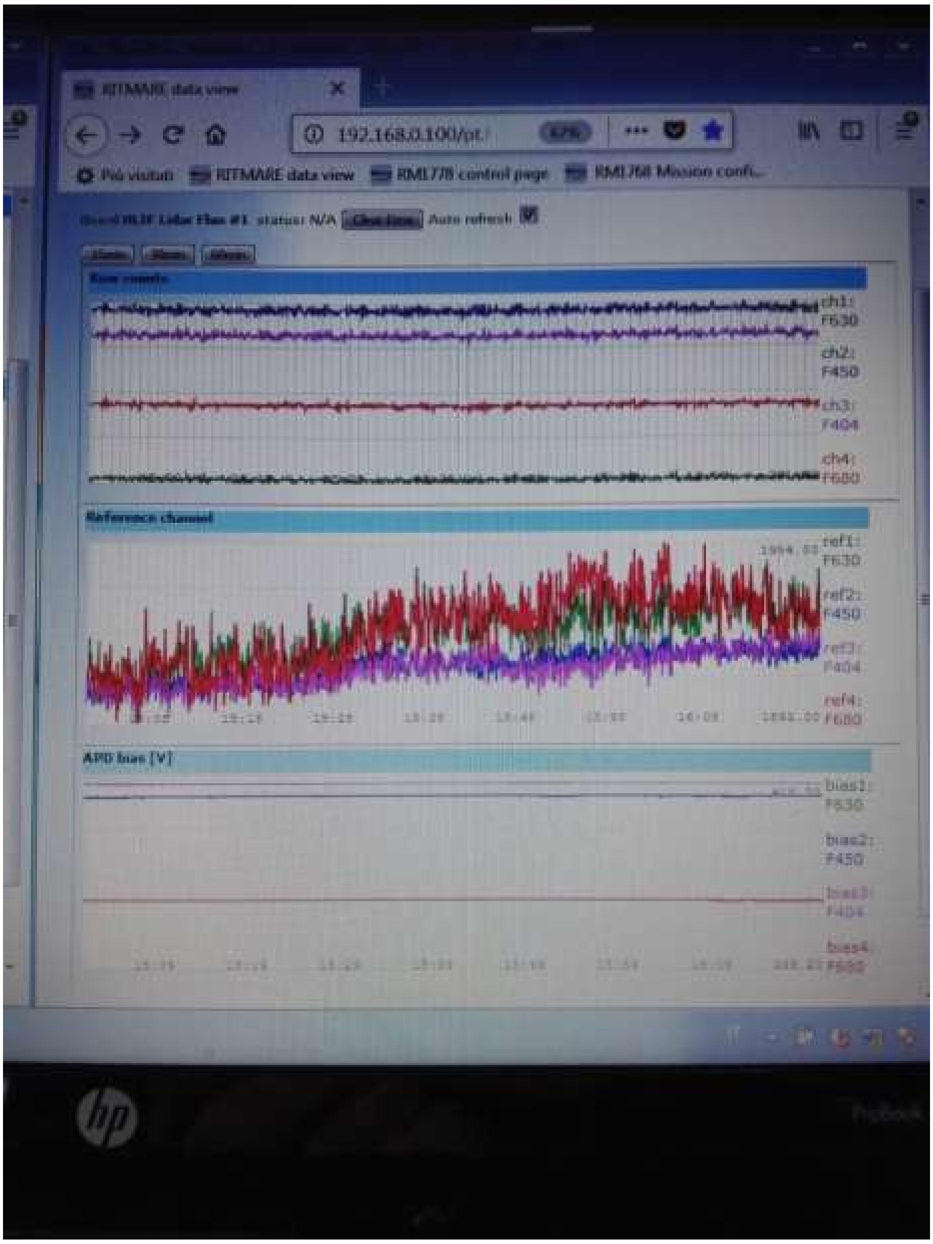

Figure 38. Signal plots

In figure 42 we can see the settings of the laser and of the various sensors of the lidar.

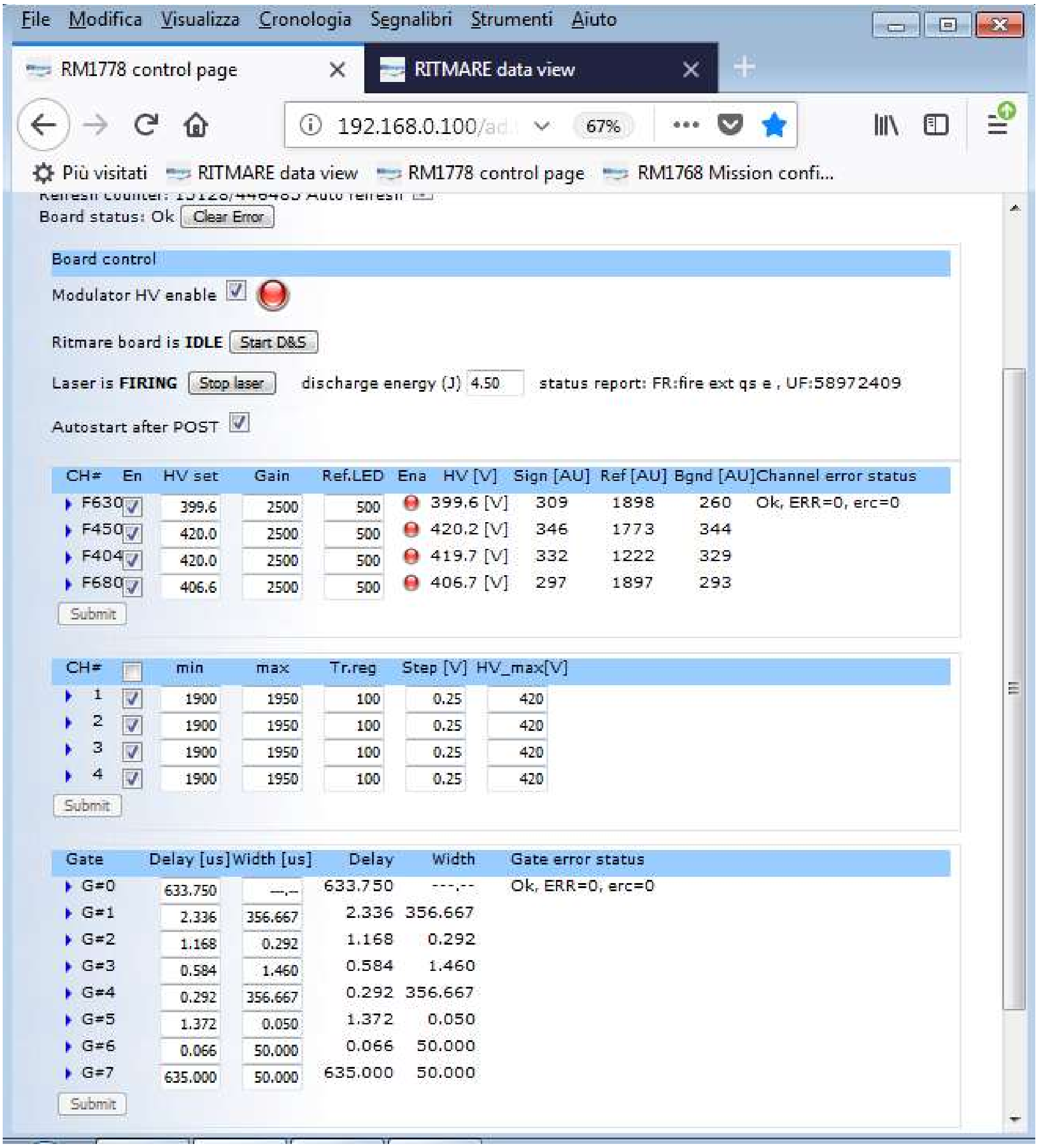

Figure 39.

All data are written to a .dat file and recorded on a micro SD card inside the instrument.

Although the 680 nm and 450 nm channels provide real time some information on chlorophyll and organic substances, the complete data processing will be carried out once the instrument will be back at Enea Frascati.

3.10 Plastic pollution (Borgogno F.)

Worldwide distribution of plastic pollution data and awareness are rapidly increasing but there were no works or studies about floating plastics (micro or macro) at the highest latitudes (over 80°N). One of the target of High North 18 was to work on this issue.

Figure 40. Manta trawling

Surface samples were collected using a Manta Trawl (0.60 m wide × 0.16 m vertical opening, net 0.333 mm mesh, 3 metres long). The net was deployed from the left stern of the vessel (at 30 m from the vessel). The net was towed in a straight line for, on average, 65 minutes at an average speed of 2 knots. Vessel speed was reduced to minimise the effect of vessel movement. A calibrated flow meter (Hydrobios) was attached to the mouth of the net to allow for calculation of the amount of water filtered. After the allocated collection time, the net was returned to the stern of the vessel where it was rinsed (handle). In the first trawl, the cod-end was removed and taken to the laboratory where it was rinsed into a sieve (0,2 mm). During the second trawl we lost the cod-end and continue tha sampling work with a strong closing on the back of the net. The volume reduced sample was transferred to a large collecting jar and stored in etanol for ir spectrometer. Analysis will be carried out by Turin Politecnico team of prof. Debora Fino.

Figure 41 Floating macroplastic

During HN18 expedition we have the opportunity to do very important and unpublished observation of floating macroplastic (>5mm) in the area over 81°N.

We can observe and shot pictures (as documentation) macroplastic <u>ON</u> and <u>IN</u> the ice pack.

In three days we collect documentation (pictures and video) about over 150 fragments (bigger then 5 cm) in almost 6 hours of sistematic observation (more fragments was seen but whitout documentation). So, we observe one fragment every 2 minutes of observation (one person, one side of the vessel, 5-10 meters from the vessel).

We reach an object as example of what is floating on the arctic ocean water: a tank more than 30 cm long.

This result is very important and complete global knowledge about distribution of macroplastic 'traveling worldwide by current': never there were documentation of a massive presence of macroplastic at high latitude

Figure 42. Plastic tank catched at 81° 37’ N

Figure 43. Cryotubes for 'plastisphere' study

We collect samples for a 'plastisphere' study of Amaral Zettler lab (Holland): looking at DNA to determine the community associated with plastic. Samples are preserved in cryotubes with a liquid called “Lysis buffer”, a non-toxic salt solution that preserves the DNA.

<u>THE MANTA TRAWL STATIONS</u>

HN18_005_MAN_01

START 74°19.975N 016°13.005E

END 74°19.066N 16°06.303E

WATER SAMPLED (QUANTITY, FLOW METER HYDRO BIOS): 5012,352L

SOME ORGANIC FRACTION AND UNIDENTIFIED PARTICLES (ANALYSIS WILL GIVE US THE DATA, POSSIBLE MICROPLASTICS)

HN18_028_MAN_02

START 76°27.552N 13°53.125E

END 76°29.622N 13°47.715E

WATER SAMPLED: 3403,584L

MASSIVE PLANCTON (KRILL), ANALYSIS WILL TELL QUANTITY OF MICROPLASTICS

HN18_034_MAN_03

START 78°21.874N 9°.39.293E

END 78°22.542N 9°28.536E

WATER SAMPLED: 2983,608L

MASSIVE PLANCTON (ZOO AND PHITO), ALGAE AND A BIG FRAGMENT (>20 CM) OF PLASTIC, ANALYSIS WILL TELL QUANTITY OF MICROPLASTICS.

HN18_037_MAN_04

START 78°35.623N 6°58.500E

END 78°38.086N 7°03.987E

WATER SAMPLED: 3477,114L

MASSIVE PHITOPLANCTON, ANALYSIS WILL TELL QUANTITY OF MICROPLASTICS.

HN18_053_MAN_05

START 81°40.309N 11°16.466E

END 81°38.703N 11°26.298E

WATER SAMPLED: 3744,558L

SOME MICROFRAGMENTS, ANALYSIS WILL TELL QUANTITY OF MICROPLASTICS.

HN18_063_MAN_06

START 81°20.638N 07°34.776E

END 81°18.891N 07°44.584E

WATER SAMPLED: 3694,968L

MACROPLASTICS, MICROPLASTIC, FIBRES, ANALYSIS WILL TELL QUANTITY OF MICROPLASTICS.

3.11 Marginal Ice Zone Navigation (Armanino E., Guideri M., Langone L.)

A Marginal Ice Zone (MIZ) navigation was performed during HN18 in order to determine the limits of this area and the characteristics of the floating ice. During the navigation, a set of pictures has been taken to integrate the observer identification with a more objective approach.

For the ice characteristics determination, the team used the "MANICE – Manual of Standard Procedures for Observing and Reporting Ice Conditions"[3] of the Canadian Ice Service as a reference.

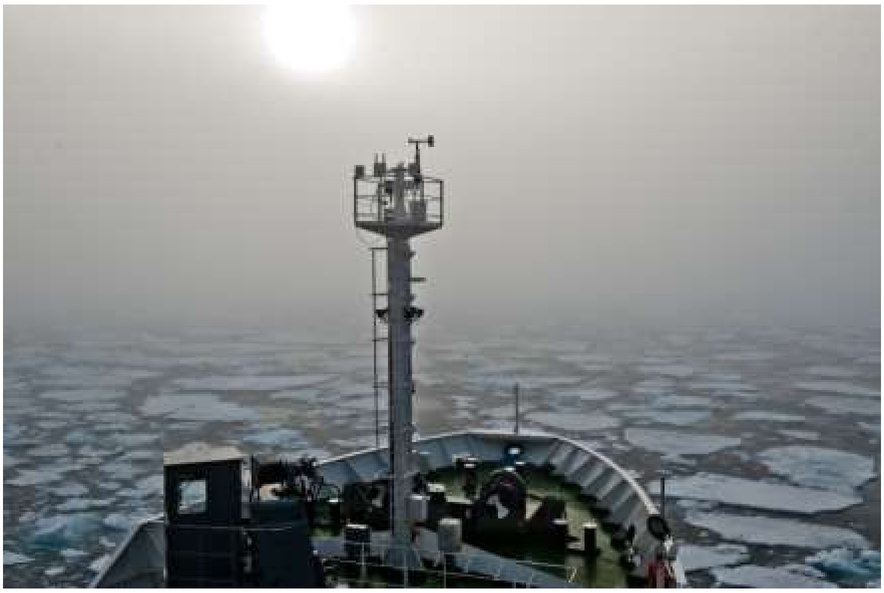

Figure 44– R/V Alliance in the Marginal Ice Zone

R/V Alliance reached the MIZ on July 16th in the late evening, then the day after moved eastward to 81° 50.27'N – 017° 40.67'E, and came back to the Yermak Plateau on July 19th.

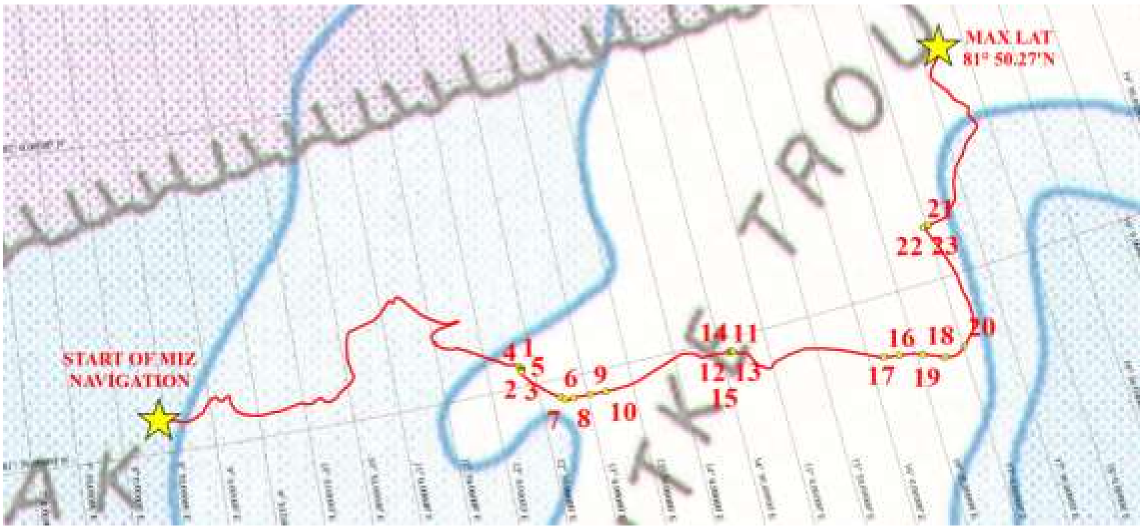

Figure 45– Route along the Marginal Ice Zone border with photo locations

[3] Revised Ninth Edition, June 2005 – ISBN 0-660-62858-9. Crown Copyrights reserved.

PHOTO STATION	DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'		LON gg° mm.mmm'		SIZE m	SHAPE	THICKNESS	TYPE	CONCENTRATION	SIDE
HN18_ICE_001	20180717	14:52	81	31.9992N	12	21.106E	15	Polygon	T	First-year Ice	Close pack/Drift	SX
HN18_ICE_002	20180717	14:56	81	31.7160N	12	22.639E	30	Triangle	M	First-year Ice	Open drift	SX
HN18_ICE_003	20180717	14:58	81	31.5800N	12	22.336E	10	Polygon	T	First-year Ice	Very open drift	SX
HN18_ICE_004	20180717	14:59	81	31.4922N	12	22.086E	70	Polygon	T	First-year Ice	Open drift	SX
HN18_ICE_005	20180717	15:00	81	31.4326N	12	21.919E	40	Polygon	M	First-year Ice	Open drift	SX
HN18_ICE_006	20180717	15:44	81	28.2488N	12	43.286E	15	Polygon	T	First-year Ice	Close pack/Drift	SX
HN18_ICE_007	20180717	15:48	81	27.9857N	12	45.481E	50	Polygon	M	First-year Ice	Very close pack	SX
HN18_ICE_008	20180717	15:56	81	27.9380N	12	51.470E	4	Polygon	M	First-year Ice	Open drift	SX
HN18_ICE_009	20180717	16:10	81	27.8931N	13	02.142E	4	Polygon	M	First-year Ice	Open drift	SX
HN18_ICE_010	20180717	16:21	81	27.8520N	13	12.330E	N.N.	Polygon	N.N.	First-year Ice	Very open drift	SX
HN18_ICE_011	20180717	17:40	81	28.6639N	14	34.794E	40	Polygon	M	First-year Ice	Close pack/Drift	SX
HN18_ICE_012	20180717	17:47	81	28.6518N	14	36.043E	25	Polygon	M	First-year Ice	Open drift	SX
HN18_ICE_013	20180717	17:47	81	28.6503N	14	36.138E	25	Polygon	M	First-year Ice	Open drift	SX
HN18_ICE_014	20180717	17:50	81	28.6218N	14	37.024E	15	Polygon	T	First-year Ice	Very open drift	SX
HN18_ICE_015	20180717	17:52	81	28.5972N	14	37.492E	4	Polygon	T	First-year Ice	Very open drift	SX
HN18_ICE_016	20180717	20:00	81	24.3091N	16	09.643E	10	Polygon	M	First-year Ice	Very open drift	DX
HN18_ICE_017	20180717	20:06	81	24.0446N	16	19.361E	10	Polygon	M	First-year Ice	Very open drift	SX
HN18_ICE_018	20180717	20:16	81	23.5006N	16	34.156E	20	Polygon	M	First-year Ice	Very open drift	SX
HN18_ICE_019	20180717	20:25	81	22.6542N	16	46.886E	12	Polygon	M	First-year Ice	Very open drift	SX
HN18_ICE_020	20180717	20:35	81	23.1147N	17	00.605E	10	Polygon	M	First-year Ice	Very open drift	DX
HN18_ICE_021	20180717	22:00	81	35.1228N	16	57.953E	30	Polygon	M	First-year Ice	Open drift	SX
HN18_ICE_022	20180717	22:10	81	35.1664N	17	00.846E	40	Polygon	M	First-year Ice	Open drift	SX
HN18_ICE_023	20180717	22:10	81	35.1743N	17	01.071E	40	Polygon	M	First-year Ice	Open drift	SX

NOTE:

THICKNESS: **V** (Very Thick) > 4m; **K** (Thick) > 2-4m; **M** (Medium) = 1-2m; **T** (Thin) < 1m

CONCENTRATION: Open water (<1/10); Very open drift (1/10-3/10); Open drift (4/10-6/10); Close pack/Drift (7/10-8/10); Very close pack (9/10).

Table 4 – Ice Photos

Most of the time, the ice was First Year Ice with a polygonal shape and an average size of 25 meters, a thickness between 1 and 2 meters, and a concentration ranging from 3/10 to 7/10.

3.12 Marine Geophysical Route Survey (Muccini F., Ferrero V., Marro M.)

Istituto Nazionale di Geofisica e Vulcanologia (INGV) and Istituto Idrografico della Marina collaborate from several years in conducting oceanographic cruises. In particular INGV focus on potential field methods (magnetic and gravimetric) for researcs in seamounts, geo-archeological purposes, volcanic and tectonic active marine areas.

Potential field methods are non-invasive, low-cost geophysical remote sensing methods used to valutate the spatial variations of the geological subsurface in terms of rock density and magnetization distributions. Gravimetric and magnetic data can be acquired during navigation at different vehicle speed, so coupled with different methodologies (multibeam, seismic, sidescan sonar) allowing rapid spatial coverage with no increasing in terms of time ship compsumption.

The basic concept behind gravity survey is to investigate variation (gravity anomalies) in the Earth's gravitational field generated by differences of density between subsurface rocks. The variation in density is induced by the presence of a causative body, such as volcanic intrusion, faults, tectonic contacts, hydrothermal alteration.

Figure 46– Example of a gravity meter for onboard installation

This method is applicable to carry survey on the ground, in the air, and into the marine environment, both from sea surface (ship) and near bottom (auv, rov) surveys.

A major challenge in acquiring gravity data from a floating platform at the sea surface is in separating the acceleration of the platform in the dynamic ocean from the acceleration of gravity. This problem is overcome by mounting marine gravimeters deployed from ships on inertially stabilized tables. These tables employ gyroscopes and accelerometers to maintain a constant attitude despite the pitching and rolling of the ship beneath the table.

The nongravitational acceleration is somewhat mitigated by mounting marine gravimeters deep in the hold and as close to the ship's center of motion as possible. Special damping mechanisms also prevent the spring in the gravimeter from responding to extremely high-frequency changes in the force on the suspended mass.

INGV is involved in the HIGH NORTH 18 oceanographic cruise to study the gravimetric anomalies of the areas investigated. The cruise took place in very interesting and remote geological areas, and the modeling of the gravimetric anomalies coupled with the others geophysical data could furnish new constrains concerning the tectonic evolution of these areas.

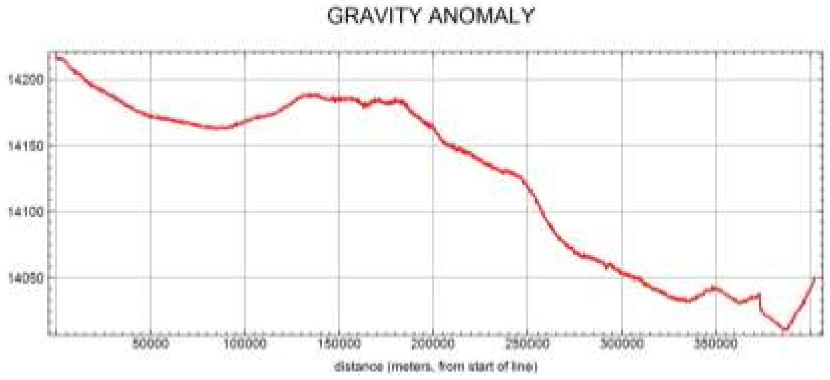

Figure 47– Gravity anomaly

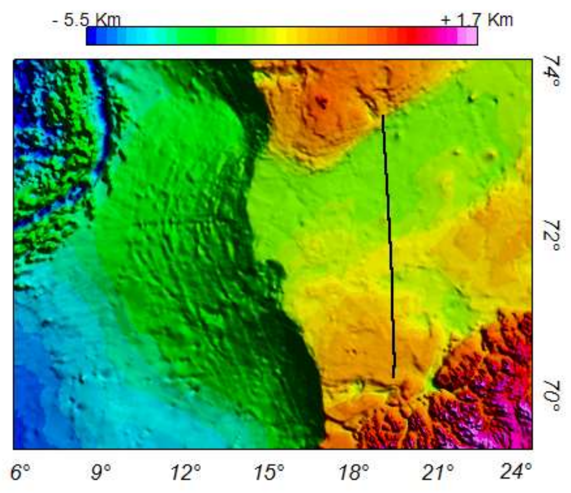

Figure 48– Positioning of the plotted line (Figure 50) on a bathymetric map (data from: Amante, C. and B. W. Eakins, ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-24, 19 pp, March 2009)

3.13 RPAS Arctic On-Ship Flight Operations (Rinaldelli S.)

Drone usage in research is developing branch of modern Flight Operations. In this Mission the primary aim was to acquire aero-photogrammetric images of the Arctic ice edge, both in visible and in infrared fields. It was also a unique opportunity to stress the technical apparels and human factors involved in RPAS Operations in such a hostile environment as a ship sailing North up to 81° 52’ Latitude.

The aircraft used is a Quadcopter, Class LIGHT (4Kg<MTOM<25Kg according to ENAC Italian RPAS Rules) with a TOM of 7,5 Kg, named IDS IA-3 **Colibrì Sda**, designed and manufactured by **IDS Ingegneria Dei Sistemi S.p.A.**

Figure 49The aircraft

This aircraft has 4 electrical engines fed by a battery with 22000 mAh capacity which guarantees an Endurance of 42 minutes at 15°C, in hovering. Propellers are mounted on top of 4 foldable carbon fiber arms and antennas are embedded in the ground skids.

The drone is composed by a carbon fiber structure enclosing all avionics, electronic devices and video-streaming camera. In its standard configuration, without belly mounted payload, the aircraft is capable of performing landing and subsequent take-off from the water surface.

In the HIGH NORTH 18 configuration there were a belly mounted, photogrammetric EO and IR cameras. A high performance GPS receiver was placed on top of the drone to enhance the geo-positioning precision of the reliefs.

Table 5 . Flight Log

Date	Place	LAT	LON	TO	LAND	FLIGHT TIME
13/07/18	Is. Svalbard	76° 26.113'N	013° 56.038'E	19.55	20.00	5’
13/07/18	Is. Svalbard	76° 26.192'N	013° 56.128'E	20.05	20.10	5’
14/07/18	Is. Svalbard	78° 21.792'N	009° 34.597'E	13.27	13.36	9’
14/07/18	Is. Svalbard	78° 21.775'N	009° 34.256'E	13.39	13.50	11’
15/07/18	Kongsfjord	79° 01.794'N	008° 24.540'E	10.58	11.06	8’
18/07/18	ICE EDGE	81° 38.986'N	018° 05.962'E	09.37	09.50	13’
18/07/18	ICE EDGE	81° 36.913'N	018° 08.949'E	14.43	15.01	18’
18/07/18	ICE EDGE	81° 36.741'N	018° 09.263'E	15.26	15.38	12’
					TOTAL	**1h21’**

Table 6 . Operative conditions

Technical Conditions	
Magnetometer:	Not operative due to metallic mass of ship
TO/LAND Deck dimensions:	4x5 m
Maneuver Limitations:	Obstacles in landing area (H: 1,5 - 5 m) 2 blind sectors approx. 30° wide toward AFT & BOW Ship in constant motion at 1,5 m/s
Meteorological Conditions	
Horiz. Visibility:	from 50 m to unlimited
Ceiling:	< 300 ft
Wind:	from 8 KT to 17 KT, Gusts and Turbulence
Weather Phenomena:	from NIL to Freezing Rain
Temperatures:	from +3°C to -3°C
Others:	Icing Conditions

Since the first test mission it became evident that the Magnetometer Sensor was heavily disturbed by the electric engines of the ship. After shutting down the engines, first calibration results with the RPAS on the deck were good, but after taking off, problems of coherence in magnetic field reappears again while the position of the aircraft was varying from deck to 10 meters from the ship. Kalman Filter check suddenly excluded Magnetometer and switched the flight mode from GPS to GYRO stabilization, forcing the Pilot to compensate manually.

The context in which the Pilot has to operate was characterized by motion inertia, wind, obstacles, induced turbulence, ship relative motion up to 1.5 m/s, narrow deck rolling due to waves motion, slippery wet metal deck, approach cone narrowed by obstacles

These elements led to a very challenging effort to conduct a safe landing for the Pilot.

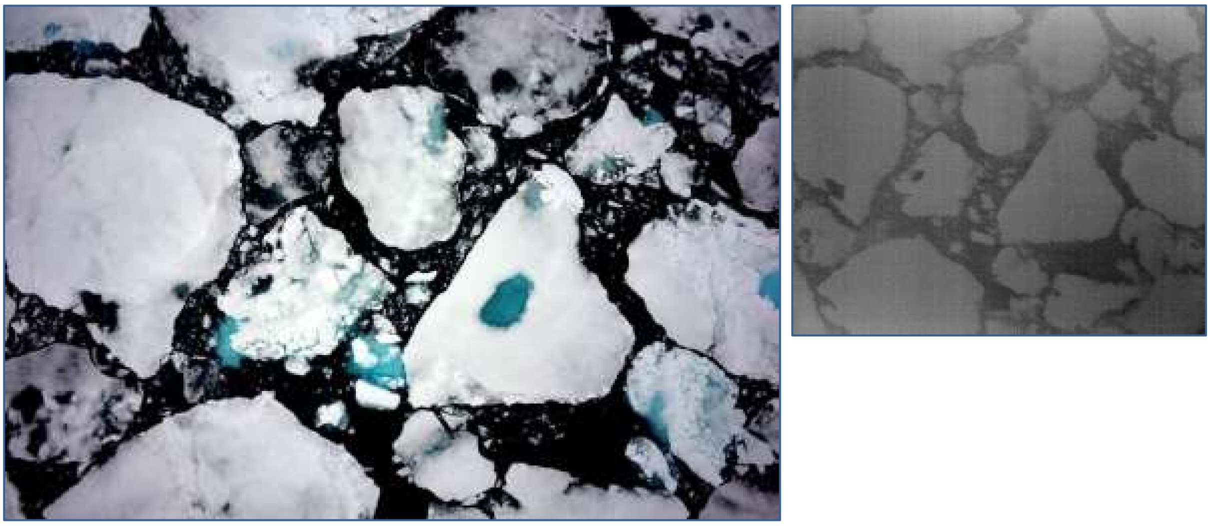

Figure 50. Ice photos

Aero-photogrammetry activity, performed during Flights n° 6, 7 and 8, has led to collect the desired images, both in EO and IR fields.

Key Factors to analyze the difficulties encountered in the Mission can be grouped in four Impact Categories: Avionics, Meteo, Logistics, Human Factor

In next page follows a diagram illustrating the chain of Key Factors in the present Flight Operation with black arrows representing causal relationships. Some Key Factors are eligible for mitigations and are represented with green borders.

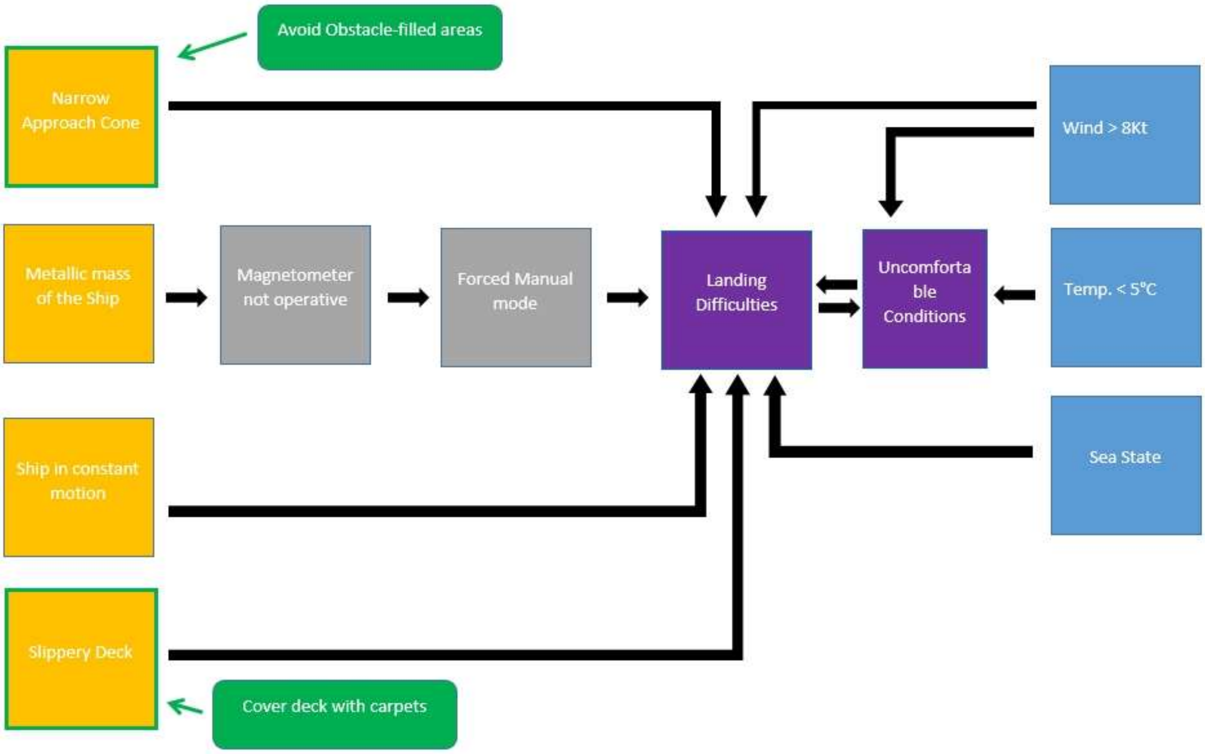

Figure 51. Chain of Key Factors

The HIGH NORTH 2018 Mission represented an interesting case study for RPAS Flight Operations and RPAS Manufacturer Industry, even if conducted with a relatively small aircraft. There were many challenging elements and their synergy had increased the test importance.

This hostile environment allowed all stakeholders to appreciate and evaluate the effective usefulness of RPAS and to deeply test the performance of the specific IA-3 Colibrì Sda RPAS.

This activity is an important precedent in On-Ship Unmanned Aircraft operations, helping to understand both technological step required to increase easiness of use and to determine a baseline of facilities needed to assure the safety of flights.

The contribution of RPAS, already largely adopted in terrestrial research operations, confirmed its importance even in marine operations demonstrating great flexibility and resistance to difficult Environment as the Arctic can be, without losing its usefulness.

3.14 Drifter (Ribotti A.)

The study of the ocean circulation in Arctic areas is important in a general study of climate as it contributes to the heat transport, but also pollutants, nutrients and organisms, from the tropics to the poles and vice versa. Circulation data are also used to validate numerical models implemented at different spatial scale. These data are obtained, during the High North 2018 campaign, also through the use of surface drifters with drogues that transmit their position at a frequency of 2 hours. Two satellite surface drifters have been launched a few nautical miles west of the Bear Island, south of Svalbard Archipelago, and two south-west of the above mentioned Archipelago. At a preliminary observation, the first two initially moved due to local hurricanes and, when closer to the Bear Island, were leaded by the tides and inertial semidiurnal oscillations. The two drifters close to Svalbard have been caught by the Western Spitsbergen Current (WSC), part of the North Atlantic Current (NAC) whose importance is given by its transport of warm and salty waters from the Atlantic Ocean inside the Arctic Ocean through the eastern part of the Fram Strait.

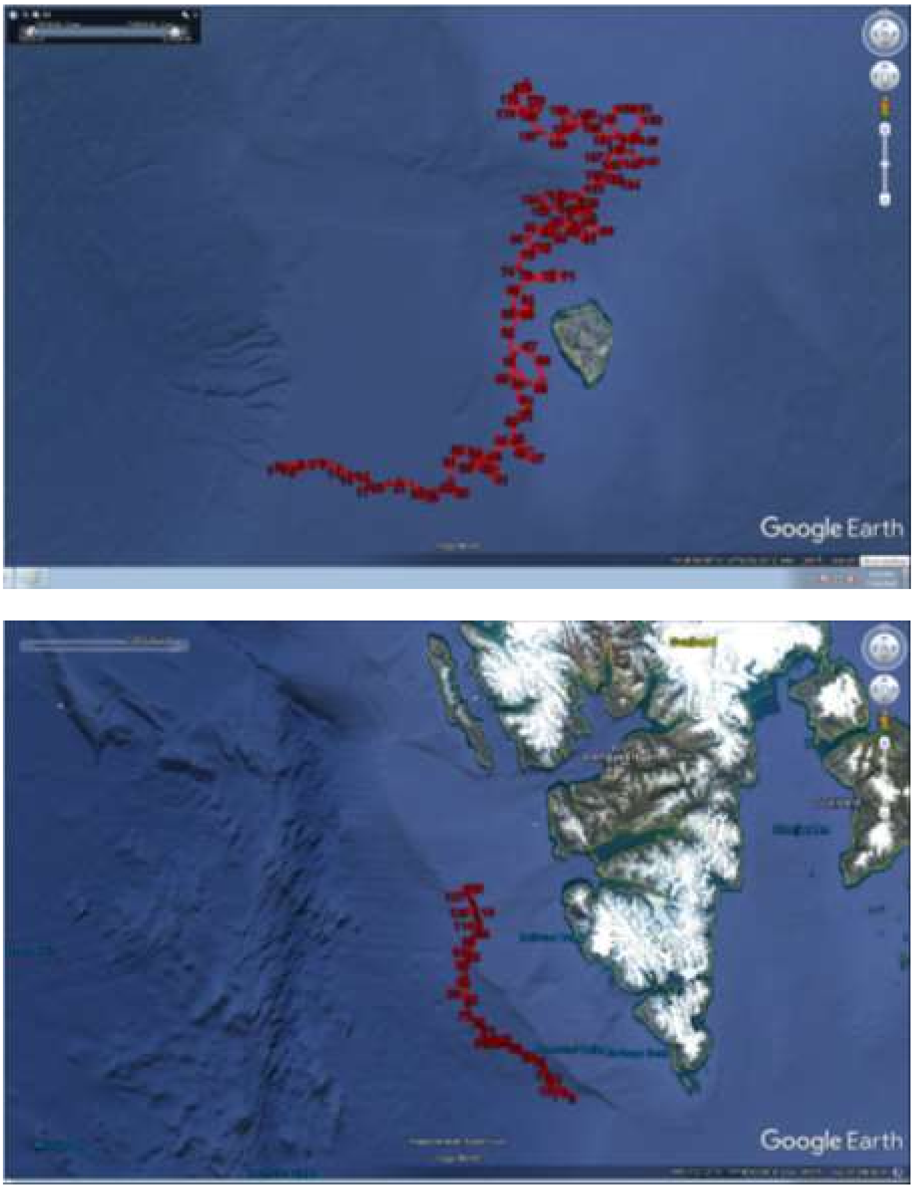

Figure 52. Drifters routes

3.15 Satellite Ice Detection

The crew of the Italian Navy Hydrographic Institute and the scientists of the HIGH NORTH 18 expedition have successfully used COSMO-SkyMed satellites data – provided by Leonardo and the Italian Space Agency through e-GEOS (a joint venture between Telespazio and ASI) dedicated team - for vessel detection and oil spill monitoring applications.

COSMO-SkyMed data have also been merged with information from multiple sources – such as Copernicus Sentinel-1 satellite and exactEarth AIS service – by SEonSE (Smart Eyes on the SEas), Leonardo's geospatial maritime security platform, launched at the Farnborough International Air Show last week, thus providing ice fragmentation mapping and the support to the navigation safety (Figure 56).

The integration between different kinds of data and the flexibility of the Italian COSMO-SkyMed constellation allowed the continuous monitoring of the Alliance vessel route, even when the ship was out of the range of the AIS or in remote areas where current satellite telecommunication may fail.

The comparison between these innovative support and the ground truth acquired during the High North 18 campaign such as the position of the ice edge boundary, the type and size of the ice, the wave and wind, should be part of the experimentation that will be conducted ashore.

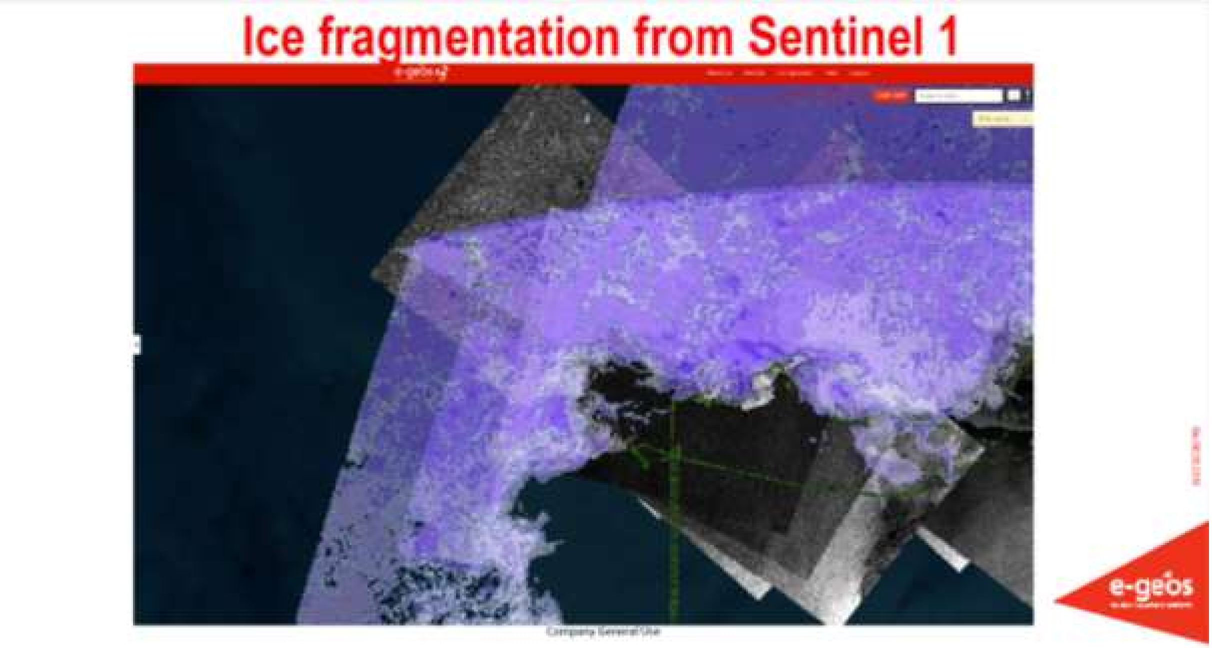

Figure 53. Drifters routes

4. Stations List

Table 7. Stations list
DRI drifter; GLI glider; BCO box corer; SCA scanfish; DRO drone; MOO mooring; MAN manta; IN deploy; OUT recovery.

STATION	NR	DATE yyyymmdd	TIME UTC hh:mm	LAT (N) gg°mm.mmm'		LON (E) gg°mm.mmm'		DEPTH m	ACTIVITY
HN18_001	1	20180709	9:50	74	8,259	16	17,528	420	DRI/IN
HN18_002	1	20180709	9:55	74	8,172	16	18,081	408	GLI/OUT
HN18_003	1	20180709	13:13	74	20,458	16	13,870	740	CTD
HN18_004	1	20180709	16:45	74	20,476	16	16,375	719	MOO/IN
HN18_005	1	20180709	17:23	74	19,922	16	12,701	829	MAN/IN
HN18_006	2	20180709	19:36	74	19,100	16	26,084	304	CTD
HN18_007	3	20180711	10:00	76	51,733	18	45,348	77	CTD
HN18_008	2	20180711	10:25	76	51,944	18	45,590	77	MAN/IN
HN18_009	2	20180711	11:35	76	54,750	19	0,235	90	MAN/OUT
HN18_010	4	20180711	11:52	76	54,883	19	1,818	95	CTD
HN18_011	1	20180711	13:02	76	55,488	18	55,320	99	SCAN/IN
HN18_012	1	20180711	14:49	77	4,136	18	55,330	129	SCAN/OUT
HN18_013	5	20180711	15:03	77	3,682	18	56,184	128	CTD
HN18_014	1	20180711	15:38	77	3,832	18	56,098	128	BCO
HN18_015	2	20180711	16:40	77	9,530	18	56,029	130	SCAN/IN
HN18_016	3	20180711	23:46	76	53,480	19	18,520		SCAN/OUT
HN18_017	6	20180712	12:03	76	26,369	13	58,318	1033	CTD
HN18_018	7	20180712	13:42	76	27,594	14	7,745	879	CTD
HN18_019	8	20180712	15:35	76	25,134	13	46,594	1128	CTD
HN18_020	9	20180712	17:17	76	23,802	13	35,086	1227	CTD
HN18_021	10	20180712	19:32	76	28,997	14	20,641	510	CTD
HN18_022	11	20180712	20:32	76	30,084	14	33,875	247	CTD
HN18_023	12	20180712	21:22	76	31,228	14	45,645	210	CTD
HN18_024	13	20180713	7:00	76	25,024	13	50,500	1088	CTD
HN18_025	2	20180713	8:27	76	25,630	13	58,400	1020	DRI/IN
HN18_026	2	20180713	9:30	76	26,484	13	56,865	1043	MOO/OUT
HN18_027	14	20180713	16:07	76	26,395	13	56,026	1054	CTD
HN18_028	2	20180713	17:45	76	26,234	13	53,470	1000	MOO/IN
HN18_029	2	20180713	20:51	76	27,552	13	53,125	1061	MAN
HN18_030	1	20180714	6:52	78	7,933	9	18,412	534	GLI/IN
HN18_031	2	20180714	8:22	78	12,200	9	19,072	520	GLI/IN
HN18_032	3	20180714	10:16	78	16,682	9	25,490	450	GLI/IN
HN18_033	4	20180714	11:29	78	21,849	9	33,595	410	GLI/IN
HN18_034	1	20180714	11:30	78	21,590	9	36,540	500	DRO
HN18_035	3	20180714	12:55	78	21,870	9	38,990	404	MAN/IN
HN18_036	3	20180714	14:06	78	22,542	9	28,536	590	MAN/OUT
HN18_037	5	20180714	17:01	78	35,634	6	57,649	1750	GLI/OUT
HN18_038	4	20180714	17:20	78	35,623	6	58,500	1800	MAN/IN

STATION	NR	DATE yyyymmdd	TIME UTC hh:mm	LAT (N) gg°mm.mmm'		LON (E) gg°mm.mmm'		DEPTH m	ACTIVITY
HN18_039	4	20180714	18:33	78	38,086	7	3,987	1530	MAN/OUT
HN18_040	6	20180714	21:54	78	20,622	9	14,531	854	GLI/OUT
HN18_041	15	20180715	2:05	78	55,225	7	49,680	1115	CTD
HN18_042	2	20180715	9:00	79	1,761	8	24,490	706	BCO/DRO
HN18_043	3	20180715	12:43	79	1,530	8	24,883	700	MOO/IN
HN18_044	16	20180715	13:30	79	1,117	8	22,608	755	CTD
HN18_045	17	20180715	20:09	80	9,881	8	30,431	538	CTD
HN18_046	18	20180715	22:42	80	18,834	8	29,672	656	CTD
HN18_047	19	20180716	1:10	80	26,868	8	27,546	936	CTD
HN18_048	20	20180716	4:32	80	35,760	8	30,478	903	CTD
HN18_049	21	20180716	7:35	80	43,939	8	29,262	943	CTD
HN18_050	22	20180716	15:27	81	14,224	8	29,384	716	CTD
HN18_050A	3	20180716	16:27	81	14,520	8	29,950		SCAN/IN
HN18_050B	3	20180716	19:50	81	30,610	8	29,620		SCAN/OUT
HN18_051	23	20180716	20:29	81	30,895	8	30,244	938	CTD
HN18_052	24	20180717	7:54	81	40,783	11	8,990	1774	CTD
HN18_053	5	20180717	8:50	81	40,309	11	16,466	1943	MAN/IN
HN18_054	5	20180717	10:02	81	38,703	11	26,298	1949	MAN/OUT
HN18_055	25	20180717	10:47	81	37,388	11	44,914	1942	CTD
HN18_056	7	20180717	13:41	81	35,874	11	29,978	2120	GLIDER
HN18_057	8	20180718	6:40	81	37,396	18	6,664	1290	GLIDER/IN
HN18_057	9	20180718	14:17	81	37,396	18	6,664	1290	GLIDER/OUT
HN18_058	2	20180718	14:43	81	37,396	18	6,664	1290	DRONE
HN18_059	3	20180718	15:26	81	37,396	18	6,664	1290	DRONE
HN18_060	26	20180718	17:33	81	25,518	17	56,944	1212	CTD
HN18_061	27	20180719	3:56	81	22,016	7	52,734	437	CTD
HN18_062	3	20180719	8:20	81	21,300	7	29,457	433	BCO
HN18_063	6	20180719	9:20	81	20,638	7	34,776		MANTA/IN
HN18_064	6	20180719	10:30	81	18,891	7	44,584		MANTA/OUT
HN18_065	28	20180719	12:01	81	19,699	8	40,494	1144	CTD
HN18_066	4	20180719	13:15	81	20,885	8	37,285	1110	SCAN/IN
HN18_067	4	20180719	16:49	81	20,700	8	37,300	933	SCAN/OUT
HN18_068	29	20180720	22:23	80	46,332	8	33,025	1185	CTD
HN18_069	30	20180720	5:58	80	20,035	8	39,167	662	CTD
HN18_070A	10	20180720	16:10	79	7,965	8	26,855	415	GLIDER/OUT
HN18_070B	11	20180720	16:30	79	7,274	8	25,802	610	GLIDER/OUT
HN18_070C	31	20180720	17:14	79	7,999	8	24,116	515	CTD
HN18_071	3	20180720	19:49	79	1,752	8	28,816	697	MOO/OUT
HN18_072	32	20180720	20:50	79	3,672	8	12,733	936	CTD
HN18_073	12	20180721	11:55	78	34,804	7	34,186	1489	GLIDER/OUT
HN18_074	4	20180721	20:08	77	38,723	10	16,844	1044	MOO/IN
HN18_075	33	20180721	21:09	77	37,324	10	2,144	1282	CTD
HN18_076	5	20180721	22:30	72	20,470	16	16,370	700	MOO/IN

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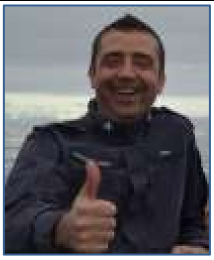	MARRO Mauro		NUVOLI Marcello
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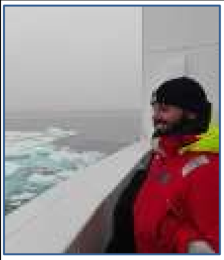
	SALVATORE Roberto		SANNA Michele
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IIM Istituto Idrografico della Marina – Genoa
CMRE Centre for Maritime Research and Experimentation – La Spezia
OGS Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - Trieste
CNR Consiglio Nazionale delle Ricerche - Roma
ADCP Acoustic Doppler Current Profiler
GLI Glider
SCAN Scan Fish
MBES Multi Beam Echosounder
DRI Drifter
LID Marine Lidar
MAN Manta Trawl
NAV Navigation
DRO Drone
MOO Mooring
SED Sediment: Sampling/Lab analyses
ICT Information and Communication Technology
GRAV Gravity Measurements
HYDRO Water: CTD/Lab analyses
MED: Media

Acknowledgements

Many people contributed to the success of the cruise. First, we wish to thank the Commanding Officer CDR Daniele CANTÚ, the Officers and the crew of R/V Alliance for their professional work and their cooperative and helpful attitude which ensured successful operation during the whole cruise and the acquisition of a vast set of high quality oceanographic and geophysical data. All Scientific Team would like to thank IT Navy Captain Massimiliano NANNINI. Special thanks to the RearAdmiral Luigi SINAPI, National Hydrographer at the Italian Hydrographic Institute for his precious support to the develop of Italian Navy High North program.

APPENDIX


ISTITUTO IDROGRAFICO DELLA MARINA
MARINA
MILITARE
HIGH NORTH 18

CRUISE: High North 18

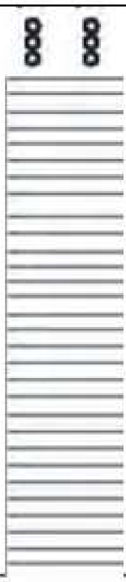
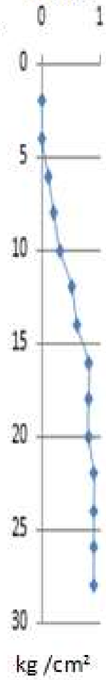
CORE: HN18_014_BCO_001 **Date:** 11/07/2018
Lat: 77° 03.832' N **Long:** 18° 56.098' E
Depth: 127 m **Sediment recovery:** ~27 cm
Area: Storfjorden (South Svalbard)

Observers: Delbono I., Ferrero V., Sanna M., Ivaldi R.

SURFACE SEDIMENT

BOX CORE LATERAL VIEW

SURFACE SEDIMENT VIEW AT MICROSCOPE

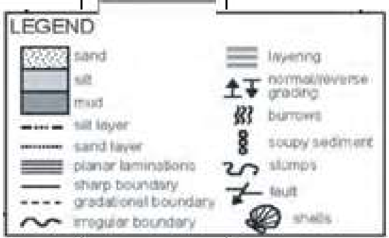
Depth (cm)	Photo	Lithology	Munsell chart colour	Sedim. structure	Water content%	Pocket penetro -meter	Lithologic description
10 20 30			2.5Y 4/2 2.5Y 4/1 2.5Y 3/2 2.5Y 2.5/1		0-1cm: 59 1-5cm: 48 5-10cm: 47		0-2 cm: very soft, soupy, silty clay sediment core with hummocky surface. 2-5 cm: less soupy sediment 5-17cm: change in colour and water content. Faintly laminated. 17-27 cm: very oxydated, black, rich in organic content sediment. Other notes: a tube worm on top (length around 4 cm). No other evident sign of tube worms downcore. The sediment core has no relevant changes in grain size (clay or silty clay).

IHO S57 top

NATSUR: 1

NATQUA: 6

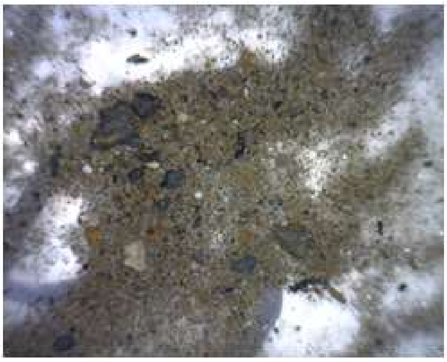
Soft mud



CRUISE: High North 18

CORE: HN18_014_BCO_001

Photos of IRD , coarse sediments and rocks, organisms



CRUISE: High North 18

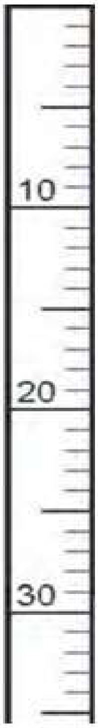
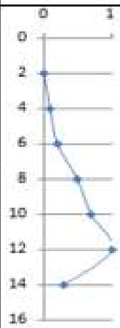
CORE: HN18_042_BCO_002 **Date:** 15/07/2018
Lat: 79° 01.761' N **Long:** 08° 24.490' E
Depth: 713 m **Sediment recovery:** ~ 15 cm
Area: Kongsfjorden (West Svalbard)

Observers: Delbono I., Ferrero V., Sanna M., Ivaldi R.

SURFACE SEDIMENT

BOX CORE LATERAL VIEW

SURFACE SEDIMENT VIEW AT MICROSCOPE

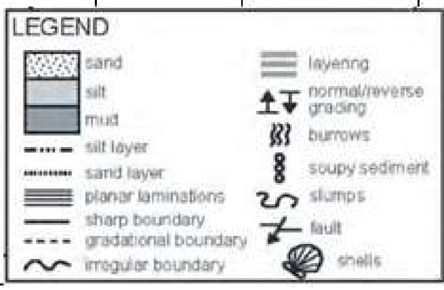
Depth (cm)	Photo	Lithology	Munsell chart colour	Sedim. structure	Water content%	Pocket penetro -meter	Lithologic description
			2.5Y 4/2 2.5Y 3/1		0-1 cm: 24 1-5 cm: 30 5-10 cm: 26	 kg /cm²	0-5 cm: coarse grained sand and gravel with large IRD cobbles and boulders up to 8 cm large, with some bryozoans on top. IRD pebbles and boulders show different lithologies. 5-7 cm: silty sand and thin worms. 7-12 cm: sandy silt sediment with cobbles and pebbles. Few thin worms inside sediments and one worm tube around 8 cm long. 12-15 cm: very fine grey silty clay, still with large pebbles and boulders on bottom.

IHO S57

NATSUR: 4, 7/ 4, 1

NATQUA: 3, /3, 5

Gravelly sand / silty sand



CRUISE: High North 18

CORE: HN18_042_BCO_002

Photos of IRD , coarse sediments and rocks, organisms

CRUISE: High North 18

CORE: HN18_062_BCO_003
Lat: 81° 21.300' N
Depth: 433 m
Area: Yermak Plateau

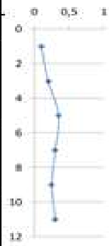
Date: 19/07/2018
Long: 07° 29.457' E
Sediment recovery: ~ 11 cm

Observers: Delbono I., Ferrero V., Sanna M., Ivaldi R.

SURFACE SEDIMENT

BOX CORE LATERAL VIEW

SURFACE SEDIMENT VIEW AT MICROSCOPE

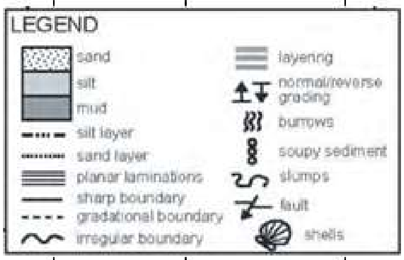
Depth (cm)	Photo	Lithology	Munsell chart colour	Sedim. structure	Water content%	Pocket penetro -meter	Lithologic description
10 20 30			2.5Y 4/3		0-1 cm: 37 1-5 cm: 36 5-10 cm: 29	 kg /cm²	top: coarse grained sand and black gravel with IRD. 0-5 cm: sandy silt. 5-bottom: silty sand sediment with cobbles and pebbles. Presence of few bivalve shells. No signs of burrows.

IHO S57

NATSUR: 4, 7/1, 4

NATQUA: 3, /7, 2

Gravelly coarse sand/ sandy stiff mud

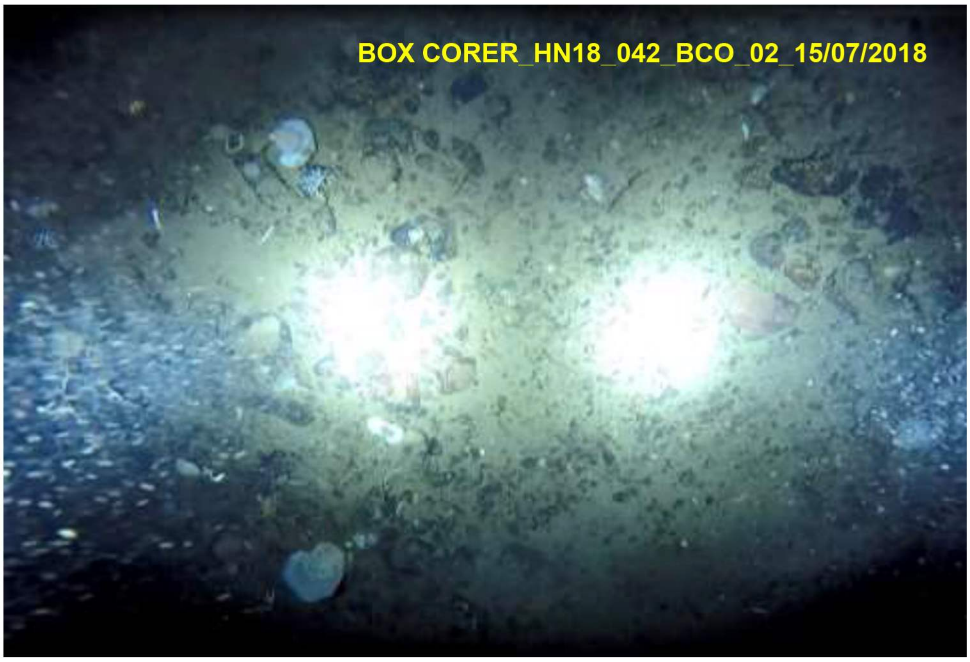


CRUISE: High North 18

CORE: HN18_062_BCO_003

Photos of IRD , coarse sediments and rocks, organisms


BOX CORER_HN18_014_BCO_01_11/07/2018


BOX CORER_HN18_042_BCO_02_15/07/2018


BOX CORER_HN18_062_BCO_03_19/07/2018

R/V Alliance A5345

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_001		20180717	14:52	81°31.999'N	12°21.106'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
15	Polygon	T	First-year Ice	Close pack/Drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_002		20180717	14:56	81°31.716'N	12°22.639'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
30	Triangle	M	First-year Ice	Open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_003		20180717	14:58	81°31.580'N	12°22.336'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
10	Polygon	T	First-year Ice	Very open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_004		20180717	14:59	81°31.492'N	12°22.086'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
70	Polygon	T	First-year Ice	Open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_005		20180717	15:00	81°31.432'N	12°21.919'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
40	Polygon	M	First-year Ice	Open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_006		20180717	15:44	81°28.248'N 12°	43.286'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
15	Polygon	T	First-year Ice	Close pack/Drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_007		20180717	15:48	81°27.985'N	12°45.481'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
50	Polygon	M	First-year Ice	Very close pack	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_008		20180717	15:56	81°27.938'0N	12°51.470'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
4	Polygon	M	First-year Ice	Open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_009		20180717	16:10	81°27.893'N	13°02.142'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
4	Polygon	M	First-year Ice	Open drift	SX

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PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_010		20180717	16:21	81°27.852'N	13°12.330'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
N.N.	Polygon	N.N.	First-year Ice	Very open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_011		20180717	17:40	81°28.663'N	14°34.794'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
40	Polygon	M	First-year Ice	Close pack/Drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_012		20180717	17:47	81°28.651'N	14°36.043'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
25	Polygon	M	First-year Ice	Open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_013		20180717	17:47	81°28.650'N	14°36.138'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
25	Polygon	M	First-year Ice	Open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_014		20180717	17:50	81°28.621'N	14°37.024'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
15	Polygon	T	First-year Ice	Very open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_015		20180717	17:52	81°28.597'N	14°37.492'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
4	Polygon	T	First-year Ice	Very open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_016		20180717	20:00	81°24.309'N	16°09.643'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
10	Polygon	M	First-year Ice	Very open drift	DX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_017		20180717	20:06	81°24.044'N	16°19.361'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
10	Polygon	M	First-year Ice	Very open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_018		20180717	20:16	81°23.500'N	16°34.156'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
20	Polygon	M	First-year Ice	Very open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_019		20180717	20:25	81°22.654'N	16°46.886'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
12	Polygon	M	First-year Ice	Very open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_020		20180717	20:35	81°23.114'N	17°00.605'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
10	Polygon	M	First-year Ice	Very open drift	DX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_021		20180717	22:00	81°35.122'N	16°57.953'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
30	Polygon	M	First-year Ice	Open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_022		20180717	22:10	81°35.166'N	17°00.846'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
40	Polygon	M	First-year Ice	Open drift	SX

PHOTO STATION		DATE yyyymmdd	TIME UTC hh:mm	LAT gg° mm.mmm'	LON gg° mm.mmm'
HN18_ICE_023		20180717	22:10	81°35.174'N	17°01.071'E
SIZE m	**SHAPE**	**THICKNESS**	**TYPE**	**CONCENTRATION**	**SIDE**
40	Polygon	M	First-year Ice	Open drift	SX