SSF Ocean Flagship Programme - recognizing the current status of oceanic research in the Svalbard region and neighboring European Arctic

Based on the first Svalbard Science Forum Ocean Flagship workshop held on June 8-9th, 2015 at the Institute of Oceanology PAS in Sopot, Poland.

Editors: Agnieszka Beszczynska-Möller and Hanne Sagen

In June 2015 a Svalbard Science Forum (SSF) workshop was held to discuss the current state and future opportunities for oceanic research cooperation in the Svalbard region and neighboring European Arctic and to initiate the SSF Ocean Flagship. SSF, a part of the Research Council of Norway, financed the workshop through the Flagship Programme.

Twenty scientists (plus four participating remotely) with extensive fieldwork and research experience in the ocean measurements in the Arctic gathered in Sopot, Poland for two days to present their current and planned work, identify gaps in knowledge and discuss the potential for and constraints on collaboration.

The workshop was designed to strengthen collaborative research that focuses on complementarity and incorporates the expertise found in all active research groups, as well as to identify opportunities for joint research activities aimed at reducing the logistical effort related to ocean observations in the high latitude region.

Participating institutions: **Norway**: Nansen Environmental and Remote Sensing Center (NERSC), University of Bergen (UiB), University of Svalbard (UNIS), Norwegian Polar Institute (NPI); Institute of Marine Research (IMR); **Poland**: Institute of Oceanology PAS (IOPAN); **Germany:** Alfred Wegener Institute in Helmholz Centrum for Polar and Marine Research (AWI); **France**: Climate and Environment Science Laboratory CNRS/CEA (LSCE); **Italy**: National Institute of Oceanography and Experimental Geophysics (OGS), Institute of Atmospheric Sciences and Climate (ISAC-CNR); **US**: University of Delaware (UDel).

Workshop background

The SSF Ocean Flagship has been established by three organizing institutes, NERSC, UNIS and IOPAN, and is open to all partners actively involved in the ocean research in the Svalbard region and more generally, in the neighboring European Arctic. The main goal of the SSF Ocean Flagship is to serve as a platform for sharing knowledge and experience and exchanging up-to-date information about all aspects of current and planned ocean observing activities, in particular short- and long-term moored and mobile platforms and repeated field campaigns. The Ocean Flagship main tools include the continuously updated web portal and open workshops for information exchange and joint planning.

Workshop goals

1. To get an overview of current status of *in situ* ocean observations in the Svalbard area and neighbouring European Arctic;
2. To review up-to-date science questions in the Svalbard area and neighbouring Arctic Ocean and how they are addressed by existing and planned *in situ* measurements;

3. To present and discuss existing and required new technologies and infrastructure for the ocean observations in the area of interest;
4. To identify and discuss challenges, needs, gaps and possible solutions in terms of observing system, available and desired instrumentation, field operation logistics, future plans and opportunities for collaborative actions, including future projects and funding opportunities.
5. To work out the general framework and details required for the most efficient setup of the Ocean Flagship web portal under the ArcticROOS with up-to-date information about in situ ocean observations in the Svalbard region and neighbouring Arctic.

Workshop planning group

- Dr. Agnieszka Beszczynska-Möller, Institute of Oceanology PAS, Poland
- Dr Hanne Sagen, Nansen Environmental and Remote Sensing Center, Norway
- Dr Torill Hamre, Nansen Environmental and Remote Sensing Center, Norway
- Dr Eva Falck, University of Svalbard, Norway

Workshop recommendations

Main workshop recommendations are related to implementation of the SSF Ocean Flagship:

- Endorse the long term observations of key parameters concerning ocean climate change
- Promote interdisciplinary ocean observations with emphasis on the impact of climate change on the Arctic ocean environment,
- Develop tools to improve exchange of information on current and planned field activities, infrastructure and available data and metadata in the Svalbard region and neighboring European Arctic.

Table of Contents

1 SCIENTIFIC BACKGROUND FOR THE SSF OCEAN FLAGSGHIP

There is growing evidence that under the recent climate change the Arctic has warmed approximately twice as rapidly as the entire northern hemisphere. Significant changes have been also observed in the Nordic Seas and Arctic Ocean with strong feedbacks to atmospheric warming and changes in large-scale atmospheric circulation. This is particularly apparent in the regions where the warm Atlantic water is transported poleward, including ocean waters west and north of Svalbard and in the southern European Arctic. Observed changes in the oceanic physical and biogeochemical conditions have a strong impact on climate, sea ice conditions and marine ecosystems in the Svalbard area and further north in the Arctic Ocean. However, a deeper understanding of on-going changes requires sustained ocean observations on adequate temporal and spatial scales. While this might be an overwhelming effort for a single institution, the well-coordinated and complementary measurement campaigns and long-term programs agreed between collaborating partners can assure the maximum gain from existing observational platforms as moorings, autonomous drifting buoys or navigated vehicles. The scientific questions, which need to be better addressed by integrating the observational effort and sharing the existing logistics and knowledge, include among others:

- Improved understanding of small and mesoscale ocean variability and its importance for improved parameterization in ocean models and in climate predictions.
- Mass and energy exchanges and dynamic processes in the European Arctic, including Fram Strait and the Barents Sea (vertical and horizontal, on small, meso and large scales).
- Long-term variability of the physical and biological Arctic environment.
- Biogeochemical monitoring and ecosystem research.
- Observations and explanation of changes in migration patterns of marine mammals.
- Improved knowledge about the variability in seismological activity in the Arctic.
- Interactions and feedbacks between ocean and sea ice.

2 CONTRIBUTION TO THE SSF'S STRATEGIC OBJECTIVES

The main goal of the proposed SSF Ocean Flagship is to increase scientific cooperation between all countries and institutions actively involved in the marine research in the Svalbard area, in particular in the coastal areas and the open ocean. At present the individual elements of the ocean observing system in Fram Strait and the European Arctic are mostly project-related and therefore relatively dispersed and independent. Moreover, the information flow between different players in ocean observations is rather limited. To increase the coordination of research activities, in particular those based on *in situ* observations and thus requiring complex field operations and significant infrastructure, the Ocean Flagship will be established as a platform for sharing the knowledge and experience and for exchanging information about all aspects of ocean research around Svalbard. The joint web platform with contributions from all partners of the Ocean Flagship will ensure open sharing of metadata, data and other types of operational information related to

marine research around Svalbard and in the European Arctic. Optimizing the implementation and use of infrastructure for long-term ocean monitoring will contribute to reducing of the environmental impact of field operations in the Svalbard maritime region.

3 THE OCEAN FLAGSHIP PROGRAM

3.1 The SSF Ocean Flagship vision

By bringing together all international partners involved in the long-term ocean observations around Svalbard a new SSF flagship program has been initiated for scientific cooperation focused on physical oceanography, biogeochemistry, marine biology and ecosystem studies in the European sector of the Arctic Ocean.

The Ocean Flagship covers all components of *in situ* observing system for the ocean around Svalbard including moorings, landers and bottom anchored buoys. Mobile platforms, both drifting (surface and ice buoys and floats) and navigated (gliders) will be also included. Repeated ship-based surveys should be also addressed in terms of mooring field operations (deployments, recoveries) and provision of complementary data.

After joint efforts undertaken during the last IPY (2007/08), a currently existing network of collaboration is significantly fragmented and organized within specific projects. There is a significant lack of information transfer and knowledge exchange about on-going field activities between institutions involved in the long-term ocean observations in the Svalbard region. The proposed SSF Ocean Flagship program will complement the existing Flagship projects, focused on terrestrial, atmospheric and glaciological research on Svalbard, by adding the joint effort focused on the key component of the Arctic environment - the ocean around Svalbard and beyond, including neighbouring waters of the European Arctic.

3.2 Main goals of the SSF Ocean Flagship

The new SSF Ocean Flagship program aims in:

- Strengthening of the ocean component in the Svalbard Integrated Observing System (SIOS) and the Arctic component of EuroGOOS – the Arctic ROOS (http://arctic-roos.org);
- Enhancing the collaboration between groups of researchers from different institutions and countries, working on variability of physical and biological ocean environment around Svalbard and in the European Arctic and facing similar scientific and logistical challenges;
- Optimal exploiting of available oceanic platforms (moorings, drifting platforms, autonomous vehicles), instruments and data sets for monitoring, long-term measurements and process studies in the ocean around Svalbard and beyond;
- Long-term use of new observing technologies for improved spatial and temporal coverage in ocean sciences with an emphasis on multifunctional and multidisciplinary observing platforms (e.g. ice tethered platforms, gliders, moorings);
- Increasing coherence and complementarity in the long-term ocean observations to

address the key questions about the Arctic climate change and related feedbacks and effects on the ocean environment;

- Improving access to and foster further development of the common infrastructure for the long-term ocean observations in the Svalbard region;
- Establishing a joint, state-of-the art web-based platform for exchanging the information about deployed platforms, short- and long-term plans for moored infrastructure, available field cruises for mooring operations, search and rescue opportunities for lost moorings and vehicles, metadata and data sharing;
- Addressing potential joint solutions for the logistic challenges (storage, work space, transportation, and pier capacity) in Longyearbyen in connection to ocean field experiments.

3.3 Main activities undertaken under the SSF Ocean Flagship

The main activities under the SSF Ocean Flagship program are focused on:

- Improving the international and institutional cooperation between research groups, working with moored and mobile ocean observing platforms around Svalbard, through joint workshops and web-based solutions for exchange of information on current and planned field activities and opportunities to co-use the existing infrastructure.
- Providing a thorough review of the current status of the long-term ocean observations from moored and drifting platforms in the European Arctic, in particular in Svalbard waters. It will also include an identification of knowledge gaps and establishing a plan for exchange of knowledge on the physical and biological ocean environment and its changes.
- Recognizing priorities in the ocean observations around Svalbard and provide recommendations for the sustained ocean observatories and data sharing.

The ocean observing system in the Svalbard region and neighboring European Arctic comprises moorings, landers, and drifting and autonomous platforms which are operated by AWI, IMR, IOPAN, NERSC, NPI, UiB, UiT, UNIS, OGS, ISMAR-CNR, LSCE-IPSL, UPMC, UDel and WHOI from Norway, Germany, Italy, France, Poland and US. Those institutions have been invited to join the Ocean Flagship as partners, to participate in the workshops and contribute to all reports and recommendations. The executive partners are NERSC, IOPAN and UNIS.

NERSC collaborates with IOPAN, UNIS, Scripps Institution of Oceanography, Woods Hole Oceanographic Institution, and GFI-UIB on moorings in Fram Strait as part of the UNDER-ICE project. NERSC also collaborates with the Norwegian Defense Research Establishment on collection and analysis of passive acoustic data.

IOPAN collaborates with NERSC on moorings in Fram Strait under the UNDER-ICE project, with IMR and NPI on moorings north-east of Svalbard under the A-TWAIN and PAVE projects and with UNIS on moorings in the Svalbard fjords under the AWAKE-2 project. IOPAN has

also a long-going collaboration with AWI, focused on data from moored array in the northern Fram Strait.

UNIS collaborates with NERSC and IOPAN and the other partners in the UNDER-ICE project, with IOPAN and NPI in the AWAKE-2 project, and with NERSC and the Polar Science Centre, University of Washington on moorings on the Yermak Plateau under the REOCIRC project.

3.4 Connections to other flagships

Connections to existing SSF Flagship programmes have been recognized as follows:

Kongsfjorden system Flagship - the hydrographic and biogeochemical variability in the West Spitsbergen Current and in the shelf waters around Svalbard strongly influences the Kongsfjorden physical environment and fjord ecosystem. Therefore the improved ocean observations around Svalbard will contribute to better understanding of the Kongsfjorden system.

Glaciology Flagship - the inflows of warm Atlantic water into Svalbard fjords may have a profound impact on accelerated melting and calving of tidal glaciers. Therefore ocean observations around Svalbard are important for studies of oceanic impact on glaciological changes in the Svalbard area.

Atmosphere Flagship - the ocean-atmosphere exchanges and processes play a key role for variability in the upper ocean as well as in the atmospheric boundary layer and above. On longer time scales the ocean-atmosphere feedbacks strongly impact climate variability in the Svalbard area. The Ocean Flagship program will contribute to better understanding of ocean-atmosphere interactions and atmospheric variability in the Svalbard region and European Arctic.

3.5 Detailed work plan of the SSF Ocean Flagship

The Flagship Consortium includes the prime institutions within ocean research around Svalbard and is responsible for implementation, development and continuation of the Ocean Flagship. Two workshops have been planned at the beginning and in the final phase of the currently funded period, the first once focused on gathering information to implement the Ocean Flagship and the second one to recognize gaps and provide recommendations for further actions.

The overall applied tasks to be accomplished by the SSF Ocean Flagship are:

1. To gather geographical and technical information about the current status and tentative plans for ocean observations by moored, bottom and drifting platform in the Svalbard region and in the European Arctic.
2. To get an overview, as detailed as possible, on deployed and available instrumentation, including the design/build of a platform. To get overview of field operations (deployments and recoveries) and available ships for potential co-using, in particular in emergency situations or for complementary activities.

3. To identify gaps and overlaps in the ocean observing system and to seek opportunities for joint actions and shared infrastructure. To identify any redundant elements that might be better distributed by agreements between partners and to recognize which gaps in the observing system could be minimized by redistribution of existing means.
4. To disseminate information about on-going and planned ocean observing activities and research programs in the Svalbard maritime region and foster collaboration for establishing new joint initiatives and research networks.

The overall work has been divided onto three main activities, including the initial workshop to collect information and build the partnership, development of the web portal and final workshop to identify gaps in the observing system and provide recommendations for further collaboration and multidisciplinary research. Three main steps in establishing the long-term SSF Ocean Flagship are:

3.5.1 Implementation of the Ocean Flagship

The initial workshop focused on defining how to implement and organize the Ocean Flagship and reviwing the current status of existing and planned moored and drifting installations in the Svalbard area was held on June 8-9, 2015 at the Institute of Oceanology PAS in Sopot, Poland. The initial workshop was organized to establish the collaboration between potential partners under the Ocean Flagship. The goal was to invite and gather the main players in ocean research in the Svalbard region, including coastal areas and the open ocean and to exchange information on on-going activities and plans of different institutions. The main focus of the initial workshop was on:

- Establishing the updated and possibly most complete overview of on-going observational activities in the maritime region around Svalbard.
- Recognizing the possibilities for collaboration in on-going activities and initiate new joint actions.
- Identifying gaps in the on-going observational programs and use this to recognize opportunities for new collaborative projects or *ad hoc* short-term joint field operations.

The workshop provided a detailed overview of on-going activities related to ocean research around Svalbard and in the European Arctic as presented by participants. Other potential partners among institutions not present at the workshop but carrying out the activities relevant for the Ocean Flagship have been identified and will be approached in future. In the next step, information collected during the workshop will be used to set up the Ocean Flagship web portal.

3.5.2 Development of the Ocean Flagship web portal

The next task following the initial workshop is to establish a website for the Ocean Flagship to improve the promotion, data sharing, and coordination of ocean research activities taking place around Svalbard. One of the main goals of the new Ocean Flagship is to collect and disseminate information about the on-going research activities involving ocean observations. The collected metadata and maps for visualization of different activities will

be timely published at the Ocean Flagship website which will provide the first major overview of all research activities involving ocean observations around Svalbard and in the European Arctic. An immediate benefit of the continuously updated website will be in easier and more direct collaboration on field logistics and operations, including ship time and shared used of infrastructure for ocean observations. In this way the research effort of individual partners can be optimized in terms of cost efficiency and a scope of planned field operations. The Ocean Flagship website will also host information about upcoming cruises, deployments/recoveries, and open and future calls for joint proposals and conferences/workshops. The Ocean Flagship website will be linked to the Arctic ROOS web portal and include a metadata repository with descriptions of the collected data sets from the different partners. The metadata will be organized in line with recommendations from ongoing e-infrastructure projects such as SIOS, NMDC (Norwegian Marine Data Centre) and NORMAP (NORwegian Satellite Earth Observation Database for MArine and Polar Research).

3.5.3 'Think Tank' workshop for multidisciplinary ocean research

In the final phase of the current funding period, the Ocean Flagship 'Think Tank' will be established during the dedicated workshop, aimed to improve multidisciplinary research and to increase the social awareness in ocean research. The outcome from the earlier tasks will be used to present an updated synthesis of on-going research, including a gap analysis and recommendation for future research and collaboration. A roadmap for continuation and further development of the Ocean Flagship will be developed. A special focus will be also put on recognizing opportunities and potential mechanism for sustained funding of the ocean observations around Svalbard. This includes the long-term continuation of the Flagship activities and how to link up to SIOS and EPOS infrastructures, and to establish links to international projects and programs. Extra emphasis will also be put on multi-disciplinary ocean research, and strengthening the role of stakeholders in the generation of new projects. The Ocean Flagship final report will contain the synthesis of ocean research in the Svalbard region, including gap analysis and recommendations.

4 OVERVIEW OF ON-GOING ACTIVITIES RELATED TO OCEAN RESEARCH AROUND SVALBARD AND IN THE NEIGHBORING EUROPEAN ARCTIC

The main goal of the SSF Ocean Flagship is to serve as a platform for sharing knowledge and experience and exchanging up-to-date information about all aspects of current and planned ocean observing activities, in particular short- and long-term moored and mobile platforms and repeated field campaigns. The Ocean Flagship main tools include the continuously updated web portal and open workshops for information exchange and joint planning.

The initial Ocean Flagship workshop, held on June 8-9th, 2015 in Sopot, Poland, provided the overview of on-going activities, long-term observations and repeated measuring campaigns, as well as current and foreseen national and international projects, involving ocean observations in the Svalbard region and the neighboring European Arctic.

Details of the ocean research included in the current report are presented by specific activities as originally presented by the workshop participants.

4.1 Physical oceanography in the Greenland Sea, Fram Strait and Svalbard fjords under the long-term AREX observational program (Physical Oceanography Dept., IOPAN, Poland)

Established in 1951 and with nearly 200 employees (with 31 professors in the staff) IOPAN is the largest marine research institute in Poland. Its mission is focused on basic marine research, including the role of the oceans in climate change and its effects on European seas as one of the IOPAS strategic directions. The main areas of IOPAN research activity are the European Arctic Seas and the Baltic Sea. IOPAN is divided into five departments with the large expertise both in environmental observations and state-of-the-art numerical models. IOPAN operates its own research vessel, *Oceania*, well suited for the longer expeditions and multidisciplinary measurements in the subpolar areas. Since 1987 IOPAN has conducted the extensive summer field campaigns in the eastern regions of the Nordic Seas, Fram Strait and Spitsbergen fjords. IOPAN also maintains oceanographic moorings in Fram Strait and northeast of Svalbard. The institute is strongly involved in international collaboration and multidisciplinary research activities in the European Arctic have been carried under national and international projects (VEINS, ASOF, DAMOCLES, IPY-CARE and coordinated by IOPAN Polish-Norwegian projects ALKEKONGE, AWAKE, PAVE, GLAERE, CDOM-HEAT and others).

Main Activities of the IOPAN Physical Oceanography Dept. in the Svalbard region and neighboring European Arctic include open-ocean repeated hydrography, long-term moorings and fjord oceanography. All activities contribute to the Fram Strait ocean observatory in the entrance to the Arctic Ocean. Since 1996 the regular summer hydrographic surveys have been performed every year, covering several sections between the northern Norway and the southern part of the Nansen Basin in the Arctic Ocean. Standard station grid included approx. 200 stations with CTD and LADCP measurements, and VM-ADCP measurements under way and on the stations. In the beginning the grid of stations was more irregular but since 2000 the same stations and sections are repeated every summer and area of measurements have been gradually extended farther north. The most recent grid of stations is shown on Fig. 4.1.

IOPAN hydrographic surveys are done as the part of the statutory long-term observational program AREX (based on national funding) and in the frames of different international projects. In the past AREX observational program contributed to VEINS, ASOF-N and DAMOCLES projects. Currently it is a part of the PAVE project (Atlantic Water Pathways to the Arctic: Variability and Effects on Climate and Ecosystems, 2013-2016) under the Polish-Norwegian research programme.

Standard measurements on CTD stations include temperature, salinity, dissolved oxygen (all with double sensors) and fluorescence (as a proxy for chlorophyll). Additionally in some years nutrients and isotopes (dO18) were analyzed on selected stations. Nutrient and isotopes measurements are not continued due to limited funding but there is possibility to collect samples during future AREX cruises if any partner is interested in joint analysis.

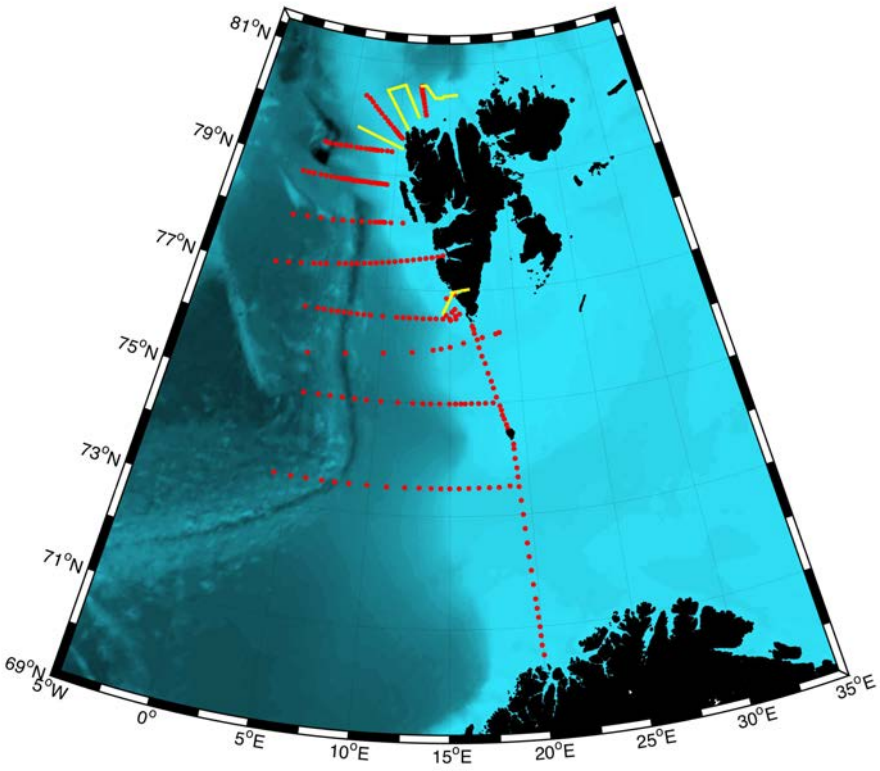

Fig. 1. Standard sections occupied annually during the IOPAN AREX long-term observational program (status 2015). Red dots depict CTD stations, yellow lines towed CTD sections.

In collaboration with the Norwegian A-TWAIN project, two IOPAN moorings have been deployed north and northeast of Svalbard since 2012 from the Norwegian research vessel *Lance*. One mooring was always deployed in the moored array located approx. at 30°E at the outermost position in the array, another one was located in the upstream location, depending on the ice conditions during deployment (at 22°E in 2012-2013, at 16°E in 2014-2015). Both moorings carried the MacLane profilers (MMP providing temperature, salinity and current measurements twice a day within 800m thick layer) and 2-3 TC sensors (SeaBird SBE37), the upstream mooring also carried RDI QMADCP 150 MHz in 2014-2015. Recovery of the array at 30°E was not possible in 2014 due to extremely severe ice conditions and all array moorings were recovered in 2015 after 2-year long deployment. In 2015 one IOPAN mooring equipped with MacLane profiler MMP, acoustic current profiler RDI QMADCP 150 MHz (from NPI) and three TC sensors SBE37 was deployed for two years at the position 81°34.518'N, 030°00.355'E at the water depth of 1210 m as the third mooring in the array. Recovery of the current A-TWAIN array is planned for September 2017. The upstream mooring could not be deployed in 2015 due to malfunctioning of the recovered MMP. The MMP will be repaired and refurbished by manufacturer and the upstream mooring will be deployed from rv *Oceania* during the IOPAN AREX cruise in 2016. There is possibility for collaboration with other partners, interested to deploy their instruments at this mooring.

In next years the annual AREX hydrographic surveys will be continued with more focus on the northern Fram Strait. Earlier section *A* cutting the Norwegian-Atlantic Current at approx. 71°N will be discontinued to use more ship time in Fram Strait and north of Svalbard and to

avoid duplication of the Norwegian measurements. More focus is planned on process studies, depending on limitations of the available ship time.

The proposal is under preparation for the National Science Center (NCN, national funding agency) with the focus on mesoscale structures in the WSC and MIZ. There is also a strong interest to join a larger consortium to answer upcoming H2020 calls. Statutory funding secures the regular hydrographic surveys but do not cover any additional work, i.e. long-term moorings or chemical measurements.

In recent years a few ARGO floats were also deployed by IOPAN in the eastern Norwegian Sea under the international program EuroARGO. In September 2015 two new ARGO floats were deployed from ms *Horyzont II* at the deeper shelf break of the western Barents Sea.

IOPAN research on fjord oceanography in the Svalbard area is focused mostly in the southernmost Svalbard fjord, Horsund. Additional measurements have been performed for last 20 years also in Kongsfjorden and occasionally in Van Mijenfjorden and Isfjorden. Regular hydrographic observations in Horsund had been collected since 1996 and since 2011 they have been augmented by seasonal (spring-autumn) land-based campaigns from the Polish Polar Station in Horsund, including measurements from the small boat, short-term moorings and meteorological observations. Prior 2011 measurements were collected as a part of statutory research program, since 2011 oceanographic research in Horsund has been continued under two Polish-Norwegian projects: AWAKE (2011-2012) and on-going AWAKE-2 (2013-2016). The main focus is on the response of Horsund tidewater glaciers to oceanic forcing in the marine part of a glacier, in particular the impact of Atlantic water warming. A good knowledge about the retreat rate of Horsund glaciers and in general, extensive glaciological and hydrological observations give this location a great advantage. Shallow water moorings occasionally deployed in Horsund included bottom-mounted ADCP and TS sensors for monitoring of the Atlantic water inflow. Deployments of moorings in the glacial bays are high-risk activities, due to likely damage by deep (and often grounded) icebergs from calving glaciers. There is also good data coverage from late spring to early autumn but winter observations are still very sparse. *In situ* observations in Horsund are complemented with high-resolution numerical simulations of the fjord circulation. The AWKE-2 project will be finished in 2016 but ship-borne summer hydrographic measurements will be continued under the long-term AREX observational program. Continuation of measurements covering different seasons depends on availability of future funding.

4.2 Long-term biological observations in the West Spitsbergen Current and the adjacent waters (Marine Ecology Dept., IOPAN, Poland)

Marine Ecology Department of the IO PAN consists of five laboratories (Plankton Ecology Laboratory, Benthos Ecology Laboratory, Laboratory of Functioning of the Pelagic Biocenosis, Laboratory of Paleoceanography and Laboratory of Ecosystem Functioning), which carry on a broad spectrum of ecological research, independently or in cooperation within the Department, the Institute or with other institutions. The laboratories specialize, first of all, in comparative field ecology studies, oriented towards the specific components of

the ecosystem (benthos, plankton) or selected group of organisms (e.g. Bivalves, Copepods). An important aspect of all the studies is biodiversity and its relation to the ecosystem functioning, and ecosystem or biota response to the climate change. What is more, all the researchers consider the taxonomy as an indispensable tool in their research, and everyone is trained in identification of her or his organisms of study.

So far the involvement of the Department units in national and international programs and projects related to ocean observations in the Svalbard and European Arctic regions included, among others, plankton studies in the West Spitsbergen Current (under the umbrella of IOPAN AREX program and the EU FP7 ATP program), in the Spitsbergen fjord Kongsfjorden (within the IO PAN and NPI bilateral cooperation, a part of international KongHau/MOSJ project), on the West Spitsbergen Shelf in Hornsund area (within the IO PAN statutory activity and the Alkekonge Polish-Norwegian Research Programme. There were also long-term studies of benthos in fjords of Spitsbergen (IOPAN statutory activity and cooperation with Akvaplan-Niva) and at deep-sea HAUSGARTEN site (cooperation with AWI).

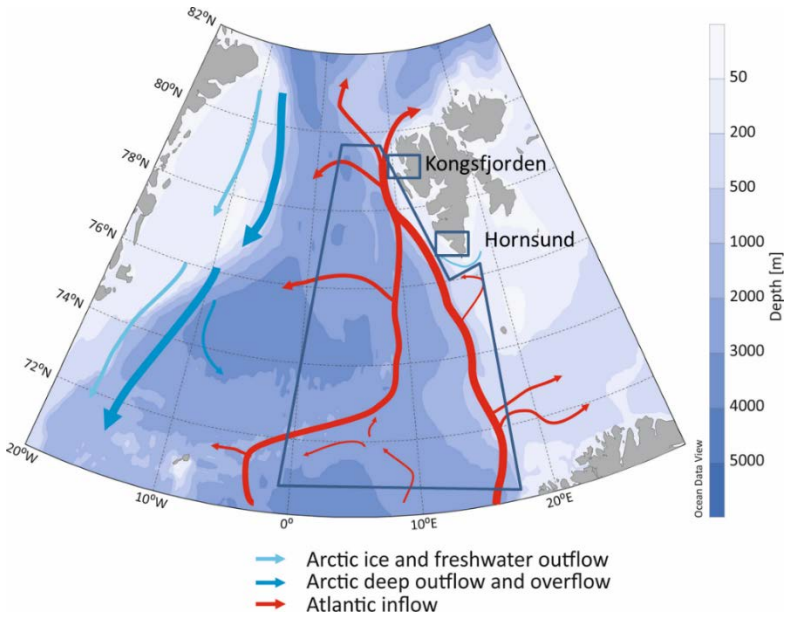

Fig. 2 Map of the West Spitsbergen Current and Fram Strait region with areas of long-term biological observations conducted by research groups from Marine Ecology Department, IOPAN, Sopot.

At present, the following long-term observations are carried out by IOPAN Marine Ecology Department. For the purpose of studies on zooplankton response to climate related environmental changes there are, first of all, observations in the oceanic waters of the West Spitsbergen Current. Sampling in this project is carried on since 2001 (with a historical reference observations from 1987-1989), yearly (in summer), within a month period. Zooplankton samples are collected from rv *Oceania*, on selected AREX hydrographic stations, by means of WP-2 net with 0.180 mm mesh size, from upper 200 m of the ocean, from pre-defined water strata. Furthermore, long-term observations of zooplankton are performed in Spitsbergen fjords Kongsfjorden (since 1996) and Hornsund (since 2001), also yearly and in summer period (July/August). Zooplankton samples are collected primarily

from aboard rv *Oceania* or other research vessels, on fixed long-term monitoring sampling stations (five in Kongsfjorden and six in Hornsund). The sampling toll is Multi Plankton Sampler (MPS), equipped with 0.180 mm net bags and sampling is in pre-defined layers, from the entire water column (bottom-surface). Last ongoing long-term study focuses on zooplankton on the Spitsbergen shelf in Hornsund fjord area. The observations there are going on since 2001, as well in summer. Similarly, main sampling platform is rv *Oceania*, and sampling is planned on a fixed grid of stations. The sampling tool is WP-2 type net with 0,5 mm mesh size, and the zooplankton is collected from the upper 50 m layer of the ocean. As far as it is possible, at all sampling stations the main hydrographic characteristics (temperature, conductivity) of the seawater are measured, either by other research teams or by plankton research teams, using standard CTD water probes. Since 2012 on selected zooplankton sampling stations additional samples (of microplankotn) or measurements (of chlorophyll), important from the point of view of the main zooplankton study, are carried on, however, they are organized on irregular bases due to logistic limitations. Moreover, since 2009 traditional plankton investigations using nets have been supplemented by remote observations using optical methods, with Laser Optical Plankton Counter (LOPC). So far the measurements with LOPC have been made regularly in summer, mainly in Hornsund fjord and the adjacent shelf waters. In 2012 a new plankton study using LOPC and net sampling has been started in the inner part of another Spitsbergen fjord Isfjorden.

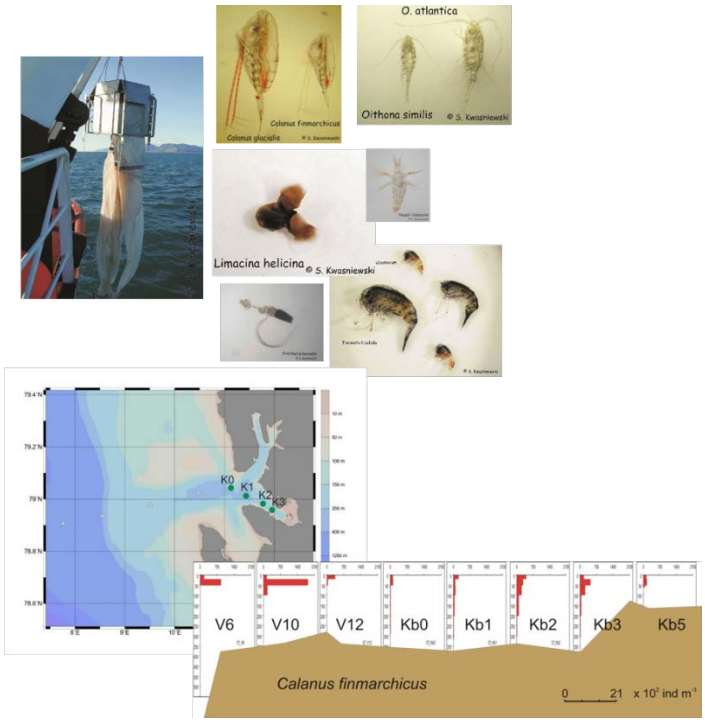

Fig. 3 Long-term observations in Kongsfjorden study area. Sampling strategy (8 stations, vertically stratified sampling), sampling tool (Multi Plankton Sampler), and study objects (various zooplankton taxa, e.g. Calanus finmarchicus and C. glacialis, Oithona atlantica and O. similis, Themisto abyssorum and T. libellula).

Zoobenthos in soft bottom fjord basins (Van Venn grabs - triplicates) has been sampled on 3 stations in Kongfjorden since 1997 and in Hornsund on 3 stations since 2000. Since 2010 the macrobenthic monitoring has been accompanied by sampling of meiofauna and sediment chemistry. Surveys of temporal patterns in benthic fjord communities include also surveys

where historical stations were revisited after a decade or so to study the persistence of spatial patterns assessed based on a larger number of stations. The IOPAN is also involved in monitoring of deep-sea benthic communities in Hausgarten area (regular meiofauna monitoring, snap-shots of macrofauna) that is performed by Alfred Wegener Institute in Bremerhaven, Germany. Additionally at two locations in Isfjorden recruitment and succession is monitored on rocky bottom. It is done by deployment and exchange of Perspex panels on annul basis. The monitoring was conducted for the first time in 2004 and has continued ever since.

Basic information on long-term observations effort by the laboratories of the Marine Ecology Department can be found on the department or laboratories web pages at: http://www.iopan.gda.pl/ekologia/sampling_stations.htm.

Some of the published results of studies dedicated the results obtained during long-term observation projects can be found in the following research articles:

Renaud P.E., Włodarska-Kowalczuk M., Trannum H., Holt B., Weslawski J.M., Cochrane S., Dahle S. and Gulliksen B. (2007). Multidecadal stability of benthic community structure in a high−Arctic glacial fjord (van Mijenfjord, Spitsbergen). Polar Biology 30: 295–305.

Kedra M., Gromisz S., Jaskula R., Legezynska J., Maciejewska B., Malec E., Opanowski A., Ostrowska K., Wlodarska-Kowalczuk M., Weslawski J.M. (2010). Soft bottom macrofauna of an All Taxa Biodiversity Site: Hornsund (77N, Svalbard). Polish Polar Research 31 (4): 309–326.

Carstensen J., Weydmann A., Olszewska A., Kwasniewski S., (2012). Effects of environmental conditions on the biomass of Calanus spp. in the Nordic Seas. Journal of Plankton Research 34(11):951-966.

Kwasniewski S., Gluchowska M., Walkusz W., Karnovsky N., Jakubas D., Wojczulanis-Jakubas K., Harding A.M.A., Goszczko I., Cisek M., Beszczynska-Möller A., Walczowski W., Weslawski J.M., Stempniewicz L., (2012). Interannual changes in zooplankton on the West Spitsbergen Shelf in relation to hydrography and their consequences for the diet of planktivorous seabirds. ICES Journal of Marine Science, 69(5), 890–901.

Weydmann A., Carstensen J., Goszczko I., Dmoch K., Olszewska A., Kwaśniewski S. (2014) Shift towards the dominance of boreal species in the Arctic: inter-annual and spatial zooplankton variability in the West Spitsbergen Current. Marine Ecology Progress Series 501: 41–52.

Most of the long-term observation programs described above, conducted by different laboratories of Marine Ecology Department, IO PAN are planned to be continued, at least in the coming three years. This is the preliminary plan of at least Plankton Ecology Laboratory, conducting long-term observations of zooplankton in the AREX study area, as well as in the Spitsbergen fjords (first of all in Kongsfjorden, if possible also in Hornsund and Isfjorden), and on the Hornsund shelf. The main reason for continuing the observations in this areas stems from the fact, that if one of the periods of cyclic events observed in the system lasts around six years (Kwasniewski et al., 2012), and taking into account that the methodological requirements of the long-term observations, suggesting that the duration of observation of periodic event should include three to five cycles, at least, the observations that started at 2000 should continue until 2020/2030 at minimum.

4.3 Observations of the physical oceanography in Fram Strait, on the East Greenland Shelf, and in the Nansen Basin. Ship-supported ice-tethered observations in the European Arctic (FRAM) (AWI, Germany)

The Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research is Germany's premier high latitude geoscience institute. It employs around 900 persons and operates the icebreaker *Polarstern* as well several other infrastructures. The physical oceanography section has been operating in the deep Fram Strait and the central Arctic for the past two decades. These observational activities have been strongly related to past project, for example the EU-funded DAMOCLES, and currently the BMBF (German science ministry) funded RACE. Buoy activities are connected to the IABP (International Arctic Buoy Programme).

A mooring array across the deep Fram Strait at 78°50'N has been operated since 1997. Its current status in 2014 was as follows: 3 moorings were recovered (F8/15/16; thanks to NPI!), 2 were deployed (F9/10). In 2014 there were propulsion problems with the German ships *Polarstern* and *Merian* impacting the work in the area. Currently, 2 moorings are damaged (F2/9). There will be an ad-hoc cruise participation in 2015 (*Polarstern*) and another ad-hoc cruise in 2015 (*Heincke*). The moorings that are in the water currently likely did not measure the 3+ years that they will have been deployed when they will be recovered. This results in a bigger gap in the time series than what had been achieved 2002-2012.

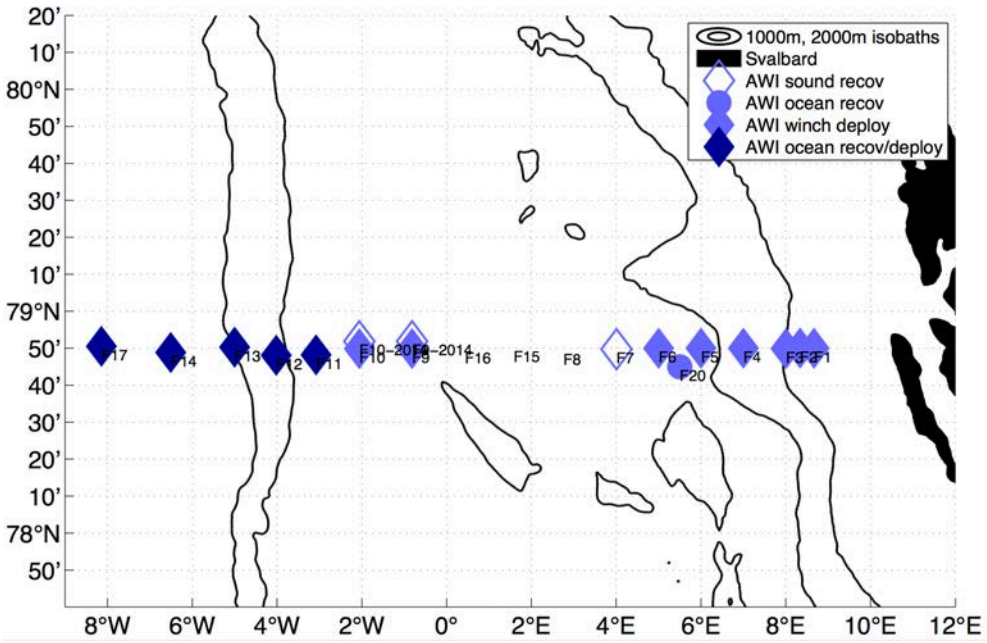

Fig. 4. Location of the oceanographic moorings by AWI and NPI in Fram Strait

The plans for the 78°50'N mooring array are: Moorings F1-6, F9/10 will be continued. The mooring measurements in the center of Fram Strait will not be continued due to the inability to measure the northward component. The Helmholtz large infrastructure investment program FRAM can provide money to keep this up for at least the next 5 years. The plan/hope is for bi-yearly mooring turn-around.

Further activities in Fram Strait in the future are as follows: Mooring F20 with an under water winch will be deployed again. The east-west CTD sections are planned to be occupied bi-yearly. In 2016 there will be a GEOTRACES section along 78°50'N. There are also plans to integrate physical and biological measurements onto the same moorings, but this is complicated by having to decide which group has to move and which group would stay in the previously occupied long-term time series location. Attempts to define the representativeness of the fixed-point observations are also ongoing.

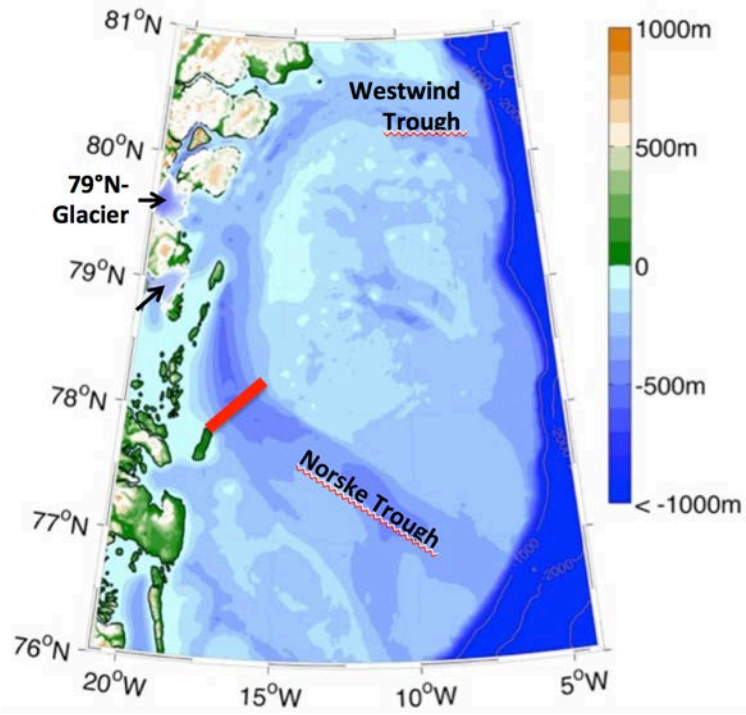

Fig. 5. Location of the mooring line and CTD line across the Norske Trough on the East Greenland shelf.

The East Greenland shelf in the vicinity to Fram Strait and the 79.5N glacier is another region where activities of the physical oceanography section are ongoing and planned. In 2014, a *Polarstern* cruise occupied a CTD section along the fast ice-edge across Belgica Trough. 7 moorings were deployed (2 by AWI and 5 by Andreas Münchow from the University of Delaware). The recovery date of those moorings has not fully been decided with options being 2015, 2016, or 2017. In 2016, a large cruise to the area will happen and the detailed planning for that cruise is currently in process. A cruise in 2017 or 2018 has been applied for, but it has not been announced yet whether the cruise application was successful.

The cruise in 2016 on *Polarstern* will support the oceanographic measurements in the deep Fram Strait, oceanography on the East Greenland shelf, glaciology and oceanography of the floating ice-shelf of 79.5N glacier, as well as glacier glaciology. The chief scientist of that cruise is Torsten Kanzow and he should be contacted if interest in that cruise exists. Some of the groups on board will be the AWI oceanography and the AWI glaciology, as well as University of Delaware and the Woods Hole Oceanographic Institution. There is a lot of logistics associated with that cruise which is why it currently is not clear how much of the initially planned work will finally be possible. It should also be noted that if instruments are

deployed on that cruise that need to be recovered afterwards, another cruise is needed and the *Polarstern* applications for 2017 or 2018 have not been decided yet.

A particular interest on the shelf is the possible pathway that warm Atlantic Water takes to the 79.5N glacier and whether it has the capability to contribute to the melting of the outlet glacier and/or its floating ice-tongue. In order to investigate this, CTD sections and surveys on shelf are planned and moorings will be deployed as close to glacier as possible. Since the bathymetry of trough not well known, activities will be carried out to identify sills. For the warm Atlantic Water to finally reach the glacier, it also needs to flow trough a chain of pinning islands. The bathymetry of those is currently not known and the 2016 cruise will attempt to improve that understanding.

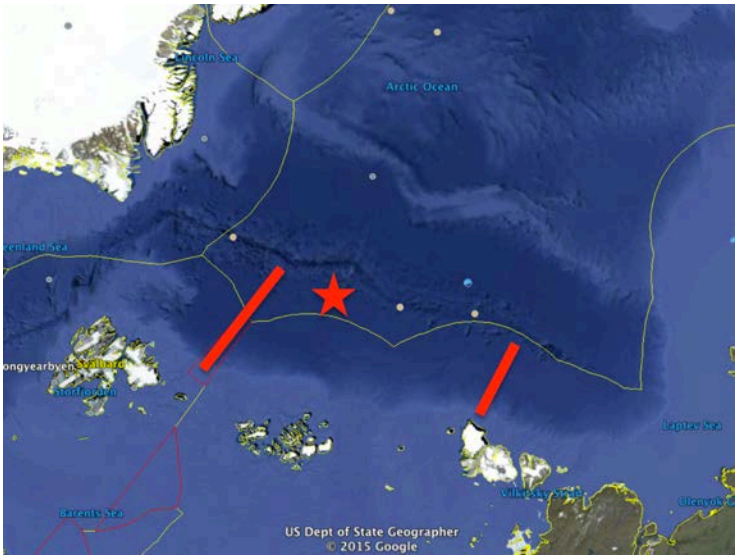

Fig. 5. Location of the A-TWAIN mooring line (no AWI involvement), of the ABC mooring line to be deployed by AWI in 2015, and the individual Central Arctic Ocean mooring to be deployed by AWI in 2015.

AWI activities north of Svalbard in the Nansen Basin include the *Polarstern* cruise TRANSIZ (May/June 2015) during which CTD profiles and turbulence between the Atlantic Water, the halocline, the surface mixed layer and the sea ice will be measured. This will allow to estimate fluxes of heat, salt, nutrients and other biogeochemical tracers. An Arctic Boundary Current Array ("ABC array") will be deployed across the Atlantic Water boundary current north of Severnaya Zemlya. The deployment is planned in 2015 as part of the Russian-US program NABOS.

In Aug/Sep/Oct 2015 *Polarstern* cruise TRANSARC (chief scientist: Ursula Schauer) will obtain CTD profiles across the Nansen, Amundsen and Makarov basins. Further field activities during that cruise are potentially relevant for SSF: the deployment of 2 bio-physics moorings near 60°E 85.5°N, with future recovery and deployment planned on an annual basis for at least the next four years; measurements of geochemical tracers, coordinated with other field campaigns within GEOTRACES. The deployment of several autonomous ice-tethered platforms will contribute to an array of upper ocean CTD profilers, including bio-optical measurements; ice buoys, including ice mass balance buoys, snow buoys; and meteorological buoys. This array, operated arctic-wide by several international partners, has

significantly improved estimates of upper ocean quantities, including variability in the liquid freshwater reservoir on seasonal to decadal timescales. Products derived from these data in combination with other CTD observations can be considered long-term observations and timeseries.

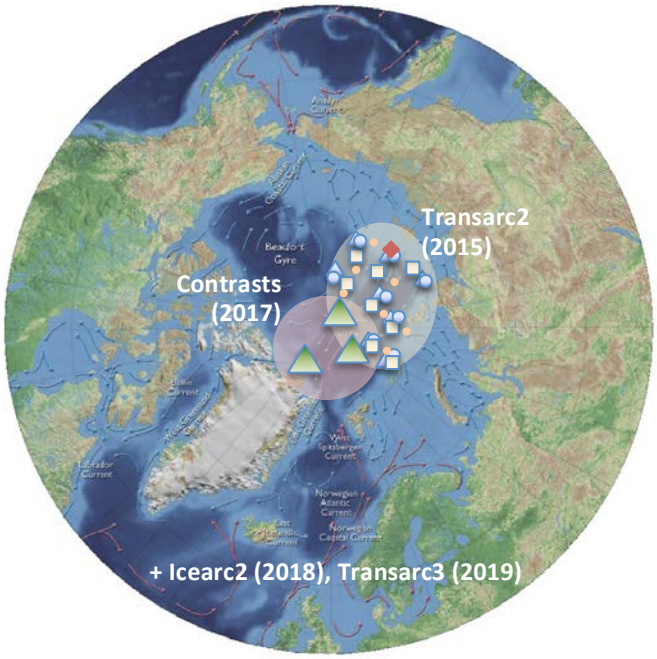

Fig. 6. Planned Polarstern expeditions in the central Arctic and the Fram Strait

Within the Helmholtz/AWI strategic investment for infrastructure the upper ocean measurements within the ice-tethered platform array will be extended by several biogeochemical and bio-optical parameters, including Chl a fluorescence and nitrate. For 2017 two sets of multi-buoy deployments are planned which will include a multitude of physical, chemical and biological parameters to be autonomously measured and sampled on and underneath the same ice floe (Figure 5). The systems are planned to be recovered in 2018 to obtain the samples collected by the autonomous systems. These plans are tentative pending decisions about *Polarstern* expedition proposals.

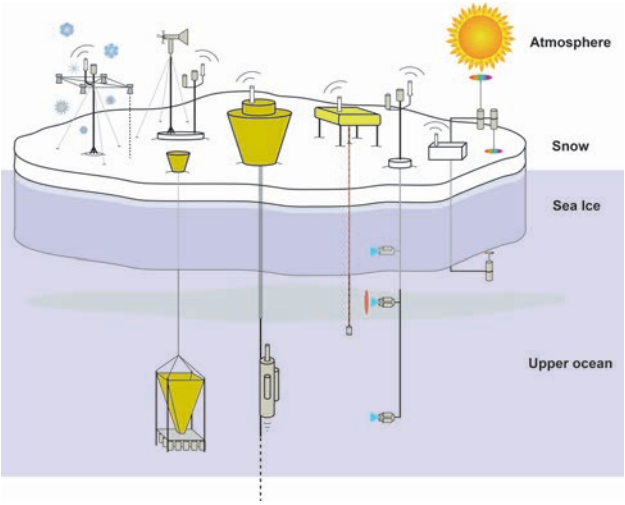

Fig. 7. Sketch of planned deployments of buoys sampling multiple parameters on a single ice floe ("multi-buoy deployments").

Since there is obligation that 50% of participants should be from outside the Helmholz institutes, possibilities exist to apply for *Polarstern* time (participation in a cruise) also for non-German scientists. This is valid for small proposals that can be fitted in the cruise program with few people (on the order of 1-2 days). The schedule of *Polarstern* is published at the AWI website and should be consulted before writing an application. It is also worth to check beforehand with the PI of already accepted proposals whether the requested work could be possibly fitted into the existing schedule and work plan (in such case there is no need to write a separate proposal).

4.4 Multidisciplinary observations in the Fram Strait at the fixed point observatory HAUSGARTEN/FRAM (AWI, Germany)

The Alfred Wegener Institute conducts research in the Arctic, the Antarctic and at temperate latitudes. It coordinates Polar research in Germany and provides both the necessary equipment and the essential logistic back up for polar expeditions. Recent additional research themes include North Sea Research, contributions to Marine Biological Monitoring, Marine Pollution Research, Investigation of naturally occurring marine substances and technical marine developments. The Alfred Wegener Institute (AWI) was established as a public foundation in 1980. It is a member of the Helmholtz Association of German Research Centres; the German Federal Ministry of Education and Research (BMBF) covers 90% of financing, the state of Bremen 8% and the states of Brandenburg and Schleswig-Holstein provide 1% each. The AWI employs over 900 staff and has a total budget of more than 100 million Euro in 2012.

Since 1997 (mooring array) and 1999 (HAUSGARTEN) the Alfred Wegener Institute operates continuous long-term observations of oceanographic and ecologic processes in the Fram Strait around 79°N. Long-term observations in the deep-sea Hausgarten observatory west of Svalbard included 17 stations, including latitudinal South-North and shallow-to-deep sections, established to study shallow pelagic and benthic ecosystems (including Kongsfjorden). Sampling is repeated normally once a year, from sea surface down to sea floor, including visual (optical) investigation of the sea bottom. In 2014 the Hausgarten observations were extended to western part of Fram Strait to get long-term information of changes in the area under influence of polar water (in EGC) down to 2500 m depth. Two moorings were deployed in northern and central part of study area and deep sea in situ experiments were performed with ROV or AUV in central part. In the pelagic zone oceanographic and biological parameters were measured. At the sediment-water interface, most important for benthologists, carbon remineralization and community oxygen consumption were measured. In sediments mostly bulk parameters were measured, including geological parameters (granulometry, porosity, organic C), organic matter inputs (pigments indicating phytodetritus), biomarkers (marine, terrigenous), biomass parameters (proteins, lipids). Benthos observations covered all components of benthic ecosystem: bacteria – meiofauna (nematods) – mega/epifauna – demersal fish (fish traps). Biodiversity, biomass, and dispersion were also addressed, resulting in true multiparameter observations.

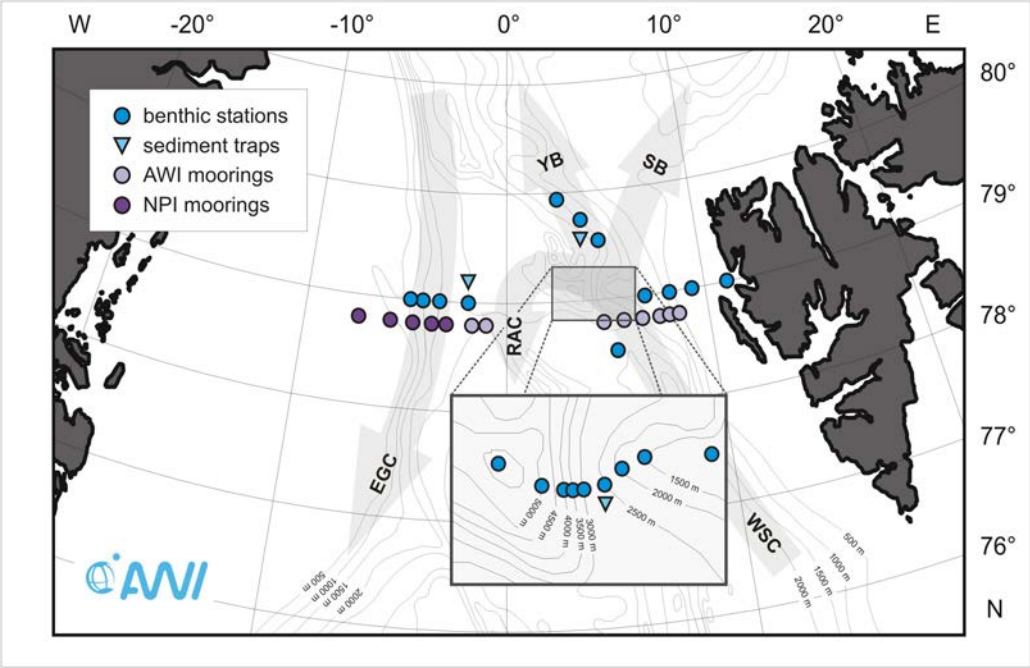

Fig. 8. Schematics of the FRAM observatory

These two long-term observatories, oceanographic moored array and Hausgarten, build the basis of FRAM (Frontiers in Arctic Marine Monitoring). With this research infrastructure project the, until now stationary observations, will be complemented by new mobile components like deep-sea robots, ice-tethered platforms, gliders and autonomously navigating underwater vehicles. They will allow us to have a broader look from the FRAM area out into the central Arctic.

System Status	Operational	**Planned Frequency**	12 month(s)
Platform Required	Deep Sea Research Vessel, Icebreaker	**People Involved**	20
Duration of Operations	14 day(s)	**Cleaning**	Yes
Replacments	Yes	**Download Data**	Yes

Fig. 9. FRAM status/maintenance

FRAM includes the array of moorings and permanent sampling sites across the Fram Strait, installed to capture the exchange of Atlantic and Arctic waters, and to study the temporal development of an Arctic marine ecosystem. It enables year-round multidisciplinary long-term observations, partially with near real-time data access. The main activities under the FRAM framework encompass:

- implementing of observatory platforms, allowing synchronous observation of relevant variables, and to study physical, chemical and biological processes in the water column and at the seafloor;
- implementing experimental and event-triggered platforms;
- providing long-term data with appropriate resolution in space and time, as well as ground-truthing information for remote sensing and ocean models.

FRAM is federally funded for five years until 2019. It is integrated into EMSO, the Long Term Ecological Research-Network (LTER) and the former ESFRI project SIOS (Svalbard Integrated Arctic Earth Observing System). Within the Fixed-point Open Ocean Observatory network FixO3, the FRAM infrastructure provides coordinated, free-of-charge access to external users under the objective of Transnational Access (TNA).

For the time period 2016 – 2019 proposals for main use of RV *Polarstern* for expeditions into Fram Strait and for maintenance of the FRAM observatory are positively evaluated. Aadditional information regarding the FRAM observatory and options for **T**rans **N**ational **A**ccess (TNA) can be found at the FixO3 website: http://www.fixo3.eu/observatory/fram/.

4.5 Study of the dense water flow over the contourite drifts offshore SW Svalbard: the EUROFLEETS2 programme (PREPARED 2014) and planned initiatives (OGS, Italy)

OGS, Istituto Nazionale di Oceanografia e Geofisica Sperimentale (National Institute of Oceanography and Experimental Geophysics) is an internationally oriented public research institution (http://www.ogs.trieste.it/en). The OGS operates and develops its own mission in the European Research Area (ERA) and internationally, prioritizing the basic and applied research fields of Oceanography (Physical, Chemical and Biological), Geophysics and Marine Geology, and Experimental and Explorative Geophysics.

OGS applies its own expertise in Earth Sciences, and in Marine and Polar regions to contribute not only to the dissemination of the knowledge, but also to the practical resolving of environmental, economic and social issues in line with the National Program of Research (PNR) and strategic objectives set by the EU, with particular referral to Horizon 2020. The oceanic research vessel OGS *Explora* is one of the strategic infrastructures of excellence (http://www.ogs.trieste.it/en/content/offshore-operations). The vessel is capable of carrying out operations in the field of Marine Geophysics, as well as in Geologic, Physical, Chemical and Biological Oceanography, in global oceanic areas. However, the ship is employed mostly in the Mediterranean Area and in the Polar regions. A collaboration with European and international institutions, with private high-tech industries and qualified enterprises has been established.

Current long-term observations are carried out in the framework of the PREPARED (PREsent and PAst flow REgime on contourite Drifts west of Spitsbergen) project. The main study area covers the region southwest of Svalbard, Characterized by relatively high and continuous accumulation rates. Stations ID1, ID2, and S1 are located southwest of Svalbard, offshore from Storfjorden, Horsund and Isfjorden (see Fig. 9). Three moorings carrying point current meters, current acoustic profilers, sediment trap and TS sensors were deployed in June 2014

during the Eurofleets2 PREPARED cruise on rv G. O. Sars. Moorings were deployed in 1000-1300 m depth, S1 mooring measured the 100 m thick layer above seabed, and other two moorings monitored the layer of 20-30 m above seabed. Additional measurements collected during the G. O. Sars cruise include CTD measurements at stations and underway (with thermosalinograph and VMDCP), core sampling, micropaleontology, plankton sampling, box cores, piston core, BGC water sampling, multibeam mapping, and sub-bottom profiling. Two moorings (S1 and ID2) were recovered and redeployed in June 2015 by rv *Helmer Hanssen.* Next expected maintenance is planned in summer 2016 (trawling of the mooring ID1, possible redeployment of two or three moorings at the same place until summer 2017).

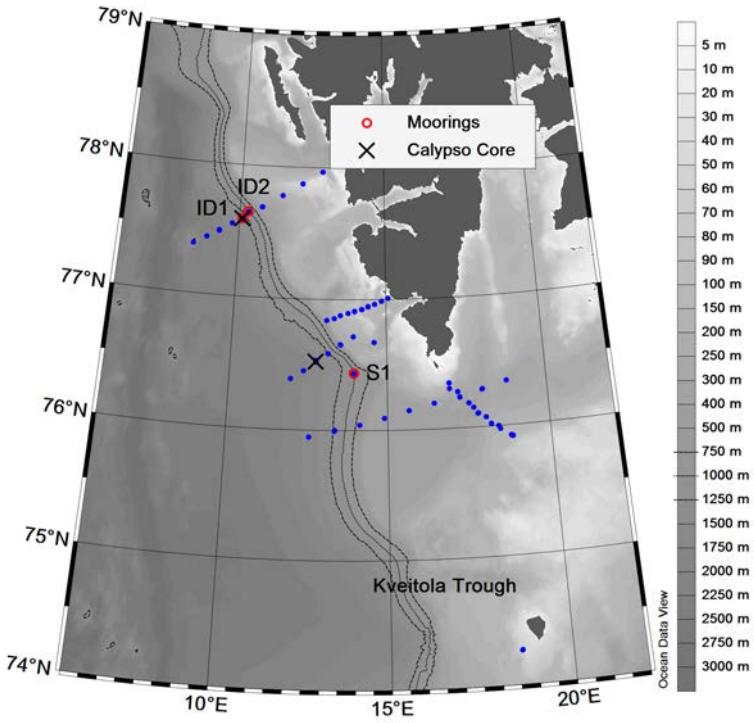

Fig. 10. PREPARED station map: CTD stations (blue dots), Calypso cores on the top of the contourite drifts (black crosses), and three moorings S1, ID1, ID2. Isobaths 750, 1000, and 1250 m are highlighted.

Future plans for ocean observations are based on three projects

1. **EDIPO project**, financed by PNRA, Italy,

Where: sediment drifts offshore Isfjorden and Bellsund, Kveitola Trough (see Fig. 1)

When: 21/9/2015 – 02/10/2015; departure from Longyearbyen, arrival Tromsø

Platform: r/v OGS Explora

Parameters: geophysics (multi channel seismic profiles, sub-bottom profile, bathymetry); oceanography (CTD, XBT, dissolved oxygen, fluorescence, turbidity, underway currents, T and S, microzooplankton)

Partners: Italy: OGS, CNR, INGV; Spain: Univ. Barcelona

6. **BURSTER** (Bottom cURrents in a STagnant EnviRonment) project, Eurofleets 2, Polar and Subpolar call, 2014

Where: Kveitola Trough (see Fig. 1)

When: summer 2016

Platform: r/v Polarstern

Parameters: geophysics (sub-bottom profile, bathymetry), geology (multicore sampling), oceanography (CTD, dissolved oxygen, fluorescence, turbidity, underway currents, T and S, water samples for biogeochemical characterization)

Partners: Italy: OGS, Univ. Pisa, Univ. delle Marche, Univ. Roma, Univ. Parma; Spain: Univ. Barcelona, CSIC Barcelona, Norway: Univ. Oslo;

7. **DEFROST** (DEep Flow Regime Off SpiTsbergen; this project is currently in the evaluation phase at Ministry of Education, University, and Research (MIUR), Italy

Where: Isfjorden and Bellsund drifts (see Fig. 1)

When: 2016-2017

Platform: mooring maintenance 2016 and recovery 2017 in collaboration with partners that conduct research cruises in the area

Parameters: geophysics (sub-bottom profile, bathymetry), oceanography (CTD, dissolved oxygen, fluorescence, turbidity, underway currents, T and S, water samples for biogeochemical characterization)

Partners: Italy: OGS, CNR-ISMAR; International: University of Gothenburg, Sweden, University of Bergen, University of Tromsø and the University Centre in Svalbard, Norway; IOPAN, Poland; potential collaboration AWI, Germany

Areas of potential collaboration in future project and joint fieldwork include mooring outfitting and maintenance, oceanographic campaigns, biogeochemical sampling and other measurements. OGS has an expertise in fields of: thermohaline properties, dense water pathways, temporal variability, small-scale mesoscale dynamics, cascading, C cycling in ventilation areas, anthropogenic CO2 influx in deep water formation areas, planktonic microorganisms in polar regions. Cruise data from past expeditions are saved on the PANGAEA platform.

4.6 Storfjorden polynya multidisciplinary study: from physical processes to its impact on biology and Greenhouse gases (LOCEAN and LSCE-IPSL, France)

The STEP (Storfjorden Polynya Multidisciplinary Study) project evolved from a physical oceanographic study to a multidisciplinary research effort. PIs are Frederic Vivier and Elisabeth Michel. The main focus is on brine formation in a context of physical processes, impact on ocean deep circulation and greenhouse gases cycles, a paleo and future climate perspective. Stofjorden is a long/studied polynya, with past research focused on dense water formation, evolution of gravity-driven plumes, water mass formation, overflow,

mixing and turbulent dissipation, supercooling, polynya dynamics and many other topics. First moored observations took place in 1991-1992 in the Storfjorden outlet.

Activities at LOCEAN Paris were started in 90s by Jean-Claude Gascard, who was the first to investigate this region with Norwegian colleagues. Several IPEV programs followed, e.g. BRINES (2005-2006) and EU DAMOCLES program with Vagabond wintering in Aagardhbukta. The IPEV project IceDyn in 2007 (Vivier and Bouruet-Aubertot) encompassed the ice-T buoy (with A. Lourenco). The current ANR/IPEV project OPTIMISM (2009-present, Vivier et al.) includes a part dedicated to studying and monitoring the Storfjorden polynya.

Studies related to Storfjorden conducted so far in the frame of IceDyn and OPTIMISM projects include internal waves, mixing and turbulent dissipation (Jardon et al., JGR, 2011; Barriquand et al., 2015, CSR), ice production in Storfjorden based on 9 years of AMSRE observations (Jardon et al., JGR, 2014) and full-depth desalination of first-year sea ice (Jardon et al., JGR, 2013). The rich dataset from OPRIMISM cruises is currently being analyzed.

OPTIMISM monitoring program in Storfjorden is motivated by the long history of observations and study of the Storfjorden polynya, making possible to start grasping the long-term changes and relatively easy access. Therefore Storfjorden polynya can be a good candidate for a long-term international observatory, possibly under the SSF/SIOS framework. A physical oceanography mooring located at the depth of 90 m at the position 77°34'N, 017°05'E has been continuously monitoring water mass transformation in the core of the polynya since 2011. Three campaigns have been conducted, sometimes in very harsh conditions (due to limited funding for these specific operations).

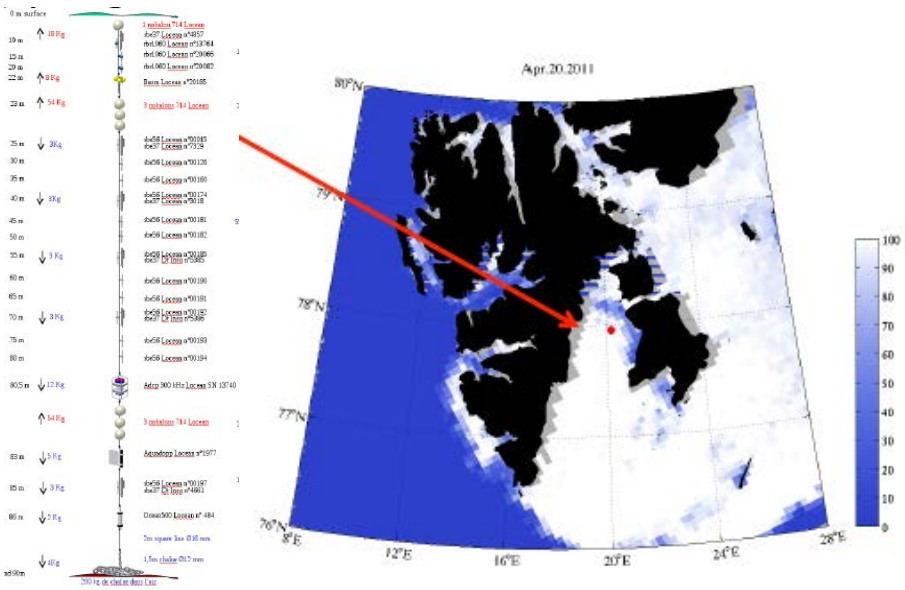

Fig. 11. Location of the OPTIMISM mooring in the Storfjorden polynya

The first mooring deployment was done in 2011 from the 36 feet sailing boat SY *Je Reve Donc Tu Vis*. Mooring recovery and redeployment on 2012 took place from SY *Albarquel* during OPTIMISM 2012 cruise and in 2013 the mooring was again recovered and redeployed as a minimalistic mooring for next 2 years (from SY *Arctica*). CTD casts performed during the

OPTIMISM cruises in summer in 2011-2013 sampled remnants of Brine Enriched Shelf Water (BSW) at the bottom.

Observational efforts in the Storfjorden polynya are complemented with numerical modeling studies. A 10-year regional high-resolution (2 km) ocean-ice coupled simulation (NEMO 3.6 and LIM 3.5) with tides and boundary values from global Drakkar simulation (Rousset et al., 2015, submitted to Geoscientific Model Dev.) was or will be used in several physical studies.

A contribution from LOCEAN to SSFOF comprises a rich dataset and 10-year simulation yet to be analyzed. Obtained results are a great motivation not only from physical oceanographers but also biogeochemists at LOCEAN (both modelers and experimentalists) to continue the monitoring of the Storfjorden polynya initiated in 2011 through:

- the planned STEeP project (2016-2017), in which LOCEAN is actively involved with multidisciplinary mooring deployment;
- (hopefully) through a long-term, international monitoring projects - if possible under the SIOS and SSF framework, if Storfjorden can be included into the SIOS area of interests as a 'observatory polynya'.

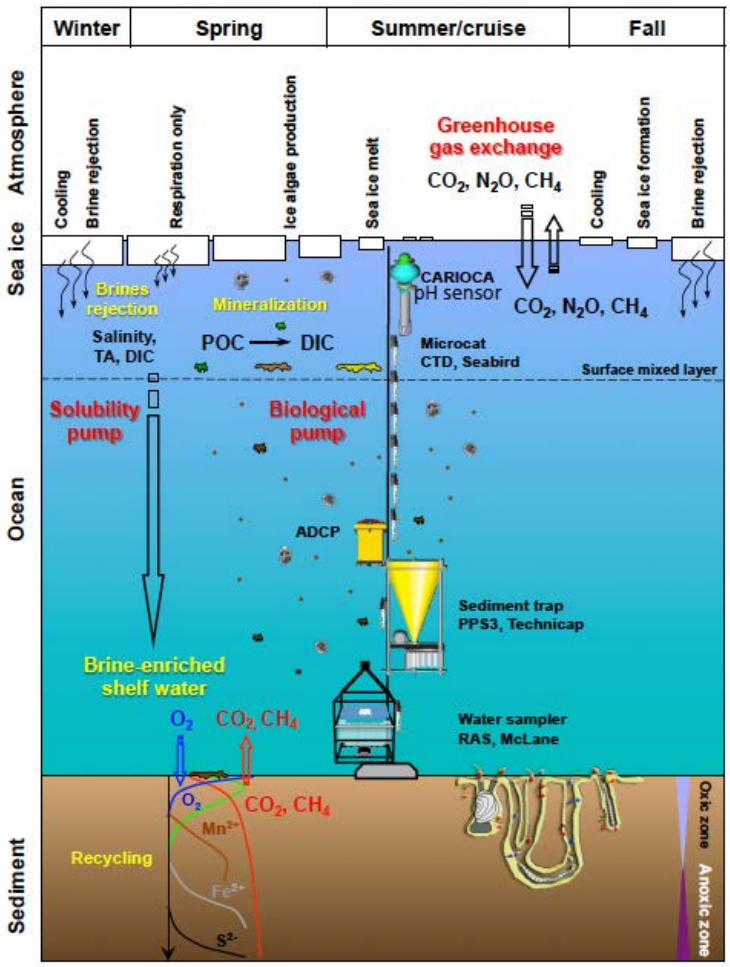

Fig. 12. A schematic of the STeP mooring to be deployed in 2016 in Storfjorden.

Future plans for the STeP mooring in 2016-2017 involve transition from a physical to a multidisciplinary mooring. Physical oceanography addressed by measurements at the mooring comprises inter-annual variability (trends) in the production (volume, properties) of dense waters as well as mechanisms and factors driving this variability. Biochemical oceanography will be focused on brine impact on biogenic/particulate fluxes and greenhouse gases exchange with atmosphere and sediments. Brine oxygen and carbon isotopic signature will provide a potential link with the volume formed and brine dense water properties. The fully equipped mooring (Fig. 11) will be deployed in 2016 during the STeP cruise on a larger vessel and recovered during the Step cruise in 2017. During both cruises mooring operations will took place, as well as station work, including CTD, SCAMP profiler and L-ADCP measurements, measurements of oxygen, chlorophyll, carbonate system CH_4, N_2O, sampling for oxygen isotopes and DIC carbon isotopes (^{13}C, ^{14}C), sampling with multi-tubes for pore-water O_2 concentration, pH, foraminifera, POC and PON, and Kullenberg cores.

4.7 Long-term variability and trends in the Atlantic Water inflow region - Fram Centre A-TWAIN project (NPI, Norway)

Inflowing AW characteristics, ice conditions and key chemical and ecosystem parameters have been measured since 2012 by a long-term array of moored instruments covering the shelf, slope, and part of the interior basin north of Svalbard. The A-TWAIN project is an effort of the Norwegian consortium (NPI, IMR, UNIS, UiT) under the FRAM Centre framework, including a strong cooperation with international institutes (WHOI, IOPAN). The obtained data are employed to increase understanding of the seasonal and inter-annual variability of the heat and freshwater fluxes into the Arctic Ocean as well as ice drift in the surface layer. The instrumentation covers basic chemical, biological and ice parameters (upward looking sonars) in addition to standard oceanographic sensors.

The moored array is located northeast of Svalbard, at the approx. longitude 30°E, and covers the Atlantic water inflow in the Fram Strait Branch before it joins the Barents Sea Branch farther east. This location is also relatively close to the Russian EEZ. The first deployment in 2012-2013 from rv *Lance* comprised 9 moorings altogether, eight moorings in the array (3 Norwegian moorings on the upper shelf break, 4 US moorings equipped with McLane profilers and one Polish mooring with McLane profiler) and one Polish upstream mooring with MMP. Data obtained during the first deployment period revealed a strong seasonality of the Atlantic water inflow with autumn/winter inflow more than twice of that in summer. Seasonal variability and fluxes of nitrates in the surface water were estimated based on one year of the nitrate measurements with ISUS.

The A-TWAIN array was redeployed in 2013 from rv *Lance* in a smaller configuration with 4 Norwegian moorings and 2 Polish moorings (one in the array and one upstream mooring). Due to extremely severe ice conditions, the moored array could not be reached by rv *Lance* in the late summer 2014 and moorings were not recovered as planned after one year. The array was successfully recovered with no loses and partially redeployed in September 2015, also during the rv *Lance* cruise. Two Norwegian moorings and one Polish mooring with MMP

were deployed for two years since no ship time is planned for 2016. The array will be finally recovered in 2017. The A-TWAIN project is open for collaboration with all partners, interested in physical and biogeochemical monitoring of the Atlantic water inflow into the Arctic boundary current northeast of Svalbard.

In addition to mooring operations, the the extensive CTD and LADCP measurements were performed during the first recovery cruise in 2013, and to smaller extent also during the 2014 and 2015 A-TWAIN cruises.

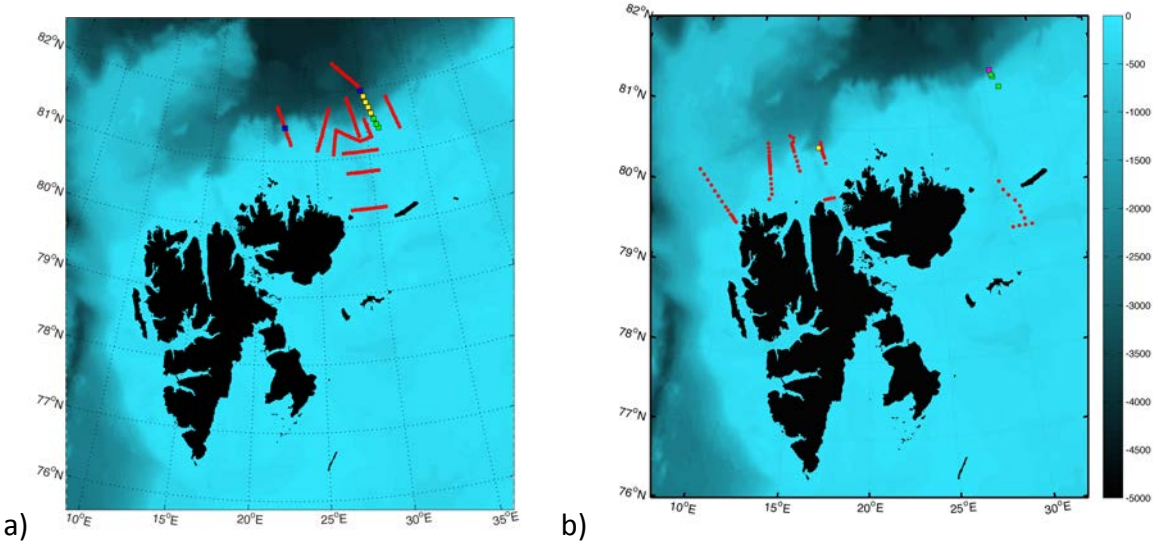

Fig. 13. Locations of deployed moorings (squares) and CTD stations (red dots) during the A-TWAIN cruises in (a) 2013 and (b) 2014.

4.8 The Arctic Ocean Outflow Observatory in the Fram Strait (NPI, Norway)

The Arctic Outflow Observatory in the western Fram Strait, established and operated by NPI, is devoted to monitor the freshwater outflow, comprising liquid freshwater and sea ice, from the Arctic Ocean towards the north Atlantic. Two main freshwater pathways for the Arctic outflow are the East Greenland Current and outflow through the Canadian Arctic Archipelago, and roughly equal amount of total freshwater is carried along each pathway. Sources of freshwater in the Arctic comprise riverine runoff, precipitation minus evaporation and the inflow of fresh Pacific water. Since 1990 an increase in freshwater transport has been observed due to several sources. Release and accumulation of freshwater in the Arctic is related to large-scale atmospheric patterns, therefore consistent long time series of observations (30+ years) are necessary to monitor the freshwater changes. At present Arctic is preconditioned for a large freshwater release (Stewart and Haine, 2013).

The Arctic Ocean Outflow Observatory consists currently of 7 moorings deployed annually during the service cruises on rv *Lance* in August/September. Moorings provide time series of temperature, salinity, currents, ice thickness and ice drift. In addition to moored instruments, CTD and LADCP section is repeated during each service cruise across the entire Fram Strait. Tracer measurements at the Fram Strait section include oxygen isotopes, total

alkalinity, nutrients, DIC and CDOM. Additional measured parameters are ice thickness (measured with EM31 and helicopter EM), ice spectral/optical properties and snow parameters.

Freshwater transports based on measurements by the moored array were published (de Steur et al., 2009; Jahn et al, 2011) showing no significant trend up to 2010. Contributions from salinity and volume flux variations are of an equal importance.

In recent years the moored array was augmented with IceCAT instrument under the pilot study. The uppermost instruments at existing moorings maintained by NPI only reach up to 50 m at the maximum, due to the high risk of instrument loss by drifting sea ice (icebergs). IceCAT consists of CTP sensor with an inductive modem to transmit data to a logger, located below a weak link. IceCAT provides measurements in the upper layer of 25 m and even when instrument is lost, data are still available. During the first deployment at the western Fram Strait moorings in 2013-2014, an IceCAT delivered 10 months of data before it was lost. The ultimate goal is to have two to three IceCATS installed permanently and providing data to improve current freshwater estimates.

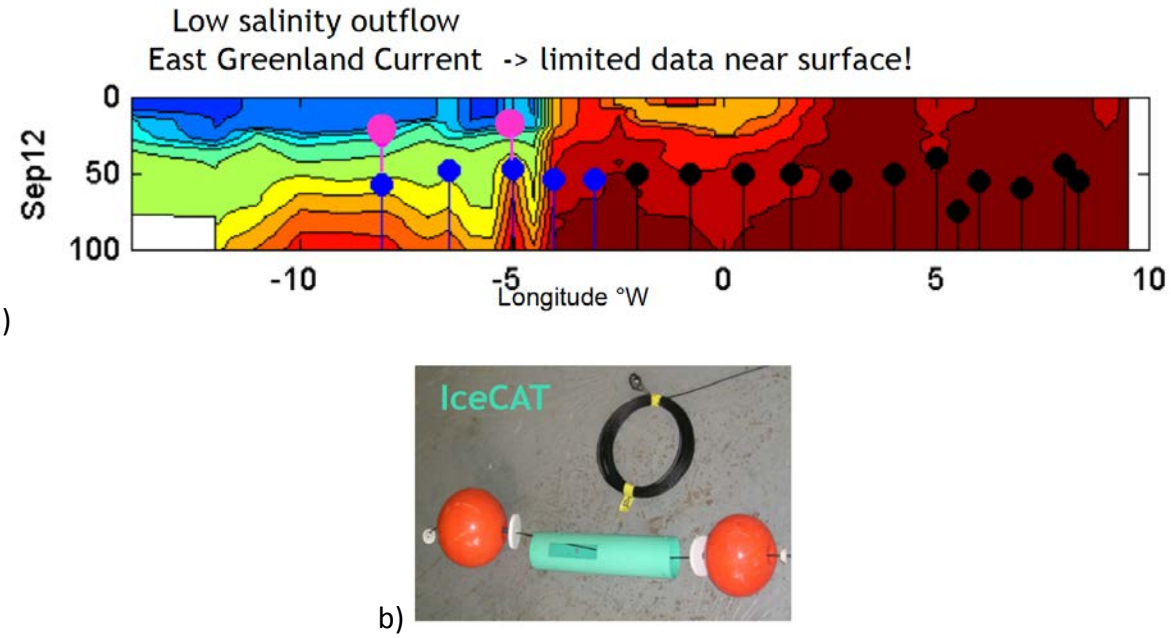

Fig. 14. (a) Section across the western Fram Strait with salinity distribution in the background and locations of the uppermost instruments at the moorings (blue - current uppermost TS sensors at NPI moorings, magenta - IceCATS, black - AWI moorings) and (b) a photo of IceCAT instrument

Sea ice thickness has been measured at the western Fram Strait moorings since early 90s with upward looking sonars (ULS). In 2000s multi-year modal thickness was down by 30% as compared to 1990s and mean thickness at the end of winter 2010-2011 was 2m, 50% less than mean thickness in 1990s (Hansen et al., 2013; Hansen et al., 2014). Sea ice volume flux is obtained by combining the ULS measurements with sea ice drift and area from satellite products. A small negative trend of 2% per year was found (not very significant), determined by changes in sea ice thickness.

Tracer measurements at the ram Strait section have been performed annually since 2008 to understand sources and composition of freshwater. Concurrent measurements of salinity $d^{18}O$, and N:P ration allow to separate three major categories of freshwater: sea ice meltwater, Pacific origin seawater and Atlantic origin seawater. Meteoric water is the largest fraction of freshwater in Fram Strait and comprises river runoff, precipitation-evaporation and meltwater from glaciers.

For quasi-continuous long-term measurements, automatic water samplers were deployed at two moorings at 5°W and 8°W in 2010-2014. The samplers provided weakly samples and data obtained in 2010-2011 revealed a strong seasonal cycle in all freshwater components. The variability seen in a decade of tracer sections is also seen in one year of data from the automatic samplers at 8°W.

To study a carbon cycle in Fram Strait, CDOM (coloured dissolved organic matter) was measured during the annual cruises. Spatial distribution of CDOM (Pavlov et al 2015) revealed that CDOM dominates absorption in the East Greenland Current while particles dominate absorption in the West Spitsbergen Current. In the future EGC CDOM can play a more important role in shaping availability of PAR vs. UV light, with a potential increase in biological productivity.

Arctic Ocean Acidification is addressed by the Fram Centre flagship and measurements of total alkalinity, pH and aragonite saturation (which is a indicator parameter for ocean acidification trends) are performed during the summer cruises. New data reveal low pH and low CaCO3 saturation in polar outflow waters, and there are indications for pH decrease in the upper 500 m in Fram Strait.

Oceanographic data (CTD and mooring data) up to 2010 are available from the NPI database https://data.npolar.no and linked to the Norwegian Marine Data Center. ULS data will be made available as a processed product.

New research vessel *Kronprins Håkon*, the DNV-Class POLAR 10 ICEBREAKER with the length of 100 m, will be available in 2017. The research vessel will be owned by Norwegian Polar Institute and run by Institute for Marine Research.

The proposal was submitted to obtain and test new biogeochemical sensors for the western Fram Strait moorings, its outcome should be known by June and perhaps resubmitted in September. There is a strong interest in community in sharing information about how to use these sensors, their year-round performance, etc.

4.9 Possible pathways for the investigations of the Atlantic inflow in the Svalbard region (ISMAR-CNR, Italy)

ISMAR-CNR is the Institute of marine sciences of the Italian National Research Council and since 2000 it is involved in several projects in the Arctic Region:

- SNOW *Sensor Network for Oceanography in Shallow Water* (Italian Project)
- ARCA *ARctic present Climatic change and pAst extreme events* (Italian Project)
- Svalbard Margin project with OGS ang UGot (Italian Project)

Since 2000 a permanent mooring has been deployed to monitor tidewater glaciers in Kongsfjorden (physics, sediments and microbiology). The mooring used to be called mooring 'K' and now is called mooring Dirigibile Italia. It is equipped with CTD sensor, currents and sediment traps and is located around 78.95°N 12.20°E. Additionally CTD casts in selected locations inside Kongsfjorden are performed every September since 2010. Sporadic data from the early 2000 are also available. New experiment with autonomous surface and underwater vehicles is planned to take place in 2015. Data will be available through the Italian Arctic Data Center that is under development.

In future plans autonomous underwater and surface vehicles will be used in Kongsfjorden and adaptive sampling based on some of the insight provided by numerical models will be introduced. ISAMR has an extensive expertise in numerical models including non-hydrostatic approach, cascading and fjord circulation and validation with observations. The new project FATE Investigation of Atlantic Inflow into the Arctic Ocean has been submitted, led byM. Ilicak with Co-PIS I. Fer, P. Isachsen, K. Nisancioglu, T. Haine, M. Magaldi, R. Sciascia, D. Ivanova, C. Guo, P. Heimbach. The unprecedented non-hydrostatic, very-high resolution (250m and 20m) simulations of the Fram Strait area nested in the 1/24°ECCO2 data product and coupled to sea-ice model. 3-hr Era-Interim forcing

The new non-hydrostatic model, nested in the 1/24°ECCO2 data product, coupled to sea-ice model and using 3-hr Era-Interim forcing, will enclose entire Fram Strait with very high spatial resolution of 250 m and vertical resolution 20 m, allowing to resolve mesoscale processes. Also nesting approach is foreseen for realistic and idealized tidewater glacier simulations with 50 m horizontal resolution, vertical resolution of 5 m and melt rate parameterizations. The partners would also like to have a transnational call and try to build up joint effort with models and observations.

4.10 North-East Greenland ice shelves and ocean warming: Canyon dynamics and real time ocean data via acoustic communication networks (University of Delaware, US)

University of Delaware, Newark, DE, US with PI Andreas Muenchow is involved in the following currently funded projects and collaboration, relevant for research activities and observational programs in the Arctic:

1. Nares Strait and Petermann Fjord observatories (NSF-funded, with IOS, Canada);
2. NE Greenland Shelf Moorings (NSF-funded, with AWI, Germany)
3. Petermann Glacier Observatories (likely NASA funded, with BAS, England);
4. Underwater Acoustic Sensor Networks (NSF-funded, with WHOI and UConn, USA);
5. Shelf-Basin Acoustics, Noise, and Oceanography (ONR-funded, with UTexas, USA)

With support from the US National Science Foundation (NSF) University of Delaware with PI Andreas Muenchow conducted collaborative fieldwork with the Alfred Wegener Institute in Germany on the shelf seas off north-east Greenland. In June 2014 they deployed seven 75 kHz acoustic Doppler Profilers across an 80 km section of Norske Ore Trough which is part of a submarine canyon system that, we hypothesize, advects warm Atlantic waters towards

79N Glacier. Moorings will be recovered in 2016 from rv *Polarstern* to potentially be re-deployed until 2017.

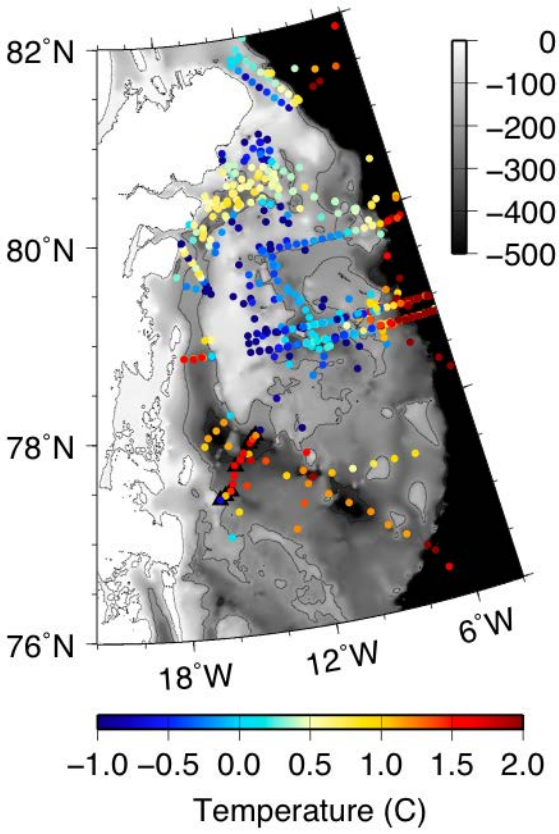

Fig. 15. Bathymetry of study area with sub-surface temperature maximum from 1979 to 2014 data (unpublished). Moorings across Norske Øre Trough are near 78°N and 15°W.

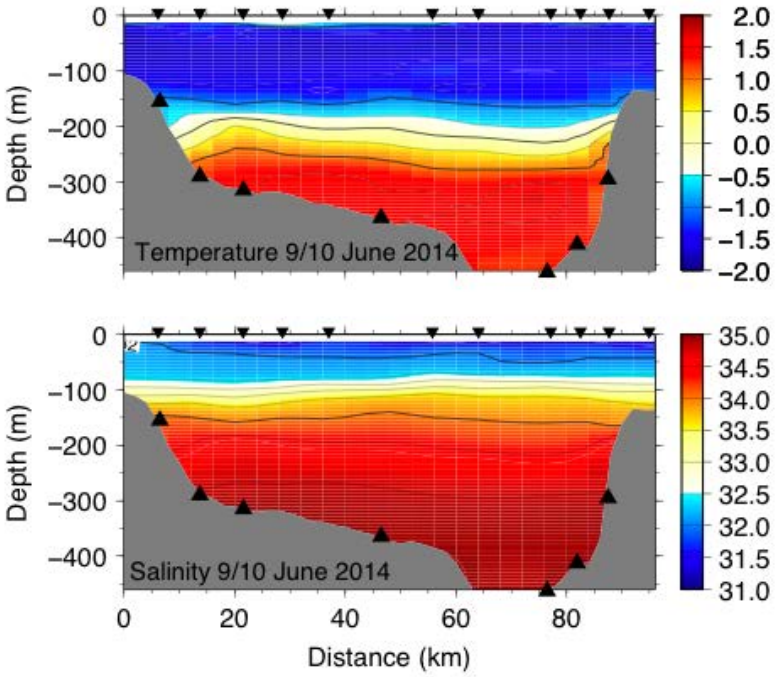

Fig. 16. Temperature and salinity across a broad canyon with 2014 CTD stations (small triangles at the surface) with ADCP mooring locations (large triangles at the bottom). View is on-shore towards the coast with Belgica Bank near km-90. Five of seven 75 kHz ADCPs were provided by University of Delaware (UDel).

A proposal to extend this 1-year mooring deployment into a 3-year project has been submitted. The core of the proposal is to deploy an available moored array across a canyon off Greenland where, as hypothesized, canyon dynamics control across-shelf property flux by the interaction of rotation and friction at tidal to inter-annual time scales. A second hypothesis posits that sea ice is dynamically irrelevant while tidal rectification is not. More specifically, a 2-year mooring record to be recovered in 2016 will be analyzed while an enhanced array will be deployed in 2016 to be recovered in 2017. Dynamically relevant time and space scales are resolved by an array of five US acoustic Doppler current profilers (ADCP) that are augmented by two German ADCPs. These seven 75-kHz ADCPs form the backbone of a German-Norwegian-US collaborative 2016-17 experiment to be augmented by eight moorings to record temperature, salinity, and pressure for horizontal heat and buoyancy flux estimation.

Other long-term ocean observing activities include NASA funded research on the circulation and ocean properties under the floating ice shelf of Petermann Gletscher (NASA-funded) and coastal physical oceanography over the steep continental slope off northern Alaska (ONR-funded).

Future potential field work could include a funded NSF project to explore underwater communication networks to move data under an ice-covered coastal area from one underwater modem to the next to be received at a final modem to relay the data to the surface and from there via telemetry to a shore-based computer. The range of each acoustic modem is 5-8 km to give, if successfully developed and deployed, a total range of 10-20 km from an ocean observing site to a site where the data can be routed to the surface.

More specifically, Andreas Muenchow is exploring possibilities to deploy this system (under development) in the spring (April/May/June) of 2017 at the Polish Research station in Hornsund. About 4 engineers and scientists would be staying for 2-6 weeks to deploy and test the system. Ideally, one modem would be deployed under sea ice in the inner portion of the fjord (“remote site”) to transmit data to a node (“relay station”) half-way towards a mooring in open water near Hornsund Station (“base station”) to telemeter data to shore. If successful, additional networked modems could exploit the new capability to extend the range onto the continental shelf outside the fjord.

There is a re-emerging interest in both Arctic Oceanography supported by the US Office of Naval Research. From a geo-political or strategic perspective, the European Arctic is as important as is the coastal border between Russia and the US.

4.11 Observations in the Atlantic Water flow toward the Arctic at IMR (IMR, Norway)

The Institute of Marine Research is Norway's largest centre of marine science. Our main task is to provide advice to Norwegian authorities on aquaculture and the ecosystems of the Barents Sea, the Norwegian Sea, the North Sea and the Norwegian coastal zone. For this reason, about fifty percent of our activities are financed by the Ministry of Trade, Industry and Fisheries. The extensive multidisciplinary research at IMR is mostly motivated by fisheries. Activities under the SSFOF are focused on physical aspects.

As part of the general monitoring of the ocean climate, relevant for the marine ecosystems, IMR operate repeated hydrographic sections and annual synoptic ecosystem surveys. Measurements include hydrography, nutrients, plankton and fish sampling. Summer cruises cover the area around Svalbard as far as ice permits. As an example Figure 16 include all oceanic CTD stations performed in 2014.

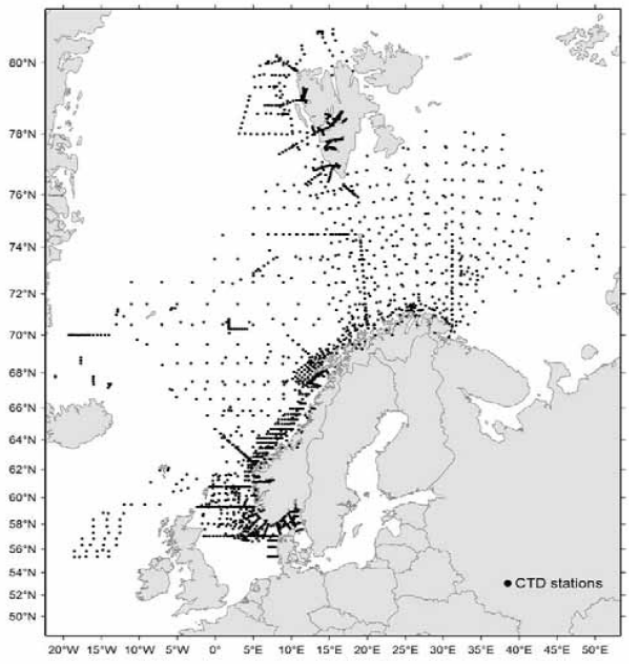

Fig. 17. CTD profiles performed by the IMR in 2014.

Also the IMR also operate long-term current meter moorings at some key sections. In particular the Atlantic Inflow to the Barents Sea has been monitored by an array of current meters since 1997 to date (2015), and is planned to continue (Figure 3). Splitting of the NwAC between BSO and WSC is the long-term question since the beginning of long-term moorings in the region in 1990s. It is difficult to see how signal propagates around but with time series getting longer the question can be better addressed.

4.12 Activities related to *in situ* ocean observations at UNIS (UNIS, Norway)

The University Centre in Svalbard (UNIS) is the world's northernmost higher education institution, located in Longyearbyen at 78°N. UNIS offers high quality courses at the undergraduate, graduate, and postgraduate level in Arctic Biology, Arctic Geology, Arctic Geophysics, and Arctic Technology. UNIS is a share-holding company, owned by the Norwegian Ministry of Education and Research. UNIS was established in 1993 to provide university level education in Arctic studies, to carry out high quality research, and to contribute to the development of Svalbard as an international research platform. UNIS' geographical position gives it a unique advantage, enabling students and faculty to use nature as a laboratory, arena for observation and data collection. UNIS researchers work in collaboration with Norwegian and foreign research institutions and are actively involved in several research projects:

1. Arctic climate system study of ocean, sea ice and glaciers interactions in Svalbard area (AWAKE 2, 2013-2016), which focus on specific processes in the Svalbard area using historical data, new observations, and dedicated model runs. It is a joint Polish-Norwegian project with partners from Poland: IOPAN, NCU (Nicolaus Copernicus University), US (University of Silesia), IGF PAN (Institute of Geophysics, Polish Academy of Sciences) and Norway: NERSC, NPI, met.no, UNIS.
2. Remote Sensing of Ocean Circulation and Environmental Mass Changes (REOCIRC, 2013-2016). The aim of this project is to study the Absolute Dynamic Topography (ADT) of the West Spitsbergen Current (WSC) by taking advantage of advances in satellite gravimetry (GOCE) and altimetry, and providing ground truth for satellite gravity solutions (GRACE) from *in situ* ocean bottom pressure measurements. Partners in this project are UNIS, NERSC, and the Polar Science Center, University of Washington.
3. Arctic Ocean under Melting ice (UnderICE, 2013-2017). Primary objective is to advance the knowledge about water masses and processes in ice-covered seas, including heat and volume fluxes, freshwater fluxes, ice-ocean processes and primary production based on observations and modelling in the European sector of the Arctic Ocean. This project is collaboration between NERSC, Scripps Institution of Oceanography (SIO), Institute of Oceanology Polish Academy of Sciences (IOPAS), and UNIS.

Current long-term ocean observations in the Svalbard area (see Figure 18 for positions of moorings) include:

- One mooring just outside Isfjorden (78°03.667N, 13°31.492E) with three current meters, since 2005 (except 2008/09 and 2009/10). Recovered and redeployed every year in August-September with RV *Håkon Mosby*.
- One mooring in Kongsfjorden (78°58N, 11°57E) with three current meters, since 2010. Recovered and redeployed every year in August-September with RV Håkon Mosby. The mooring in Kongsfjorden was moved to Isfjorden in August 2015 (78°10.829N, 13°22.737E).
- One mooring west of the Yermak Plateau (79°44N, 5°56E) with two current meters (Aanderaa Seaguard with oxygen sensor, 50 m and 150 m). Deployed September 2014 and recovered in August 2015.
- Five moorings with bottom pressure recorders (SBE-26) deployed in August-September 2014, two outside Hornsund (77°00.307N, 15°11.380E and 76°57.598N, 14°04.212E) and three on the Yermak Plateau (79°47.96N, 10°44.65E, 79°50.41N, 10°29.60E, and 80°10.467N, 8°08.71E). In addition a mooring with three current meters (80°07.10N, 8°32.043E) was also deployed on the Yermak Plateau at the same time. These moorings were recovered and redeployed in August-September 2015 with RV *Håkon Mosby*.

Several UNIS student cruises takes place every year and CTD measurements are repeated at the same stations every year (Figure 18).

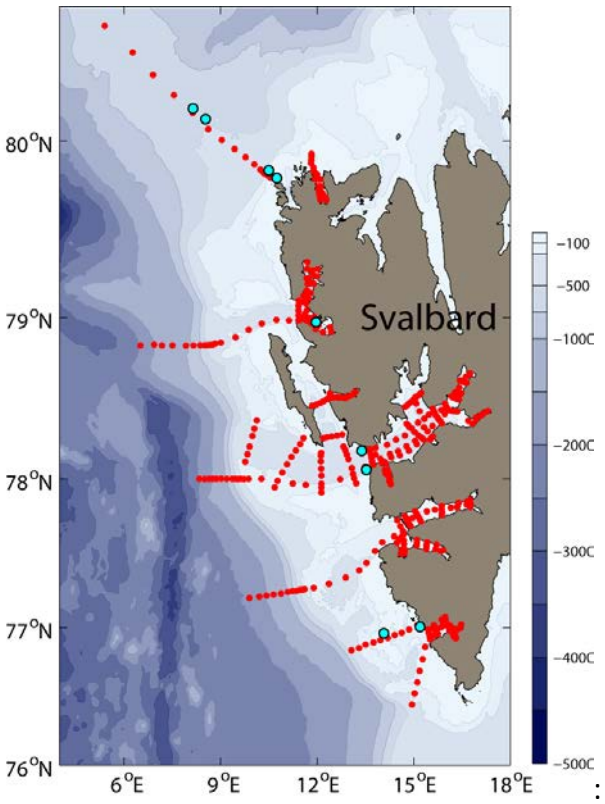

Figure 18. Map with CTD positions (red dots) taken during UNIS student cruises and mooring positions (cyan).

4.13 Sensing the Fram Strait ocean environment by acoustics – status and future plans (NERSC, Norway)

Nansen Environmental and Remote Sensing Center is a non-profit research center affiliated with the University of Bergen, with focus on marine and Arctic science. NERSC is a project-based center with major funding from the European Union research programmes, Norwegian Research Council, the European Space Agency, the Norwegian Space Center, industry and other governmental and international agencies. NERSC hosts projects within acoustic tomography, passive acoustics, and acoustic communication in Arctic regions. At NERSC we focus on acoustic tomography/thermometry that can be used to obtain synoptic measurements of a large volume of the ocean's interior (e.g. Mikhalevsky et al., 2015). Ongoing acoustic projects are funded by Research Council of Norway, ONR-global, and GDF SUEZ.

Observing based research at NERSC include satellite remote sensing, ocean acoustics and development of information systems where observational data are integrated with models and disseminated to users. One important focus of our research is to use innovative observing methods, technologies and platforms for improved understanding of the Arctic Ocean environment. Acoustic methods, includes tomography and passive acoustics, which is used to observe the interior of the ocean environment.

NERSC has built up expertise in exploiting acoustic oceanography, in particular ocean acoustic tomography, to observe and understand the Arctic environment. This expertize is used in combination satellite remote sensing, ice-ocean modelling (operational and climate), data assimilation and systems for data management.

Acoustic tomography builds on accurate measurements of the travel times between positioned source and receivers, which through inversion provide synoptic range, averaged sound speed. Sound speed is converted to mean ocean temperature and currents over pre-defined ocean volumes with high temporal resolution. Retrieval of currents relies on very accurate measurements of two-way acoustic travel times. Range-depth averaged ocean temperature uses one-way transmissions – between source and receiver - this is called *Acoustic thermometry*. The integrated measurements of travel times (or sound speed) are useful for detection of fingerprints of climate change, constraining and validating ice-ocean models (e.g. Haugan et al. 2012, Sandven et al., 2013, Mikhalevsky et. al. 2013).

An advanced acoustic thermometry system has been developed for the Fram Strait. A prototype single-track ocean acoustic tomography system was deployed in 2008 as part of DAMOCLES Integrated project (Sandven et al., 2013, Mikhalevsky et al. 2015). This was followed up in ACOBAR by the development and implementation of the Fram Strait multipurpose acoustic system for acoustic thermometry, low frequency passive acoustics and glider navigation for a two-year operation (see http://acobar.nersc.no). In September 2014 a continuation and extension of the acoustic system was implemented within the UNDER-ICE project. The system consists of five moorings between 78 - 80 degrees north (see Figure 19). The UNDER-ICE system builds on new advanced acoustic receiver technology and state of the art organ pipe source technology. The acoustic system will provide accurately measured travel times along 7 sections criss-crossing the deep part of the Fram Strait every three hours for two years. Travel time measurements will be inverted to average sound speed (mean ocean temperature) along the sections. The moorings in UNDER-ICE are augmented with a significant number of oceanographic instruments such as thermistors and Acoustic Doppler current Profilers. XCTD and CTDs are obtained along selected sections as background for inversions. UNDER-ICE moorings will be recovered in summer 2016.

Passive acoustics. The acoustic receiver arrays in UNDER-ICE will record not only the acoustic transmissions, but also the sounds generated by natural processes (e.g. waves, sea ice break-up), marine mammals and human activities (e.g. ships, air guns, sonars). Acoustic noise in the ocean is one of the environmental descriptors used by Marine Strategy Framework Directive. It is therefore important to include passive acoustics into an ocean observing system (Mikhalevsky et al. 2015). The UNDER-ICE system will provide temporal and spatial variability of the ambient noise of the Fram Strait. Data from UNDER-ICE can be used as benchmark data for future environmental assessments. An example of detection of different sounds recorded in the Fram Strait marginal ice zone is shown in Figure 20 (Geyer et al. 2015).

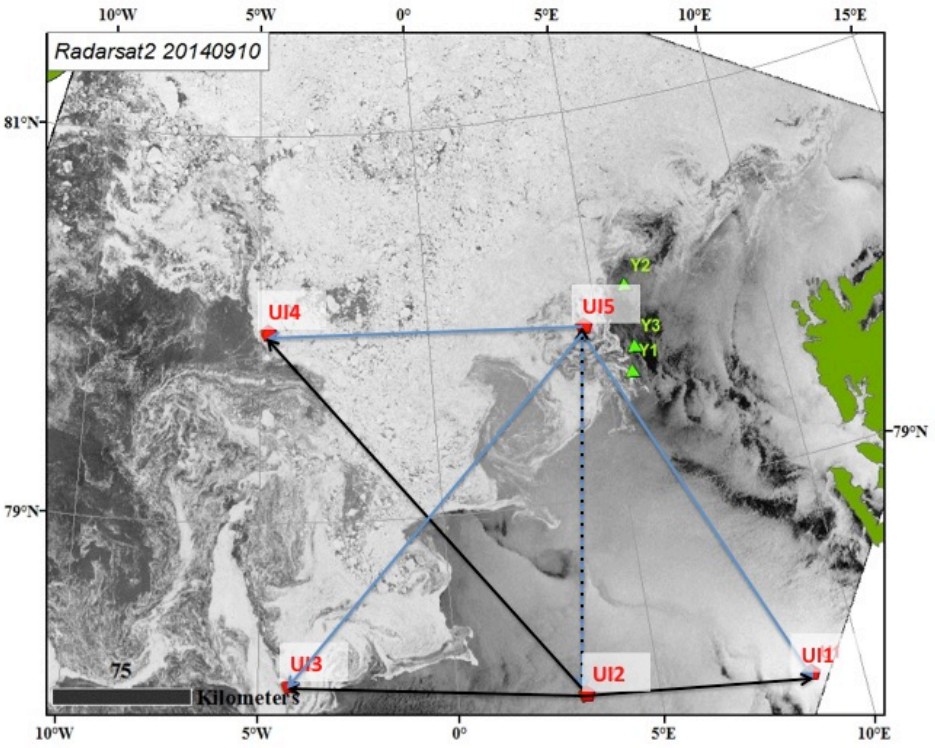

Figure 19. The UNDER-ICE tomographic experiment deployed September 2014, and planned recovery August/September 2016. UI-5 and UI-2 are transceiver moorings, each carrying an acoustic source and vertical array of hydrophones. The other moorings carry a vertical array of 10 hydrophone modules, each. In this set up acoustic travel times are measured along all the lines within 9 minutes. The blue and black dashed line indicates two-way propagation. Hydrophone modules in all moorings include high accuracy thermistors. In addition mooring UI4 and UI5 carries a significant amount of additional oceanographic sensors. The Green Y1,Y2,Y3 are oceanographic moorings deployed by University in Bergen 2014-2015 (PI: Ilker Fer)

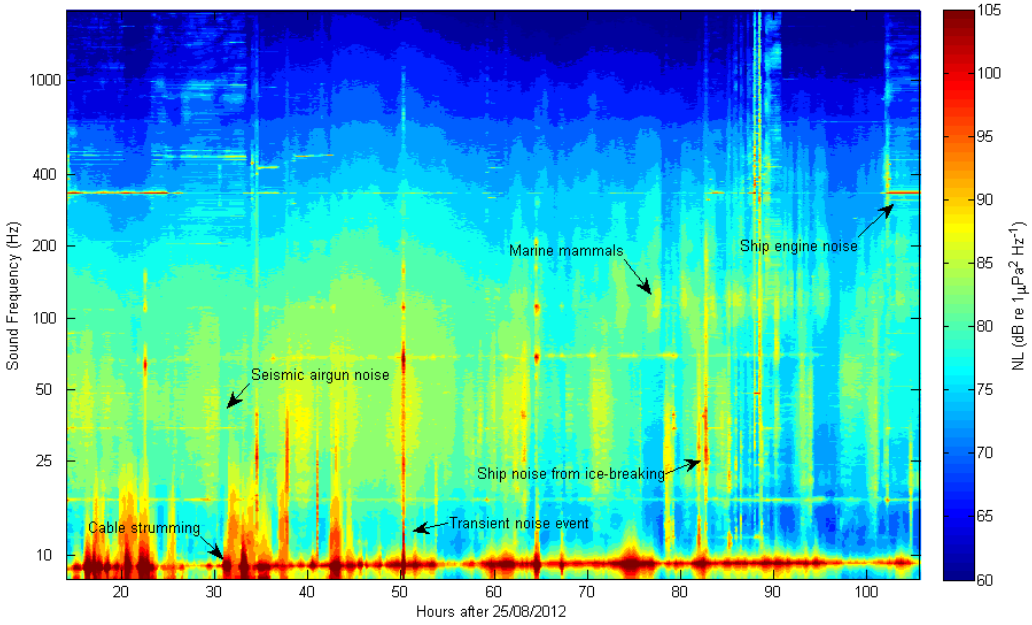

Figure 20. An example of passive acoustic recording from the 2012 experiment. The main different sound types visible are ice breaking noise, seismic exploration noise, marine mammal vocalizations and ship engine noise.

Data management structure of acoustic measurements, thermometry and passive acoustics, is currently under development at NERSC as part of UNDER-ICE.

Future plans. Our goal is described in the paper "Multipurpose acoustic networks in the integrated Arctic Ocean observing system" by Mikhalevsky et al. (2015). This will be an important contribution to the development and improvement of underwater and under-ice navigation and communication, essential for supporting underwater operations in the high Arctic (e.g. Mikhalevsky et al. 2015). Our first step is to develop and implement a pilot acoustic experiment across the Arctic Basin based on state-of-the-art low-frequency acoustic technology. This proposal has already been developed and submitted to several funding sources together with national and international partners.

References

Mikhalevsky, P.N., H. Sagen, P. Worcester, et al., (2015). "Multipurpose acoustic networks in the integrated Arctic Ocean observing system". Paper invited for special thematic issue on Arctic Ocean observing, Arctic, 2015.

Tollefsen, D. and H. Sagen (2014). ”Seismic exploration noise reduction in the Marginal Ice Zone”. J. Acoust. Soc. Am. **136**, EL47.

Sandven S., H. Sagen et al. (2013). ”The Fram Strait integrated ocean observing and modelling system”. In *Sustainable Operational Oceanography*, Proceedings of the Sixth International Conference on EuroGOOS, 4–6 October 2011, Sopot, Poland, pp. 50-58.

Haugan, P., H. Sagen, & S. Sandven (2012). Ocean observatories for understanding and monitoring Arctic change. OCEANS'12 MTS/IEEE YEOSU, Korea.

Geyer, F., P. Worcester, H. Sagen G. Hope, Mohamed Babiker (2015). Identification and quantification of soundscape components in the Marginal Ice Zone. Ready for submission to Journal of acoustical society.

4.14 ArcticROOS activities and potential links to the Ocean Flagship

Arctic Regional Ocean Observing System (ArcticROOS) was established as a contribution to IPY in 2006. Initially it consisted of 14 member institutions from nine European countries working actively with ocean observations and modeling systems for the Arctic Ocean and adjacent seas. ArcticROOS works to promote, develop and maintain operational monitioring and forecasting of ocean circulation, water masses, ocean surface conditions, sea ice and biological and chemical constituents. Another goal of ArcticROS is to contribute to preservation of the IPY and other data collections initiatives in the Arctic, aiming to maintain a cost-effective and useful observing systems for the region. As of May 2015, there are 20 members of ArcitcROOS, 10 of them being also partners in EuroGOOS.

Main components of ArcticROOS are:

- In situ observation systems: ship-borne systems, moorings, ice buoys, floats and drifters i.e. (MyOcean i*n situ* Thematic Assembly Centre TAC);
- Satellite remote sensing: polar orbiting satellites using active and passive microwave, optical and infrared instruments;

- Modelling: data assimilation, nowcasting, short term forecasting, seasonal forecasting, model comparison and validation (e.g. TOPAZ + +).

Main ArcticROOS activities in 2014-2015 included:

- Renewal/updating of the web site (http://arctic-roos.org), supported by a secretariat at NERSC (Morten Stette);
- Consistent look & feel with EuroGOOS portal;
- Adding more data to the portal, including •Cooperation with EMODnet Physics to increase in situ data availability and integration of the Arctic ROOS data portal from IMR
- ESA CCI programme: Sea ice project: produce climate data sets for ice concentration, ice thickness and ice drift;
- Copernicus Arctic Marine Forecasting Center, continues the work under MyOcean, distribution of observational and model products the marine community.

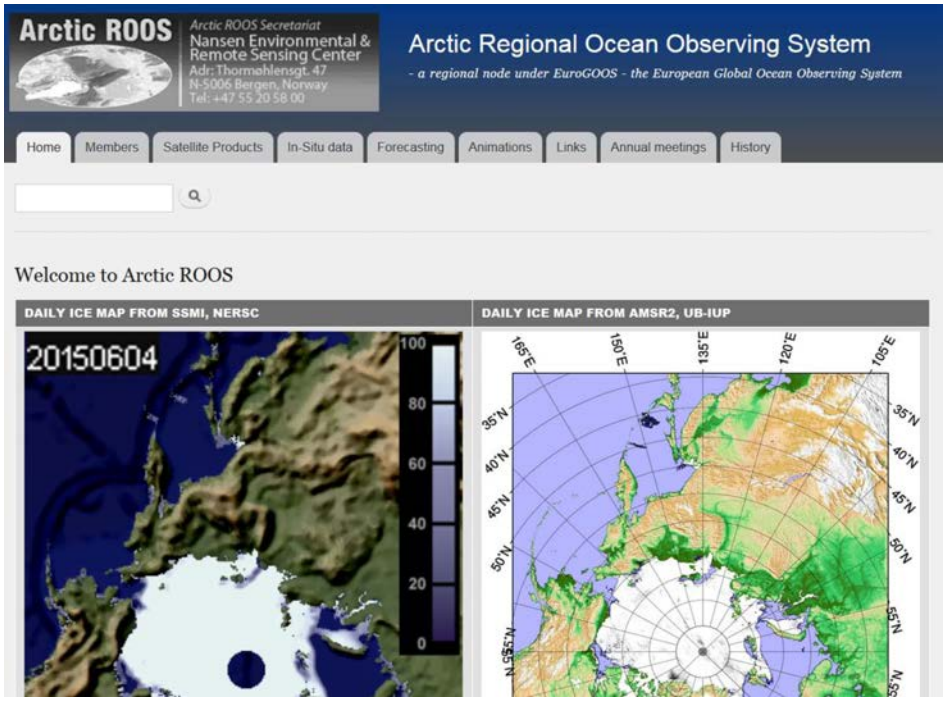

Fig. 21. The front page of the ArcticROOS web portal.

Satellite data collections accessible through the ArcticROOS website are divided into daily and seasonal and long-term observations, origination from different sources. Daily products include:

- Arctic ice concentration maps from SSMI (NERSC);
- Daily Arctic ice area and extent curves from SSMI (NERSC);
- Global and regional ice concentration from AMSR2 (UB-IUP);
- Arctic and Antarctic thickness of sea ice (< 50 cm) (UB-IUP);
- Browsing system for all maps from UB (UB-IUP);

- Global ice maps, sea ice concentration, ice edge and MY-FYI type (Eumesat OSI-SAF);
- Global ice drift based on merged ASCAt and SSMI and AMSR2 (Ifremer);
- Sea ice concentrations from SSMI available at CERSAT (Ifremer);
- Time series available for last 20 years, daily updated (Ifremer);
- Regional ice charts ((MET);
- Ocean color and SST (NERSC);
- SST and ice charts for Greenland and Arctic (DMI).

Seasonal and long-term observations include:

- Monthly sea ice area and extent from 1978 to present (NERSC);
- Total monthly sea ice area and extent in Arctic (NERSC);
- Climatology sea ice concentration in the Arctic (NERSC);
- Regional monthly sea ice area and extent from 1978 to present (NERSC).

In situ data at the ArcticROOS web portal encompass:

- Near-real-time data: In the Arctic-ROOS area, near-real time data includes CTD data from vessels, Argo floats, gliders, and ice-tethered profilers. Dissemination of these data is mainly based on the In Situ TAC under MyOcean and coordinated with the EMODnet Physics dissemination system.
- Delayed mode data: Current meter moorings providing time series of data are operated in several areas: Fram Strait, around Svalbard, in the Barents Sea and Norwegian Sea. Sea ice data and other oceanographic data are provided from ship expeditions.

ArcticROOS data portal is under development by IMR. Last 30 days of data are available through the Copernicus In Situ TAC, there are also plans to include reprocessed data. Retrieval of data from CTD sections is also possible. Portal structure (between layers) needs standard interfaces so that you can easily switch from one web map server to another.

Making data available is possible through ArcticROOS In Situ TAC. Currently only NetCDF are accepted but possibly other formats will be incorporated in the future. Any requests for default available formats can be sent to datahjelp@imr.no. Real time quality control follows EuroGOOS DataMEQ RTQC guidelines. All data are flagged (good, bad, no quality control).

Model data in the ArcticROOS system are provided by ocean and sea ice forecasting systems. Currently the following forecasts are available:

- Daily forecast for the Nordic Seas and Svalbard (MET.NO);
- Arctic Ocean Monitoring and Forecasting My Ocean (NERSC, MET.NO);
- SST forecast for Greenland and North Atlantic (DMI);
- Daily forecast for the Arctic Ocean (MERCATOR OCEAN).

The operational TOPAZ4 Arctic ocean system uses the HYCOM model and a 100-member EnKF assimilation scheme. It is run daily to provide 10days of forecast (one single member)

of the 3D physical ocean, including sea ice. Data assimilation is performed weekly to provide 7 days of analysis. The TOPAZ4 system has been run at MET Norway since 2008 with the ecosystem module coupled online in January 2012.20 years of reanalysis is available at NERSC (it took 2 years to produce with approx. 4 million CPU hours). 3 years of ecosystem reanalysis include assimilation of both physical and ocean color data. My Ocean system (Arctic MFC since 2015) provides free distribution of data with dynamical viewing (Godiva2).

The relevant ArcticROOS links:

- ArcticROOS http://arctic-roos.org
- Arctic ROOS in situ portal http://webprod1.nodc.no/arctic-roos/arctic-roos.html
- Helpdesk for the Arctic TAC datahjelp@imr.no

Discussion during the SSFOF workshop identified other data products that could be easly incorporated in the ArcticROOS data portal. One of them is a product provided by the open data portal of the Drift&Noise company (link http://driftnoise.com/data-delivery.html). Sea-ice concentration data are obtained from the Advanced Microwave Scanning Radiometer 2 (AMSR2) of the Global Change Observation Mission 1-Water "SHIZUKU" (GCOM-W1) of the Japanese Aerospace Exploration Agency. While currently existing sea-ice concentration maps display the sea-ice condition averaged over the past 24 hours (a *mean composite*), the sea-ice concentration maps provided via the Open Data Portal are based on *running composites* that are updated for each satellite swath. By doing this, features such as leads are much better resolved. In addition, the user can obtain sea-ice concentration data with less than 2 hour's delay, up to 8 times a day depending on the location. Data can be downloaded or sent as maps, geolocated raster files, or binary data files optimized for data transfer to remote locations. Data acquisition time for each grid cell is included in the data product. Data can also be delivered for free by email (important during cruises).

5 THE INITIAL CONCEPT OF THE SSF OCEAN FLAGSHIP WEB PLATFORM - POTENTIAL CONTENT AND LINKS TO OTHER PROJECTS AND PROGRAMMES.

The main objective of the SSFOF WP2 is to establish a web portal for the Ocean Flagship to improve the promotion, data sharing, and coordination of ocean research activities taking place around Svalbard. Instrumentation (oceanographic, biogeochemical, acoustic and seismic sensors) and platforms (moorings, landers, drifting platforms and gliders) worth of tens of millions Norwegian kroner are deployed in the ocean around Svalbard. One of the main goals of the new Ocean Flagship is to collect and disseminate information about the on-going research activities involving ocean observations.

The collected metadata and maps for visualisation of different activities will be timely published at the Ocean Flagship web portal which will provide the first major overview of all research activities involving ocean observations around Svalbard and in the European Arctic. An immediate benefit of the continuously updated web portal will be in easier and more direct collaboration on field logistics and operations, including ship time and shared used of

infrastructure for ocean observations. In this way the research effort of individual partners can be optimized in terms of cost efficiency and a scope of planned field operations.

The Ocean Flagship web portal will also host information about upcoming cruises, deployments/recoveries, and relevant conferences/workshops. The Ocean Flagship web portal will build on development of the UNDER-ICE and Arctic ROOS web portals, and include a metadata repository with descriptions of the collected data sets from the different partners. The metadata will be organized in line with recommendations from ongoing e-infrastructure projects such as SIOS, NMDC (Norwegian Marine Data Centre) and NORMAP (NORwegian Satellite Earth Observation Database for MArine and Polar Research).

Initial version of the Ocean Flagship web portal can be found at ocean-flagship.nersc.no. At the moment the web portal includes tabs: About, Arctic Rigs, Galleries, Links and Members. More tabs will be added when necessary to include more extensive information as recommended by the Ocean Flagship partners and users. The Arctic Rigs tab contains exemplary information on deployed moorings (in this case deployed by NERSC), including mooring ID, deployment date, positions and contact person. In future more detailed information will be incorporated in a dynamical way: description of instruments (or at least type of instrumentation), planned recovery data, servicing cruises, possibility to add instruments by external partners, etc. At the same time providing the required information should be as simple as possible for a mooring owner with only basic data obligatory and more detailed added voluntarily (but the website should include necessary tools to add more detailed information). The tab Galleries will contain graphical information about moorings or repeated cruises as interactive maps. It should be decided in open discussion how much information is needed to make the web portal useful but not overloaded. The Links tab should provide useful links to other projects, data centers, networks, cruise plans published by institutions active in the ocean observations in the Arctic, collaboration ideas and opportunities, etc.

The main discussion points relevant for developing the useful and flexible web portal should include among others the following topics:

- What additional features should be added?
- How do we prioritize the new features?
- How do we maximize use of the portal within the frames of the flagship project?
- How can we use the portal to promote the project and attract new members?
- How to link the Ocean Flagship portal with RiS to avoid duplication of the requested information? Can metadata be automatically harvested from the RiS portal by the OF portal? The same question is relevant for the Arctic ROOS website. If there are data (metadata) already available there, we can just mirror them.

Discussion on the future development of the SSF OF portal covered also other issues as:

- What additional information could be optionally provided for moorings: list of measured quantities, measuring intervals, a flag showing whether the mooring is past, in operation

or planned, mooring schematics, planned service cruises, links to data (for data sets already submitted to data centers), possibility to upload cruise reports from deployment and recovery cruises, etc.

- A question arose whether the cruise reports (also for cruises not linked to mooring operations) should not be also more visible as a dedicated tab, comprising information about past (with cruise reports) and planned (with cruise plans) cruises. At least links to existing original documents at the individual websites should be provided.
- Is there necessity to create a newsletter or at least an email message when a new information is uploaded to the SSF OF website? It could be done on request for registered users.
- There is a strong need for two-way communication between OF and RiS to make a maximum use of information submitted to any of these web portals. Agreements should be made with owners of other data portals to automatically obtain updated information.
- One idea to convince people to supply information about their activities could be based on mutual benefit - if anybody needs in depth information from the SSF OF portal about moorings, cruises, etc., the portal will ask for registration and providing information on own assets and activities. Using a sort of «currency» in exchanging information – basic information is free, but if you want more detailed information then you also have to provide information.
- With many data portals around a scientist shouldn't notice whether he or she is on one or another, where the data are stored or how they are harvest. Important part that you only have to enter data once and they are widely available through other portals as well. It is also important to get the data in one place without clicking through a series of webpages.
- EuroGOOS and Arctic-ROOS more about operational oceanography and their websites contain mostly the near real-time data and operational info. But delayed data from moorings and cruises are a bit out of the scope of Arctic-ROOS.
- One of the main questions is what is information that we cannot get now from the existing portals. Mainly: planned activities. Even the ones that are available are not very strictly defined. It should include a shiptime table with area, person and cruise period. Closer to the cruise the info about planned work, sections, what kind of sampling should be added. Some institutes (IMR, AWI) have already similar information about planned cruises available at their websites.
- After IPY there was a collection of all mooring sites where all the work was done. It would be also useful to see from the SSF OF website where older work has been. Might be able to get from other data centers, but would be useful to be able to look at both old and new/planned info. Some information is available f. ex. from PANGAEA but it is not straightforward to find the relevant info. There are some search tools you can use. Play with them, get more out of it. But it would need a tutorial.
- We aim for a portal that would integrate info from different webpages so you didn't have to go to the separate institutes web pages. Using different existing tools, e.g.

6 THE AGENDA OF THE FIRST SSF OCEAN FLAGSHIP WORKSHOP

Svalbard Science Forum (SSF) Ocean Flagship Workshop

Institute of Oceanology PAS, Powst. Warszawy 55, Sopot

June 8-9, 2015

AGENDA

Monday, June 8

09:00 - 09:30	Arrival of workshop participants, coffee
09:30 - 09:50	Welcome by IOPAN Director, housekeeping matters
09:50 - 10:10	Svalbard Science Forum and research in Svalbard (Karoline Bælum, SSF)
10:10 - 10:30	Presentation of the SSF Ocean Flagship initiative (Hanne Sagen, SSF Ocean Flagship coordinator)
10:30 - 10:50	Physical oceanography in the Greenland Sea, Fram Strait and Svalbard fjords under the long-term AREX observational program (Agnieszka Beszczynska-Möller, Waldek Walczowski, IOPAN)
10:50 - 11:10	Long-term biological observations in the West Spitsbergen Current and the adjacent waters by Marine Ecology Department in IO PAN (Slawomir Kwasniewski, IOPAN)
11:10 - 11:25	*Coffee break*
11:25 - 11:45	Observations of the physical oceanography in Fram Strait, on the East Greenland Shelf, and in the Nansen Basin - Status and future plans (Wilken-Jon von Appen, AWI)
11:45 - 12:05	Ship-supported ice-tethered observations in the European Arctic: plans within FRontiers in Arctic-marine Monitoring (FRAM) and scientific

	scope (Benjamin Rabe, AWI)
12:05 - 12:25	Multidisciplinary observations in the Fram Strait at the fixed point observatory HAUSGARTEN/FRAM - past and future (Ingo Schewe, AWI)
12:25 - 12:45	On the dense water flow over the contourite drifts offshore SW Svalbard: the EUROFLEETS2 programme (PREPARED 2014) and planned initiatives (Vedrana Kovačević and Manuel Bensi, OGS)
12:45 - 13:05	Storfjorden polynya multidisciplinary study: from physical processes to its impact on biology and Greenhouse gases (Elisabeth Michel, LSCE-IPSL)
13:05 - 14:00	*Lunch at IOPAN*
14:00 - 14:20	(Remote presentation) A-TWAIN project (Arild Sundfjord, NPI)
14:20 - 14:40	(Remote presentation) Recent highlights from the Arctic Outflow Observing system (Laura de Steuer, NPI)
14:40 - 15:00	(Remote presentation) Possible pathways for the investigations of the Atlantic inflow in the Svalbard region (Roberta Sciascia, ISMAR-CNR)
15:00 - 15:20	North-East Greenland ice shelves and ocean warming: Canyon dynamics and real time ocean data via acoustic communication networks (Andreas Münchow, UDEL)
15:20 - 15:40	*Coffee break*
15:40 - 16:00	IMR observations in the Atlantic Water toward the Arctic (Øystein Skagseth, IMR)
16:00 - 16:20	Activities related to *in situ* ocean observations at UNIS (Eva Falck, UNIS)
16:20 - 16:40	Sensing the Fram Strait ocean environment by acoustics – status and future plans (Hanne Sagen, NERSC)
16:40 - 17:00	Presentation of the ArcticROOS website (Torill Hamre, NERSC)
19:30	*Workshop dinner at the restaurant 'Bulaj' (see attached map)*

Tuesday, June 9

09:30 - 10:00	Summary of the previous day presentations and discussions
10:00 - 11:00	Presentation of the planned SSF Ocean Flagship web platform (Torill Hamre, NERSC). Discussion of its potential content and links to other projects and programmes (including ArcticROOS)
11:00 - 11:15	*Coffee break*
11:15 - 11:25	SSF grants and other relevant funding options (Karoline Bælum, SSF)
11:15 - 12:00	Discussion of potential joint actions and collaboration, including review of upcoming calls and funding opportunities
12:00 - 12:30	Other issues related to Ocean Flagship activities, ad hoc ideas and plans for future. Preparation of the workshop report. Discussion of 'Think Tank' Workshop in Longyearbyen in 2016.
12:30 - 13:30	*Lunch at IOPAN*
13:30 - 14:00	Wrap-up of the workshop
Afternoon	Continuation of discussions if necessary

7 LIST OF PARTICIPANTS IN THE FIRST SSF OCEAN FLAGSHIP WORKSHOP

Institution	Name	Email	Area
NERSC Norway	Hanne Sagen	hanne.sagen@nersc.no	Ocean acoustics
	Torill Hamre	torill.hamre@nersc.no	Data bases, SIOS
	Jenny Ullgren	jenny.ullgren@nersc.no	Oceanography
	Florian Geyer	florian.geyer@nersc.no	Oceanography
UNIS Norway	Eva Falck	eva.falck@unis.no	Oceanography
IOPAN Poland	Waldek Walczowski	walczows@iopan.gda.pl	Oceanography
	Agnieszka Beszczynska-Möller	abesz@iopan.gda.pl	Oceanography
	Ilona Goszczko	ilona_g@iopan.gda.pl	Oceanography
	Sławomir Kwasniewski	kwas@iopan.gda.pl	Biology
IMR Norway	Øystein Skagseth	oystein.skagseth@imr.no	Oceanography
AWI Germany	Ben Rabe	Benjamin.Rabe@awi.de	Oceanography
	Wilken Jon von Appen	wjvappen@awi.de	Oceanography
	Ingo Schewe	Ingo.Schewe@awi.de	Biology
	Christiane Hasemann	Christiane.Hasemann@awi.de	Biology
LSCE France	Elisabeth Michel	Elisabeth.Michel@lsce.ipsl.Fr	Oceanography
University of Delaware USA	Andreas Münchow	muenchow@udel.edu	Oceanography
OGS Italy	Manuel Bensi	mrebesco@ogs.trieste.it	Marine geology
	Vedrana Kovacevic	vkovacevic@ogs.trieste.it	Oceanography
SSF Norway	Karoline Bælum	kab@forskningsradet.no	Research Council of Norway

Participated by Webex or Skype

ISAC-CNR Italy	Roberta Sciascia	R.Sciascia@isac.cnr.it	Oceanography
	Marcello Magaldi	marcello.magaldi@sp.ismar.cnr.it	Oceanography
NPI Norway	Laura de Steur	laura.de.steur@npolar.no	Oceanography
	Arild Sundfjord	arild.sundfjord@npolar.no	Oceanography
UiB Norway	Tor Gammelsrød	Tor.Gammelsrod@uib.no	Oceanography