Integrated Arctic Observation System

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Deliverable 3.8

First implementation and data: Fram Strait

Data delivery and report on results of the observing systems in Fram Strait

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EXECUTIVE SUMMARY

This document presents the state-of-the-art in the implementation of new observing systems developed within the INTAROS project as well as the optimization of existing systems in Fram Strait. In addition, it reports on results from the observing systems and describes ways for the delivery of data retrieved by these systems.

AWI developed the experimental system arcFOCE (arctic Free Ocean Carbon Enrichment) that enables scientists to study impacts of ocean acidification on small, sediment-inhabiting deep-sea organisms. arcFOCE was deployed for its first long-term experiment in September/October 2018 in 1500 m water depth at the LTER observatory HAUSGARTEN. In August/September 2019, a ROV was used to take sediment samples to study anticipated changes in bacterial and meiofaunal numbers, biomasses and community composition due to artificially reduced pH values in bottom waters. Because these analyses are extremely time-consuming, data from the experiment will be available not before mid 2020. All data from the arcFOCE experiment will finally be stored in the PANGAEA data repository.

RNS-UIEM installed a passive acoustics system at Kongsfjorden, Svalbard, which is identical to another system already deployed and running in Greenland, to allow direct comparison of results from these monitoring systems in western and eastern part of the Fram Strait. Acoustic data from the two systems will finally be available via SEANOE (https://www.seanoe.org) or SEXTANT (https://sextant.ifremer.fr/).

CNRS-LOV continued and improved their measurements at the AWIPEV CO_2 time-series monitoring site in Kongsfjorden, Svalbard. Time-series data generated by in-situ sensors in the fjord and in a Ferrybox flow-through system at AWIPEV is, to our knowledge, the first one at such high frequency. Raw data from the deployed sensors are available in near real-time: https://awipev-co2.obs-vlfr.fr . Data will be quality-controlled and uploaded to the World Data Center Pangaea in 2019-2020.

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1. Introduction

Observing systems implemented by INTAROS in the Fram Strait, including Svalbard fjords, encompass a moveable experimental set-up to study impacts of ocean acidification on benthic organisms and communities was implemented to extend the observational capacities at the LTER (Long-Term Ecological Research) observatory HAUSGARTEN in Fram Strait, a passive acoustic system to monitor the activity of benthic species (bivalves) and sounds produced by icebergs (including localization and detection), and autonomous systems to conduct real-time measurements of pCO_2 and pH measurements, supplemented by weekly discrete measurements of dissolved inorganic carbon and total alkalinity.

The autonomous arcFOCE (arctic Free Ocean Carbon Enrichment) system will build on an existing deep-water system at MBARI, but will be adapted to greater water depths (4000 m), extremely low temperatures (< 1°C), and autonomous operation (in contrast to the MBARI system, no cable connection to land). The arcFOCE deep-water system will add to other currently existing moored observations on the shelf and in the Arctic fjords on western Svalbard. The directional acoustic system with hydrophones was deployed in Kongsfjorden to match a similar system on the Greenland side, while continuous measurements at the AWIPEV Underwater Observatory in Kongsfjorden provide the first time-series for the carbonate chemistry of Arctic coastal waters.

This report gives an update on the level of implementation of the observing systems as well as information on data delivery and the reporting on results from these systems.

2. First implementation and operational use of the observing systems in Fram Strait

2.1. AWI

Contributors: Thomas Soltwedel, Christiane Hasemann, Jonas Hagemann, Michael Hofbauer, Sascha Lehmenhecker, Johannes Lemburg

2.1.1. Results of the first operational implementation

Within Task 3.3., the AWI developed and implemented an experimental system that enables scientists to study impacts of ocean acidification on small, sediment-inhabiting deep-sea organisms. The so-called arcFOCE (arctic Free Ocean Carbon Enrichment) experimental setup was integrated in a modular free-falling system (GEOMAR Modular Lander, GML) regularly operated by AWI (Fig. 1). The bottom-lander frame is designed to sink to the seafloor unattached to any cable. After a certain time period, mesocosms (40 cm in diameter) integrated in the system are lowered to the sediment surface. The water body enclosed by these mesocosms is subsequently acidified at a certain constant level in time by repeatedly adding in-situ acidified seawater via a pumping system. By the end of the experiment (after several months), sediments and the inhabiting small benthic biota are sampled from the mesocosms using push-corers handled by a Remotely Operated Vehicle (ROV). Afterwards, ballast weights of the bottom-lander are released on acoustic demand and the lander then floats back to the surface by virtue of its positive buoyancy.

