# SVALBARD CONNECTION

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## POLISH-NORWEGIAN cooperation in marine European Arctic research

(selected Arctic grants at IO PAN funded by Polish-Norwegian Research programe)

Institute of Oceanology PAN , Sopot 2017

**Institute of Oceanology Polish Academy of Sciences**

**Project liders and editors:**
Waldemar Walczowski – project AWAKE-2
Maria Włodarska-Kowalczuk – project DWARF
Jan Marcin Węsławski – project GLAERE
Piotr Kukliński – project POLNOR

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R/v OCEANIA at stormy sea near Spitsbergen.

Polish Polar Station in Hornsund in summer.

Nie ma w Arktyce drugiego tak szczególnego miejsca jak Svalbard, maleńki archipelag położony mniej więcej w połowie drogi między północnymi brzegami Norwegii a biegunem północnym. To obszar unikalny, mimo że nie tak olbrzymi jak Grenlandia z jej gigantycznym lądolodem i bez takich siarczystych mrozów jak w Arktyce kanadyjskiej czy rosyjskiej. Ale choć na tle innych arktycznych wysp i archipelagów jest malutki, mieści w sobie niezwykłe bogactwo. Nigdzie indziej nie znajdziemy tam na tak niewielkim terytorium tak dużej różnorodności – od najbardziej wysuniętej na południe Wyspy Niedźwiedziej, o wręcz atlantyckim klimacie, przez zachodnie fiordy Spitsbergenu aż po jego surowe, arktyczne wschodnie wybrzeże albo w całości skutą lodem wyspę Kvitoya. Nad skrajnie południowym fiordem Hornsund, gdzie znajduje się polska baza polarna, można przejść kilkaset metrów na wschód, by znaleźć się poza zasięgiem atlantyckich ciepłych prądów. Wtedy z zielonej tundry z pasącymi się gęsiami i reniferami wchodzi się w inny świat – tam tylko skała i lód, na którym leżą foki obrączkowane, przechadzają się niedźwiedzie i ciągną lodowcowe wiatry.

Svalbard to świat morski. Nie można spotkać tu rodzimych gryzoni, takich jak lemingi albo polarne zające, nie wychowują młodych sowy śnieżne. Niemal wszystko, co tu żyje, zależy od morza, od tego, jakie ono jest i co zostanie z niego wyniesione. Poza reniferami i pardwami nie ma typowo lądowych zwierząt, bo nawet lisy polarne często wyruszają na morskie lody, by upolować młodą fokę lub pożywić się resztkami po uczcie niedźwiedzia.

Ten różnorodny świat w obliczu błyskawicznych zmian klimatu także bardzo szybko się zmienia. Niektóre symptomy widać gołym okiem. Inne nie są widoczne, choć ich konsekwencje będą ogromne – nie tylko dla ekosystemów arktycznych, ale dla całej ludzkości. Svalbard i okalające go morza przez swoją „kieszonkowość" i wspomnianą różnorodność stanowią idealne miejsce, żeby się tym procesom przyglądać. Tutaj kluczowe zmiany będzie widać być może szybciej niż w innych punktach Arktyki. Niestety, wygląda na to, że rozpędzonej machiny, jaką są globalne zmiany klimatu, nie da się już zatrzymać. Jednak, by zmagać się z ich konsekwencjami, musimy zdawać sobie sprawę, jak przebiegają i w jaki sposób wpływają na ekosystemy. Wiedzieć nie tylko, jak szybko ubywa lodu i w jakim stopniu zagraża to polarnym niedźwiedziom, ale też co się dzieje z najmniejszymi organizmami, takimi jak plankton roślinny i zwierzęcy, bo na nich właśnie oparte są te ekosystemy. Pozwoli nam to przynajmniej przewidzieć, co czeka nie tylko Arktykę, ale też resztę świata, w tym Europę i Polskę.

Dlatego takie istotne są prowadzone tam badania. Cieszę się, że wspólnie pracują przy nich naukowcy z Norwegii i Polski, bo znam wielu z nich i nie mam wątpliwości, że są to specjaliści światowej klasy. Na efekty tych badań czekam z dużą ciekawością, ale i z niepokojem, bo wiem, że nasza planeta za sprawą nas, ludzi, weszła w epokę gwałtownych i w wielu wypadkach katastrofalnych zmian.

**Adam Wajrak**
dziennikarz i autor

There is no other place in the Arctic like Svalbard, an archipelago situated halfway between the coasts of northern Norway and the North Pole. It is a unique site, though not as large as Greenland with its huge ice cap, and not as cold as the continental Canadian or Russian Arctic. Although Svalbard seems tiny compared to other Arctic islands and archipelagos, it is an unusual place: from the southernmost, nearly boreal Bear Island, through the fjords of western Spitsbergen, to the harsh, cold, eastern coast and the entirely ice covered island of Kvitoya, there is a rich diversity of life seen nowhere else in the Arctic. This diversity is evident even on a very small area. There are parts by the southernmost Hornsund fjord (where the Polish Polar Research Station is situated) were one can walk from the lush green tundra with geese and reindeer a few hundred metres eastwards to experience the cold interior of the fjord, away from the warmth of the Atlantic waters. Here, there is bare rock and ice, with ringed seals on ice floes and polar bears walking by in the cold wind blowing off the glacier. Svalbard is a marine environment par excellence, as there are no native rodents like lemmings or Arctic hares. Nor are there any snowy owls. With few exceptions, almost all the local creatures depend on the sea: on what can be retrieved from the sea and on the type of sea. Except for reindeer and ptarmigan, there are no terrestrial animals, as even the polar fox patrols the pack ice to get at young seals or feed off the remains of a polar bear catch.

In response to the changing climate, this diverse world is changing, and changing fast. Some of these changes are visible to the naked eye. Others are not so obvious, but their consequences are going to be profound, not only for the Arctic ecosystem, but also for the whole of humanity. Svalbard, with its adjacent seas and their unusual diversity, all packed into a pocket-sized space, is an ideal place to observe these key changes, easier and faster than anywhere else in the Arctic. Unfortunately, we don't seem to be capable of slowing down or halting global climate change. In this situation, we have no choice but to acquire knowledge about the mechanism of this process if we are to cope with its consequences. We need to know how fast the ice is disappearing, how this is endangering not only polar bears, but also the tiny planktonic organisms in the sea that are the backbone of the ecosystem. This knowledge will help us to predict the future of the Arctic and the rest of the world, including Europe and Poland. In this context, the research being carried out on Svalbard is of very great significance, and I am happy that Norwegian and Polish scientists are working together there. I know many of them personally and am convinced that their expertise and knowledge are second to none. I await the effects of their researches with trepidation, all the more so that I'm aware that our planet is embarking on a journey during which we shall have to face up to a whole range of unpredictable, violent and possibly catastrophic events.

**Adam Wajrak**
environmental journalist and author

Gnalberget. One of the largest seabirds colonies in Hornsund.

**CONTENT**

*Anonyx nugax*, large (5 cm) carrion feeding crustacean, common in deep muddy seabed in Spitsbergen fjords.

# AWAKE-2

Arctic Climate System Study of Ocean, Sea Ice and Glaciers Interactions in Svalbard Area.

**Main message**

The aim of the AWAKE-2 project was to understand the interactions between the main components of the climate system in the Svalbard region, i.e. ocean, atmosphere and ice, in an attempt to identify mechanisms of interannual climate variability and long-term trends. The Svalbard region was chosen because the Arctic fjords are a link between the land and the ocean. Therefore, they are highly vulnerable to warming and are expected to exhibit the earliest environmental changes resulting from anthropogenic impacts on climate.
The main hypothesis was that the Atlantic Water inflows over the Svalbard shelf and into the fjords have become more frequent during recent decades owing to changes in the ocean and atmosphere. The integrated effect of these events results in new regimes and changes in the atmosphere, ocean, sea ice and glaciers in Svalbard. Their possible feedbacks are also complex and interrelated. Fjords of the western Svalbard can serve as a field laboratory where processes and interactions shaping the Arctic climate system can be studied on smaller scale.

Participants

**Institute of Oceanology PAN**

**Nansen Environmental and Remote Sensing Center**

**University of Silesia**

**Norwegian Meteorological Institute**

**Nicolaus Copernicus University**

**The University Centre in Svalbard**

**Norwegian Polar Institute**

**Institute of Geophysics PAN**

***HAIKU on AWAKE***

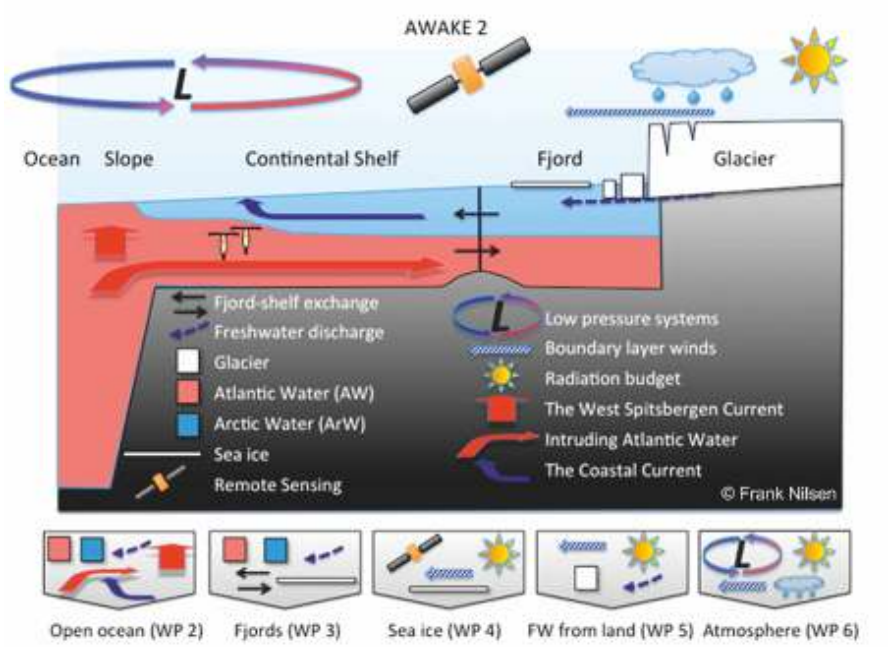
***Big waves from shelf***
***Warm the icy fjord, or***
***Was it the warm wind?***

Glacier ice in Kongsfjorden.

# AWAKE-2

**Methods**

AWAKE-2 is a multidisciplinary research project investigating the Arctic climate system where the ocean interacts with the atmosphere, sea ice, fjord waters and tidewater glaciers. Therefore, a multidisciplinary approach had to be adopted to achieve the project's aims. A wide variety of meteorological, oceanographic, glaciological and hydrological observations was collected in a coordinated manner during four field seasons to take advantage of simultaneously measured, complementary data sets from different disciplines. While the main focus was on the oceanic heat fluxes from the West Spitsbergen Current to the west Svalbard fjords, glaciers and atmosphere, all the components of the climate system had to be addressed to account for complex interactions. The new field measurements during the project were complemented by analyses of historical data and numerical simulations with high-resolution ocean models.




A conceptual model of ocean-air-ice interactions in the Hornsund area (upper right) and different instruments used for ocean, atmospheric and glaciological observations in the project – a CTD probe (left), an automated meteorological station (bottom middle), and a GPS station for monitoring glacier activity (bottom right).

# AWAKE-2

**Methods**

Glaciers that flow into the sea and terminate in an ice cliff from which icebergs are discharged during calving are called tidewater glaciers. Tidewater glaciers are a characteristic feature of the Svalbard environment, where they constitute more than 60% of the total ice-covered area. During AWAKE-2 special attention was given to observing and attempting to understand how oceanic forcing can directly influence calving intensity and submarine melting of tidewater glaciers. Year-round observations of selected glaciers were carried out, as were seasonal measurements of temperature, salinity and ocean currents in the close vicinity of the tidewater glaciers and also in neighbouring waters. Concurrent meteorological and oceanographic observations were collected to explore causal relationships between different components of the fjord system. Time series of historical and contemporary data were analysed using advanced statistical methods and simple conceptual models. The results of the numerical simulations were calibrated and validated against available observations.

Oceanic heat released to atmosphere increases air temperature, warmer air enhances surface melt of glaciers, and warmer fjord waters at the tidewater glacier front accelerate iceberg calving and melting of its submerged part. More freshwater discharged into the fjord from melting or calving glaciers, or from terrestrial sources changes fjord circulation and potentially influences its sea ice cover. This can have an effect on heat exchange between ocean and atmosphere. Possible feedbacks in the ocean-atmosphere-sea ice-glaciers-land system are complex and interrelated. Fjords of the western Svalbard can serve as a field laboratory where processes and interactions shaping the Arctic climate system can be studied on smaller scale.

Small boats and snow scooters were important suplement to the research vessel operations.

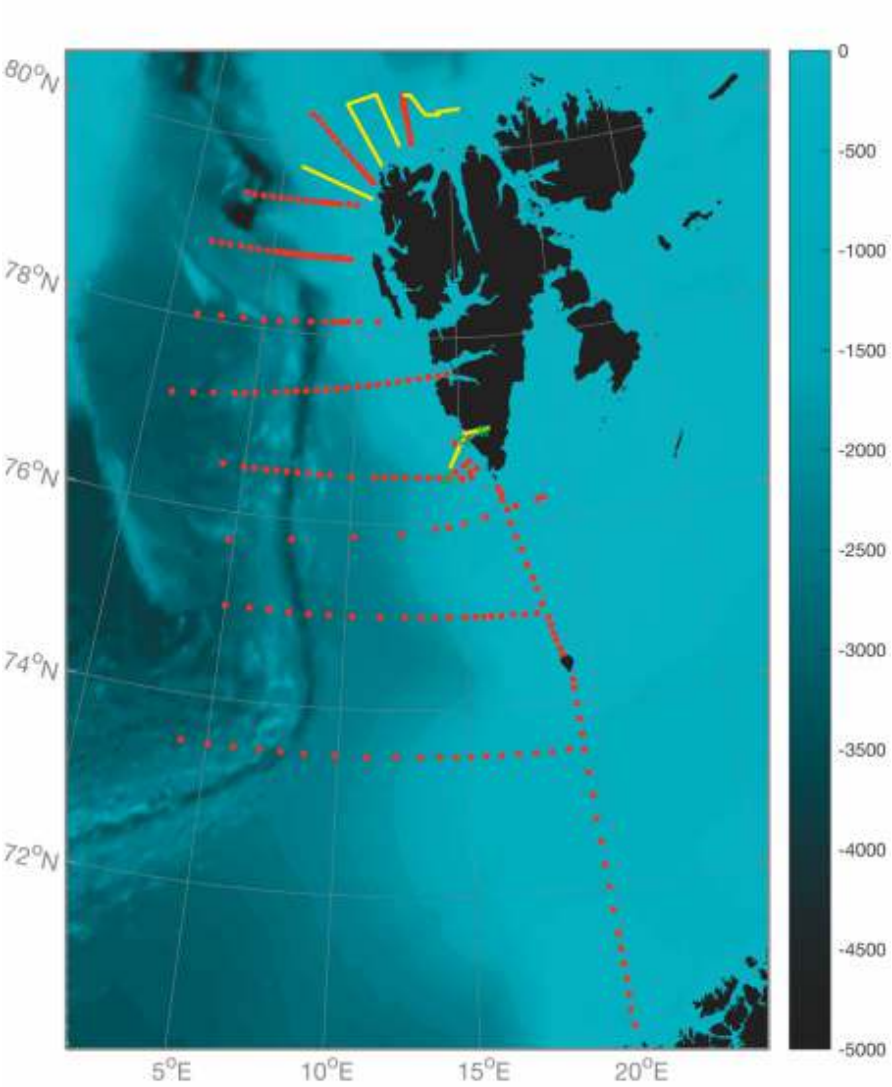
# AWAKE-2

**Field work**

Open ocean measurements were carried out by Polish and Norwegian research vessels – r/v Oceania, r/v Lance and r/v Haakon Mosby. During the annual summer surveys r/v Oceania collected hydrographic, meteorological and biological observations, covering the eastern regions of the Nordic Seas and the Fram Strait from northern Norway to the southern Nansen Basin of the Arctic Ocean. Every year more than 200 full-depth profiles of water temperature, salinity, dissolved oxygen and ocean currents were measured to study the variability of Atlantic Water properties and transport in the West Spitsbergen Current.

However, most of the field activities during the AWAKE-2 project were concentrated in the Svalbard fjords. The main field campaigns took place in Hornsund, the southernmost Svalbard fjord. Hornsund can be regarded as a typical Arctic fjord, characterized by open exchange with shelf waters, a deep but sill-limited inner basin, estuarine circulation and numerous tidewater glaciers. Therefore it can be considered a model example of a high latitude fjord and serve as a field laboratory to study processes that are similar in all Arctic fjords, and also Greenland. The logistic and scientific support provided by the Polish Polar Station in Hornsund was of very considerable benefit for the logistically challenging field work in this high Arctic fjord, especially during the longer observational periods from early spring until late autumn.

Numerous autonomous stations collecting meteorological, oceanographic and glaciological data were installed in different locations in the fjord basins, on glaciers and on land. Hydrographic measurements were carried out in direct proximity to tidewater glacier termini in order to resolve small-scale processes at the ocean-ice boundary. The unprecedented measurements of ocean microstructure at the front of marine terminating ice walls were collected from a small boat operating next to a tidewater glaciers. The large amount of original, multidisciplinary data from a wide range of the state-of-the-art sensors and samplers was collected during AWAKE-2.



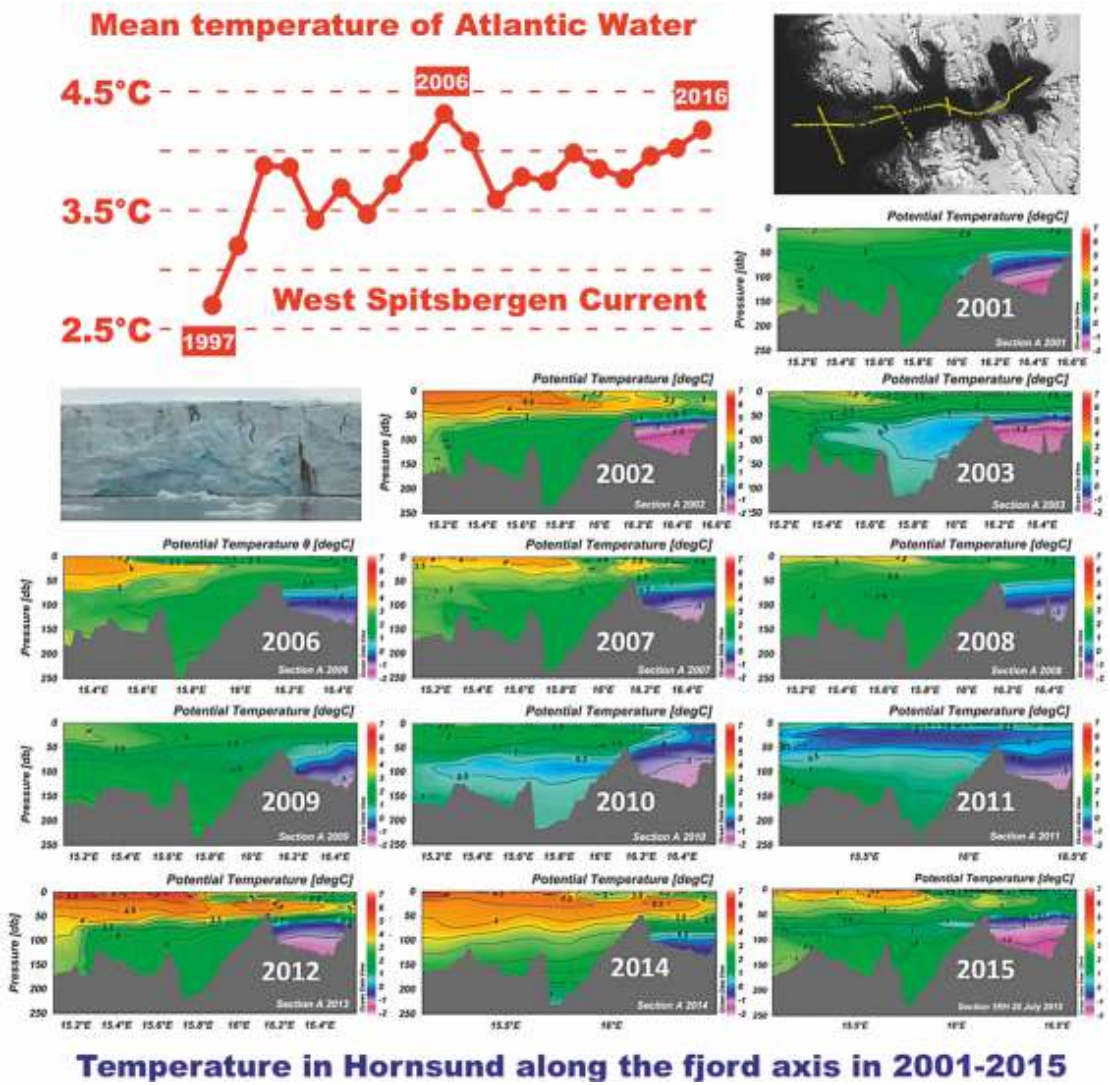

A map showing standard hydrographic stations (red dots) occupied by r/v Oceania during each summer survey and deployment of the bottom-mounted current meter in the fjord.

# AWAKE-2

**Results**

The multidisciplinary observations during AWAKE-2 revealed complex interactions between the main components of the climate system, i.e. ocean, atmosphere, cryosphere and land. The heat capacity of the ocean enables it to store a vast amount of thermal energy and is therefore a major factor causing long-term climate variability. But the ocean can also act at intermediate and short time scales, the effect of which is clearly visible in the Svalbard fjords. Interannual and decadal changes in Atlantic Water properties, mostly temperature increases, influence Svalbard's climate, the sea ice cover in the fjords and the rate of tidewater glacier recession. The mechanisms of oceanic forcing may be very different, including the direct impact of warm water on sea ice and submerged parts of tidewater glaciers and the remote driving of atmospheric warming as a result of ocean-air heat exchange. The large-scale atmospheric circulation is also the main factor forcing northward oceanic heat transport from the North Atlantic towards the Arctic, while oceanic exchanges between the deep ocean, continental shelf and the Svalbard fjords are mostly set-up by local atmospheric circulation patterns. Shelf-fjord exchanges between the West Spitsbergen Current and the western Svalbard fjords play a key role in setting up interactions between ocean, atmosphere, sea ice and tidewater glaciers. The more frequent Atlantic Water inflows during winter may inhibit ice production and limit sea ice cover in the Svalbard fjords, while in summer, warmer Atlantic Water can significantly accelerate the calving of tidewater glaciers and intensify their underwater melting. Ocean-atmosphere heat fluxes contribute to the observed increase in air temperature, especially during the winter months. Inflows of Atlantic Water into the Svalbard fjords also play an important role in shaping background physical conditions in fjord ecosystems.

Time series of mean Atlantic water temperature in the West Spitsbergen Current (upper left) and year-to-year changes of temperature distribution in summer, measured at the hydrographic section along the main axis of the Hornsund fjord.



# AWAKE-2

**Outreach**

The AWAKE project has own website (*http://www.iopan.gda.pl/projects/AWAKE2/overview.html*) and Facebook account. The project activities and results were presented during numerous conferences and meetings.
A special session entitled "Atlantic water in the main gateways to the Arctic Ocean - impact on climate, sea ice, tidewater glaciers and ecosystem" was co-organized by AWAKE-2 during the 2016 General Assembly of the European Geophysical Union in Vienna and served as a broad forum for presenting the project results. AWAKE-2's field activities, scientific questions, measurement techniques and results were also presented to the general public every year during the Sopot Science Days. Several papers based on the scientific outcome of AWAKE-2 have been published in recognized international peer-reviewed journals.


Open events like scientific picnics, presentations of oceanographic models and open lectures were an important part of the AWAKE-2 dissemination activities.

# AWAKE-2

**Conclusions and future perspective**

The retreat rates of Svalbard glaciers, observed during the AWAKE-2 period, provide convincing evidence for rapidly progressing climate change. Detailed analysis of the observations and numerical simulations carried in AWAKE-2 reveals that in the Svalbard region, the ocean plays a key role in this process. However, the interactions between different components of the climate system are complex with many feedback mechanisms, which are not yet fully understood. The temporal and spatial resolution of observational data still poses a significant problem, and long-term sustained measurements of key variables in critical locations, which are indispensable for addressing climate change at appropriate time scales, have not yet been implemented. Even state-of-the-art numerical models rarely have a sufficiently high spatial and vertical resolution to reproduce the complex circulation in Svalbard fjords, especially in the glacier bays. Representation of important processes at the ocean-glacier boundary is either inadequate or has yet to be attempted, and the bottom topography is often unrealistic. The future challenge is to establish a sustained, multidisciplinary monitoring system, covering all components of the climate system and measuring key climatic and oceanic variables at scales enabling different modes of variability to be recognized.


Working deck preparations before deploying a CTD rosette on a hydrographic station in the fjord during the r/v Oceania summer cruise in 2015.

# AWAKE-2

**Project participants**

**WP 1  Project management and dissemination**
**leader Waldemar Walczowski**, Małgorzata Merchel, Sylwia Sutuła

**WP 2 Open ocean oceanography**
**leader Agnieszka Beszczyńska-Möller**, Waldemar Walczowski, Piotr Wieczorek

**WP 3 Fjord oceanography**
**leader Eva Falck**, Arild Sunfjord, Agnieszka Promińska, Waldemar Walczowski, Piotr Wieczorek

**WP 4 Sea Ice**
**leader Frank Nilsen**, Stefan Muckenhuber

**WP 5 Freshwater from the land**
**leader Mariusz Grabiec**, Małgorzata Błaszczyk, Adam Nawrot, Dariusz Ignatiuk, Tomasz Wawrzyniak

**WP 6 Atmosphere and climate change**
**leader Rajmund Przybylak**, Øyvind Nordli, Ketil Isaksen, Andrzej Araźny, Przemysław Wyszyński

**WP 7 Synthesis**
**leader Stein Sandven**, Waldemar Walczowski, A. Beszczyńska-Möller, Eva Falck, Frank Nilsen, Mariusz Grabiec, Rajmund Przybylak

Part of the AWAKE -2 team during on of the project meetings in Sopot.

Automated weather station onboard r/v Oceania.


Bottom-mounted mooring with a current meter, successfully recovered from the depth after year-long deployment in Hornsund.

# DWARF

Declining size – a general response to climate warming in Arctic fauna?

Project funded by Norwegian Funding Mechanism in 2013 nr DZP/POL-NOR/201992/93/2014

**Main message**

Body size is a fundamental biological unit that is closely coupled to key ecological properties and processes. Decline in organisms' body-size has been recently predicted to be the third universal biological response to global warming (alongside changes in phenology and distribution of species) in both aquatic and terrestrial systems. The main goal of the project is to test hypothesis that elevated temperatures will induce size reductions in a large range of animals in the Arctic. The natural selection towards smaller forms in warming Arctic may have a far-reaching influence on the high latitude ecosystems functioning, especially the food web dynamics and carbon cycle.

Participants

**Institute of Oceanology PAN**

**Adam Mickiewicz University in Poznań**

**Norwegian Institute for Nature Research (NINA), Tromsø**

**University of Oslo (UiO)**

**Akvaplan-niva (APN), Tromsø**

***H A I K U  o n  D W A R F***

***W a r m e r  t h e  w a t e r***
***F a s t e r  I  c a n  r u n  a n d  e a t***
***S m a l l  b o d y  i s  f i t***

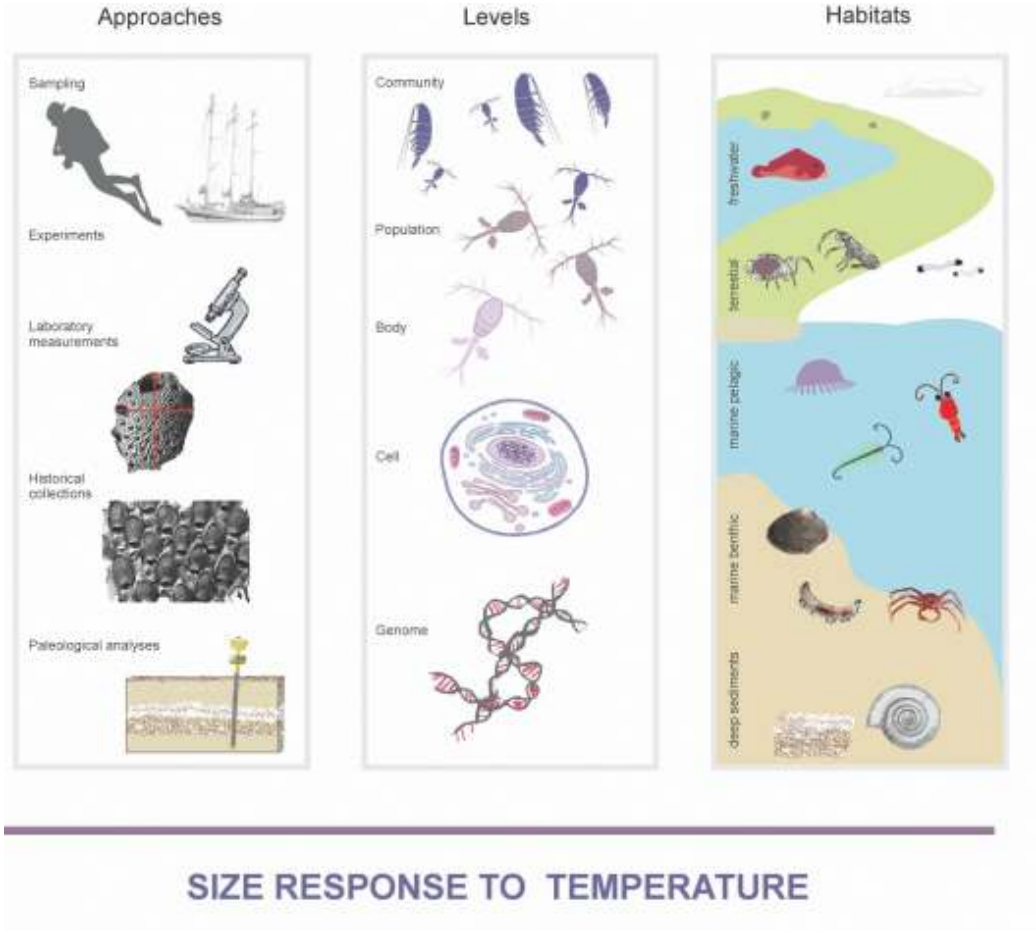
Hyttevika, calm bay at the North coast of Hornsund.

# DWARF

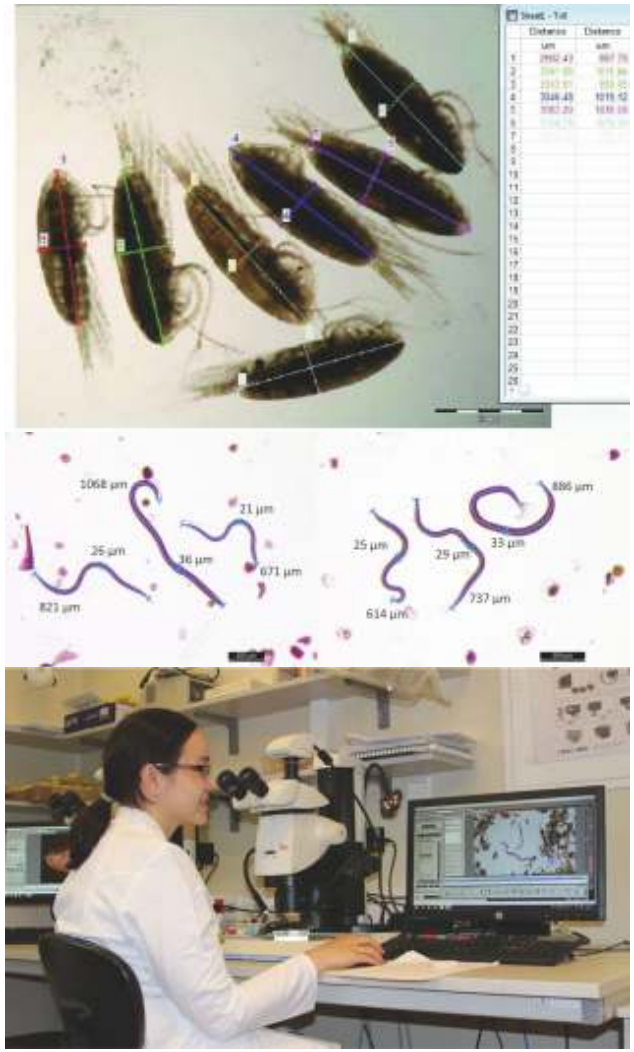
**Methods**

Temperature effects on size were explored at a range of levels of biological organization (genome, cell, body, population and community). The project was focused on selected animal taxa, including both invertebrates and fish and aimed to compare size related patterns in terrestrial, limnetic and marine systems. Thus, the study encompassed different dimensions of the possible climate warming impacts on biological size (related to organization level, taxonomic group and habitat).
The methods involved field sampling, experimental studies, body-, cell- and genome size measurements, deep sequencing of genomes for selected taxa as well as size spectra analyses at the population and community levels. Comparative study of populations and communities occurring along a thermal gradient from temperate to high Arctic areas was an application of 'space for time analogue' approach to predict climate warming effects in the Arctic ecosystems.
The survey of specimens from museum collections and paleoceanographic cores provided the historical perspective and insights into past size changes in the studied regions.

Schematic overview of methodological approaches employed in the project




Measurements of collected marine organisms (planktonic copepods and benthic nematodes)



# DWARF

**Methods**

The terrestrial and limnetic study covered tardigrades, springtails (Collembolla) and insects (particularly dung flies) as well as freshwater crustaceans dwelling in Svalbard lakes and ponds. Special focus was on the Arctic char, the fish were collected with nets and examined for morphology and genetics. Cell size and genome size of selected species and populations dwelling in various temperature regimes were analyzed using flow cytometry. Besides measurements of specimens collected in the field, the laboratory experiments on the growth rate of organisms cultured in different temperatures were performed. Also a survey relating the genome size to temperature regimes on a worldwide scale was performed based on the data stored in animal genome data bases.

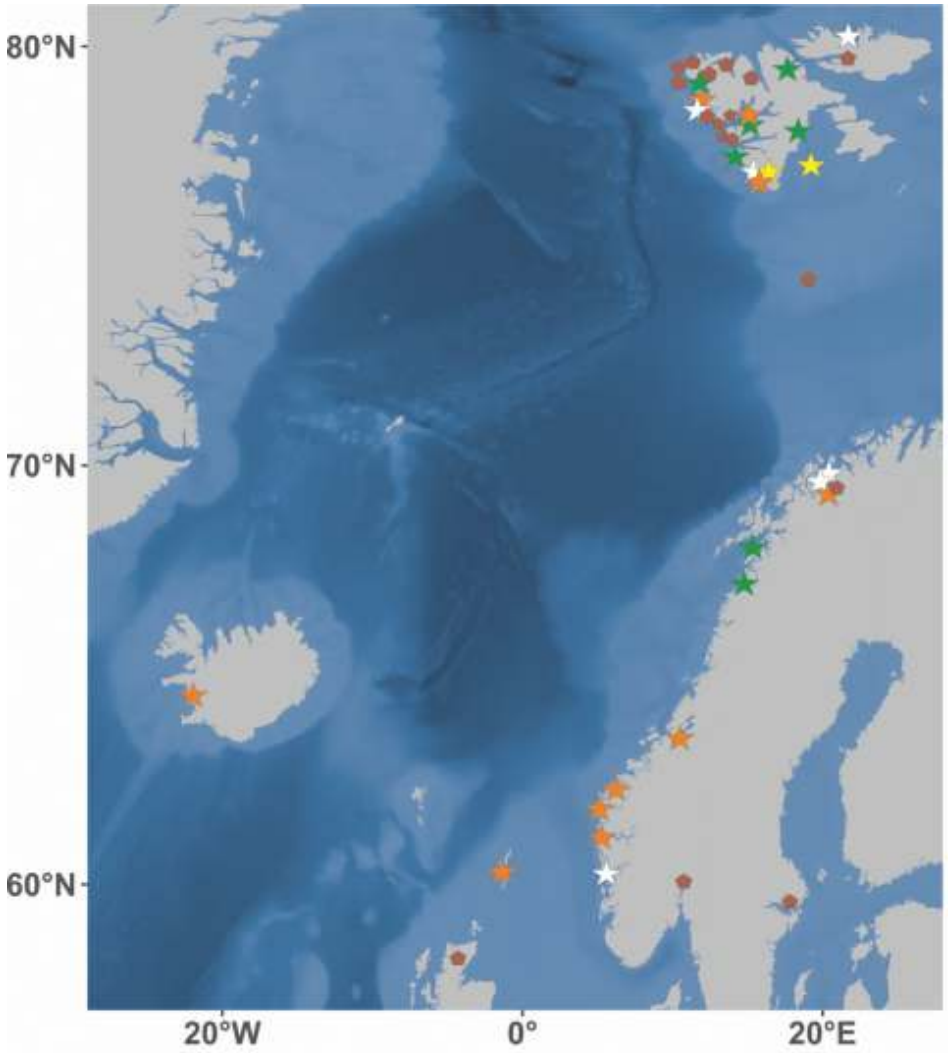
The marine study was focused on populations and communities of zooplankton, benthic fauna of soft and hard bottom. The key methodological challenge was the reliable measurement of organism size – from unicellular microorganisms to large benthic shrimps. For statistical reasons hundreds of individuals had to be measured in each locality or population compared. A novel method was introduced for the fast and reliable size analyses in nematodes – minute meiofauna organisms. A semi-automated method based on image analyses proved to be more accurate and less time-consuming than traditional procedures based on manual measurements. This was a major improvement in processing large numbers of samples. For zooplankton the direct measurements of collected specimens were complemented with the high resolution in situ measurements of plankton size spectra with the use of a Laser Optical Plankton Counter. This automatic method, supplemented by detailed taxonomic analyses and laboratory measurements of particular taxa enabled the reliable comparisons of zooplankton size spectra among sampling sites and the analysis of their relationships to environmental data.

In addition to the analyses based on recent populations, the temporal changes in body size were studied in Bryozoa (based on historical museum collections) and Foraminifera (based on Holocene sediment cores).

# DWARF

**Field work**

Terrestrial and limnetic invertebrates were sampled in Sweden, Southern and northern Norway regions, Bjornoya Island and islands of Svalbard archipelago. Fish (Arctic char) sampling was done with use of gill-nets and net-hauls in Norwegian and Svalbard lakes.
The marine field work covered a large area from southern Norway (60°N) to north-west Svalbard (80°N). Fjords in Norway (Raunefjord, Ullsfjord and Ballsfjord) and on Spitsbergen (Hornsund, Kongsfjord and Rijpfjord) that were selected for zooplankton and benthic sampling represented the summer sea surface temperature span from 11°C at the southern limit to 0°C at the northern one. Two research vessels were involved in sampling – r/v Oceania from Poland and r/v Hellmer Hansen from Norway. Zooplankton was sampled with the use of multinet sampler, WP2 nets and surveyed with use of LOPC (Laser Optical Plankton Counter). Sediment and benthic samples (both meiofauna and macrofauna) were collected with grabs and corers. Hard bottom fauna (Bryozoa) was sampled with dredges and by direct underwater collecting of rocks by SCUBA divers. Gammarid crustaceans were collected on rocky shores.
Paleontological cores covering the Holocene period were collected with the gravity corer at two sites (in Hornsund and Storfjorden) with a well-documented history of strong hydrographic variability within the last 14 000 years.




DWARF sampling stations: ● Terrestial & Limnetic fauna; ☆ Marine Plankton & Benthos; ★ Litoral fauna; ★ Hard bottom bryozoans; ★ Paleooceanographic cores

Dwarf arctic char prey fish in gill net – Svalbard.

# DWARF

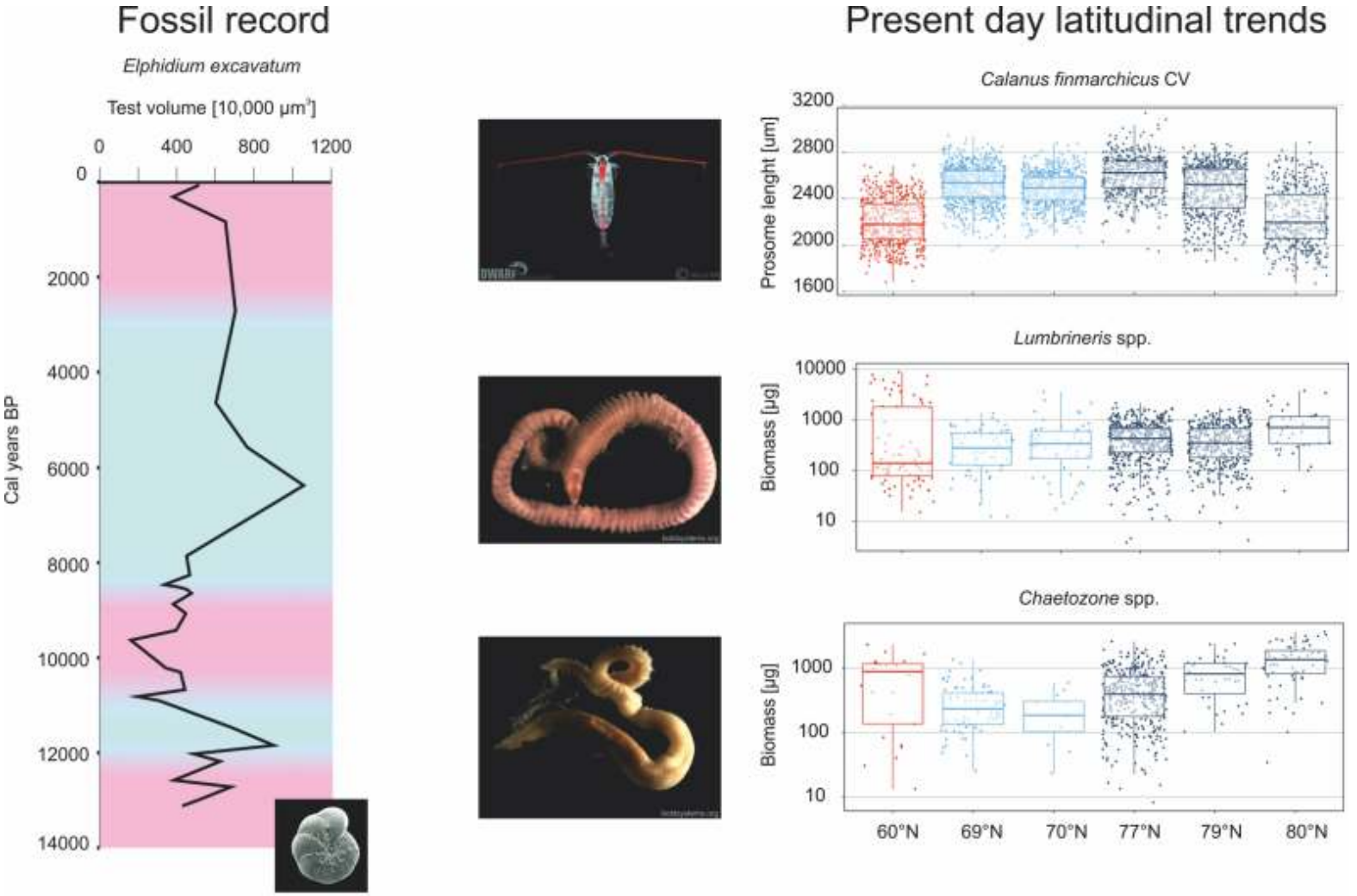
**Results**

As we have been working with a great variety of organisms, each one with a different life cycle (from short-lived pelagic copepods to long-lived bivalves on the sea bed), the response to warming also varied across the studied species and habitats. However, signals of declining size in organisms confronted with higher temperature were documented.

In both pelagic and benthic systems we observed the declining trends in size characteristics of selected species rather than shifts in the size structure of the whole communities. For example, the average individual size of some marine benthic polychaete (e.g. *Lumbrineris* spp.) or pelagic crustacean (*Calanus* spp.) taxa displayed a declined trend towards the lower latitudes/warmer waters. At the community level the size structures remained conservative in both marine pelagic and benthic assemblages across the studied latitudinal and thermal gradients. The representatives of the largest size classes were observed only in northern locations. The amount of food may reduce the effect of latitudinal size increase (in areas poor in food the animals may not attain their maximum size). In sessile colonial animals such as Bryozoa, the average size of a colonial unit (zooid) in an assemblage increased towards higher latitudes/lower temperatures, however this was produced by compositional shift towards species with larger zooids rather than by changes in zooid size within species.

The relationship between the organism size and temperature was also reported from palaeontological perspective – the smaller species were found to dominate in the warm Bølling Allerød period (14 500 years ago), whereas the larger ones in the cold younger Dryas (12 000 years ago).

The growth rate increased while the offspring and adult size decreased in collembolan populations that were sampled in Norway and Svalbard and exposed to growing temperatures in experiments. The observed changes in genome size were not necessarily translated into similar changes in body size. The growth patterns for Arctic char differed between resident and migratory populations.




Signals of increasing size in colder periods (left side) and locations (right side) in common marine plankton (*Calanus* spp.) and benthic (polychaetes *Lumbrineris* spp. and *Chaetozone* spp., foraminifera *Elphidium excavatum*) taxa.

# DWARF

**Outreach**

The DWARF project was presented at a number of Science Picnics and Festivals in Gdynia, Sopot, Gdańsk and Poznań – altogether a few thousands of visitors passed the DWARF stands and presentations. A special event was the exhibition of photos presenting the Arctic animals and fieldwork. It was shown in the Gdynia Aquarium Exhibition Hall for two months in 2016 and later at a public school in Grodzisk Mazowiecki in Central Poland and University of Adam Mickiewicz in Poznań.
A workshop on Arctic wildlife and climate change for schoolchildren was conducted under the auspices of the joint GLAERE and DWARF projects. The event was linked with a painting and creative art competition and the best works were subsequently exhibited in the seminar room of the Institute of Oceanology PAN and on its website. A popular book and a set of school lesson scenarios focused on Arctic ecology and size issues were also prepared.
Over 50 presentations were made at numerous international conferences. A special session focused on climate warming effects on organism size in the Arctic was organized during the Arctic Science Summit Week held in Prague in April 2017.

The DWARF Dissemination Action during "Biologist's Night" Festival at University of Adam Mickiewicz in Poznań.

Explaining the prey size effects on carnivore feeding success with use of jelly-candies experiment.

Children's art work inspired by DWARF and GLAERE projects.

Exhibition of DWARF field work photos.

# DWARF

**Conclusions and future perspective**

A change in size was found to be a universal response to climate change in most of the ecosystem elements examined. The most important consequences of such changes are possible alterations in the carbon cycling and food web structures – this is an aspect worth further examination. It is equally important to understand the mechanisms of the observed patterns – how the size changes are regulated by individual physiology as well as the extent to which this becomes embedded in genetics.

Two carnivorous planktonic crustaceans occurring in Svalbard waters, smaller one is boreal *Themisto abyssorum*, bigger one is the Arctic species *Themisto libellula*.

Carnivorous sea slug *Natica clausi*, large species from Spitsbergen.

# DWARF

**Project participants**

**WP 1  Terrestrial Fauna**
**leader JHans Petter Leinaas**,  Krzysztof Zawierucha

**WP 2 Limnetic Fauna**
**leader Martin-A. Svenning**

**WP 3 Marine Pelagic Fauna**
**leader Sławomir Kwaśniewski**,  Katarzyna Błachowiak-Samołyk, Mateusz Ormańczyk, Emilia Trudnowska

**WP 4 Marine Benthic Fauna**
**leader Maria Włodarska-Kowalczuk**, Barbara Górska, Piotr Kukliński, Joanna Legeżyńska, Mikołaj Mazurkiewicz, Paul Renaud, Anna Stępień

**WP 5 Paleontological Record of Size Spectra in Holocene**
**leader Joanna Pawłowska**, Magdalena Łącka, Marek Zajączkowski

**WP 6 Database and literature survey on relationships between genome, cell and body size and temperature (or habitat)**
**leader Dag Olav Hessen**, Kristian Alfsnes

**WP 7 Synthesis of the Results, Transfer of Knowledge and Public Outreach**
**leader Jan Marcin Węsławski**, Joanna Piwowarczyk

DWARF team during kick-off meeting in Sopot.

Boulders in Isfjorden, Spitsbergen at 15m depth.

Boulders in Isfjorden, Spitsbergen at 15m depth.

# GLAERE

Glaciers as Arctic Ecosystem Refugia

Project funded by Norwegian Funding Mechanism in 2013 nr DZP/POL-NOR/1876/2013 6th August 2013, RIS 6783

**Main message**

Seabirds feeding near the sea surface, ringed, common and bearded seals, belugas and polar bears all need glacial bays, where their food (krill) is concentrated. Such hotspots are not stable: they depend on the one hand on food being advected from the adjacent shelf, and on other on the hydraulic pressure of the meltwater that concentrates the food. The depth of the adjacent water is of key importance for the development of this phenomenon..

Participants

**Institute of Oceanology PAN**

**Norsk Polarinstitutt**

**Department of Vertebrates Ecology**
**University of Gdańsk**

**Geographic Information Center**
**University of Gdańsk**

**National Marine Fisheries Research Institute**

**University Studies on Svalbard**

**University of Tromsø**

***HAIKU on GLAERE***
***Meltwater discharge***
***Creates feeding paradise***
***Not always, not everywhere***

Active tidal glacier in Hornsund.

# GLAERE

**Methods**

The project was interdisciplinary, so various methods were employed. Besides the work on archives and data bases, the field work covered a wide range of disciplines. The first was the physical environment (salinity, temperature and turbidity profiles near the glacier cliffs) measured in situ from r/v Oceania, r/v Hellmer Hansen, r/v Lance and the yachts used for the supplementary sampling. As the research vessels and boats could not sail close up to the glacier front, however, remotely operated vehicles and a helicopter were used to obtain samples from the vicinity of the cliff. Those measurements were supplemented with satellite data analyses that show the extent of meltwater plumes. The seabed near the glaciers was sampled with sediment cores and sediment traps, which enabled us to assess the amount of solids (stones, sand and clay) that fall from the glacier to the sea bottom. Chemical analyses of sediments was performed to assess the amount of carbon stored in the glacial bays. Basic data on the glacier melting rate and mass balance complemented the description of the physical environment. Acoustic measurements were used to record the ambient noise around the glacier and to assess the underwater profile of the glacier and the sediment plume pathways.

GLAERE team in rubber boat tow the remotedly operated sampler closer to the ice cliff.

# GLAERE

**Methods**

As important as the physical, chemical and sedimentological observations were the studies of the organisms dwelling near the glaciers. These covered all size classes of organisms from microbes in the water column, through krill to benthic dwellers like starfish. An important part of the study was devoted to top predators, such as fish, seabirds (kittiwakes and fulmars) and marine mammals (white whales, ringed and bearded seals). Plankton nets of different mesh, dredges and trawls were used for sampling invertebrates. Seabirds were studied both at the nearby colonies and at sea. The main method for studying seabirds and marine mammals was telemetry – animals were fitted with transmitters revealing their geographical position. The biological part of the field work was performed from research vessels, land-based stations and small boats. Besides the collection of data on the distribution, density and biomass of all organisms, we were also interested in their diet. This we studied indirectly by means of isotopic, lipid profiles, and directly by analysing stomach contents of invertebrates and fish.

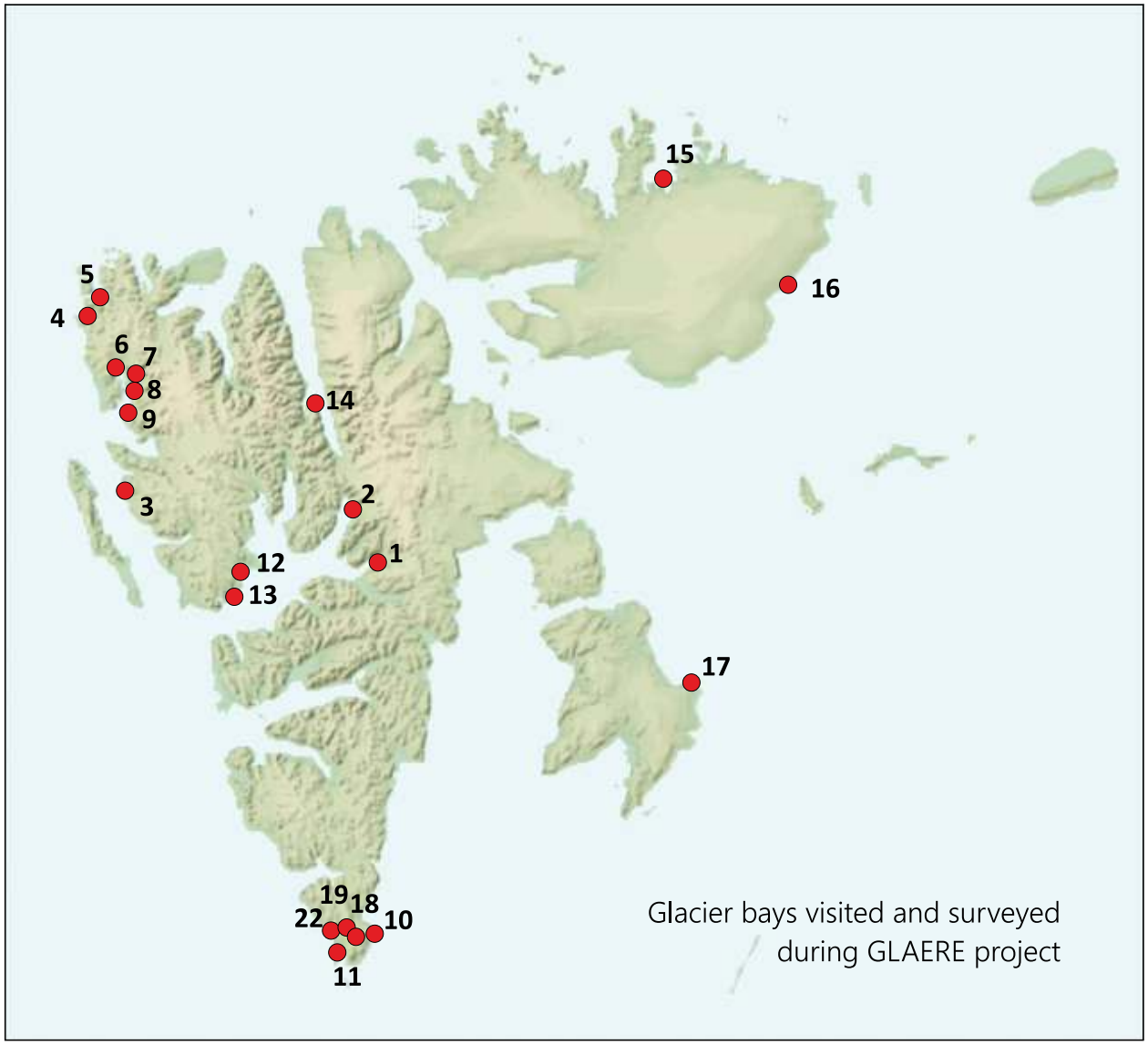
*Acantostepheia malmgreni*, hyperbenthic crustacean,
common in cold waters in Svalbard.

# GLAERE

**Field work**

The GLAERE field work was performed mainly in the two best studied fjords – Hornsund in SW Spitsbergen at 77°N and Kongsfjord in NW Spitsbergen at 79°N. Hornsund has several glaciers, the most interesting and active ones being adjacent to the fjord's inner basin (Burgerbukta and Brepollen). The area is also the site of a large Kittiwake colony at Gnalodden with over 10 000 birds. Kongsfjorden has very active glaciers in its inner part (Kongsbreen and Kongsvegen) and a number of smaller seabird colonies. Field measurements were performed as close to the glaciers as possible, and for comparison, at stations some distance from the glaciers. Sampling was less intensive at a number of Svalbard locations near the glaciers along the archipelago; for this, ships of opportunity and specially commissioned yachts (Meridian, Magnus Zaremba, Toroa, Barlovento) were used.

1. Tempelfjord
2. Adolfbukta
3. Hornbaeckbukta
4. Magdalenafjorden
5. Smeerenburgfjorden
6. Lillehoekbreen
7. Kollebreen
8. Mayerbreen
9. Kongsfjorden-Kronebreen
10. Hamberkbukta
11. Olsokbreen
12. Borebukta
13. Ymerbukta
14. Wijdefjorden
15. Rijqfjorden
16. Nordgustlandet
17. Edgeoya
18. Brepolen
19. Burgerbukta
20. Tinayerbreen
21. Conwaybreen
22. Hansbreen

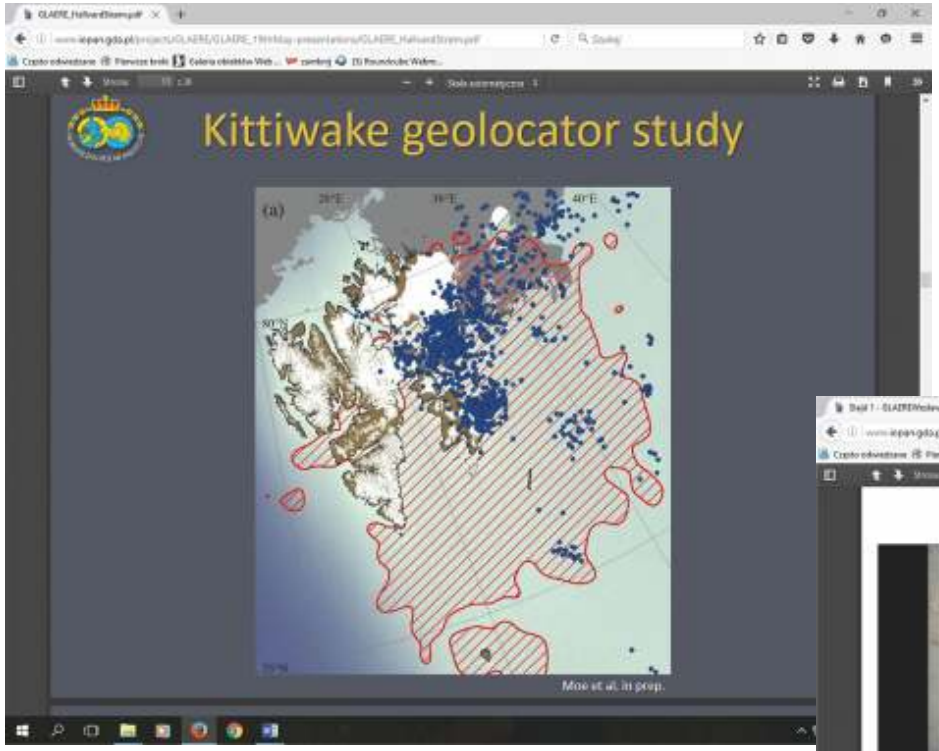


Glacier bays visited and surveyed during GLAERE project

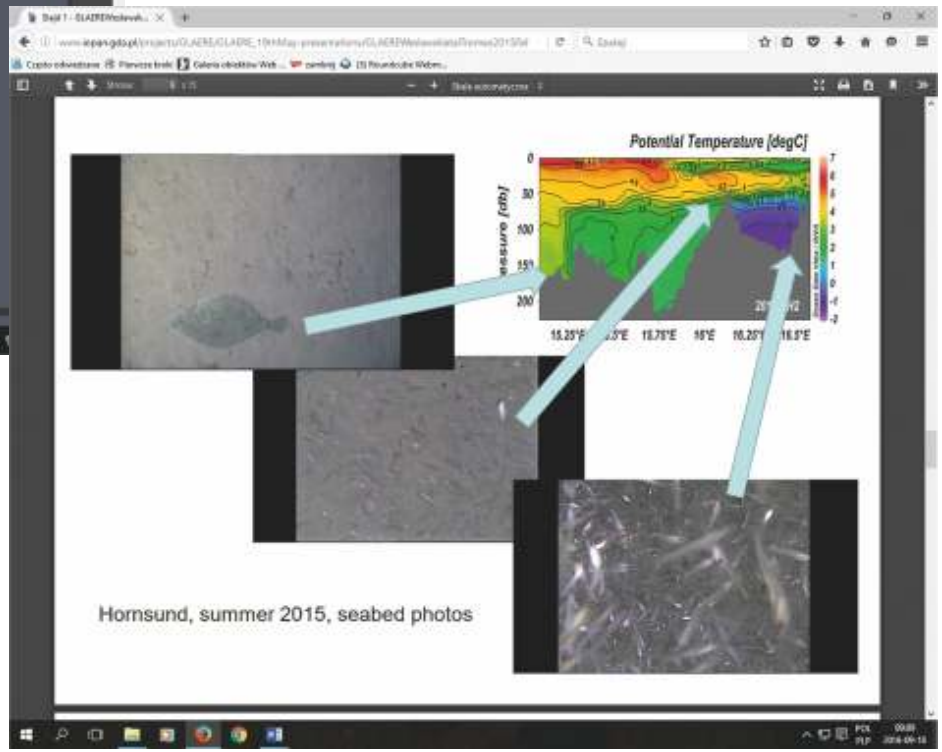
# GLAERE

**Results**

The main results of the project show that the expected concentrations of marine food (krill) and predators near the glaciers are not a stable and easily predictable phenomenon. In many cases the glacier bays were not "hot spots" for feeding animals. Among the factors responsible for the effectiveness of a feeding site is the character of the meltwater discharge. When the freshwater is taking form of potent jest stream, the hydraulic force can mix and take to the surface the large plankton from the water column. On the other hand, advection of macroplankton from the shelf is also needed, as the fjord itself does not host its "own" population of krill. Fish, especially polar cod that concentrate near the glacier, are apparently both searching for food and avoiding predators (Atlantic cod) that are more abundant in the outer and central parts of the fjord. Cold waters of local origin (derived from winter cooling, freezing and vertical mixing) can maintain isolated populations of invertebrate species that prefer cold waters, in true Arctic conditions. For surface feeding seabirds, glaciers may occasionally play a very important role in feeding the colony, but when food is not concentrated there, the birds have to fly long distances to the open sea.




Examples of project results – distribution of Kittiwakes during feeding trips, seabed photos show near bottom concentration of krill in glacial bays.

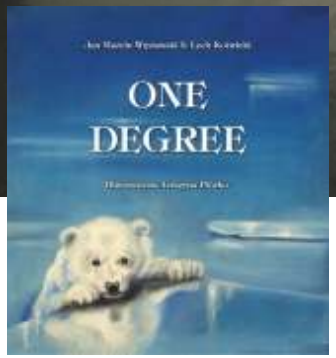


# GLAERE

**Outreach**

Communication with the general public (especially schools) was deemed important from the very outset of the project. We used both a passive approach (dissemination of information on the project, leaflets, photo exhibits and booklets) and an active one. The active approach started with talking to children from several schools about the Arctic and climate change and the activities involved in the GLAERE project. Later on, the children that took part in the courses were asked to prepare a play about the Arctic – the performance was recorded in a professional theatre in Sopot and is available on the internet (www.iopan.gda.pl). An art workshop was also run, following which the children organized an exhibition of drawings of Arctic animals. Especially interesting was a competition to find how best to present the problem of glacier melt. The children put forward several concepts in the form of posters, power point presentations and short films.
Finally a short, illustrated story entitled "One degree" was published and edited in Polish and English. The book is also available on the web: *www.iopan.gda.pl/projects/GLAERE/dissemination.html*

Children from Gdańsk school perform in theatre a short drama about Arctic animals seeking remnant of ice in warmed Arctic, photo W. Ostrowski.
Below: book, children art and art exibition about Arctic.




# GLAERE

**Conclusions and future perspective**

The role of melting glaciers as creators of feeding grounds for top predators was confirmed, albeit this role depends on complex conditions and is not easy to predict. The role of glacial bays as refugia for cold water fauna was confirmed, in places where tidal glacier bays are partly isolated by a sill. The large-scale sinking (mortality) of marine plankton to the seabed in glacial bays was confirmed and the feeding of benthos on pelagic organisms demonstrated. Near-bottom "super concentrations" of krill were recorded near glaciers, yet their real nature is not clear (avoidance of predators, escape from turbidity, feeding on sinking plankton – all these reasons were considered).
Future studies should address the part played by microbes in the functioning of near-glacial bays, the burial balance of organic carbon and the role of glacial suspensions in removing organic particles from the water column.

Fast melting glacier in Hornsund.

# GLAERE

**Project participants**

**WP 1  Management, Dissemination, Synthesis and Data base**
**leader Jan Marcin Węsławski**, Harald Steen, Joanna Piwowarczyk, Marcin Wichorowski, Lech Kotwicki

**WP 2 Physical drivers**
**leader Agnieszka Beszczyńska-Möller**, Waldemar Walczowski, Jack Kohler, Sławomir Sagan, Joanna Szczucka

**WP 3 Remote sensing & GIS**
**leader Jacek Urbański**, Agnieszka Wochna

**WP 4 Marine mammals**
**leader Christian Lydersen**, Kit Kovacs

**WP 5 Seabirds**
**leader Hallvard Strøm**, Lech Stempniewicz, Dariusz Jakubas

**WP 6 Fish**
**leader Jørgen Berge**, Dariusz Fey, Paul Renaud

**WP 7 Lower trophic levels**
**leader Maria Włodarska-Kowalczuk**, Kajetan Deja, Marta Głuchowska, Mateusz Ormańczyk

Project participants near the r/v OCEANIA during meeting in Hel Marine Station, Poland, May 2016.


Magnus Zaremba – one of the yachts that supported our survey in GLAERE.

Tidal glacier in Magdalena fjorden – August 2016.

# POLNOR

POLNOR – The Changing Ocean of the Polar North

Project funded by Norwegian Funding Mechanism in 2013 nr POL-NOR/196260/81/2013, 13th December 2013, RIS 6866

**Main message**

The Arctic is the region of the globe that is most influenced by ongoing global climate change. Sea ice retreat in the central Arctic Ocean due to warming is leading to higher $pCO_2$ values in the surface waters, reduced $CaCO_3$ saturation states and increased biological production. The Arctic ecosystem will respond to these multiple stressors arising from ocean warming and chemistry change caused by ocean acidification (OA). OA is a decrease in the pH in the oceans caused by the uptake of anthropogenic $CO_2$ from the atmosphere and is recognized as having negative effects on many groups of marine invertebrates with calcareous skeletons. The project's aim was to provide an assessment of how the Arctic ecosystem responds to multiple stressors arising from ocean warming and chemistry change caused by ocean acidification. The following questions were addressed: (1) What is the rate and regionality of recent past, present and future ocean warming, freshening, productivity and ocean acidification? (2) What is the present biodiversity and distribution of calcifying benthic macrofauna from Atlantic to Arctic waters? (3) Does an organism's skeletal geochemical properties track recent and present changes in the physical and biological properties of oceans?

Participants

**Institute of Oceanology PAN**

**Institute of Paleobiology PAN**

**Norwegian Institute for WaterResearch**

**Institute of Marine Research**

**Akvaplan-niva**


***HAIKU on POLNOR***

***In the acid sea***
***The calcareous wonders***
***May vanish at all***

Sea star over a mound of calcareous algae and barnacles.

# POLNOR

**Methods**

To achieve the goals the project was divided into five individual but closely related and inter-dependent work packages, from investigations of environmental factors/components (hydrology, primary production, $CaCO_3$ saturation, $CO_2$) to evaluations of their influence on biodiversity distribution and community composition. The project investigated the distribution of calcium carbonate secreting skeleton organisms and their biochemical composition in relation to the combined effect of sea water warming, primary production and $CaCO_3$ saturation. All this information was integrated by system modelling.
The biodiversity and ecological functioning aspects of the project were partly based on analyses of an extensive inventory of benthic data collected by the Institute of Oceanology (IO PAN) and AkvaPlan-Niva (APN) in the last 25 years of research conducted in Arctic seas.


Divers getting ready to collect new samples.

# POLNOR

**Methods**

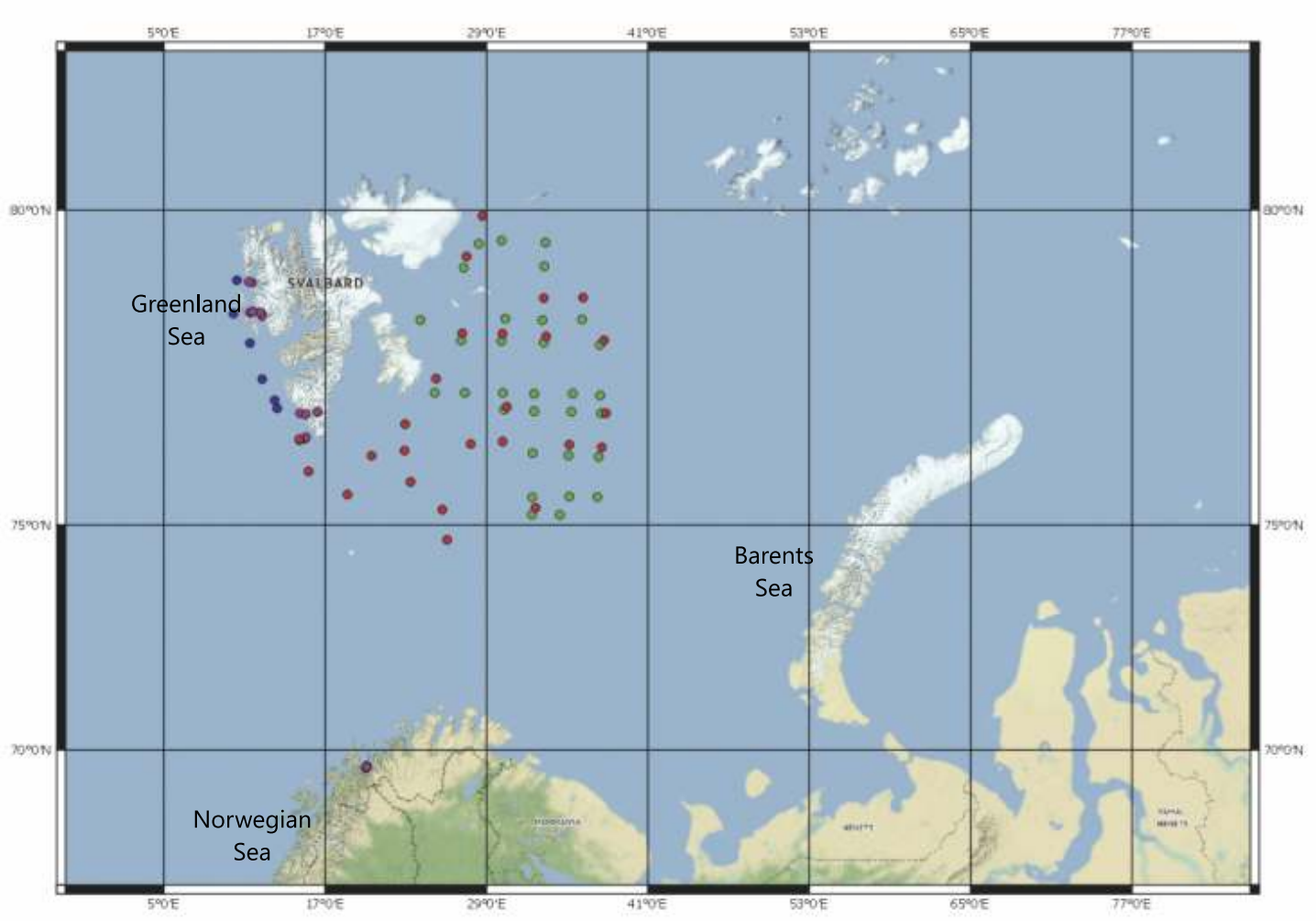
To assess the influence of physicochemical (mostly geochemical) factors on biomineral formation, a series of aquarium experiments were conducted.
Analysis of skeletons included crystallographic determination of calcium carbonate polymorphs (e.g., calcite, aragonite) using a high precision Nonius XRD-PSD X-ray diffractometer with position- sensitive detector (PSD). Contents of major and trace element, e.g. Mg, Mn, Fe, were measured using Inductively Coupled Plasma Atomic Emission Spectroscopy (IPC-AES).
The data gathered were analysed spatially and temporally. Relationships between the geochemical properties of the water column and sediment as well as animal skeletons were sought. Distribution maps of calcifying species density, biomass and diversity were constructed using GIS based methods of spatial data analysis.

High tech equipment helps to analyse microstructures of calcareous skeletons.

# POLNOR

**Field work**

The study area included the European part of the North Atlantic, