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Deliverable 3.7

First implementation and data: North of Svalbard

Data delivery and report on results of the observing systems north of Svalbard

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CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

EXECUTIVE SUMMARY

The main goal of Task 3.2 is to deliver *in situ* ocean and sea ice observations collected during two INTAROS field seasons and to provide recommendations for future implementation of the moored observing system north of Svalbard that can be applied to define a roadmap for observing future changes in the Arctic. The aim is to make comprehensive observations of the ongoing climate and environmental change that can be also applied as a validation tool for conceptual and three-dimensional modelling. This report describes the ***First implementation and operational use of the observing systems. Data delivery and report on results of the observing systems North Svalbard***

The first implementation was deployed successfully in August 2018 using the Coast Guard icebreaker KV Svalbard and retrieved with KV Svalbard in August/September and with the research icebreaker RV Kronprins Håkon in September and November 2019. All recovered instrument and sensor provided full data return therefore a full annual cycle of multidisciplinary data was obtain that can be employed to address the following goals:

- Document the performance of instruments and systems selected/integrated for measurements of key ocean physical variables on INTAROS moorings, including temperature, salinity and ocean currents;
- Document the performance of instruments and sensors selected/integrated for measurements of key biogeochemical variables including dissolved oxygen, nutrients and carbonate system parameters on the multidisciplinary BGC11 mooring;
- Document the performance of novel instruments selected for sea ice measurements on the moorings along the INTAROS (22°E) and A-TWAIN (31°E) lines north of Svalbard;
- Document the performance of novel combination of ADCP with echo sounder selected for ocean currents and zooplankton/small fish abundance measurements;
- Document the performance and the state of technical development for a moored multisensor Octopus system for biological measurements, including an Underwater Vision Profiler, nutrient sensor and chlorophyll-a and CDOM fluorometer;
- Document the performance and technical development for microplastic samplers;
- Document the performance of technologies and deployment methodology for the sensors mounted at the seafloor, including Ocean Bottom Pressure sensors and Ocean Bottom Seismometers;

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1. Introduction

This report describes the multidisciplinary moored array operated by the Task 3.2 partners during the first INTAROS field season in the entrance to the Arctic Ocean north of Svalbard. The mooring array was deployed successfully in August 2018 using the coast guard vessel KV Svalbard and retrieved during three different cruises with KV Svalbard in August/September and with RV Kronprins Haakon in September and November 2019. Data are now being processed and their quality is assessed following the best practices for all different measured variables. The goal is to prepare the final data products for delivery to WP5 and WP6, following WP5 instructions and for the carbon data ICOS protocols as soon as possible. Most of data have been initially assessed and the results look very promising, but at this point of time they can be only regarded as preliminary results. At the writing moment there is no report on instruments or sensors failures that in practical terms means that we have a full annual multivariable cycle of data from August 2018 to August 2019, covering ocean physics and biogeochemistry in the wide scope. Specifically it provides opportunity to make atmospheric source function for precipitation, fresh water supply by sea-ice melting and potential also riverine input to the Arctic Ocean based on stable isotope geochemistry, ocean physics (sea-ice condition like sea-ice drift and thickness, currents, pressure, temperature and salinity), ocean chemistry (ocean pCO_2, NO_3^-, oxygen, salinity), and biology (particular fluxes based on optical observations and ADCP based observations zooplankton and small fish, measurements of microplastic and based on the chemistry measurements mentioned above, the rate of change of ocean acidification), solid earths physics (earthquakes related to fracture zones and faults) and acoustics monitoring of the mean temperature and its potential changes on a basin-wide scale.

2. First implementation and operational use of the observing system north of Svalbard

The following work has been performed by partners responsible for Task 3.2.

2.1. UiB-GFI

Contributors: Truls Johannessen, Nicholas Roden, Are Olsen, Tor de Lange, Harald Sodemann, Alexandra Touzeau and Lars Henrik Smedsrud

2.1.1. Results of the first operational implementation

Stable isotope observations of water:

We pursued two key objectives regarding the water isotope composition of the Arctic hydrological system: (1) evaluate the ability of current measurement equipment to endure Arctic weather conditions when deployed on a ship, and (2) to assess the representativeness of the stable isotope composition of different system components (atmosphere, ocean, sea ice). Data collection was performed during two field deployments in the Arctic onboard KV Svalbard, lasting from 30th of July 2018 to 20th of August 2018 and from 17th of July 2019 to 6th of September 2019. For both cruises, a commercially available cavity ring-down spectrometer (L2140-i, Picarro Inc) continuously measured the isotope composition in ambient atmospheric vapor through a heated inlet system, interrupted by automated calibration periods. For reasons of redundancy, three different weather stations were set up during the CAATEX cruise to reliably collect weather information at the level of the inlet (local vapor content, temperature, humidity). An automated camera was installed on port-side to take regular pictures of sea-ice (every 5 minutes). The isotope analyser itself proved to be unaffected by ship motion and Arctic weather, and provided a nearly continuous data series, even during a 4-week period without surveillance. Challenges remain regarding the accidental sampling of vapour originating from the ship itself, and smaller issues regarding the reliability of daily calibrations, and redundancy of auxiliary meteorological and sea(ice) state observations. In general, the results so far indicate high feasibility of this kind of system for routine observations of the vapour composition on ships of opportunity.

In order to characterize the representativeness of different water isotope observations in the Arctic hydrological system, liquid and solid samples of precipitation, sea water and sea ice were taken during both cruises (Table 2.1.1).

Table 2.1.1: Sampling strategy for stable isotope measurements.

July-Aug. 2018 (177 samples)	Aug.-Sept. 2019 (248 samples)
Rainfall and snowfall samples: 8	Rainfall and snowfall samples: 31
Surface snow (over sea-ice): 13	Surface snow (over sea-ice): 60
Surface sea-water (bucket): 30	Surface and sub-surface sea-water (bucket & hand-CTD, down to 25 m): 32
Sub-surface sea-water (hand-CTD): 19	
Deeper sea-water samples (main CTD): 90	N/A
Sea-ice samples: 14 (+3 glacier ice samples)	Sea-ice samples: 125

Biogeochemistry observations:

A suite of biogeochemical sensors was deployed on a mooring (BGC11, Figure 2.1.1) north of Svalbard on 11 August 2018 and successfully retrieved, 408 days later, on 23 September 2019. The purpose of this deployment was to monitor the carbon cycle dynamics in the West Spitsbergen Current over a full annual cycle. A series of ten instruments were deployed and will be described in the following text. Five SAMI-CO_2 sensors were deployed at three different depths, two at 31 metres, another two at 175 metres and one at 300 metres below the surface. The SAMI-CO_2 sensors measure the partial pressure of carbon dioxide (pCO_2) in seawater by equilibrating a pH sensitive indicator solution (Bromothymol Blue) to the sampled seawater. The equilibrated indicator solution is pumped through an optical cell where the optical absorbance is measured and the pCO_2 can be calculated based on a calibration curve. The manufacturer, Sunburst Sensors, reports an accuracy and precision of measurements to be ±3 µatm and <1 µatm, respectively.

As an indicator of biological production, nitrate concentrations were measured using two Sea-Bird Scientific SUNA V2 nitrate sensors. One at 30 metres and the other at 173 metres below the surface. The SUNA V2 is a chemical-free nitrate sensor that lights the water sample with a deuterium UV light source and measures the absorption spectrum with its spectrometer. The nitrate concentration is calculated from this absorption spectrum and a calibration file. Three other instruments that are commonly deployed on moorings were utilized to measure conductivity, temperature, pressure and dissolved oxygen. These instruments included one Sea-Bird Scientific SBE37 (deployed at 32 metres below the surface) and two Aanderaa SeaGuard RCMs, with additional current meter functionality, at 174 metres and 300 metres below the surface.

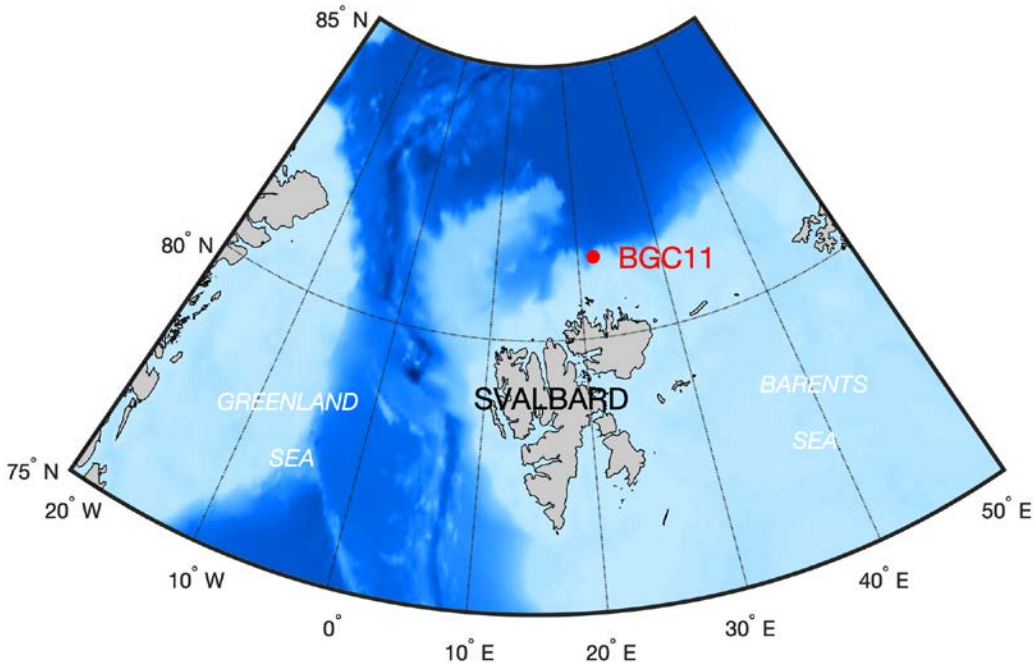


Figure 2.1.1: Location of BGC11 mooring on the slope north of Svalbard.

Water samples were also collected for quality assurance and quality control of data from the sensor packages. Duplicate water samples from 12 depths (with accompanying CTD profiles) were collected from the full depth of the water column at the beginning and end of the deployment period. The samples collected at the beginning of the deployment were analysed at UiB for dissolved inorganic carbon, total alkalinity and nutrients. Samples collected at the end of the deployment period are still in transit and will be analysed shortly.

Physical oceanography and sea ice observations:

Two Nortek Signature 250 acoustic doppler current profiler (ADCP) instruments, with sea ice draft (thickness of sea ice below the water) and sea ice drift measurement capability, were moored in the upper ocean north of Svalbard in two different locations. One instrument owned and operated by IOPAN was deployed for one year in 2017 and retrieved in August 2018. The data from this instrument were made available to UiB-GFI for testing post-processing algorithms in preparation for the return of the second instrument. This second instrument from UiB-GRI was set up for a two-year deployment and will be recovered in November 2019. The ADCPs acoustically measure current velocity and direction along a predefined measurement path by using the Doppler effect. When these measurements are combined with a high-accuracy pressure sensor, sea ice draft and sea ice drift measurements are also possible.

2.1.2. Description of provided data

Water isotope observations:

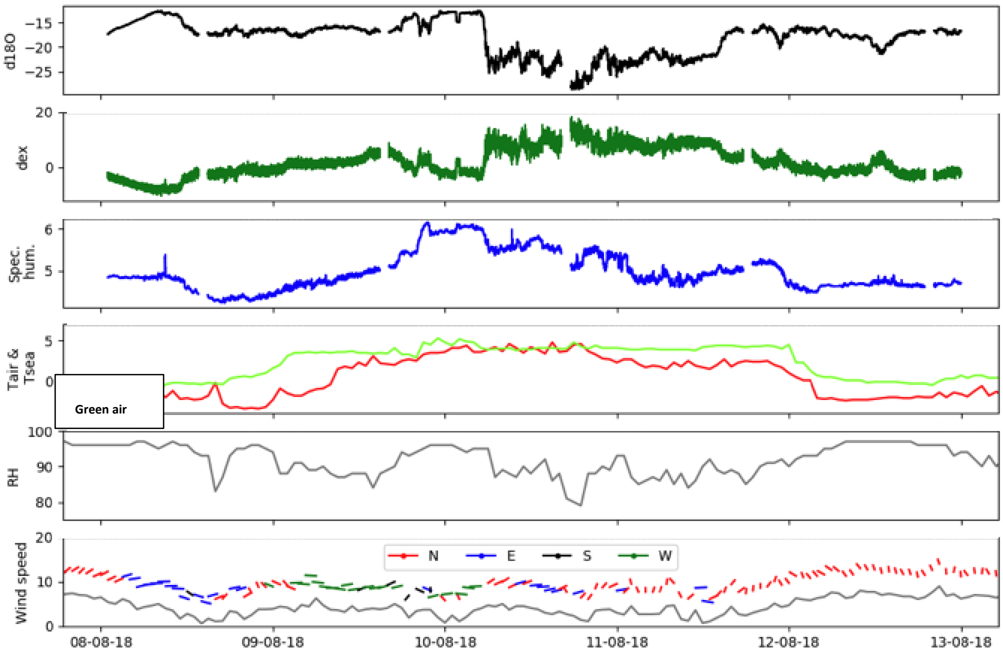


Figure 2.1.2: Time series of isotopes and ship meteorological variables during the first INTAROS cruise (showing 8th to 13th of August 2018). From top to bottom: $\delta^{18}O$, d-excess, specific humidity from laser instrument; air and sea temperatures, relative humidity and wind speed and direction from the ship.

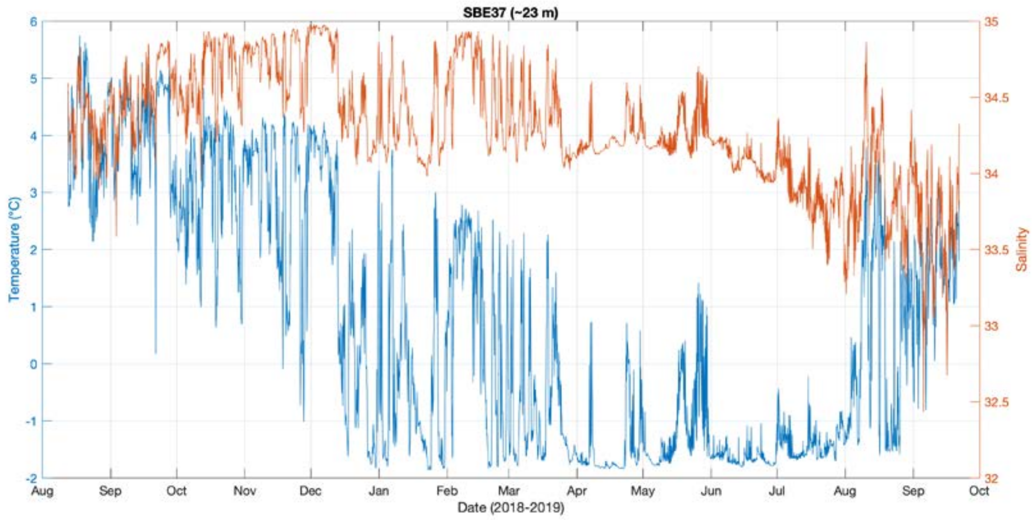
The key dataset consists of time series of water vapor isotopes from both KV Svalbard cruises, supplemented by meteorological variables, and the water samples retrieved during the cruises. The main isotopic variables are the $\delta^{18}O$ (and δD), the d-excess (all in per mil VSMOW), and specific humidity (g kg^{-1}). A flag for data quality will be included. The 10-min standard deviations are 0.27 for $\delta^{18}O$ (and 1.5 for δD), 1.4 for d-excess, and 0.026 for specific humidity. The series are quasi-continuous, except for 1h per day dedicated to calibration (and a 8h data gap on the 6th of August 2018). All 2018 water samples are analysed at UiB FARLAB and all 2019 samples will be analysed as soon as possible at FARLAB. Typical standard deviations per sample are about 0.2 for δD, 0.08 for $\delta^{18}O$ and 0.6 for d-excess. Sample metadata will include sampling time, location, sample type, and further sample-specific properties. About 30 samples showed clear signs of evaporation after sampling (during storage/shipment), which has led to improved protocols for sample storage on the second cruise.

The weather data includes wind speed, air temperature, relative humidity from the ship's onboard system and additional measurements in the vicinity of the inlet system. Sea salt caused rapid sensor deterioration and careful quality assessment by cross-checking between redundant systems will be performed.

Still-camera pictures provide quasi-continuous objective information on sea-ice state (ice floe size, sea-ice cover). This still requires objective analysis regarding contrast and shapes.

Similar datasets of continuous measurements of isotopes in vapour have been published by Benetti et al. (2017) for the Atlantic, and by Bonne et al. (2019) for the Arctic, Atlantic and Antarctic seas. Bonne et al. used their dataset to test which variables control d-excess in the vapor during evaporation, and concluded that sea surface temperature, relative humidity and sea-ice cover (at high latitudes) are the main contributors to d-excess signature.

Biogeochemistry observations:



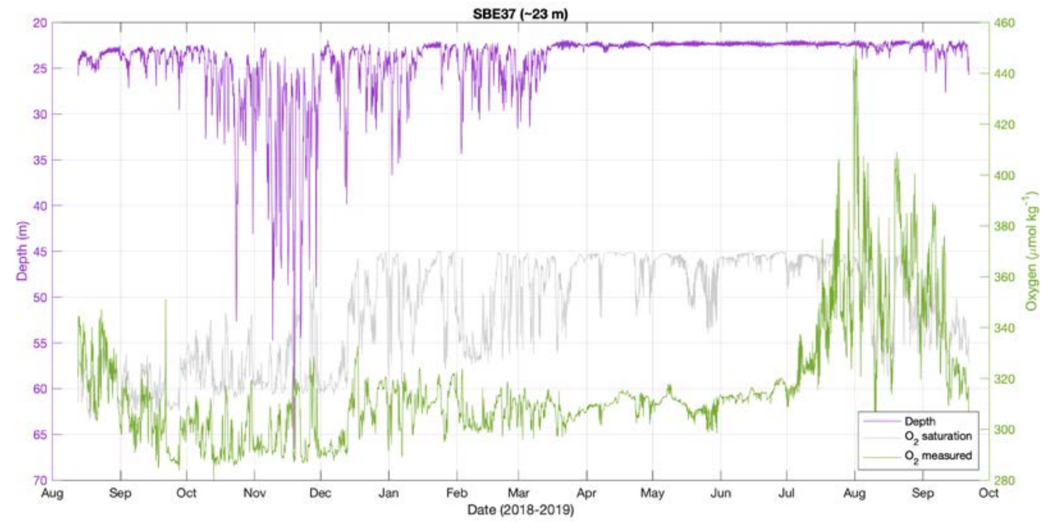


Figure 2.1.3: Data measured by the Sea-Bird Scientific SBE37 with temperature and salinity in the top panel and depth and oxygen concentration in the bottom panel.

Final calibration and validation of data will not be completed until the water samples, collected at the end of the deployment, are analysed and the oxygen optodes are returned to the manufacturer for post-deployment calibration. Therefore, only a brief representation of preliminary results will be discussed in this section. All instruments logged data continuously for a full year, or more, at 1- or 3-hour intervals. An initial inspection of pCO_2 data from the SAMI-CO_2 sensors reveals potential measurement drift in duplicated sensors. This will be fully investigated once the final calibration water samples are analysed. Data will be stored at the INTAROS WP5 repository and in the PANGAEA database.

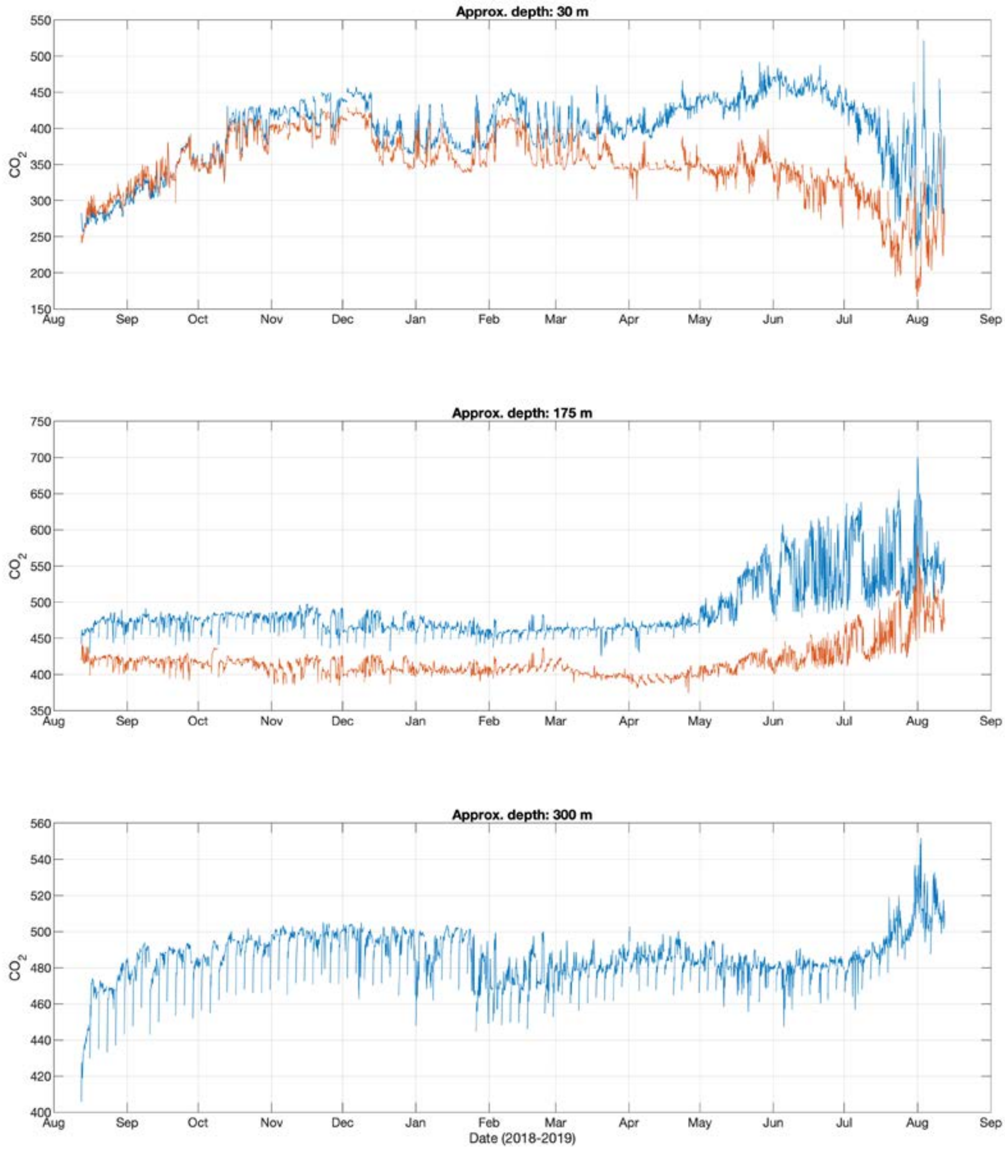


Figure 2.1.4: pCO_2 data measured from the SAMI-CO_2 sensors from three different depths. For redundancy, two sensors were used at each of the two shallowest depths.

Physical oceanography and sea ice observations:

Preliminary investigations of the Signature 250 AD2CP data from the IOPAS11 mooring operated by IOPAN and deployed in 2017 show significant changes in upper ocean current strength associated with strong wind events in the region (Figure 2.1.5). Although not shown here, this instrument has also new capability to measure sea ice draft (thickness of ice below the water) and drift. However, during the 2017-2018 deployment, the IOPAS11 location was ice-free for the prevailing time therefore nearly none ice measurements were collected by the Signature 250. The data from this ADCP were resolved approximately every hour, and measured current velocities and direction in 27 separate bins/cells throughout 108 metres of water column. The instrument, for most of the deployment period, was located ~100 metres below the surface. However, during some strong wind events the strengthening currents in the upper layer caused the mooring to “dive”, sometimes by an additional 100 metres. This is a well-known issue and is caused mostly by the drag imparted on the mooring wire rather than the instruments themselves.

Once we have the data from the UiB-GFI owned instrument available, comparison between the two will be possible, but the initial data quality control from this first deployment has been done and the instrument is working as intended.

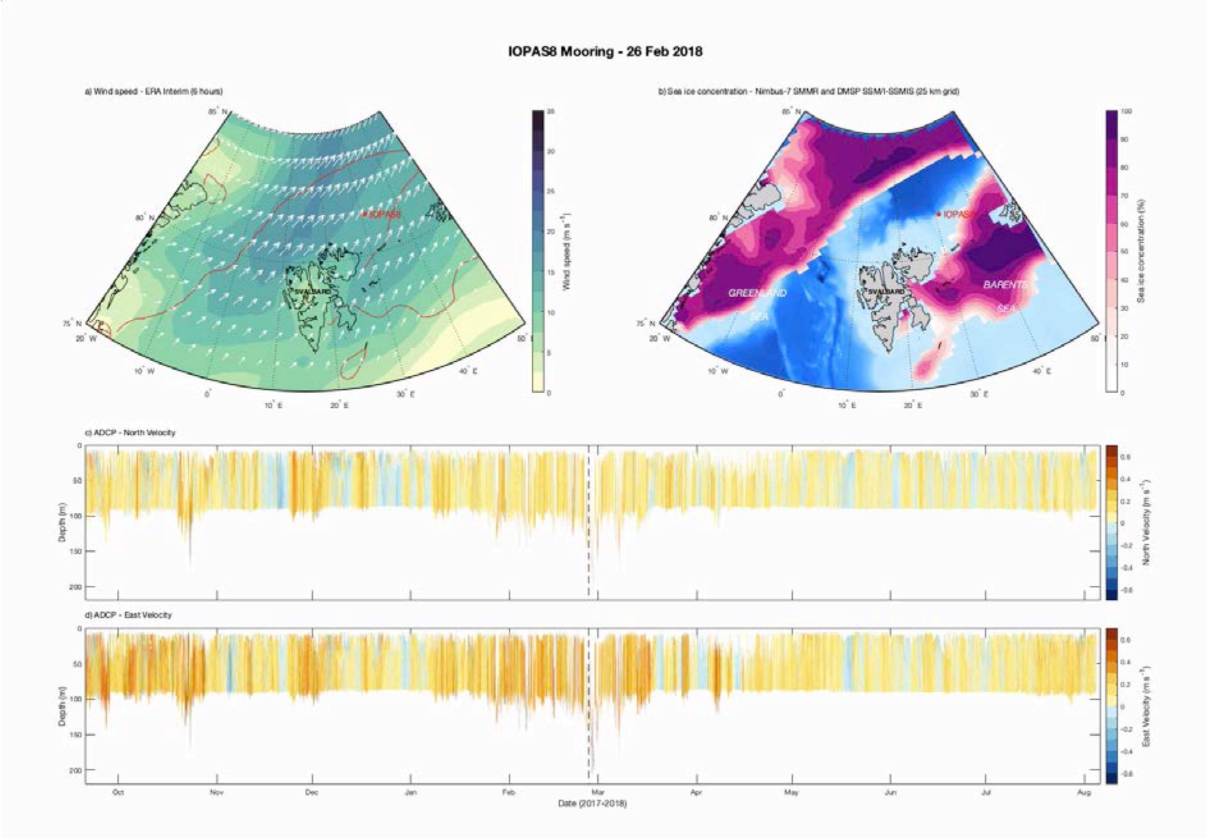


Figure 2.1.5: Windspeed, sea ice concentration and current velocity from the IOPAS11 mooring location north of Svalbard. The first two panels show the a) windspeed estimates from the ERA-Interim atmospheric reanalysis product (the red line shows sea ice extent) and b) sea ice concentration from satellite observations for the region on the 26th February 2018. This date is represented by a dashed line in panels c) and d), which show the full timeseries of north and east current velocity measurements from the ADCP.

2.1.3. Plans for the final implementation

Water isotope observations:

Future plans are to quantitatively assess the representativeness of the Arctic hydrological system in terms of stable isotope composition, in particular in comparison to conventional atmospheric variables (temperature, precipitation, humidity). The dataset will be compiled into a self-descriptive format (netCDF) with rich metadata. Analysis of the remaining water samples will also be completed.

On the second cruise, vapor isotope measurements were left fully unattended for several weeks. This requires a suitable sampling location, including robust installation and meteorological sensors, also for auxiliary sea-ice observations from a still camera system. Regarding the final implementation, we will formulate recommended best practices regarding the underway sampling of the water isotope measurements for the coupled Arctic hydrological system for future operationally deployable systems. Substantial effort will be needed to complement the near-operational water vapour sampling with equally advanced sampling of precipitation, sea-ice, and sea water without human intervention.

Biogeochemistry observations:

We are continuing our biogeochemical measurements during the second field season with a series of three SAMI-pH and three SAMI-CO_2 sensors on the NERSC-4 mooring north of Svalbard (82°06.5'N, 26°19.5'E). A pH and pCO_2 sensor will be placed at 47, 155 and 305 metres below the surface. This mooring was deployed from the KV Svalbard during the INTAROS/CAATEX cruise in August 2019 and will be retrieved at approximately the same time in 2020.

Physical oceanography and sea ice observations:

The selected location of the moored array on the shelf break north of Svalbard is crucial for monitoring the Atlantic water (AW) inflow into the Arctic Ocean boundary current as well as its exchange between the boundary current and deep basin. While there is a significant recirculation of Atlantic water along a few pathways in Fram Strait, most of AW that reached the moored array will circum-travel the Arctic Basin. Polyakov et al. (2017) proposed that the eastern part of the Eurasian Basin located downstream of the INTAROS moored array is under an increasing influence of Atlantic water - a process termed 'Atlantification' - that can have potential impact on the sea ice cover but direct observations in this region are very sparse, both of AW inflow properties and dynamics, and also of sea ice drift and thickness in the area.

2.2. IOPAN

Contributors: Agnieszka Beszczynska-Möller, Waldemar Walczowski

2.2.1. Results of the first operational implementation

The pilot phase 2017-2018:

The mooring IOPAS21 was deployed for the period 2017-2018 as the third and outermost mooring of the new A-TWAIN array (Figure 2.2.1a). IOPAS21 was deployed from RV Lance on September 20, 2017 at the depth of 1210 m at the position 81°34.508'N and 031°00.301'E, located at the moment of deployment in the open water. Before deployment the recovered MMP was refurbished with new battery pack and new sensor cables, went through the full range of bench tests and was reprogrammed to profile between the nominal depths of 87m and 985 m every 12 hours. In addition to the MMP profiler, the mooring IOPAN21 carried two Acoustic Doppler Current profilers. The upward-looking Nortek Signature 250 was located in the top flotation and programmed to measure ocean currents (with 30 min interval) and sea ice drift and draft (with 1 min interval). The downward-looking TRDI QMADCP 150 kHz was located below the second flotation, above the MMP. Four SeaBird SBE37 sensors (with T, C, P) were positioned on the mooring line, one attached to the top flotation (at 77 m), one above the upper MMP bumper (at 87 m), one below the lower MMP bumper (at 866m) and one above the lower glass floats pack (at 1196 m). Two sets of larvae trap and sediment plates were attached to the mooring line, one below the second subsurface float (at 83 m) and one above the releases chain (at 1202 m). The mooring IOPAS21 was equipped with a double set of the ORE 8242XS acoustic releases and Benthos XT-6000 transponder as a recovery aid.

The mooring IOPAS21 was recovered from KV Svalbard on August 4, 2018 after one-year long deployment. All instruments were recovered in a good shape with no visible damage. The upward-looking acoustic Doppler current profiler Nortek Signature250, recording the speed and directory of ocean current and sea ice drift, was also equipped with the fourth beam (altimeter) for measuring sea ice draft. The Signature250 was located at the nominal depth of 77 m and recorded the full year of ocean current data, covering the upper water column up to the surface. Additionally, the full year of altimeter measurements was recorded albeit sea ice draft could be obtained only for short periods when there was sea ice above the mooring. Due to the exceptionally low ice concentration north of Svalbard, the mooring IOPAS21 remained in the open water conditions for a large part of the deployment period 2017-2018. The downward-looking acoustic Doppler current profiler TRDI QMADCP 150 kHz was located above the upper MMP bumper at the nominal depth of 84 m and covered the layer of about 150-200m. The QMADCP delivered full data set for one year with 30 min interval. The mooring was equipped with the Moored McLane Profiler (MMP), programmed to travel twice a day between 87 m and 985 m, measuring temperature, salinity and sea currents. MMP profiled twice a day and provided 634 profiles of temperature, salinity and sea currents, covering the period from September 22, 2017 until August 5, 2018. However, at the beginning of May the instrument stopped to profile the water column and recorded data only at the fixed level (at the lower end of the Nilspin wire). A detailed post-recovery inspection of the profiler revealed the motor failure due to wearing down the projections of the motor cogs. Additionally, four SeaBird Microcat sensors SBE37 (with C, T, P) were located at the upper Nortek frame (at the upper flotation), above the upper and below the lower MMP bumpers and 210 m below the MMP. Time series of pressure, temperature and salinity were collected every 15 min by four Microcat sensors located at the nominal depths of 77, 87, 986 and 1195 m and all of them provided one year of temperature and salinity data (except the instrument at the lower Nilspin end that recorded erroneous conductivity).

The IOPAS11 mooring (Figure 2.2.1b) was deployed from RV Lance on September 22, 2017 along the upstream INTAROS line along 022°E, at the position 81° 29.3870'N and 022° 00.2295'E and the water depth of 854 m. The mooring was equipped with the Moored McLane Profiler (MMP), programmed to travel twice a day between 81 and 829 m, measuring temperature, salinity and sea currents. The top floatation of IOPAS11 was equipped with a double set of Acoustic Doppler Current profilers. The upward-looking Nortek Signature 250 was programmed to measure ocean currents (with 30 m interval) and sea ice drift and draft (with 1 min interval). The downward-looking Signature 55 was programmed with a concurrent measurement plan, including high-resolution profiles down to approx. 600 m every hour and low-resolution profiles, covering the whole water column every 4 hours. Two SeaBird SBE37 sensors (with T, C, P) were positioned on the mooring line, one above the upper MMP bumper (at 80 m) and one below the lower MMP bumper (at 830 m) and programmed with 10 min interval. One set of larvae trap and sediment plates was attached to the mooring line above the releases chain (at 841 m). The mooring IOPAS9 was equipped with a double set of the ORE 8242XS acoustic releases.

The IOPAS11 mooring was recovered from KV Svalbard on August 4, 2018. The mooring was equipped with the Moored McLane Profiler (MMP), programmed to travel twice a day between 81 and 829 m, measuring temperature, salinity and sea currents. The MMP delivered the full year of data, including 632 profiles of temperature and salinity (two profiles per day) between approx. 80 and 830 m. The top floatation of IOPAS11 was equipped with a double set of Acoustic Doppler Current profilers. The upward-looking Nortek Signature 250, programmed to measure ocean currents with 30 min interval) and sea ice drift and draft with

1 min interval, delivered full year of measurements. However, even if altimeter measurements were recorded correctly, due to the extremely low ice concentration north of Svalbard the mooring IOPAS11 remained in the open water for the entire deployment period 2017-2018 so no sea ice data could be retrieved from the Signature 250 measurements. The downward-looking Signature 55, programmed with a concurrent measurement plan, including high-resolution profiles down to approx. 600 m every hour and low-resolution profiles, covering the whole water column every 4 hours, also provided full one-year-long data set. From two SeaBird SBE37 sensors (with T, C, and P), the one located above the upper MMP bumper (at 80 m) delivered the full-year data record while the second one below the lower MMP bumper (at 830 m) recorded erroneous salinity for the second part of measurements. One set of larvae trap and sediment plates attached to the mooring line above the releases chain (at 841 m), was also recovered. The samples from the trap and plates were secured and transferred to NPI/UNIS to be prepared for shipment to the owner.

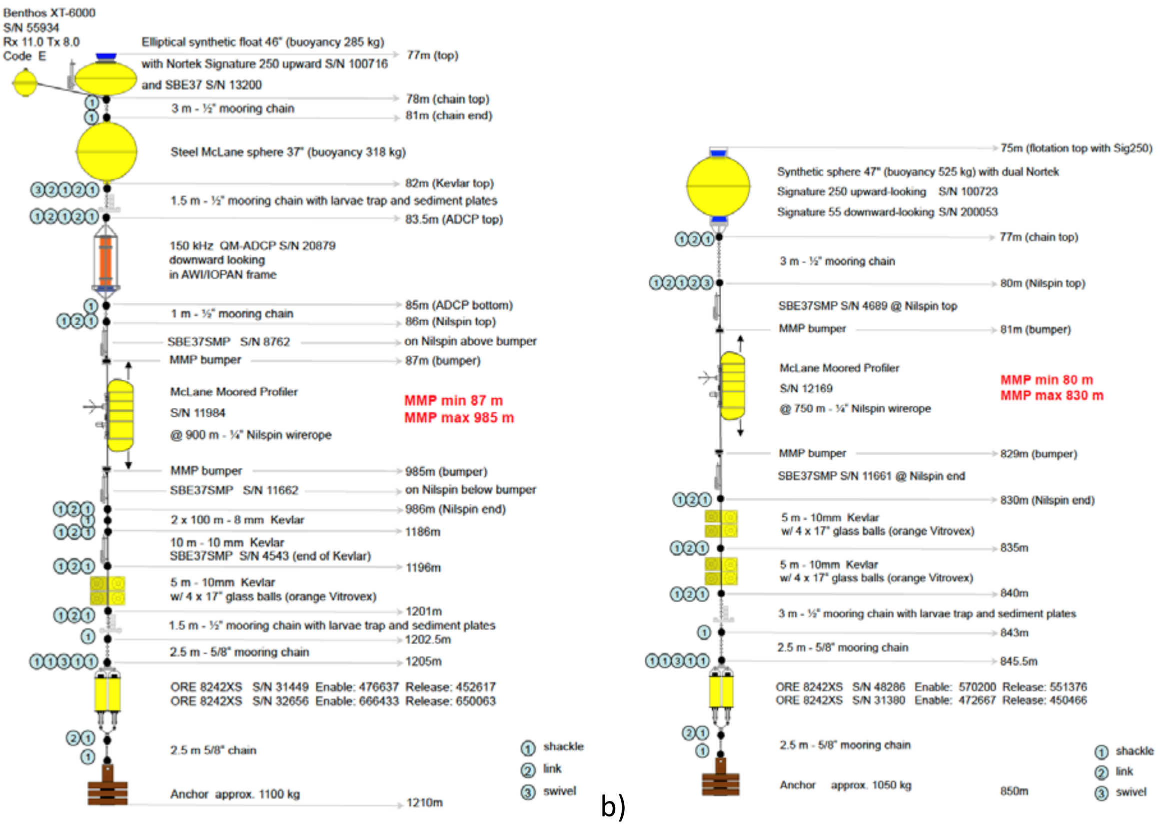


Figure 2.2.1: Schematics of the instruments distribution and mooring design for (a) mooring IOPAS21 and (b) mooring IOPAS11 during the pilot phase deployment in 2017-2018.

The first INTAROS field season 2018-2019:

The mooring IOPAS21 recovered during the KV Svalbard cruise in 2018 was redeployed as the mooring IOPAS22 (Figure 2.2.2a), at the same position as the third and outermost mooring of the A-TWAIN array. IOPAS22 was deployed on August 9, 2018 at the depth of 1228 m at the position 81°34.4887'N and 030°59.5304'E, located at the moment of deployment in the open water. The mooring was deployed anchor last in the open water and the final position was estimated from triangulation of the releases after deployment. Due to the MMP failure that could not be repaired on board, the original deployment design of IOPAS22 had to be modified by replacing the MMP with a set of SeaBird Microcat SBE37 sensors (with C, T and P) and RBR temperature sensors. Three SBE37 sensors, 10 RBR Solo temperature sensors and one RBR Duet sensor (measuring temperature and pressure) were distributed along the Nilspin wire between 95 and 995 m (for sensor depth see the mooring drawing). Due to the lack of moving profiler, the recovered Nilspin wire was used. In addition to the temperature and salinity sensors, the mooring IOPAN22 carried two Acoustic Doppler Current profilers. The upward-looking Nortek Signature 250 was located inside the top flotation at the depth of 78 m and programmed to measure ocean currents (with 30 min interval) and sea ice drift and draft (with 1 min interval). The downward-looking TRDI QMADCP 150 kHz was located below the second flotation at the nominal depth of 96 m. The mooring IOPAS22 was equipped with a double set of the ORE 8242XS acoustic releases and Benthos XT-6000 transponder as a recovery aid.

At the moment of this report writing, the mooring IOPAS22 is still in water. Because no dedicated ship time of KV Svalbard was granted for the recovery of INTAROS moorings in 2019, the recovery of IOPAS22 was planned either from RV Oceania in July or from RV Kronprins Haakon (in collaboration with the Nansen Legacy and A-TWAIN projects) in November. Due to the extremely heavy ice conditions north of Svalbard in 2019, the mooring could not be recovered from RV Oceania in July because the vessel was not able to reach the mooring position. IOPAS22 will be recovered during the RV Kronprins Haakon cruise that takes place from November 12 to 25.

The mooring IOPAS11, recovered during the KV Svalbard cruise in 2018, was redeployed as IOPAS12 (Figure 2.2.2b) at the position 81° 29.1891'N, 021° 59.5609'E at the water depth 861 m. The mooring was deployed anchor last on August 11, 2018 in the open water area and its position was estimated by the triangulation of releases. The recovered MMP was refurbished and reprogrammed for one-year deployment with two profiles per day between 75 and 825 m. The top floatation of IOPAS12 was equipped with a double set of Acoustic Doppler Current profilers. The upward-looking Nortek Signature 250 was programmed to measure ocean currents (with 30 m interval) and sea ice drift and draft (with 1 min interval). The downward-looking Signature 55 was programmed with a concurrent measurement plan, including high-resolution profiles down to approx. 600 m every hour and low-resolution profiles, covering the whole water column every 4 hours. Due to failure of MMP at IOPAS21 that had to be replaced on IOPAS22 with a combination of SBE37 and RBR sensors, no additional temperature and salinity sensors were left for deployment on IOPAS12. The mooring IOPAS12 was equipped with a double set of the ORE 8242XS acoustic releases.

The mooring IOPAS12 was recovered from KV Svalbard during the CAATEX cruise that took place from August 14 to September 9, 2019 in the central Arctic Ocean. No dedicated ship time was devoted to the INTAROS mooring operations during this cruise except one day during the return trip to Longyearbyen. The IOPAS12 mooring was recovered on September 6 in very difficult ice conditions (sea ice coverage 90-95%) during the very short time window when a small open lead drifted over the mooring position. The mooring was recovered from under the ice (partially dragged) with the ship breaking the ice around the mooring position to increase the opening. As the result, the McLane Profiler was partially damaged (the ACM and CTD sensors were broken) but the rest of instruments (the Nortek Signatures 250 and 55) were recovered in a good shape with no visible signs of damage. Fortunately, despite of the instrument damage during recovery, MMP data were recovered in a full length and included 782 vertical profiles of temperature, salinity, pressure and current speed and direction, measured every 12 hours between August 11, 2018 and September 6, 2019. Both Nortek Signature instruments (250 and 55) also provided the full-length data record, according to the programmed intervals. No additional TS sensors were placed on IOPAS12 due to moving the planned instruments to IOPAS22 before deployment in 2018.

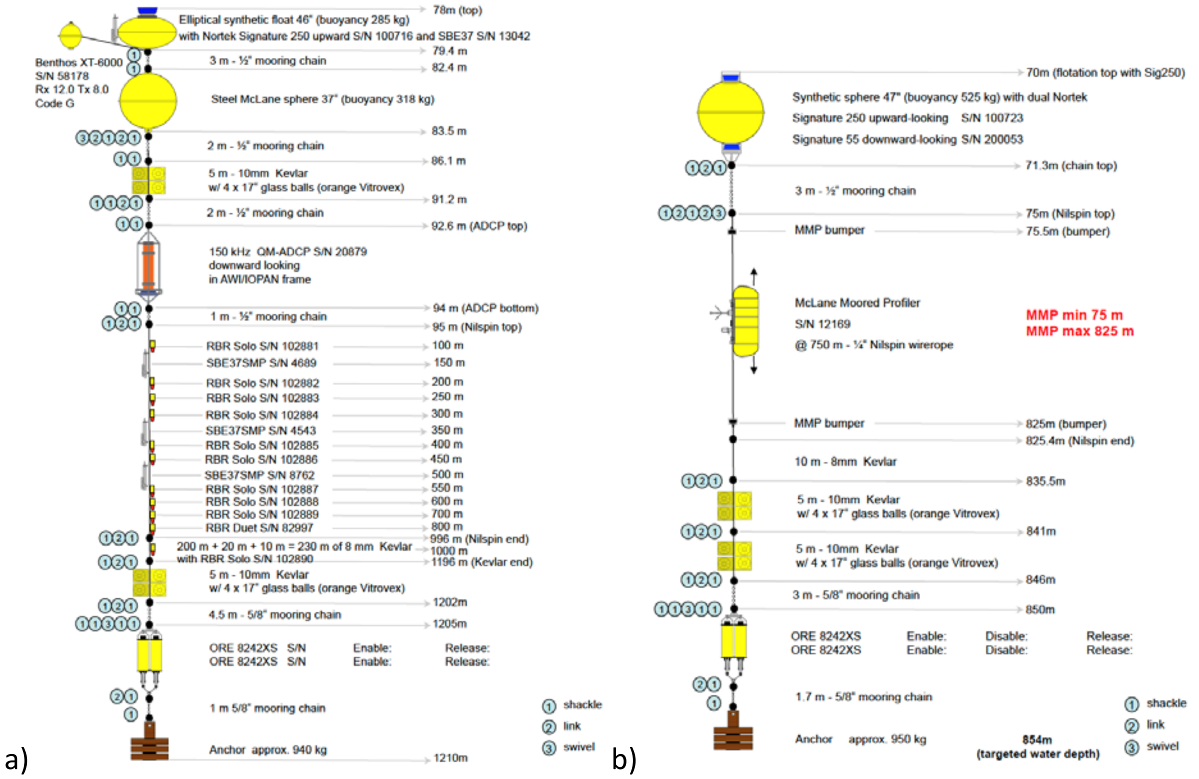


Figure 2.2.2: Schematics of the instruments distribution and mooring design for (a) mooring IOPAS22 and (b) mooring IOPAS12 during the first INTAROS deployment period in 2018-2019.

2.2.2. Description of provided data

The pilot phase 2017-2018:

IOPAS11 and IOPAS21 McLane Moored Profilers:

- Measurement type: time series of vertical profiles
- Measured variables: temperature, salinity, pressure, current speed, current direction
- Measurement interval: 12 h
- Data processing steps: conversion to engineering data, despiking, filtering, binning in depth bins, averaging, interpolation onto a regular grid
- Final product: NetCDF files with matrices representing interpolated profiles of temperature, salinity, and current components.

IOPAS21 and IOPAS11SeaBird SBE37 CTD sensors:

- Measurement type: time series of point measurements
- Measured variables: time series of temperature, salinity, and pressure
- Measurement interval: 15 min
- Data processing steps: conversion to engineering data, despiking, filtering, calculating derived properties, averaging

- Final product: NetCDF files with vectors representing time series of temperature, salinity and pressure.

IOPAS21 Nortek Signature250:

- Measurement type: time series of vertical profiles
- Measured variables: current speed, current direction
- Measurement interval: 30 h
- Data processing steps: conversion to engineering data, despiking, filtering, binning in depth bins, averaging, interpolation onto a regular grid
- Final product: NetCDF files with matrices representing interpolated profiles of current speed, current direction, and current components.

IOPAS21 TRDI QMADCP 150 kHz:

- Measurement type: time series of vertical profiles
- Measured variables: current speed, current direction
- Measurement interval: 30 h
- Data processing steps: conversion to engineering data, despiking, filtering, binning in depth bins, averaging, interpolation onto a regular grid
- Final product: NetCDF files with matrices representing interpolated profiles of current speed, current direction, and current components.

IOPAS11 Nortek Signature55:

- Measurement type: time series of vertical profiles (high resolution - cell size 4 m/low resolution cell size 12 m)
- Measured variables: current speed, current direction
- Measurement interval: high resolution 1h/low resolution 4h
- Data processing steps: conversion to engineering data, despiking, filtering, binning in depth bins, averaging, interpolation onto a regular grid
- Final product: NetCDF files with matrices representing interpolated profiles of current speed, current direction, and current components.

The first INTAROS field season 2018-2019:

IOPAS22 SeaBird SBE37 CTD sensors:

- Measurement type: time series of point mesurements
- Measured variables: time series of temperature, salinity, and pressure
- Measurement interval: 15 min
- Data processing steps: conversion to engineering data, despiking, filtering, calculating derived properties, averaging
- Final product: NetCDF files with vectors representing time series of temperature, salinity and pressure.

IOPAS22 and IOPAS 12 Nortek Signature250:

- Measurement type: time series of vertical profiles
- Measured variables: current speed, current direction
- Measurement interval: 30 h

- Data processing steps: conversion to engineering data, despiking, filtering, binning in depth bins, averaging, interpolation onto a regular grid
- Final product: NetCDF files with matrices representing interpolated profiles of current speed, current direction, and current components.

IOPAS22 TRDI QMADCP 150 kHz:

- Measurement type: time series of vertical profiles
- Measured variables: current speed, current direction
- Measurement interval: 30 h
- Data processing steps: conversion to engineering data, despiking, filtering, binning in depth bins, averaging, interpolation onto a regular grid
- Final product: NetCDF files with matrices representing interpolated profiles of current speed, current direction, and current components.

IOPAS22 RBR Solo3 T sensors:

- Measurement type: time series of point measurements;
- Measured variables: time series of temperature
- Measurement interval: 1 min
- Data processing steps: conversion to engineering data, despiking, filtering, averaging
- Final product: NetCDF files with vectors representing time series of temperature.

IOPAS22 RBR Duet3 TD sensors:

- Measurement type: time series of point mesurements
- Measured variables: time series of temperature and pressure
- Measurement interval: 1 min
- Data processing steps: conversion to engineering data, despiking, filtering, averaging
- Final product: NetCDF files with vectors representing time series of temperature and pressure.

IOPAS12 McLane Moored Profiler:

- Measurement type: time series of vertical profiles
- Measured variables: temperature, salinity, pressure, current speed, current direction
- Measurement interval: 12 h
- Data processing steps: conversion to engineering data, despiking, filtering, binning in depth bins, averaging, interpolation onto a regular grid
- Final product: NetCDF files with matrices representing interpolated profiles of temperature, salinity, and current components.

IOPAS12 Nortek Signature55:

- Measurement type: time series of vertical profiles (high resolution - cell size 4 m/low resolution cell size 12 m)
- Measured variables: current speed, current direction
- Measurement interval: high resolution 1h/low resolution 4h
- Data processing steps: conversion to engineering data, despiking, filtering, binning in depth bins, averaging, interpolation onto a regular grid

- Final product: NetCDF files with matrices representing interpolated profiles of current speed, current direction, and current components.

All data from the IOPAN moorings deployed during INTAROS will be available after data processing is completed. Data files in NetCDF format will be initially available from the dedicated password-protected ftp server and at the later stage submitted to the IOPAN data repository and to PANGAEA or NMDC or Zenodo to obtain DOI. All observations will be also registered in the INTAROS data catalogue.

2.2.3. Plans for the final implementation

Two INTAROS moorings, one at the INTAROS line at 22°E and another one at the A-TWAIN line at 31°E, will be deployed for the second field season in a similar confguration as before during the Nansen Legacy/A-TWAIN cruise of RV Kronprins Haakon on November 12-27. Due to the extension of the Norwegian A-TWAIN moorings, the INTAROS mooring at 31°E will be shifted towards the deeper water (approx. 1800-2000m instead 1200 m as in 2018-2019). In combination with the A-TWAIN moorings, these two INTAROS moorings constitute a backbone of the moored observing system north of Svalbard that should/will be prioritized in terms of the sustained operational implementation for monitoring of the Atlantic water inflow into the Arctic Ocean.

2.3. NIVA

Contributors: Luca Nizzeto, Ian Allan

2.3.1. Results of the first operational implementation

A methodology and deployment system were put in place for the secure deployment of silicone rubber passive sampling devices at various sampling locations and depths. Locations and sampling depth are given in the table below. Samplers were exposed for an entire year and retrieved in September 2019.

Table 2.3.1: Locations and sampling depths of microplastic samplers.

Samples	ID/depths	Coordinates		Depths	Cage type(s)	Passive samplers
		Longitude	Latitude			
1	500 m	022° 16.00’E	81° 23.00’N	2 depths (50 m below surface, 300m)	Jerico-next Ptfe holder	SR
3	850 m	21°50.00’E	81°29.00’N	2 depths (50 m and 500m)	Jerico-next Ptfe holder	SR
5	1500 m	022° 15.00’E	81° 36.00’N	3 depths (50 m, 800 m and 1300 m)	Jerico-next Ptfe holder	SR

2.3.2. Description of provided data

No data yet provided since the samplers have just been recovered or are to be recovered in November 2019. Samplers are yet to be analysed.

2.3.3. Plans for the final implementation

No plans for further implementation of the sampling system.

2.4. IMR

Contributors: Angelika Renner

2.4.1. Results of the first operational implementation

Purchase of the combined Acoustic Doppler Current Profiler (ADCP) / echosounder Signature 100 produced by Nortek was completed in early summer 2018, but the instrument was not deployed yet due to lack of space on the INTAROS moorings. A test deployment was conducted in January-February 2019, which helped us to get more familiar with this new instrument, and we obtained good data on water velocity and from the broadband echosounder for plankton biomass.

2.4.2. Description of provided data

The data will be collected in 2019-2020 and for this reason cannot be addressed at this point of time.

2.4.3. Plans for the final implementation

The Signature100 will be deployed in November 2019 alongside the A-TWAIN mooring array at 31° E on the 800 m isobath. Recovery and redeployment are planned for late summer 2020.

2.5. AWI

Contributors: Anya Waite, Andreas Rogge

2.5.1. Results of the first operational implementation

We compiled a horizontally free-moving sensor pack (Figure 2.5.1), hosting the latest prototype of the camera system Underwater Vision Profiler 6 (UVP 6; Hydroptic), a miniaturized and for long-term operation optimized version of the high frequency UVP 5hd (Picheral, 2010). Reduced power consumption (0.1 W) and an acquisition frequency of 0.1 Hz of the UVP6 allowed year-long acquisition of particle and zooplankton data, whereas a resolution of 5 MP and a pixel size of 0.73 µm ensured acquisition of high-quality images. The instrument harbors an intelligent camera, which automatically identifies and counts particles within a defined sample volume (0.65 L) and cuts and stores them as separated vignettes. This reduces the required storage space and eases post-processing. The light unit of the camera system produces red light at a frequency of 635 nm, which reduces interferences with sunlight and avoids attraction of animals. The constructed mooring frame featured a fin and was thereby fully rotational and tiltable so that a pointing of the camera into the current was ensured. This allows realistic quantification of vertical as well as lateral transported particles. The sensor package also included a SUNA nitrate sensor (SeaBird), as well as an Ecotriplet fluorometer (SeaBird) for chlorophyll and cDOM to measure environmental conditions, such as nutrient supply and the bloom situation. An additional fluorescence channel for particle backscatter within the Ecotriplet further allowed quality control for the small particle fraction measured by the UVP6.

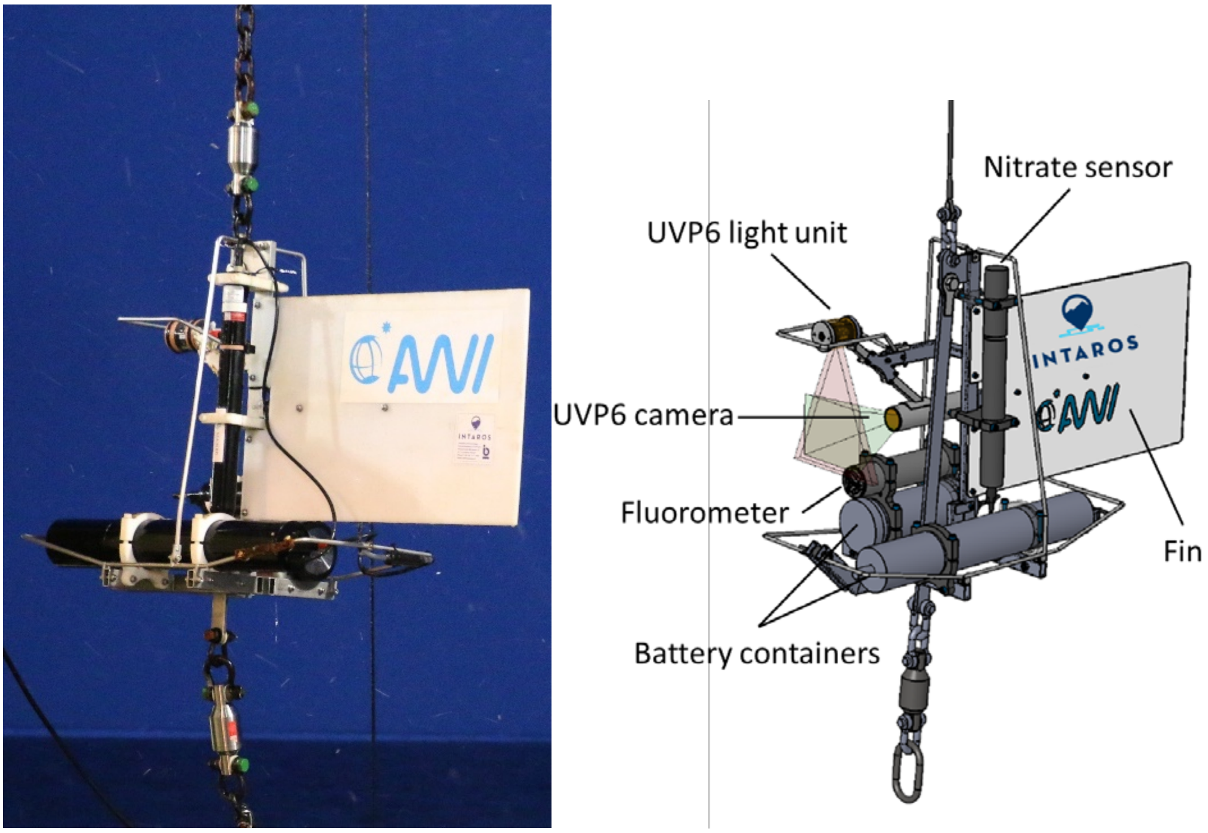


Figure 2.5.1: The deployed sensor package: left picture shows system during recovery (credit: Helge Bryhni, UiB). Right picture describes the individual compounds.

The system was deployed in August 2018 connected to a biogeochemical mooring (BGC11) of the INTAROS mooring array at a depth of ~50 m at appr. 22 °E and 81.5 °N. The mooring also included a profiling CTD and several other biogeochemical sensors at several depths and was located in the inflow region of Atlantic water at the continental slope north of Svalbard with a depth ~800 m. Recovery in September 2019 was successful and the system was being transported back to the Alfred-Wegener-Institute for data download and maintenance during the time of report preparation. Hence, presentation of data was prevented but minimal biofouling at the lens and the light unit, as observed during recovery, pointed towards complete field of view acquisition during the whole operation time.

2.5.2. Description of provided data

The raw particle data set will consist of measured sizes and abundances of particles larger than ~70 µm, as well as stored images of automatically identified particles larger than ~500 µm. The time series of the particle size distribution, as well as particle volume per sample volume of all defined size classes will be calculated and checked for consistency and quality using particle backscatter from the Ecotriplet during the post-process period. Particle images will be sorted semi-automatically using the web-based platform Ecotaxa (https://ecotaxa.obs-vlfr.fr; Picheral et al., 2017). Images will be grouped into plankton and detritus, whereas plankton images will be further categorized into taxonomic groups based on the UniEuk taxonomic tree (Universal taxonomic framework and integrated reference gene databases for Eukaryotic biology, ecology, and evolution). Targeted image depository will be Ecotaxa, whereas particle data and image classification and plankton abundances will be available at Ecotaxa, as well as PANGAEA (https://www.pangaea.de).

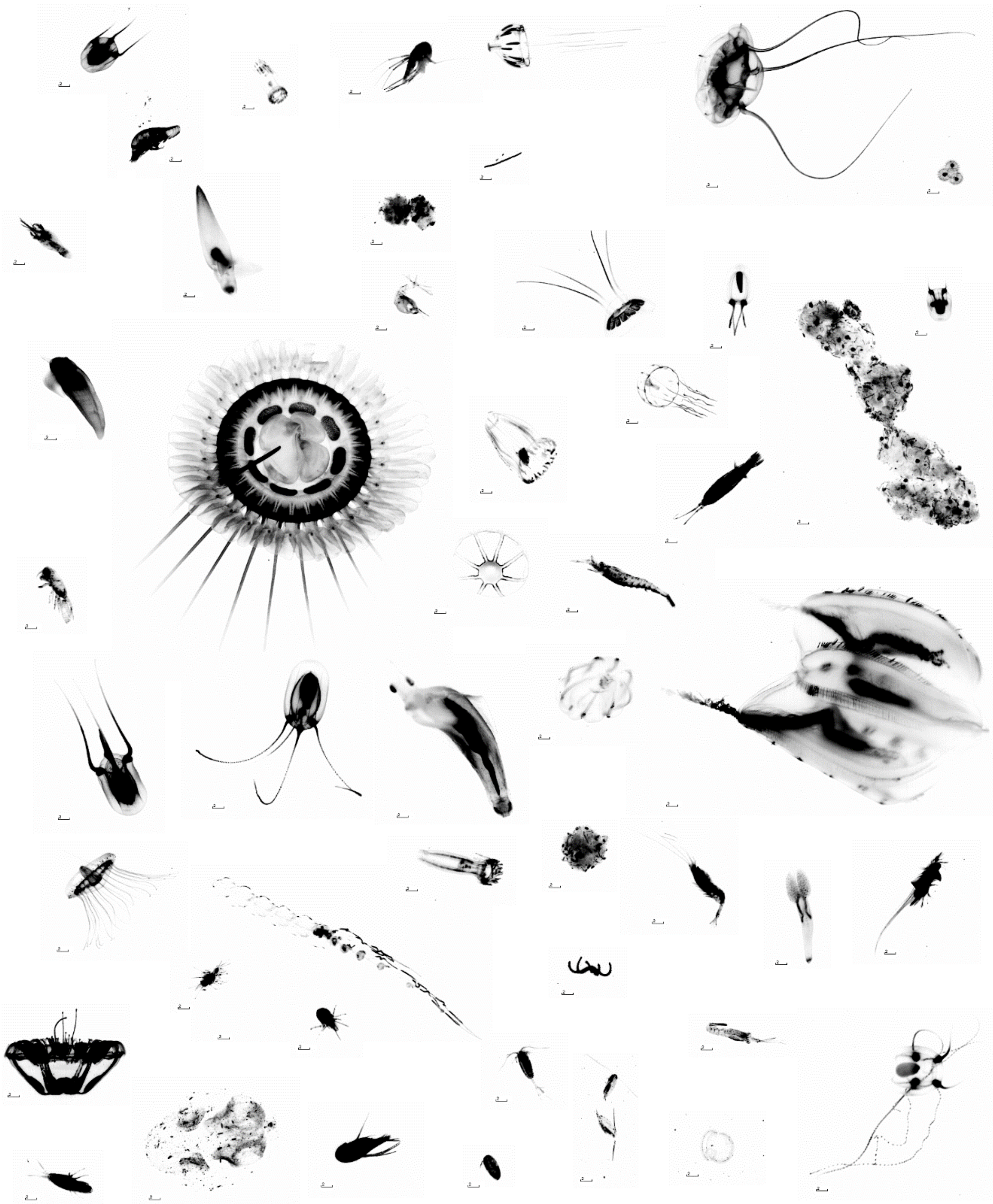


Figure 2.5.2: Example images of zooplankton and aggregates based on measurements from the UVP 5 hd from the Siberian shelf region. Due to a smaller sampling volume and a higher camera resolution, the image quality of the deployed UVP 6 system will be even higher. Scale bars represent 2 mm.

The time series of the nitrate data as well as fluorescence data of chlorophyll, cDOM and particle backscatter will be checked for consistency and quality. Nitrate data will be drift corrected using taken reference samples. Resulting environmental data will be available through PANGAEA.

Particle size distributions and detritus images will be further used to estimate carbon flux, whereas plankton images will be used to calculate organism abundances throughout the annual cycle. In combination with environmental data from SUNA and Ecotriplet, as well as other sensors of the mooring array and satellite observations of sea ice coverage, we envisage to characterize particle flux and plankton dynamics with respect to sea ice coverage and Atlantic water inflow. Comparable data sets, although performed with the earlier version UVP 5hd, have been published by e.g. Biard et al. (2016), Christiansen et al. (2018), or Kiko et al. (2017). Those studies already provided a lot of new knowledge regarding plankton and particle dynamics in various regions of the world oceans, but only based on snapshots of the spatial distribution at single points in time due to the fact that the UVP 5hd is constructed for depth profiles. The first year-long field application of the newest UVP prototype on a mooring in the framework of INTAROS, however, will provide long-term optical data and hence, allow for the first time the consideration of the temporal dimension as well. We thus expect new information regarding the annual cycle of particle dynamics and the interaction of sea ice, ocean currents, and plankton dynamics.

2.5.3. Plans for the final implementation

Following data download and maintenance, another year-long field season in the INTAROS mooring array is planned, starting in late summer 2020. If possible, the system will be connected to a profiling CTD, providing regular depth profiles of the particle and zooplankton distribution throughout the year.

2.6. UNIS

Contributors: Frank Nilsen, Marcos Porcires

2.6.1. Results of the first operational implementation

A bottom pressure recorder (SBE26) operated by UNIS was tied onto the frame of the *CNRS12* mooring (81° 22.967'N, 22° 14.899'E) at 500 metre depth. In addition to the tall *BGC11* moorings, and in connection to the shallower bottom pressure recorder on *CNRS12*, a short bottom mooring *BPR11* was deployed next to the cluster of *IOPAS12* and *BGC11* moorings. The *BPR11* mooring is operated by UNIS and equipped with the bottom pressure recorder Aanderaa SeaGuard WTR (Wave and Tide Recorder). The instrument is located at the bottom anchor (attached to it with a single acoustic IXI release) with a small package of four glass balls above to provide buoyancy for recovery. *BPR11* was deployed on August 11, 2018 by free fall at the position 81° 29.1565'N, 021° 55.3338'E at the water depth of approx. 870 m.

2.6.2. Description of provided data

Moorings have not yet been recovered due to problematic sea ice cover north of Svalbard, making a recovery process unsafe. The recovery is scheduled for the RV Prins Haakon cruise in November 2019.

2.6.3. Plans for the final implementation

Decisions on redeployment will be taken when the mooring is revered safely.

2.7. CNRS-LOCEAN

Contributors: Marie-Noelle Houssais, Christophe Herbaut

2.7.1. Results of the first operational implementation

The CNRS-LOCEAN moorings sites complement the site at 81°30'N 22°E, instrumented by other INTAROS partners, by extending the mooring array across the northern Svalbard slope, both towards the shelf and in the offshore direction. A couple of moorings, CNRS1 and CNRS2, was deployed 0.3 nm apart on the upper slope (500 m bottom depth) in summer 2017, then recovered and redeployed in summer 2018 together with an additional mooring, CNRS3, deployed farther offshore on the midslope (bottom depth 1500 m). This deployment strategy allows us to monitor contrasts across the slope, in particular their dependency on the ocean bottom geometry. With the goal to monitor the dynamics and physical properties of the Atlantic Water flow at it enters the Nansen Basin, the 22°E mooring array is complementary to the A-TWAIN array at 30°E. It will provide a description of the flow immediately downstream of the Yermak Plateau where the Svalbard branch and the Yermak Plateau branches of the current merge while allowing to address the evolution of the current as it flows along the southern Nansen Basin slope.

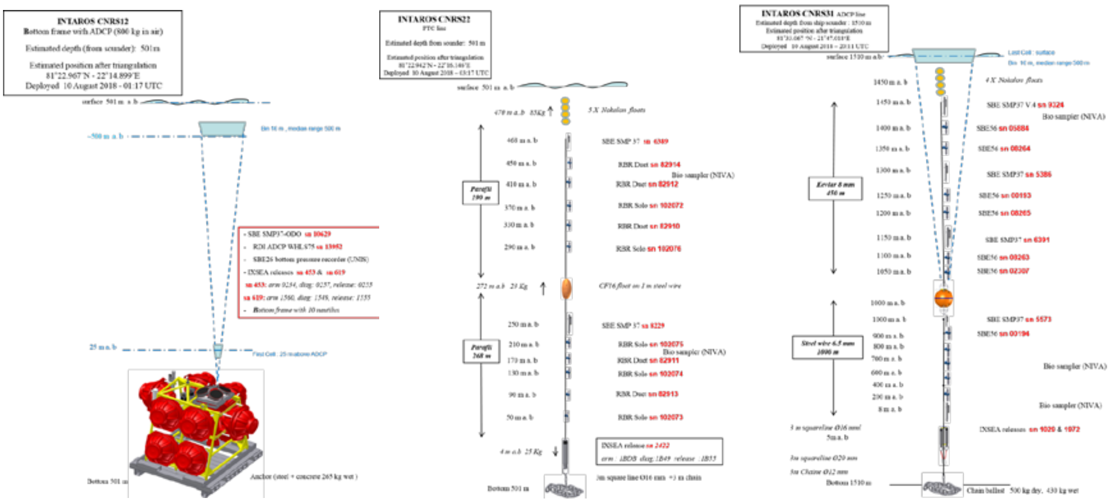


Figure 2.7.1: Mooring design: Upper slope (left) bottom frame (CNRS1) and (middle) mooring line (CNRS2), both deployed in September 2017, and mid-slope (right) mooring line (CNRS3), first deployed in August 2018.

The CNRS moorings are dedicated to measurements of key physical variables (Figure 2.7.1). Sensors combining point measurements of temperature and, for some of these, conductivity and/or pressure have been deployed on the upper and mid slope along two mooring lines (CNRS2 and CNRS3) extending from the subsurface (30 m) to the bottom. At the bottom a CTD recorder with an optical dissolved oxygen sensor was added at the upper slope site (CNRS1). Two acoustic Doppler current profilers (ADCP) in upward looking configuration, one on the bottom frame on the upper slope, and the other on the mooring line at mid-slope were also deployed. Both ADCPs have 75kHz transducers and should provide profiles of the 3D ocean velocity from close to the instrument depth (near bottom) to a depth varying according to the actual range of the instrument which depends on the environmental conditions (between surface and 140 m).

At the time of the report, the instruments that have been deployed in August 2018 have not been recovered yet due to adverse ice conditions during last summer. So far, only the data collected during the first deployment period (16 September 2017- 3 August 2018) have been available for analysis.

2.7.2. Description of provided data

Several 10.5-month long time series of ocean physical variables have been obtained from the moorings that were recovered in August 2018 at CNRS1/CNRS2 upper slope site. Out of all sensors, only one CTD recorder at 250 m failed. Time series of the following parameters were retrieved:

- High frequency (3 seconds time interval) ocean temperature every 40 m between 30 m below surface down to the bottom (500m) at high frequency
- Ocean temperature and conductivity at two different levels: subsurface (30 m) and bottom, at 10 minutes time interval.
- Ocean dissolved oxygen content at the bottom at 30 minutes time interval.
- Ocean velocity at 16 m depth intervals from a level ranging between surface and 140 m depth down to near bottom (475 m), at 30-minute time interval.

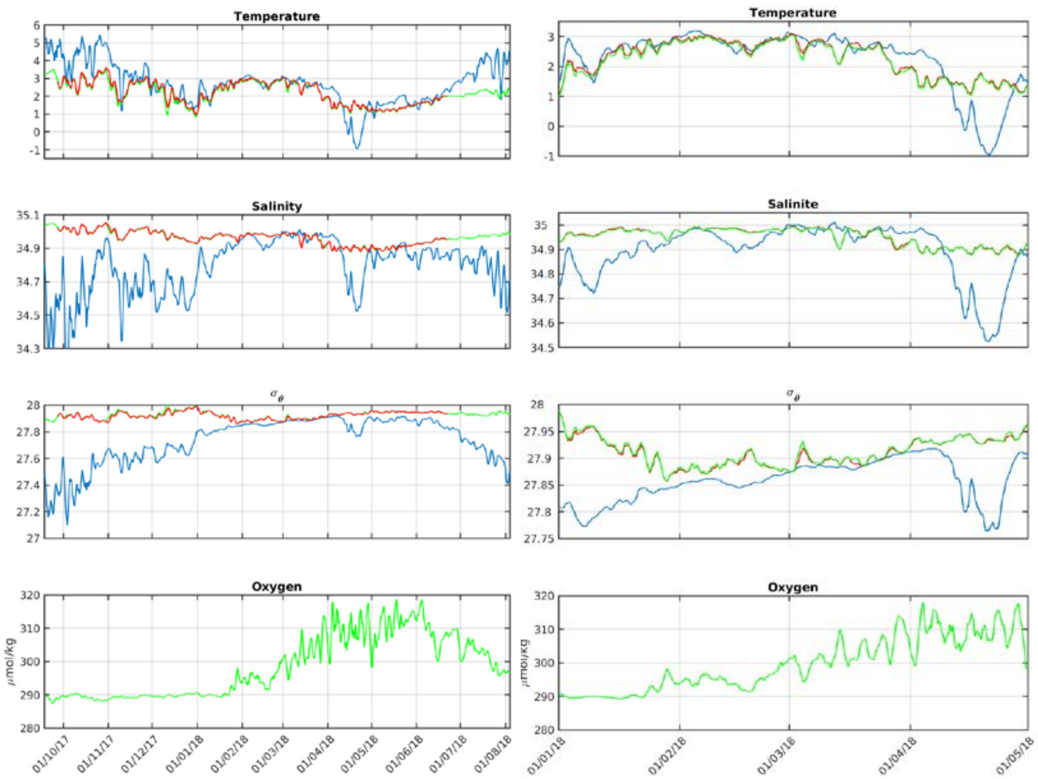


Figure 2.7.2: Time series of temperature (°C), salinity, potential density referred to surface (in sigma units) and dissolved oxygen concentration (µmol/kg) as a function of time at about 30 m (blue) and 500 m (green at CNRS1, red at CNRS2) over the period (left) 16/09/2017-3/08/2018 and (right) 01/01-01/05/2018. Data have been smoothed with a 2-day moving average. Note that values have not been corrected for instrument depth changes due to vertical excursions of the mooring line.

Combining this different information should allow us to address the time variability of the Atlantic boundary current over the upper slope, at scales ranging from days to season, and to link it to the atmospheric forcing and sea ice distribution. Some characteristics can already be highlighted:

- The presence of warm AW from the subsurface down to the bottom all year around except in April when a cold, fresh upper layer overlays the AW layer for a few weeks (Figure 2.7.2 left).
- Relatively warm bottom temperatures in winter compared to late fall or spring, leading to a seasonal maximum.
- Progressive destratification of the water column through fall and early winter which can be attributed to the upper layer becoming more saline and colder.
- Lowest values of the mean vertical stratification observed in March, with shorter episodes of complete vertical homogenization of the water column which are associated with increased dissolved oxygen content. Two of them do not coincide with vertical homogeneity in temperature and salinity but rather with temporarily colder, fresher, lighter bottom water (Figure 2.7.2, right).
- A largely barotropic flow during most of the observation period except in late March when the flow becomes surface intensified (Figure 2.7.3).

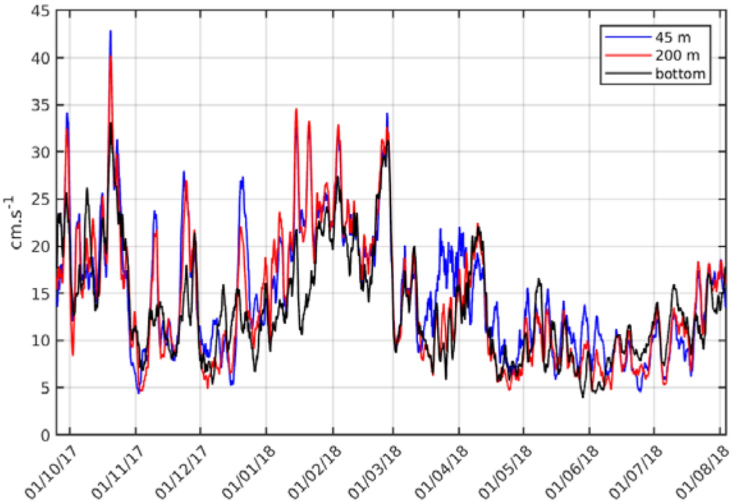


Figure 2.7.3: Time series of ocean velocity (cm/s) at three different levels as recorded by the ADCP at mooring CNRS1.

Final calibration and validation of the data is currently under progress. Once this is completed, they will be disseminated to SeaDataNet through the SEANOE national marine data portal.

2.7.3. Plans for the final implementation

Documenting and explaining the nature of the observed variability will be made possible by considering the spatial context offered by the different moorings of the 22°E array. The challenges are to better understand the annual cycle as well as shorter term events, to disentangle the origin of the ventilated bottom waters with regards to the source regions (local, upstream in the boundary current, over the shelf or off-slope) and the responsible mechanisms (mixing, lateral advection, upwelling, eddies), and to evaluate the role of the ocean variability in the sea ice distribution.

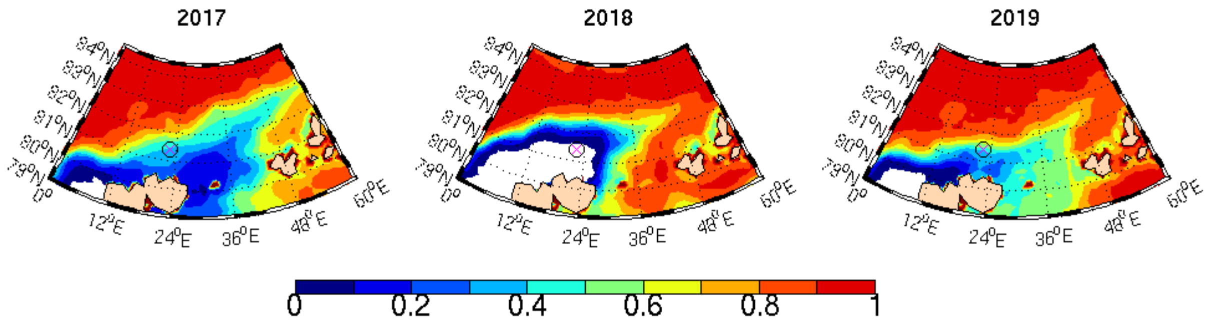


Figure 2.7.4: Mean winter (DJFM) sea ice concentration (based on SSM/I ASI algorithm data) in 2017, 2018 and 2019. The year refers to the January of the given winter.

During the second field season, we plan to maintain the two mooring sites on the upper and mid-slope in order to be able to contrast different years and assess the robustness of the features observed during the first period over the upper slope. Winter sea ice conditions in 2018 were relatively light on average (Figure 2.7.4) and it will be of upmost interest to check how the 2018 ocean conditions compare with conditions observed in the following winters. To this aim, the moorings to be deployed next year will incorporate an upward looking transducer at the top of the mooring lines in order to measure ice draft and drift velocity.

2.8. NERSC and international partners SIO, WHOI and NPGS

Contributors: Hanne Sagen

2.8.1. Results of the first operational implementation

KV Svalbard cruise 2018: INTAROS field experiment:

NERSC coordinated and organised the KV Svalbard cruise for INTAROS in 2018, contributed with acoustic releases to the BGC mooring, but did not deploy any instruments for the INTAROS project. This cruise was used by IOPAN, UiB and CNRS to deploy their moorings north of Svalbard, and to carry out oceanographic sections along 22°E. This work is reported under the different institutions.

KV Svalbard cruise 2019: Coordinated Arctic Acoustic Thermometry Experiment (CAATEX):

Also, in 2019, NERSC contributed with ship time for INTAROS activities during the CAATEX field experiment with KV Svalbard. The INTAROS activities were such as atmospheric measurements reported by UiB-GFI, deployment of the NERSC-4 mooring (IOPAN/NERSC/UiB), drone and radar measurements by NORCE. One INTAROS rig was picked up which was deployed in 2018 as part of the INTAROS project. This mooring is described under the Section for IOPAN. In addition, nine ice stations were carried out as a collaboration between partners within INTAROS and CAATEX.

Planning and implementation of the KV Svalbard cruise involved more than 40 scientists from CAATEX, INTAROS and other projects. The CAATEX is a coordinated effort funded primarily by Office of Naval Research and the Research Council of Norway. The contributing institutions and scientists to the field experiment are:

CAATEX:
NERSC, Norway: Hanne Sagen, Espen Storheim, Florian Geyer, Stein Sandven **Students:** Henrik Hellem, Bjørnar Røsvik

Scripps Institution of Oceanography, USA: Peter Worcester, Matthew Dzieciuch, David Horwitt, Matt Norenberg
Woods Hole Oceanographic Institution (WHOI), USA: John Kemp, Rick Krishfield, Andrey Proshutinsky, John Kemp, James Ryder, Nico Llanos
Norwegian Polar Institute (NPI), Norway: Mats Granskog, Bonnie Raffel.
Naval Postgraduate School (NPS), USA: John Colosi, Chris Miller
DRDC, Canada: Christopher Whitt, Sean Pecknold, (Drifting Acoustic buoy)

INTAROS:
IOPAS, Poland: Agnieszka Beszczynska-Møller, Piotr Wieczorek.
Geophysical Institute, UiB: Alexandra Touzeau, Harald Soedemann, Børge Hamre, Truls Johannessen, Nicholas Roden, Tor de Lange and Are Olsen
NORCE, Norway: Tom Rune Lauknes, Andre Kjellstrup, Rolf Ole Jenssen, Rune Storvold

Other contributing institutions and projects:
Kystverket, Norway: Andreas Kjøl
NIOT, India: G. Latha
FFI, Norway: Dag Tollefsen, Ivar Forsmo
Maritimt Forum: Hans Sand, Terje Brinck Løyning, Richard Norland
Metno: Nick Huhges, Ole Jakob Hegelund
Department of physics and technology, UiB: Håkon Sandven, Børge Hamre.

Summary:

The Coordinated Arctic Acoustic Thermometry Experiment (CAATEX) research cruise was conducted with the Coast Guard vessel KV Svalbard in the Arctic Ocean from August 14 to September 9. Field experiments were conducted by Nansen Center in collaboration with eight other Norwegian and international research institutions. The main goal of the cruise was to deploy three acoustic rigs, four buoys, and an oceanographic rig. The rigs are deployed in the Nansen Basin and will collect data daily that contributes to new knowledge about how the temperature of the ocean under the polar sea ice cover will vary over the coming year. Several drifting ice buoys were deployed. The buoys will gather information about the ice, how it will grow and vary in thickness throughout the winter and how it will melt during the coming summer season. This experiment is coordinated with the deployment of acoustic moorings in the Beaufort Sea and Canada basin. Fully deployed CAATEX system is shown in Figure 2.8.1.

Details about the KV Svalbard deployment cruise CAATEX- 2019:

During the four-week CAATEX-2019 cruise with KV Svalbard four rigs were deployed in the Nansen basin north of Svalbard. Each rig is around 4000 m long and stands vertical in the water column by means of heavy anchor and buoyancy spheres (See Figure 2.8.2). Three of the rigs (NERSC1-3) are part of a larger international acoustic thermometry network that measures mean ocean temperature across the entire Arctic Ocean from the areas north of Svalbard to the Beaufort Sea north of Alaska (see: http://caatex.nersc.no). The acoustic thermometry rigs are also equipped with oceanographic instruments for point measurements of salinity and temperature, ocean currents, ice parameters and the bottom pressure. The acoustic sources and moorings were funded by Office of Naval Research, USA and Research Council of Norway. The instruments for the NERSC 1-3 were contributed by NERSC, Scripps Institution of Oceanography, Woods Hole Oceanographic Institution and Naval Postgraduate School.

The CAATEX system is complemented by an oceanographic rig (NERSC-4) funded through INTAROS. This deep ocean mooring is a joint contribution under Task 3.2 and Task 3.4. This rig includes similar instrumentation for measuring physical ocean parameters, but also instruments for measuring biogeochemistry and passive recordings of sound in the ocean. The physical oceanography instruments and mooring hardware were provided by IOPAN under the Task 3.4 (32 instruments and double acoustic releases, batteries and calibration for 3 NERSC instruments), and by NERSC under Task 3.2 (3 instruments, mooring Kevlar and flotation, underwater locators). A detailed description of the deep INTAROS mooring is provided in the deliverable D.3.14. Instruments for passive acoustic were contributed by collaborators outside the INTAROS consortium National Institute of Ocean Technology (NIOT) and National Centre for Polar Ocean Research, Ministry of Earth Sciences, Govt and by FFI (Norwegian Defense Research Establishment).

In CAATEX sound signals are transmitted between source and receiver moorings across the Arctic Basin every 36 hours. Sound signals travel faster in warm water than in cold water. In acoustic thermometry the travel time of the sound signal is measured, and through sophisticated inversion the range depth averaged sound speed is obtained and converted to mean ocean temperature. A key question in CAATEX is to investigate how the temperature and processes in the ocean under the sea ice has changed over the last decades. This knowledge is essential to learn how the extent and thickness of the sea ice is affected by changes in the temperature and processes in the water masses below the sea ice. Similar transarctic temperature measurements using acoustic thermometry were last collected in the nineties and the CAATEX measurements will therefore be able to provide unique information about possible temperature changes in the water masses under the sea ice over the last 20 years.

The combination large scale measurements of ocean temperature through acoustic thermometry with point measurements from oceanographic instruments are complementary. Point measurements are important for process studies on a local scale in different parts of the Arctic. The measurement program is designed to provide necessary and unique data that will help to increase the knowledge of the properties of the water masses under the Arctic sea ice and their variations over one year. When the four rigs are taken up again in 2020, they will have unique and complementary measurements that can be used together with data from other oceanographic rigs and buoys in other parts of the Arctic Ocean. This makes the CAATEX observing system unique for the Arctic.

The deployment of the rigs was challenging due to varying ice drift conditions and that the bottom topography in large parts of the Arctic Ocean is not adequately mapped and known. Therefore, before deploying each rig, the bottom topography must be measured and mapped in an area with a radius of more than 30 kilometers around the selected position. This mapping was challenging in tight pack ice. Furthermore, variation in ice drift must be carefully monitored before and during the 7-9 hours it takes to put the rig to a depth of 4000 meters. With the careful planning, previous experience, good information about the weather and ice conditions on site and a skilled crew, all four rigs were successfully deployed.

During the KV Svalbard cruise, four ice-ocean buoys were placed on the sea ice. All buoys now drift with the ice from the North Pole towards the Fram Strait, while continuously collecting environmental information about the sea under the ice, about the nature of the sea ice and about the air near the ice. The data from these buoys can provide information on where and in what part of the year the ice melts most from the underside that is in contact with a warmer seawater or where and when it melts from the surface in contact with warmer air layers. It is reported by FMI, WHOI and JASCO that the buoys are working.

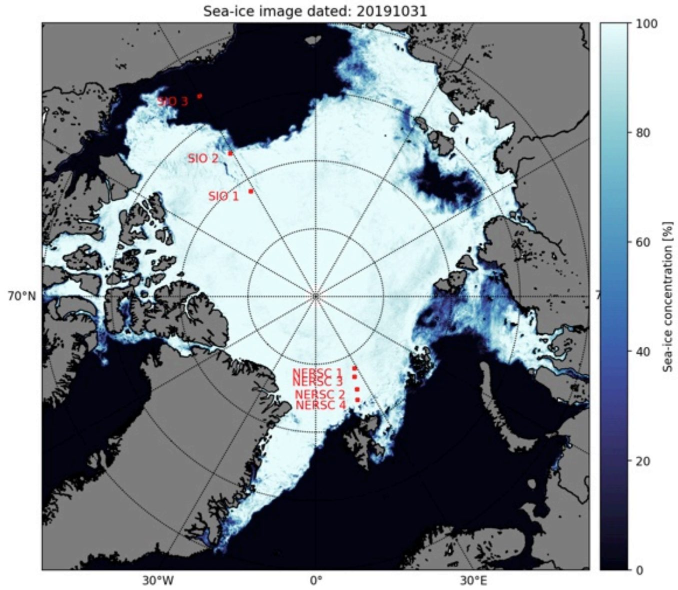


Figure 2.8.1: The geometry of the 2019–2020 CAATEX experiment. The acoustic transceivers are located at SIO1 and NERSC1. There are four vertical receiving arrays: SIO2, SIO3, NERSC2, and NERSC3. The SIO 1-3 were deployed by the Scripps Institution of Oceanography from the USCGC *Healy*. NERSC 1-4 were deployed from the Norwegian Coastguard Icebreaker KV Svalbard. The mooring at NERSC4 has conventional oceanographic instrumentation and funded by INTAROS and own contributions. All of the NERSC moorings are in the Nansen Basin south of the Gakkel Ridge; ice conditions prevented deployment further north. The sea-ice concentration on 31 October 2019 is from the Advanced Microwave Scanning Radiometer 2 (AMSR2) dataset provided by the University of Bremen (Source: https://seaice.uni-bremen.de/sea-ice-concentration/).

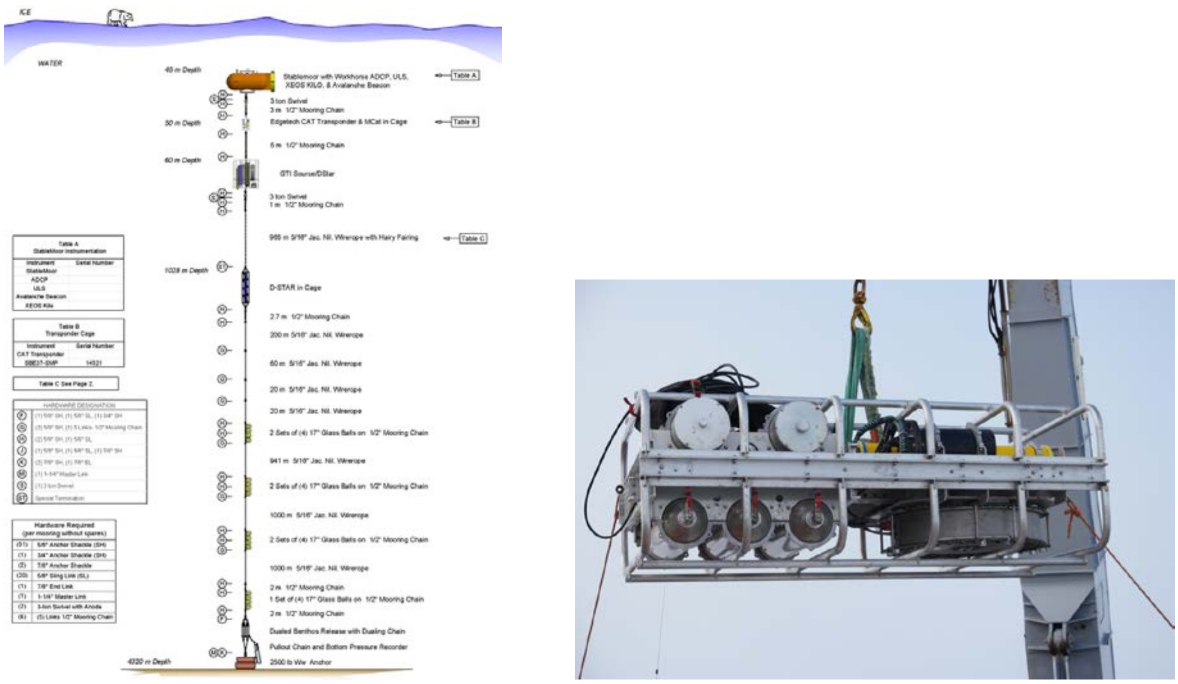


Figure 2.8.2: To the left the mooring design of the source mooring, and below the Geo-spectrum source used in the mooring. All NERSC moorings are heavily equipped with 55 instruments for acoustics and for oceanographic measurements.

Table 2.8.1: The deployments during the KV Svalbard CAATEX deployment cruise.

Mooring/buoy ID	Operation	Date	Operation time	Lat/Long (Drop)
ITP, SIMBA-1	ITP and SIMBA deployment	21 August	12:00-18:30	89°59.4614 N 47°41.45076 E
JASCO	Deployment of a drifting acoustic buoy	22 August	13:45-15:13	88°47.516' N 49°42.745' E
SIMBA-2	Deployment	24 august	12:30-1530	87°59.389' N 55°52.08928' E
NERSC -3	Deployment	29 August	09:00-16:37-	83°26.585' N 25°39.831' E
NERSC-1	Deployment	31 August	09:06-16:36	84°00.149' N 28°22.00' E
NERSC -2	Deployment	3 September	06:38-13:38	82°30.207' N 23°55.506' E
NERSC-4	Deployment	5-September	06:30-15:14	81°47.0540' N 22°00.1415' E

Ice stations were conducted at nine locations with extensive observations of the characteristics of the sea ice, and seawater under the ice. At the ice stations, ice cores were drilled and taken to study the structure of ice in laboratories. Measurements of ocean currents and turbulence under the ice, measurements of light and algae, as well as passive measurements of sound were made. Larger areas around KV Svalbard were investigated using drones equipped with various remote sensing sensors to map sea ice and leads. Regular sea ice observations were conducted using the Arctic Shipborne Sea Ice Standardization Tool (ASSIST) developed by the International Arctic Research Center in Fairbanks. CAATEX complete measurements taken during the MOSAiC drift expedition.

2.8.2. Description of provided data

No data are provided yet as the moorings were deployed in 2019. Data will be available after recovery of moorings in summer 2020 scheduled for the KV Svalbard cruise.

2.8.3. Plans for the final implementation

The implementation of the CAATEX system is described above. This system will be recovered in 2020 together with the INTAROS mooring NERSC-4. Ship time is applied for and will include an oceanographic section starting as far north as possible and between the NERSC moorings and if time allows into the shelf areas.

2.9. UiB-GEO and GEUS

Contributors: Mathilde Sorensen, Zeinab Jeddi, Peter Voss, Thomas Funck

2.9.1. Results of the first operational implementation

In early August 2018, researchers from the Department of Earth Science, University of Bergen (UiB-GEO), deployed broadband Ocean Bottom Seismometers (OBS) in open water in the Fram Strait from the vessel KV Svalbard. NERSC (Nansen Environmental and Remote Sensing Center) was leading the cruise. The initial plan was to deploy using the ROV from vessel G.O. Sars, but since we were able to deploy instruments with ROV in 2017, we decided to use free-fall deployment in this field campaign, in order to be able to compare data quality. The deployment locations were chosen at deeper parts of the Fram Strait, close to the Mid-Atlantic ridge where there is greater earthquake activity (Figure 2.9.1). Three OBS were prepared on board the ship and dropped to the sea floor at predefined locations (Figure 2.9.2).

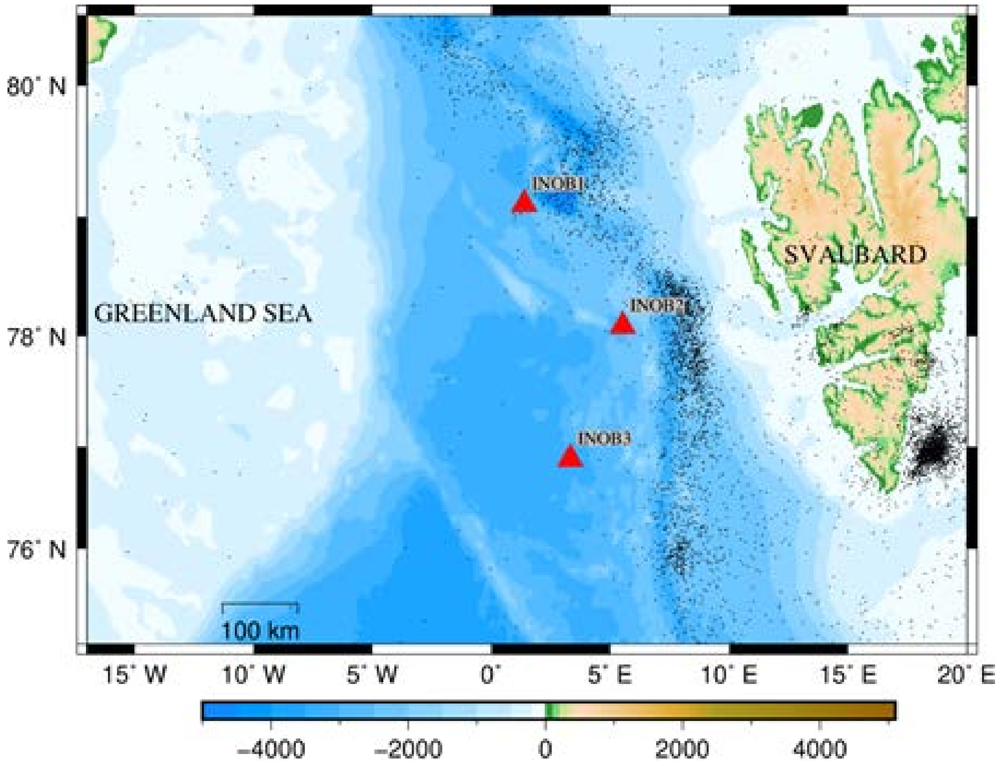


Figure 2.9.1: Location of three OBS deployed from KV SVALBARD during August 2018. Black dots are recorded seismic activity (reported by Norwegian National Seismic Network, NNSN) in the region since 1990. Bathymetry: ETOPO1 taken from National Oceanic and Atmospheric Administration (NOAA).

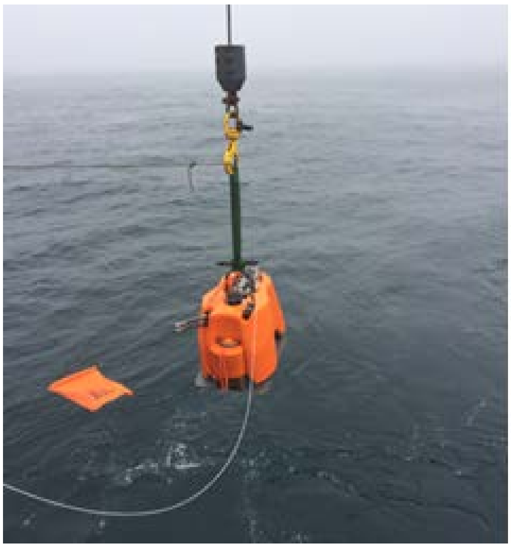


Figure 2.9.2: Deployment of OBS in Fram Strait in Aug. 2018 from KV SVALBARD using crane. (Photo: Zeinab Jeddi)

The three deployed OBS in the Fram Strait were in operation for one year and the seismology group of UiB organized an individual cruise in August 2019 to recover them (Figure 2.9.3). The cruise was planned for 13-20 August 2019 with the vessel 'ACC MOSBY' (see http://intaros.eu/news/recent-news/new-film-ocean-obs-cruise-2019/).

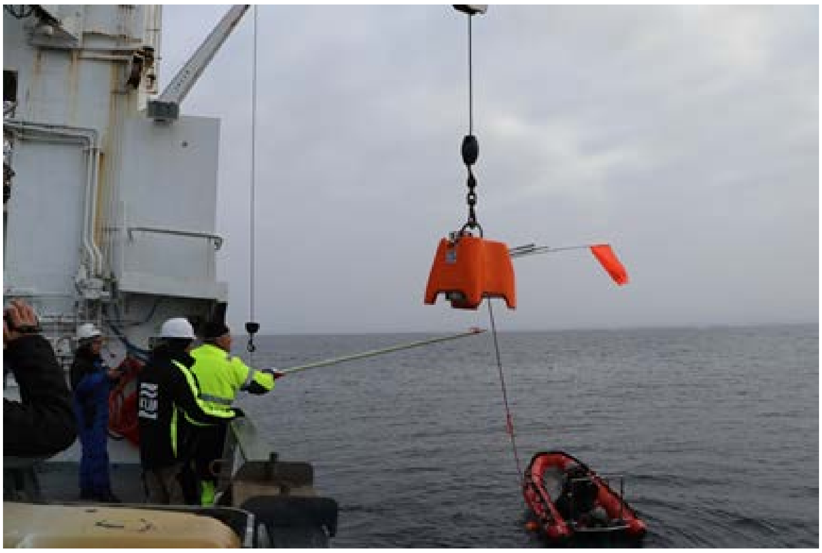


Figure 2.9.3: Recovery of OBIN1 from ACC MOSBY using small boat and crane- August 2019. (Photo: Zeinab Jeddi)

The recorded data will be used to analyse earthquake sources and provide better monitoring coverage for detecting smaller earthquakes. The outcome will create a baseline to study seismic hazard in the region and possible temporal variation in earthquake activity associated with long-term climatic changes.

In another campaign, the Geological Survey of Denmark and Greenland-GEUS participated in the deployment of nine Ocean Bottom Seismometers (OBS) in September 2018 to gain experience in deploying OBS instruments in potential ice filled waters (Figure 2.9.4). The experiment was carried out to for further insight to deeper crustal structures on the shelf north of Greenland and the Morris Jessup Rise and to measure seismic activity and small earthquakes in the area. The expedition was on board the research vessel Polarstern and the program was headed by the German Federal Institute for Geosciences and Natural Resources and the Alfred Wegener Institute.

The ice cover in the area is potentially very high and careful adaptations of the seismic program have to be made to minimize risks to the instruments. The seismometers that were deployed remained on the sea floor for a week to record seismic signals. The data will be used to analyse crustal structures. The experience gained from deploying OBS instruments in high Arctic areas will improve future OBS expeditions to the region that aim to improve the monitoring coverage and thereby will allow for detecting smaller earthquakes.

Figure 2.9.4: An OBS instrument surfaced close to a sheet of ice. (Photo: Thomas Funck)

See PS115.1 – weekly report Nr.3 20.08.-26.08.2018:
https://www.awi.de/en/expedition/ships/polarstern/weekly-reports-rv-polarstern/single-view/presse/surprising-ice-conditions-favor-measurements-further-north.html

2.9.2. Description of provided data

The seismometer is a sensor that is placed directly on the ground (preferably flat bedrock) and converts very small motions of the earth into digital recordings. The seismic waves which are generated by either earthquakes at depth or by man-made devices near the surface of the earth are travelling through the earth and recorded in these sensors. The information combined with precise timing, source location and the seismometer location, can provide details of seismic activity, the velocity and the geometry of the earth structure. In our experiment, we used a new generation of OBS, NAMMU, which is developed at K.U.M (Umwelt- und Meerestechnik Kiel, Germany) and the sensors were recording to four components: vertical, two horizontals and hydrophone channel. Day by day availability of data from each OBS is shown in Figure 2.9.5. Our temporary OBS network recorded continuous data successfully with a total uptime of 100%.

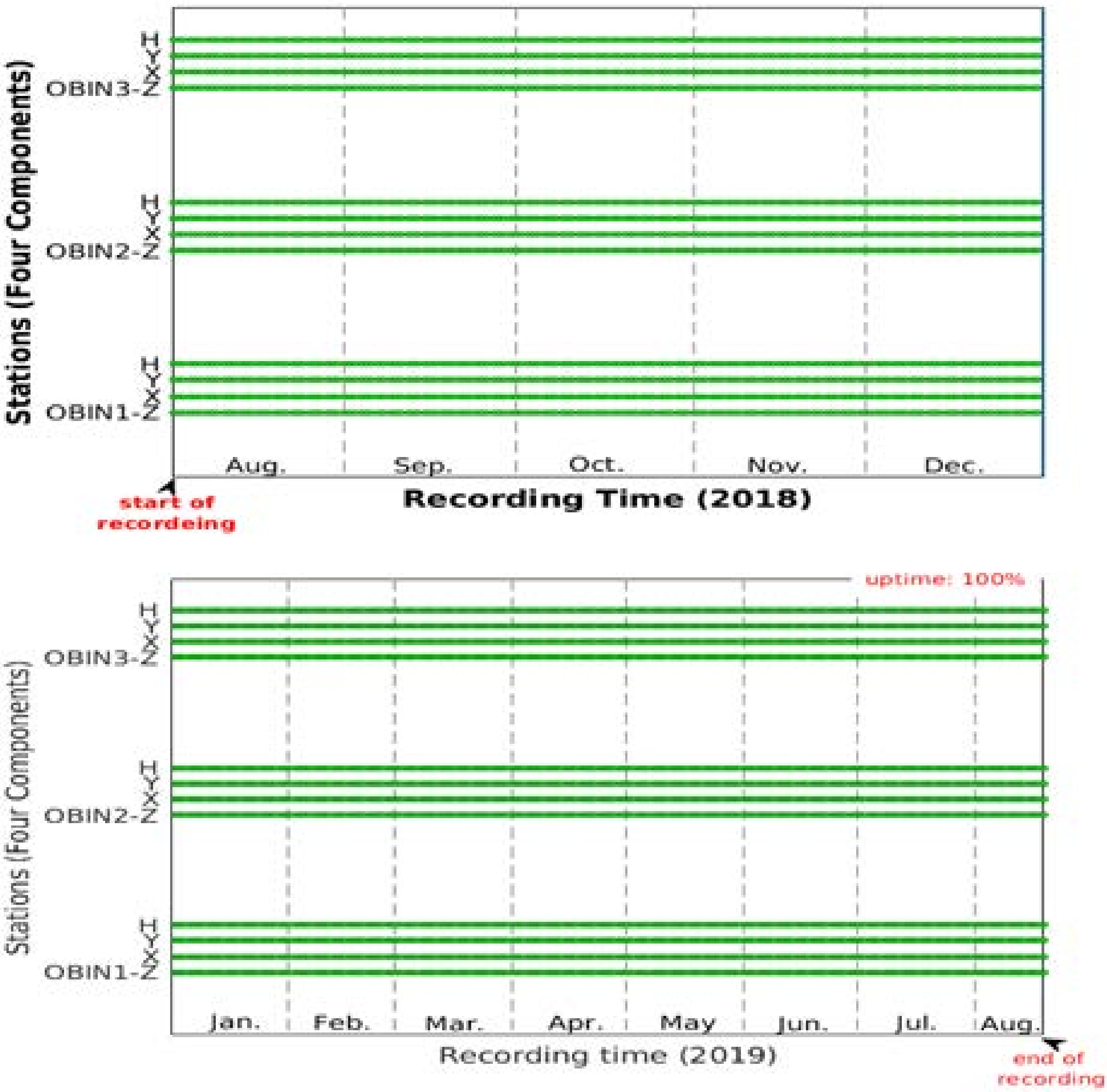


Figure 2.9.5: Availability of seismic data between August 2018 and August 2019. Green shows when data are available and red when data are missing after deployment. Each line is for one component at an OBS, as listed to the left. Vertical lines separate months.

The quality of data was also assessed by computing hourly power spectral density (PSD) for the entire deployment period with the noise computation implemented in SEISAN software (Ottemöller et al., 2018). Then it is plotted as probability density function (PDF) and spectrogram, the vertical component of OBS is given as an example in Figure 2.9.6. Both microseismic peaks are observed in the PDF similar to the land stations. Spectrograms are also showing good and ordinary recordings.

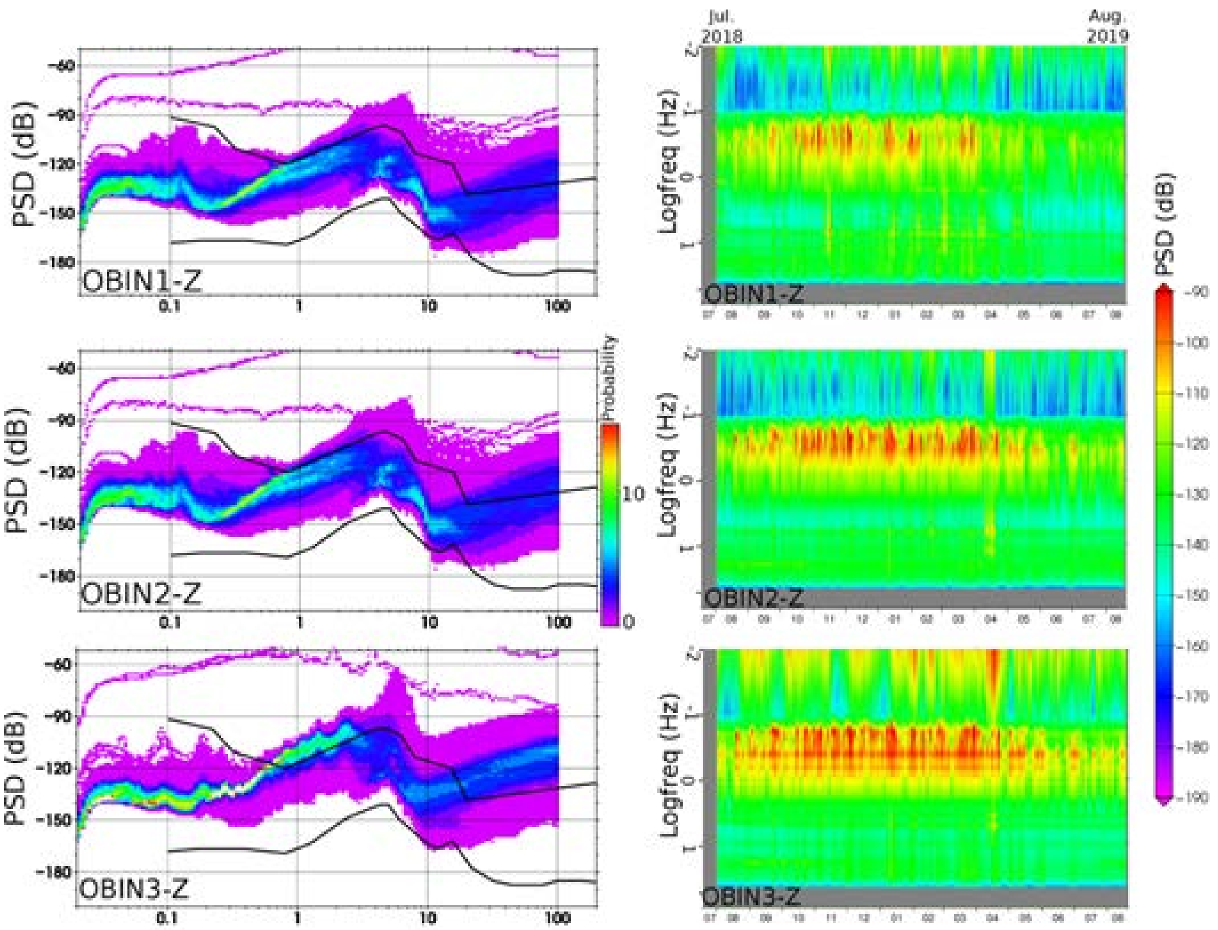


Figure 2.9.6: Left) Hourly PDFs and **Right)** hourly PSDs for vertical components of OBS. The solid black lines in the left panel show the NHNM and NLNM of Peterson (1993), respectively.

The OBS were dropped from vessel (free-fall deployment) and travels to the seabed by the weight of an anchor which is attached to its bottom. Before any detailed processing, we need to locate the instrument precisely and therefore the triangulation technique was used such that the vessel was placed at three different locations (~2 km from the drop point) for the range measurements to obtain an approximate position of the OBS at the seafloor. The approximate location of OBS was then calculated using the ranging measurements. The estimation showed ~200 m of drift between the drop point and the calculated point for the instrument in each case (Figure 2.9.7)

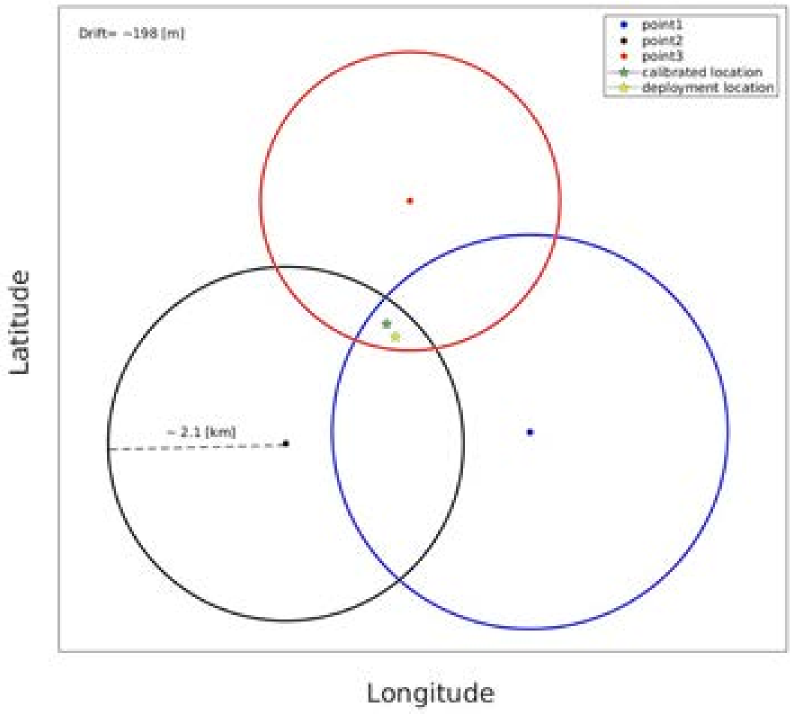


Figure 2.9.7: Triangulation at station OBIN3.

In addition to ranging measurements, active source experiment was performed close to OBIN3 to improve the location of the instrument. This experiment was done from G.O. SARS in August 2019 (some days before the recovery of instrument) in collaboration with the project KNIPSEIS (Structure of the Knipovich Ridge Based on Seismic Investigations) involving colleagues from the Polish Academy of Sciences and UiB. There were 150 airgun shots along a profile which was passing through OBIN3 location (calculated from ranging measurements). Having the origin time and location of the shot and considering the OBIN3 location, we can improve the location of OBIN3 calculated from ranging measurements. The smallest travel time expected appear while passing close to the OBS (Figure 2.9.8).

In addition to location, OBS data cannot be time stamped using GPS during deployment, and therefore time correction is required. The time drift is typically derived by synchronizing the internal clock with GPS before and after deployment and linear correction is then applied at recovery. Other methods such as ambient noise cross correlation functions (CCF) or P-wave arrival times are commonly used for the time correction. We have used both time synchronization and CCF measurements to correct the timing of our OBS.

After time correction, the data is ready to explore further. The OBS were close to the Mid-Atlantic Ridge where most of seismic activity occurs in the region. The processing of data is separated in two steps:

1. Processing known earthquakes in the area between August 2018 and August 2019 (Figure 2.9.9). This step will provide us information about how our OBS network can improve the location of known events.
2. Improving the existing catalogue by adding new events (Figures 2.9.10 and 2.9.11). This step will provide us information about detection capability of our network.

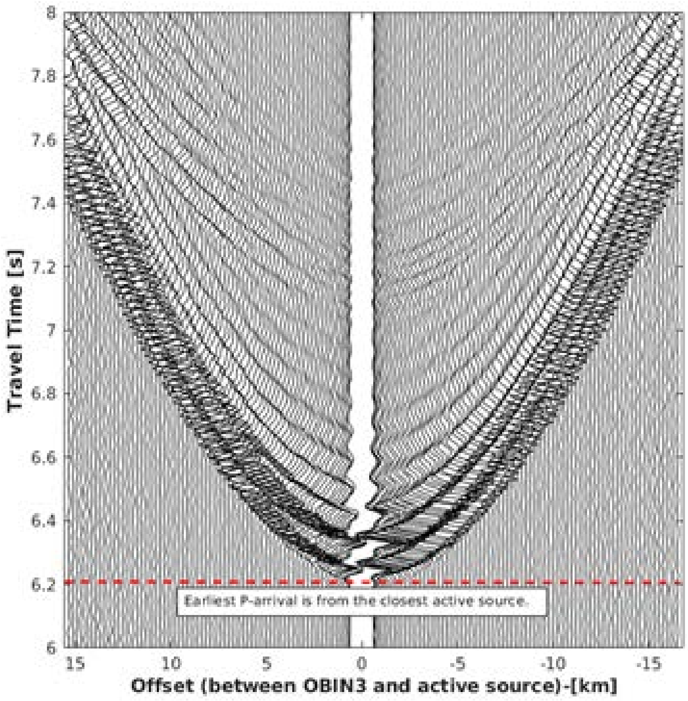


Figure 2.9.8: Each of the shots are plotted considering the offset (distance between OBIN3 and airgun position) and traveltime (observed arrival time in real data – origin time of shot). The smallest travel time is seen around zero offset which is confirming the location of the OBS calculated from the ranging measurement.

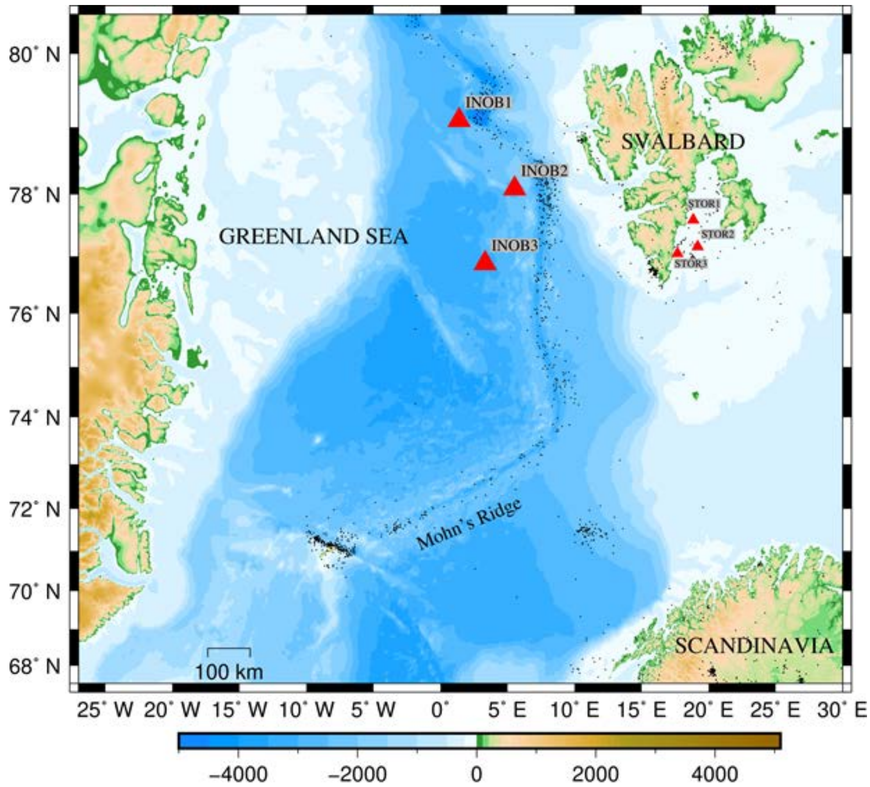


Figure 2.9.9: OBIN1-3 were recording between August 2018 and August 2019. Black dots are recorded seismic activity (reported by Norwegian National Seismic Network, NNSN) in the region during the recording time. Bathymetry: ETOPO1 taken from National Oceanic and Atmospheric Administration (NOAA).

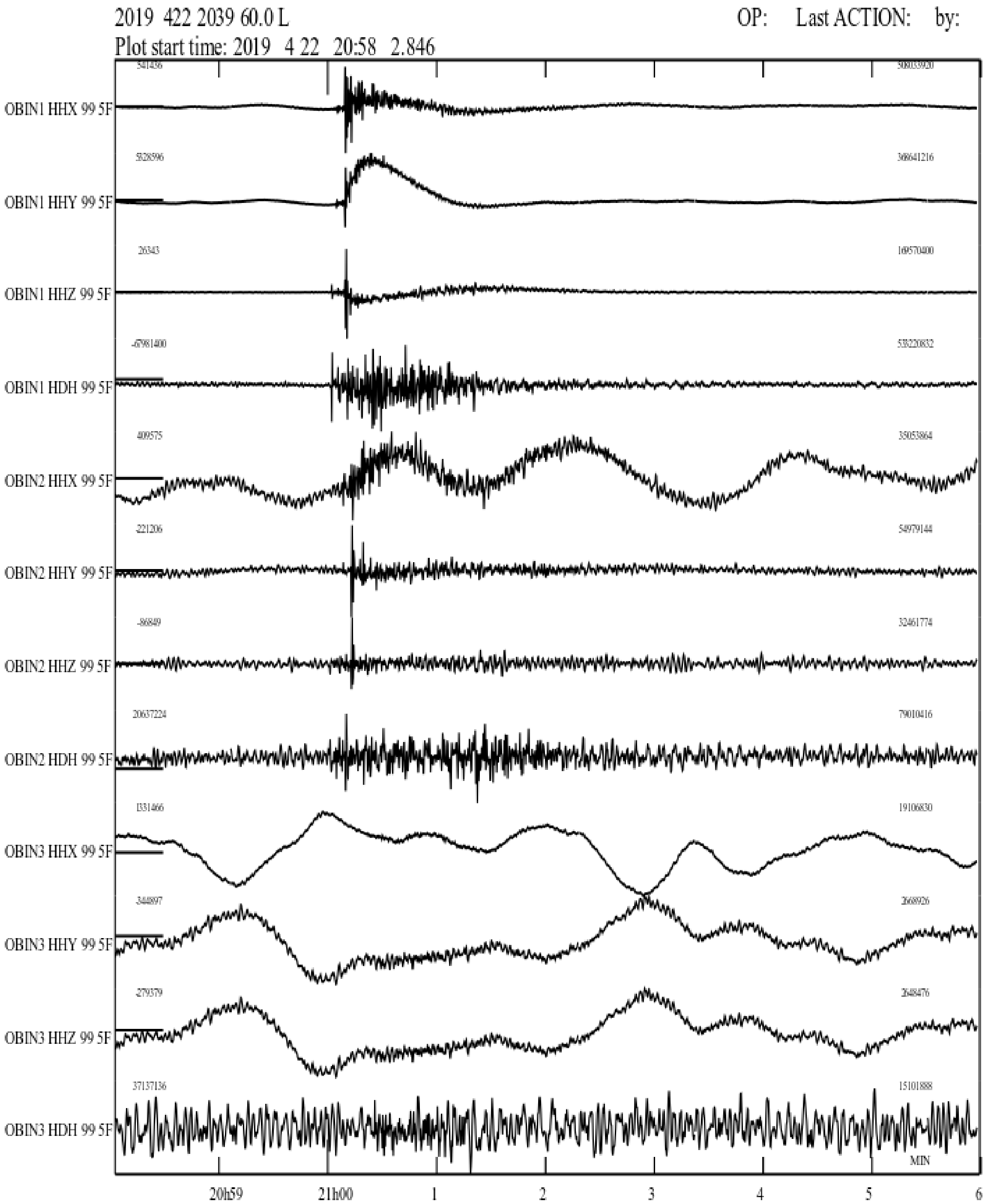


Figure 2.9.10: Waveform of an event in North of Fram Strait close to OBIN1. The event is not registered in the NNSN catalog.

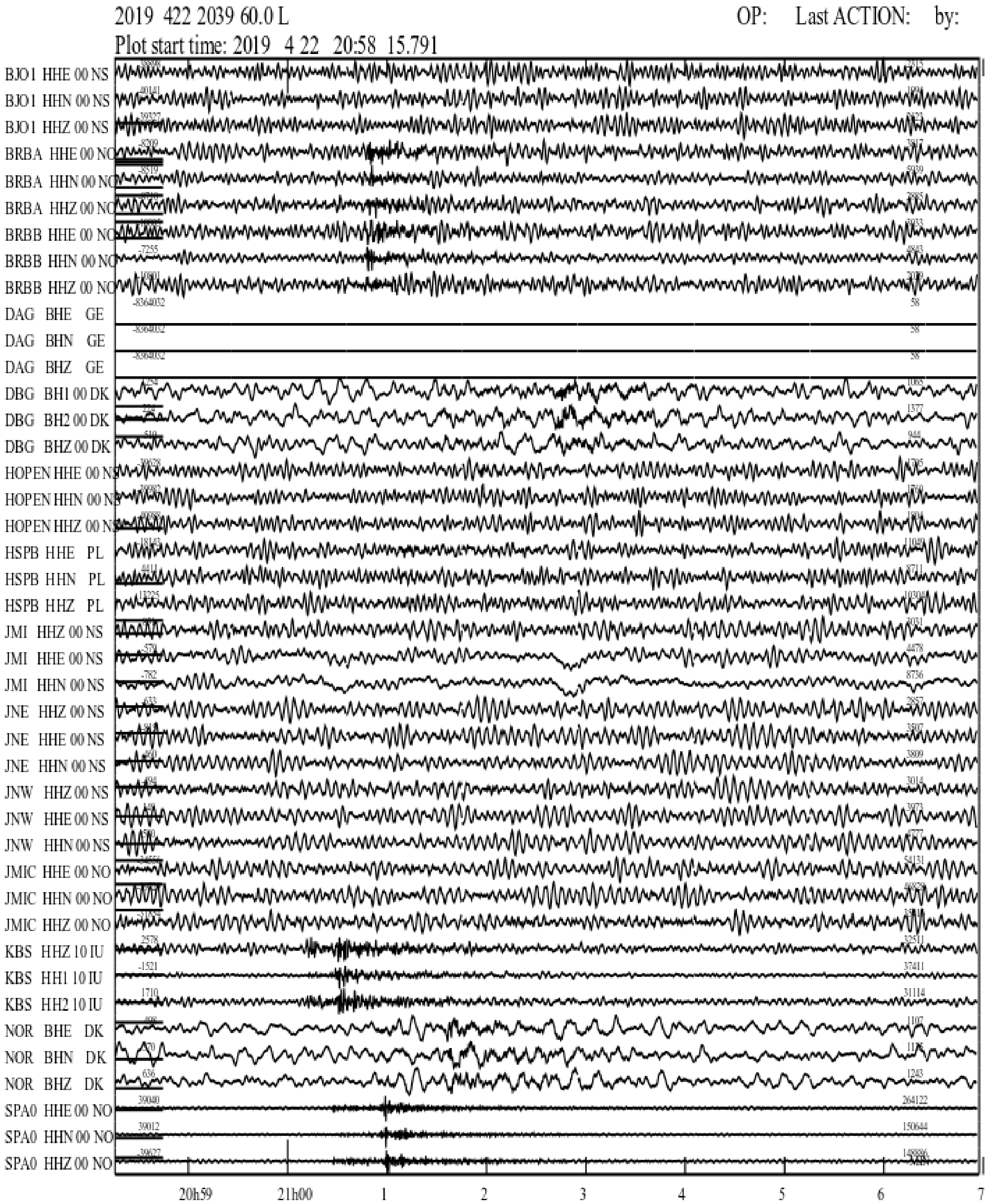


Figure 2.9.11: Same event as shown in Figure 2.9.10 on permanent land stations. The event is observed clearly in OBS.

The hydrophones on the OBS instruments provide information about pressure changes at the sea bottom. The data from these instruments can be used to confirm detection of seismic signals. In addition, other signals from e.g. marine life can add to the multidisciplinary use of the recorded data. Figure 2.9.12 shows the quality of hydrophone recordings as daily spectrogram for whole period (similar to Figure 2.9.6). This potential is currently being explored by colleagues at GEUS.

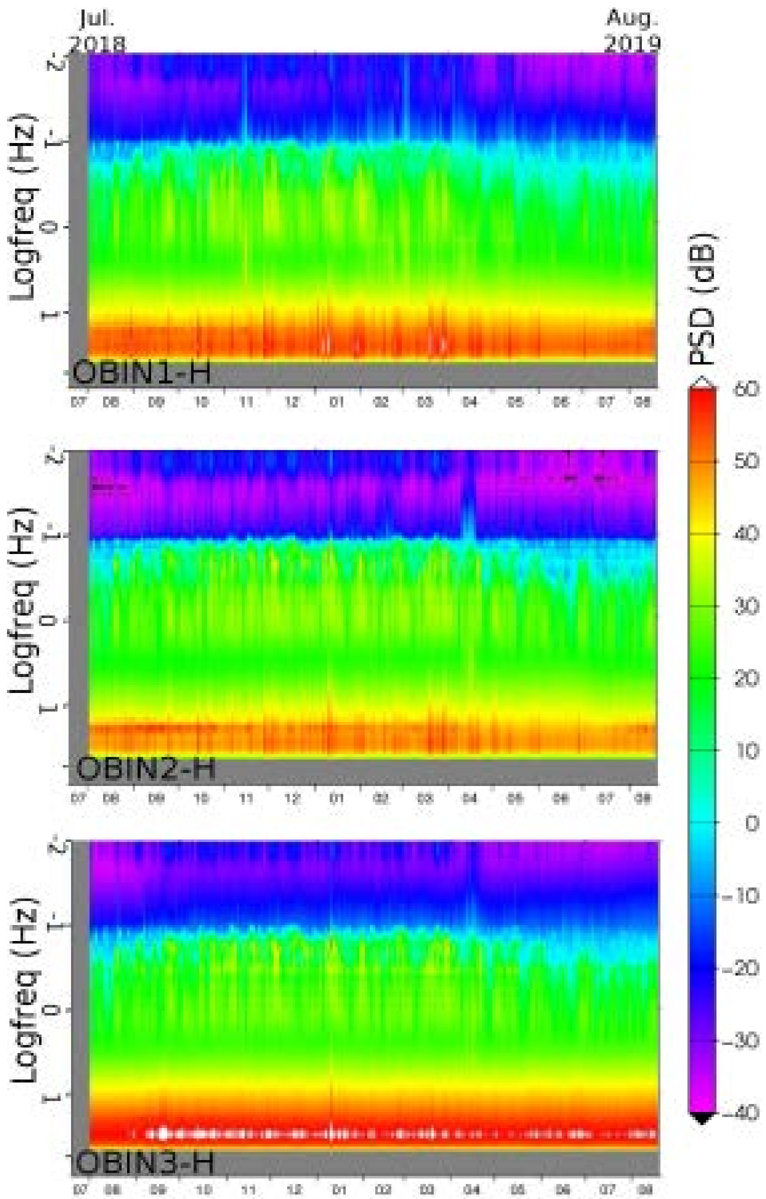


Figure 2.9.12: Hourly PSDs for vertical components of OBS.

2.9.3. Plans for the final implementation

The processing of continuous data is ongoing as described in two steps. At the same time, in the second part of the cruise in August 2019 from ACC MOSBY, the recovered instruments were prepared for another deployment in Storfjorden (South of Svalbard) in cooperation with the EPOS-Norway project funded by the Norwegian Research Council (Figure 2.9.13). Seismic activity in Storfjorden increased after a Mw 6.2 event on 21. February 2008. The seismicity is persistent until present and nearby continuous monitoring of the region is an interesting and important target in Norwegian territory. The recovery of the Storfjorden network is planned for summer 2020.

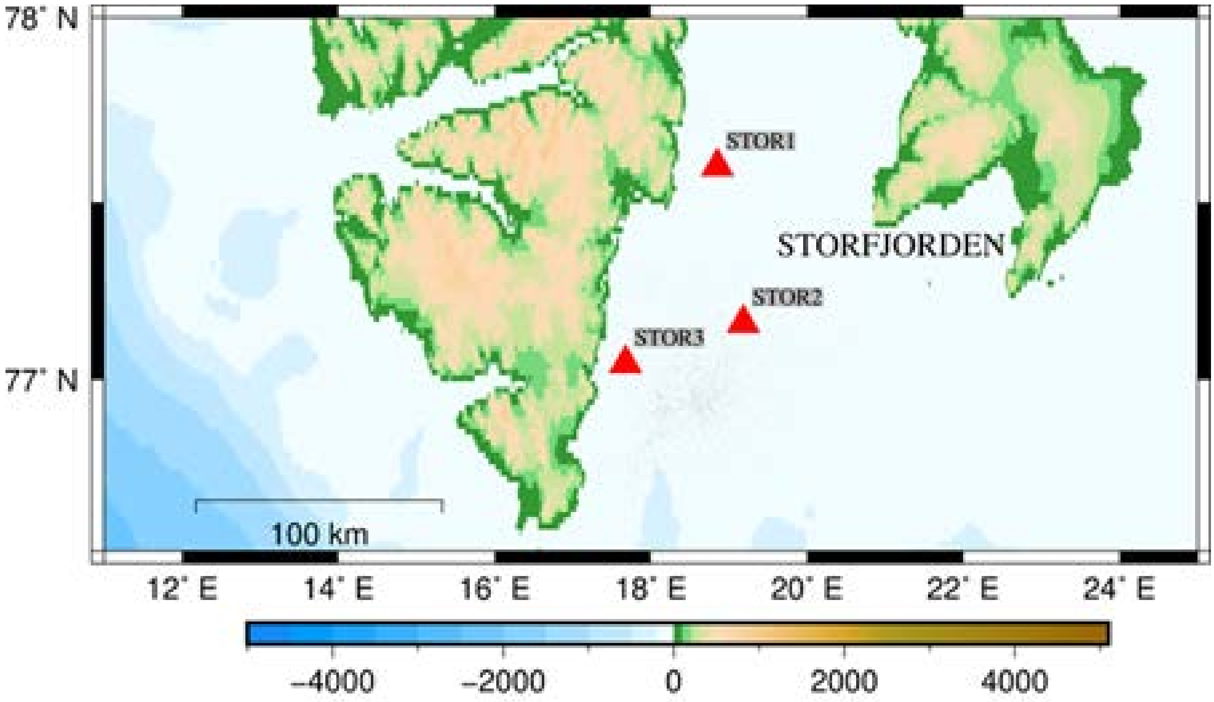


Figure 2.9.13: Storfjorden deployment locations.

3. Future plans for the final implementation of the observing system

Long-term ambitious plans that need to be sustained with long term funding

In general, there is a strong need to extend the INTAROS observational concept of essential ocean variables (EOV's) to other hot spot areas in the Arctic as well. The north of Svalbard section is critical in the sense it measure the mass, heat, salt, carbon transport and transport of other important substances like nutrients or biological matter (organisms) from the North Atlantic Sector into the Arctic Ocean. Advection together with air sea exchange control the rate of ocean acidification and particular the effect on omega for aragonite and calcite, that are particular critical for ecosystems in the Arctic domain due to the low buffer effect in cold water regimes. In conclusion the north of Svalbard section is one of the key areas to observe the ongoing Atlantification of the Arctic Ocean and need to be sustained for a long term.

There is also a strong need to monitor the transformation of Arctic Ocean waters also as a function of runoff from the Russian river systems that will bring dissolved carbon and methane from the melting permafrost areas on land into the Arctic ocean, an additional mechanism to increase the rate of change of ocean acidification and can potentially contribute severely to the increase of atmospheric GHG content. The INTAROS technical concept can be a valuable platform to studies changes in these systems as well but will require a close cooperation with our Russian colleges and sustained funding.

Short term plans based on the redeployment of moorings by INTAROS partners based upon existing funding

UiB-GFI

Water isotope observations

Future plans are to quantitatively assess the representativeness of the Arctic hydrological system in terms of stable isotope composition, in particular in comparison to conventional atmospheric variables.

Make unattended and robust installations of meteorological sensors on ships, perform auxiliary sea-ice observations from a still camera system and formulate recommended best practices regarding the underway sampling of the water isotope measurements for the coupled Arctic hydrological system for future operationally deployable systems.

Biogeochemistry observations

We are continuing our biogeochemical measurements during the second field season with a series of three SAMI-pH and three SAMI-CO_2 sensors on the NERSC-4 mooring north of Svalbard (82°06.5'N, 26°19.5'E). A pH and pCO_2 sensor will be placed at 47, 155 and 305 metres below the surface. This mooring was deployed from the KV Svalbard during the INTAROS/CAATEX cruise in August 2019 and will be retrieved at approximately the same time in 2020.

Physical oceanography and sea ice observations

Redeployment of the Nortek Signature 250 AD2CP for ocean currents and sea ice monitoring will be performed on RV Kronprins Haakon in November 2019.

IOPAN

The IOPAS moorings at the INTAROS line along 22°E and at the A-TWAIN line along 31°E will be redeployed in November 2019 during the A-TWAIN cruise on RV Kronprins Haakon for the third one-year long deployment period under INTAROS. Recovery of these moorings is planned for summer 2020 with KV Svalbard. Further implementation of the IOPAN moored system north of Svalbard beyond 2020 depends on future projects and availability of internal funding as no sustained funding is secured for this activity on a long-term basis.

NIVA

No plans for further implementation of the sampling system.

IMR

The Nortek Signature100 for ocean currents and biological monitoring will be deployed in November 2019 alongside the A-TWAIN mooring array at 31° E on the 800 m isobath. Recovery and redeployment are planned for late summer 2020.

AWI

Following data download and maintenance, another year-long field season in the A-Twain mooring array is planned, starting in late summer 2020. If possible, the system will be deployed in 2020 and connected to a profiling CTD, providing regular depth profiles of the particle and zooplankton distribution throughout the year.

UNIS

Decisions on redeployment will be taken when the mooring is revered safely.

CNRS-LOCEAN

Documenting and explaining the nature of the observed variability will be made possible by considering the spatial context offered by the different moorings of the 22°E array. The challenges are to better understand the annual cycle as well as shorter term events, to disentangle the origin of the ventilated bottom waters with regards to the source regions (local, upstream in the boundary current, over the shelf or off-slope) and the responsible mechanisms (mixing, lateral advection, upwelling, eddies), and to evaluate the role of the ocean variability in the sea ice distribution.

During the second field season, we plan to maintain the two mooring sites on the upper and mid-slope in order to be able to contrast different years and assess the robustness of the features observed during the first period over the upper slope. Winter sea ice conditions in 2018 were relatively light on average and it will be of upmost interest to check how the 2018 ocean conditions compare with conditions observed in the following winters. To this aim, the moorings to be deployed next year will incorporate an upward looking transducer at the top of the mooring lines in order to measure ice draft and drift velocity.

NERSC

The implementation of the CAATEX system is described above. This system will be recovered in 2020 together with the INTAROS mooring NERSC-4. Ship time is applied for and will include an oceanographic section starting as far north as possible and between the NERSC moorings and if time allows into the shelf areas.

GEUS and UiB-GEO

The processing of continuous data is ongoing as described in two steps. At the same time, in the second part of the cruise in August 2019 from ACC MOSBY, the recovered instruments were prepared for another deployment in Storfjorden (South of Svalbard) in cooperation with the EPOS-Norway project funded by the Norwegian Research Council (Figure 2.9.13). Seismic activity in Storfjorden increased after a Mw 6.2 event on 21. February 2008. The seismicity is persistent until present and nearby continuous monitoring of the region is an interesting and important target in Norwegian territory. The recovery of the Storfjorden network is planned for summer 2020.

4. Summary

The main goal of Task 3.2 in the reported project period was to implement the INTAROS multidisciplinary moored observing system north of Svalbard along 22°E for continuous measurements during the first INTAROS field season. The INTAROS moored array builds on and significantly extends the existing infrastructure of the A-TWAIN oceanographic moorings. To extend capacity of current local platforms focused on specific measurements (mostly of physical variables) towards multidisciplinary observations, a rich suite of multidisciplinary sensors and samplers have been developed or carefully selected from existing mature technologies and integrated in the moored array. The main focus was on establishing a system of autonomous sensors and instruments installed on moorings and/or mounted at the seabed, collecting year-round measurements. Single moorings were already deployed during the INTAROS pilot phase in 2017-2018 and the first deployment of the full system took place in 2018-2019 during the first INTAROS field season. Despite extremely difficult ice conditions in summer and autumn 2019 in the region north of Svalbard, all INTAROS moorings were successfully recovered during three cruises, one with the Norwegian Coast Guard icebreaker (KV Svalbard in August/September) and two with the research icebreaker (RV Kronprins Haakon in September and November). The last-minute message came during finalizing this deliverable that three remaining INTAROS moorings were successfully recovered during the RV Kronprins Haakon cruise that ended on November 28. One INTAROS mooring located at the depth of 1500 m could not be recovered on any of the above cruises due to heavy ice cover and will remain in water until 2020. Nearly all instruments and sensors recovered in 2019 provided time series of measured variables, resulting in the most comprehensive data collection from the area north of Svalbard, covering the whole annual cycle of physical and biogeochemical variability. However, it has to be highlighted that during a year with severe sea ice conditions north of Svalbard, the moored array can be turned around only with the use of vessels with icebreaking capacity.

The processing of collected data is going on, according to the best practices documentation and methodology for each measured variable. All data will be quality-controlled and archived in standarized formats dedicated to individual data set. Derived data products will be obtained and stored together with measured properties. quality of the date now needs to be assessed and best practices methods for data handling will be used. Data processing and standarization will follow the procedures developed for data handlining in WP5 and final data sets will be submitted to the relevant international databased as PANGAEA, ICOS-RI, SeaDataNet, EMSO-RI, ICES, and others. The final data sets from the first INTAROS field season will contribute to multidisciplinary studies, covering atmospheric processes (based on stable isotope measurements of water vapour), evolution of sea ice cover, oceans physics and dynamics, marine biogeochemistry and Arctic marine ecosystems.

The design of an observing systems in WP3, including the moored observatory north of Svalbard, partially stems from the assessments and gap analyses performed in WP2. However, due to the overlap in time between these two WPs and results from WP2 not being yet available during the design phase of WP3, the choice of new sensors and observing technologies was to a high degree based on initial analysis of existing observations and identification of the missing ones in the region north of Svalbard, done within Task 3.2. After a release of the final WP2 assessment of the ocean and sea ice observing systems we can conclude that sensors and technologies selected for enhancing the observing system north of Svalbard will provide observations required to fill some of the main gaps identified by WP2.

Newly collected physical, biogeochemical and biological data will be preprocessed under WP3 to provide standardized data products ready for integration in WP5, use in demonstration actions in WP6, and for the consultations with stakeholders (WP7).

Result that are applicable for the society will be disseminated through WP4 and WP1. Final results and recommendations that will be summarized in the final set of deliverables after two field seasons of INTAROS measurements, will also provide a valuable tool for Task 1.5 activities. They will contribute to establishing a Roadmap towards the sustained Arctic observing system that will be capable to provide observations of climate and environmental change that might have significant socioeconomic impacts in the Arctic region.

5. Literature

Biard, T.; Stemmann, L.; Picheral, M.; Mayot, N.; Vandromme, P.; Hauss, H.; Gorsky, G.; Guidi, L.; Kiko, R.; Not, F. (2016): In situ imaging reveals the biomass of giant protists in the global ocean. Nature: 7600. 504-507.

Christiansen, S.; Hoving, H.-J.; Schütte, F.; Hauss, H.; Karstensen, J.; Körtzinger, A.; Schröder, S.-M.; Stemmann, L.; Christiansen, B.; Picheral, M.; Brandt, P.; Robison, B.; Koch, R.; Kiko, R. (2018): Particulate matter flux interception in oceanic mesoscale eddies by the polychaete Poeobius sp.. Limnol. Oceanogr.: 63. 2093–2109.

Kiko, R.; Biastoch, A.; Brandt, P.; Cravatte, S.; Hauss, H.; Hummels, R.; Kriest, I.; Marin, F.; McDonnell, A. M. P.; Oschlies, A.; Picheral, M.; Schwarzkopf, F. U.; Thurnherr, A. M.; Stemmann, L. (2017): Biological and physical influences on marine snowfall at the equator. Nature Geosci: 11. 852-858.

Picheral, M. (2010): The Underwater Vision Profiler 5: An advanced instrument for high spatial resolution studies of particle size spectra and zooplankton. Limnol. Oceanogr. Methods: 9. 462-479.

Picheral, M.; Colin, S.; Irisson, J.-O. (2017). EcoTaxa, a tool for the taxonomic classification of images. http://ecotaxa.obs-vlfr.fr.

Polyakov, I. V, Pnyushkov, A. V, Alkire, M. B., Ashik, I. M., Baumann, T. M., Carmack, E. C., et al. (2017). Greater role for Atlantic inflows on sea-ice loss in the Eurasian Basin of the Arctic Ocean. *Science (New York, N.Y.)*, *356*(6335), 285–291. https://doi.org/10.1126/science.aai8204

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