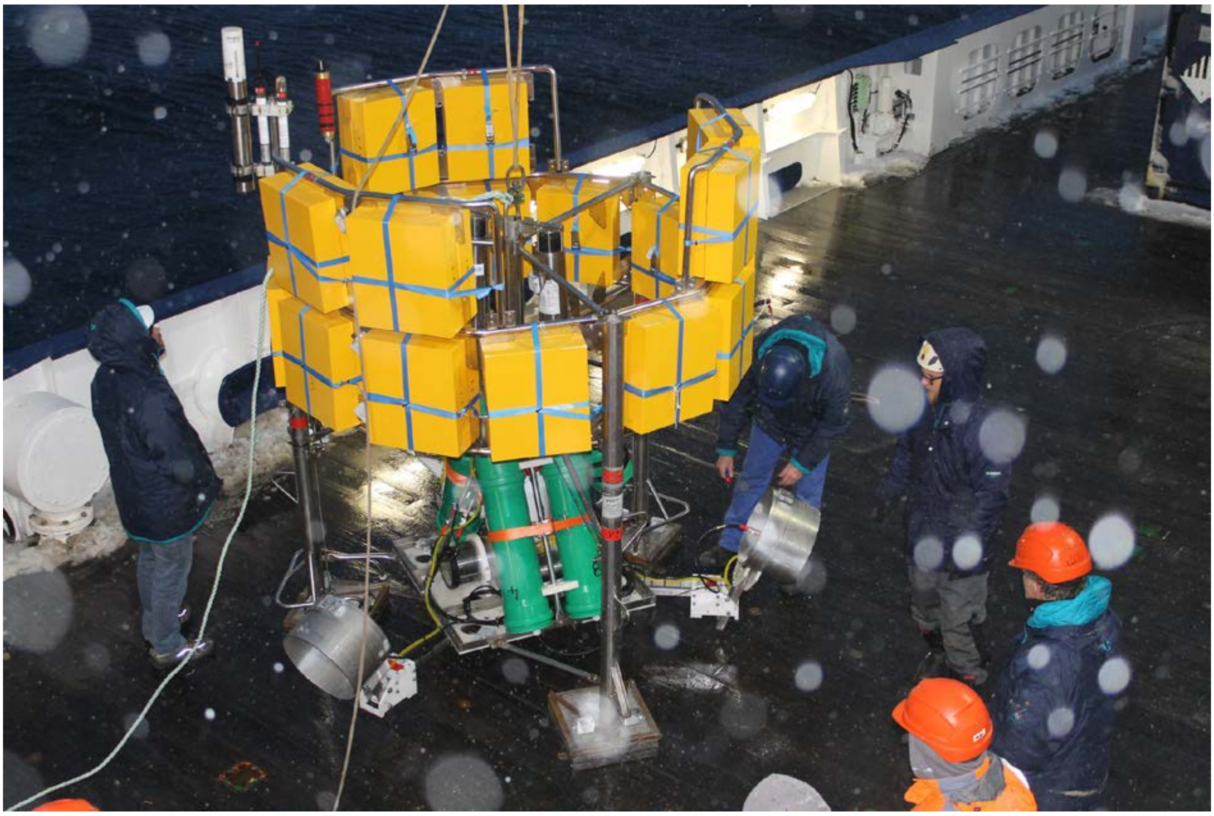

Fig. 1: The arcFOCE experimental setup prior to its first long-term deployment from board RV Maria S. Merian in Autumn 2018.

Acidification of the sediment-overlying water in the benthic mesocosms is done in two steps: In a first step, ambient seawater is mixed in a separate housing to the anticipated (lower) pH values by adding liquid CO_2 from pressure cylinders (Fig. 2a). Subsequently, the acidified seawater is pumped into the mesocosms (Fig. 2h). pH-values in the mixing container and in the mesocosms are constantly monitored by pressure adapted glass pH sensors, which are calibrated in-situ. Pumps are regulated by a PC and special software to keep pH values in the mesocosms at the desired levels. Figure 3 shows a sketch with the main components of the experimental set-up and the control circuit of the acidification system.

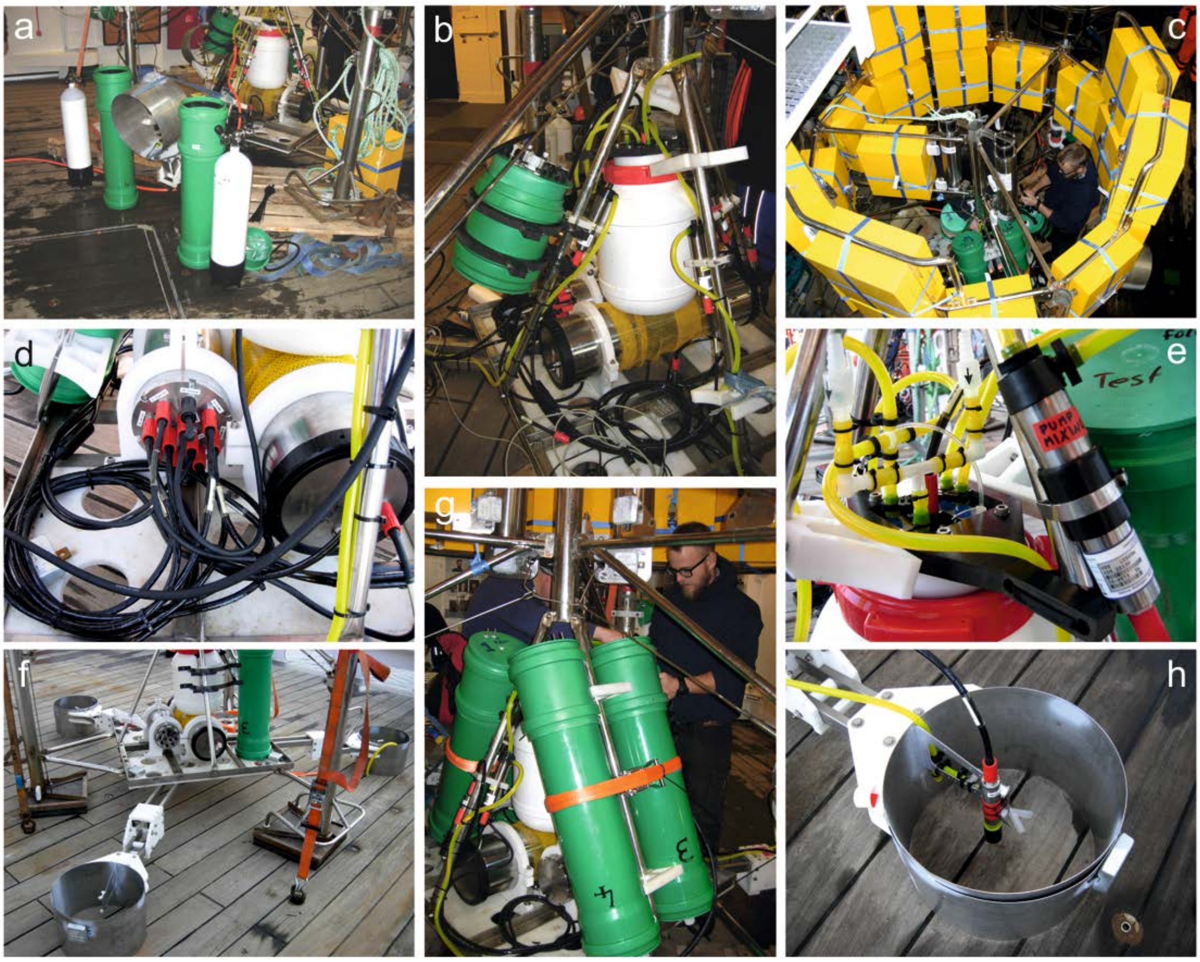

Fig. 2: Details of the arcFOCE experimental setup: a) pressure cylinders containing CO_2, b) in-situ calibration unit (green) and mixing container (white), c) ring of syntactic foam bricks of the bottom-lander system, d) control unit and battery housing, e) pumps delivering acidified seawater to the mesocosms, f) lander frame carrying a total of three mesocosms, g) tubes housing the pressure cylinders, and h) pH sensor in one of the mesocosms.

Following some short-term test deployments of a few days each to check the general performance of the system, the arcFOCE experimental setup was finally deployed for about one year during the RV *Maria S. Merian* expedition MSM77 (15.09. – 13.10.2018; Longyearbyen – Tromsø) at station HG-II (1500 m water depth) of the LTER (Long-Term Ecological Research) observatory HAUSGARTEN. As the amount of CO_2 in the pressure chambers was limited, acidification of the sediment-overlying waters in the mesocosms was pre-programmed to start beginning of February 2019, to ensure still lowered pH levels by the end of the experiment in summer 2019. Consequently, the initial long-term experiment lasted for approx. 6 months.

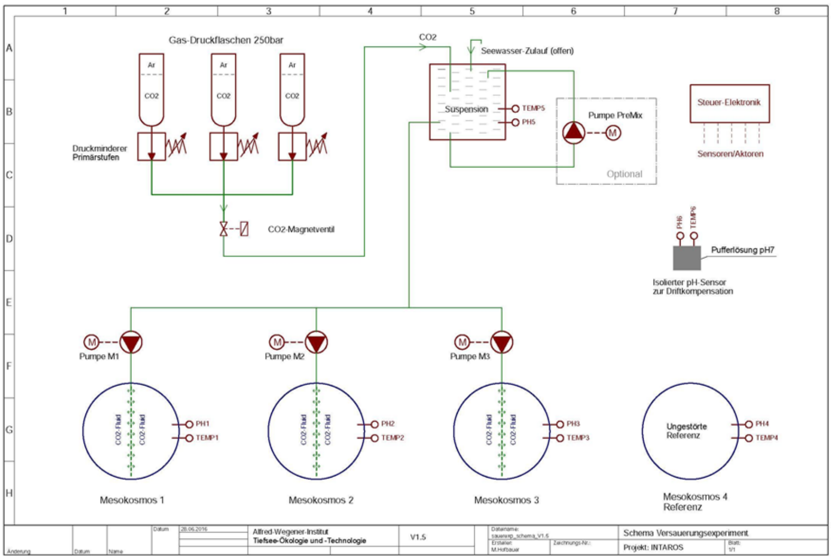

Fig. 3: Sketch showing the main components of the experimental set-up and the control circuit of the acidification system.

Sediment sampling inside and outside (as controls) of the mesocosms was conducted during RV *Polarstern* expedition PS121 (10.08. – 13.09.2019; Bremerhaven – Tromsø) using push-cores handled by the Remotely Operated Vehicle PHOCA of the GEOMAR Helmholtz Center for Ocean Research in Kiel, Germany (Figs 4, 5). Subsamples from the sediment cores will be analyzed for bacterial and meiofaunal numbers, biomasses and community composition as well as a number of sediment parameters (e.g. organic carbon content, total microbial biomass).

Fig. 4: Deployment of the ROV PHOCA during RV Polarstern expedition PS121.

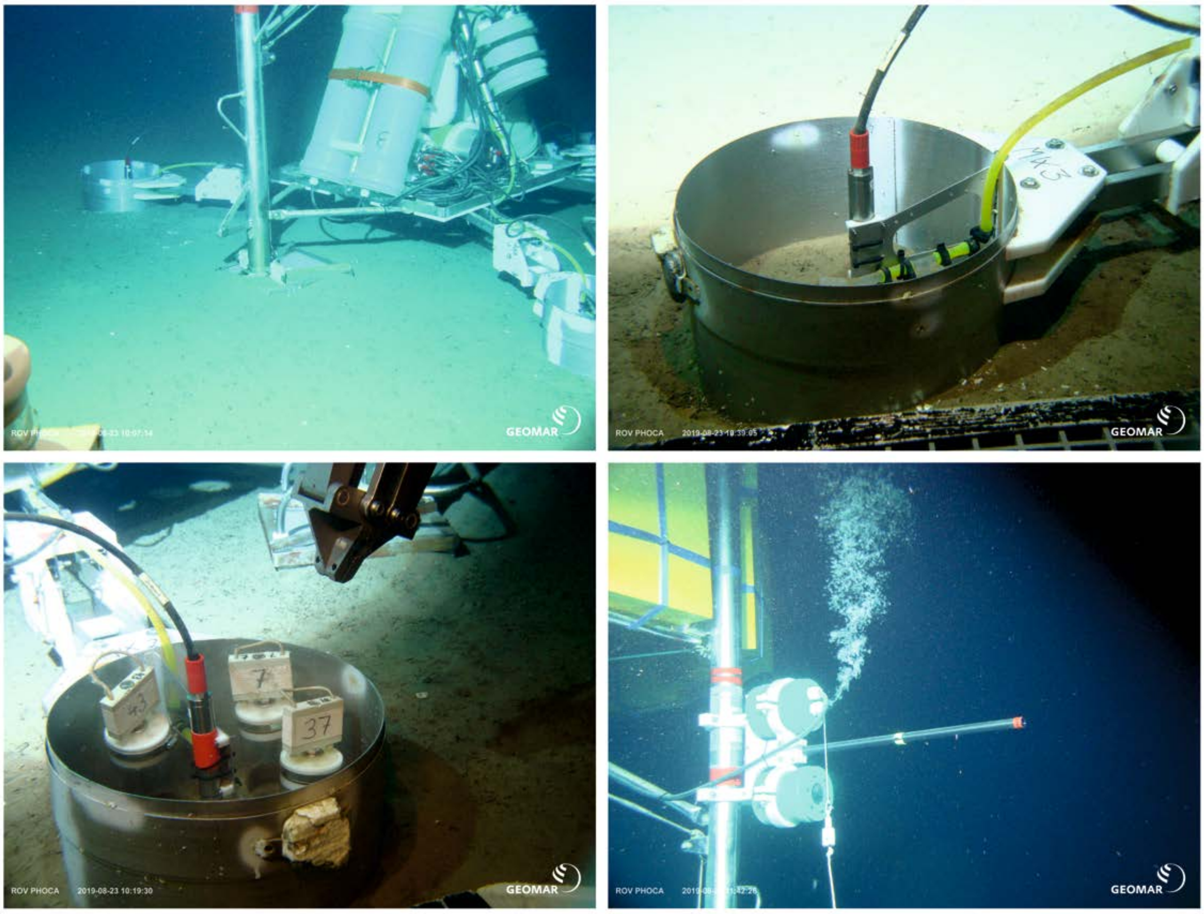

Fig. 5: Sampling of the arcFOCE experiment during RV Polarstern expedition PS121: experimental setup at 1500 m water depth in Fram Strait off Svalbard (top left), close-up of one of the mesocosms perfectly in place at the seafloor (top right), sediment sampling inside a mesocosms using ROV-handled push-corers (bottom left), blowing off excess CO_2 before recovering the bottom-lander (all images copyright GEOMAR).

2.1.2. Description of provided data

The analysis of sediment samples from the initial acidification experiment will start in November 2019. First data on expected differences in bacterial and meiofauna densities, biomasses and community composition due to reduced pH values inside the mesocosms compared to surrounding sediments are expected for mid 2020. Background data, including information on various biogenic sediment compounds indicating the ecostatus at the experimental site as well as hydrographic data from the larger area, result from the regular sampling campaigns to LTER observatory HAUSGARTEN, and could be found at <https://catalog-intaros.nersc.no/dataset?tags=HAUSGARTEN>

2.1.3. Plans for the final implementation

The arcFOCE system is designed as a moveable system to be used in repeated experiments at different locations and varying water depths. Results from the first long-term deployment in 2019 will be used to optimize the system for future experiments. As we will have no access to sea-going expeditions in 2020, the next arcFOCE deployment is foreseen for a RV *Polarstern* expedition in summer 2021.

2.2. CNRS-UIEM

Contributors: Laurent Chauvaud, Erwan Amice, CNRS-IUEM; Delphine Mathias, Aurélie Jolivet, SOMME

2.2.1. Results of the first operational implementation

- May 2018: first deployment of long-term acoustic recorders in Kongsfjorden (Svalbard, WP 3.3)

The passive acoustics equipment implemented at Kongsfjorden, Svalbard, was chosen identical to those already deployed in Greenland: four channel acoustic recorder RTSYS EA-SDA14 equipped with HTI-92-WB hydrophones and an additional battery pack suited for long-term deployments.

Two RBR solo3 pressure sensors were also acquired to record tide and swell data during the deployment of the passive acoustic equipment.

The instruments were tested in March 2018 and shipped to Ny-Alesund by IPEV. Laurent Chauvaud, Erwan Amice and Delphine Mathias travelled to Ny-Alesund for 7 days in May 2018 to deploy this equipment for the first operational implementation.

The acoustic recorder and the pressure sensor were deployed at 10 m depth close to Kongsfjordneset point (Fig. 6).

Another pressure sensor was deployed at 10 m depth just outside of Kongsfjorden.

The acoustic recorder and the pressure sensors were set up to acquire data until their recovery September 2018.

- April 2019, October 2019: recovery and re-deployment of long-term acoustic recorders in Kongsfjorden (Svalbard, WP 3.3)

In April 2019 and in October 2019, the acoustic equipment was recovered, the data uploaded and then redeployed at the same location to ensure the long-term acoustic monitoring of the environment. A Loggerhead LS1 acoustic recorder was deployed in addition to the RTSYS EA-SDA14 acoustic recorder in case of battery failure of the RTSYS equipment (Fig. 7).

Fig. 6: Deployment of two acoustic recorders (RTSYS) at 10 m depth close to Kongsfjordneset point.

Fig. 7: Deployment of the loggerhead LS1 acoustic recorder off Kongsfjordneset point.

2.2.2. Description of provided data

- **Analysis conducted on the acoustic dataset**

- Construction of 10 sec spectrograms
- Construction of long-term spectrograms
- Median spectra
- Centiles of Median spectra
- Wideband levels time-series
- Soundscape description and sound dictionary

- **Description of the soundscape diversity**

- Overall sound levels: Long-term spectral averages are registered in several frequency bands (15-100 Hz, 100 Hz-1 kHz, 1 kHz-3 kHz, 3 kHz-10 kHz, 10 kHz-30 kHz)
- Seasonal patterns in the acoustic data are investigated by analyzing daily median band levels in several frequency bands.
- This « reference state » is needed before monitoring changes over time.

- **Data sharing**

The volume of acoustic data acquired so far for Task 3.3 (Fram Strait – Ny-Alesund acoustic datasets and results) is extremely large due to the high sampling rate (800 Gb). We are currently searching a solution for sharing the raw data (or only samples or preprocessed acoustic metrics). The publisher of scientific data SEANOE (https://www.seanoe.org) might be an appropriate solution, otherwise SEXTANT (https://sextant.ifremer.fr/) might be another line to follow (bigger volumes of data are allowed).

- **Dissemination of results in 2019**

Results were presented at the ASSW 19 conference in Arkhangelsk in May 2019 and at the Sea Ice Workshop in Brest in June 2019:

"Arctic and Antarctic soundscapes: contributors and acoustic levels" by
D. Mathias, S. Chauvaud, F. Olivier, A. Jolivet, C. David-Beausire,
M.-N. Houssais, E. Amice, L. Chauvaud

One publication is being prepared for a submission in *Polar Research* or the *Marine Pollution Bulletin*.

2.2.3. Plans for the final implementation

We plan to continue the acoustic monitoring in Kongsfjorden by recovering and deploying an acoustic recorder once a year, using the same deployment location. This will allow us to build a sound level time-series and to monitor anthropogenic noise levels and associated boat traffic in the fjord.

The deployment location (10 m depth, close to Kongsfjordneset point), halfway between the fjord entrance and Ny-Alesund harbor is ideal to record both natural (e.g. benthic animals, marine mammals, wind, ice, water flow) and anthropogenic sound sources (mainly cruise boats of various sizes).

2.3. CNRS-LOV

Contributor: Jean-Pierre Gattuso

2.3.1. Results of the first operational implementation

Below are listed the instruments and measurements performed, with dates of implementation. Other sensors of the AWIPEV Underwater Observatory and Ferrybox such as salinity and temperature are also available.

- The Arctic version of the Contros-Kongsberg HydroC CO_2 FT (Carbon Dioxide partial pressure Flow Through surface water sensor) has been installed before INTAROS began (July 2015). Molecules of dissolved CO_2 diffuse through a thin composite membrane into the internal gas circuit leading to a detector chamber, where the partial pressure of CO_2 is determined by means of infra-red absorption spectrometry. Concentration-dependent IR light is converted into the output signal from calibration coefficients stored in firmware and data from additional sensors within the gas circuit. The measuring range is 200-1000 µatm, resolution is <1 µatm and accuracy is ±1% reading. The sensor is the first instrument in the measuring loop; data are logged every minute. This instrument requires yearly factory calibration; two sensors are available to allow a continuous time series.

- Since February 2016, total alkalinity (AT) is measured every 90 min with a Contros-Kongsberg HydroFIA TA (Total Alkalinity analyzer flow through system). Fifty ml of seawater is filtered (0.2 µm) using a Contros-Kongsberg cross-flow filter and then acidified using dilute hydrochloric acid (0.1 N). CO_2 is then flushed out (open-cell titration) and the final pH measured by means of an indicator dye (bromocresol green) and visible absorption spectrometry. Together with salinity and temperature at the time of measurement, the pH reading is used to calculate AT. According to the manufacturer, the measuring range is 400 µmol kg^{-1} dynamic range, resolution 0.1 µmol kg^{-1}, accuracy 25 µmol kg^{-1} (±1%) and precision 5 µmol kg^{-1} (± 0.2%).

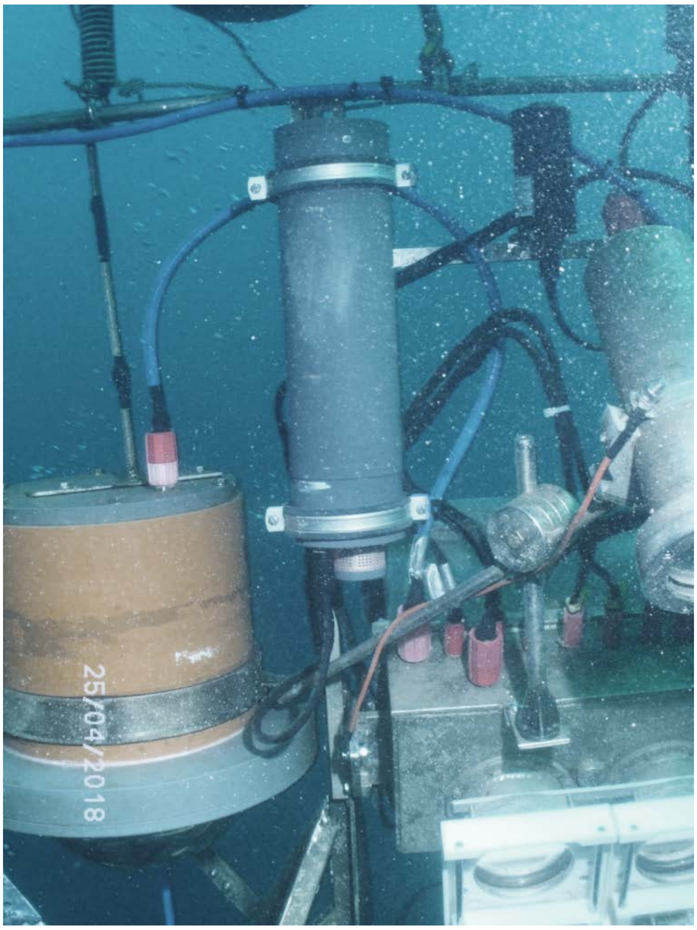

Fig. 8: Sub-sea installation in Kongsfjorden: ADCP profiler, seaFET pH sensor and a camera system (from left to right).

- In August 2017, a seaFET Ocean pH sensor (Sea-Bird Scientific) has been added to the underwater observatory. This new sensor continuously measures pH at 11 m using an ISFET (Ion Sensitive Field Effect Transistor). According to the manufacturer, the measuring range is between 6.5 and 9 pH units, initial accuracy is 0.02 pH units and precision is 0.004 pH units. Operating salinity and temperature range are 20 to 40 PSU and 0 to 50°C respectively.

- In August 2017, a Durafet III pH electrode connected to a UDA2128 Analyzer (Honeywell) was also implemented to the Ferrybox flow-through system. This electrode continuously measures pH, in the Ferrybox, through an ISFET. According to the manufacturer, the measuring range is between 0 and 14 pH units.

- Discrete weekly and monthly samplings for determination of spectrophotometric pH, dissolved inorganic carbon and total alkalinity. Seawater samples are collected weekly. Samples are poisoned with $HgCl_2$ and stored as recommended by Dickson et al. (2007). The Service National Analyse des Paramètres Océaniques du CO_2 of Sorbonne Université (Paris) determines CT and AT potentiometrically (Edmond, 1970). Spectrophotometric pH is measured at CNRS-LOV.

Fig. 9: Ferrybox flow-through system at AWIPEV, including a pCO_2, pH, and total alkalinity (TA) sensor.

2.3.2. Description of provided data

- pCO_2 at 11 m depth measured in Ferrybox (µatm)
- Total alkalinity at 11 m depth measured in Ferrybox (µmol kg^{-1})
- pH measured in situ at 11 m depth (pH units)
- pH at 11 m depth measured in Ferrybox (pH units)

Raw data from the deployed sensors are available in near real-time: https://awipev-co2.obs-vlfr.fr. Data will be quality-controlled and uploaded to the World Data Center Pangaea in 2019-2020.

2.3.3. Plans for the final implementation

These measurements will continue during the lifetime of INTAROS. It is critical to continue this time-series in order to have enough data to be able to estimate long-term trends despite large interannual variability. Other funding is sought to do that.

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

The moveable arcFOCE system will repeatedly be used for experiments at different locations and varying water depths. The next arcFOCE deployment is foreseen for a RV *Polarstern* expedition in summer 2021 in western parts of the Fram Strait. The acoustic monitoring in Kongsfjorden will be sustained by replacing acoustic recorders once a year, always using the same deployment location, to build a sound level time-series of anthropogenic noise levels and associated boat traffic in the fjord. Measurements to assess the carbonate chemistry of Arctic coastal waters at AWIPEV will at least continue during the life time of INTAROS. Other funding is sought to continue this time-series, finally to be able to distinguish between natural and antropogenically-induced changes in the marine carbonate system.

4. Summary

This document describes the progress of work carried out to improve the observational capacities in the Fram Strait region. An experimental setup is developed and implemented to study impacts of ocean acidification on benthic deep-sea organisms and communities at the LTER (Long-Term Ecological Research) observatory HAUSGARTEN. The implementation of a passive acoustics system in Kongsfjorden similar to an existing system off Greenland is completed. New pH sensors were integrated in the AWIPEW CO_2 time-series monitoring site in Kongsfjorden to provide redundancy and increase confidence in the calculations of the various parameters of the CO_2 system in the marine environment. Data from the observatories will be quality-controlled and uploaded to the World Data Center Pangaea as well as the publisher of scientific data SEANOE or SEXTANT.

5. Literature

Dickson, A.G., Sabine, C.L., Christian, J.R. (eds) (2007). Guide to best practices for ocean CO2 measurement. Sidney, British Columbia, North Pacific Marine Science Organization, 191pp. (PICES Special Publication 3; IOCCP Report 8). https://cdiac.ess-dive.lbl.gov/ftp/oceans/Handbook_2007/Guide_all_in_one.pdfhttp://hdl.handle.net/11329/249.

Edmond, J.M. (1970). High precision determination of titration alkalinity and total carbon dioxide content of sea water by potentiometric titration. Deep-Sea Research, 17(4), 737-750, doi:10.1016/0011-7471(70)90038-0.

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INTAROS

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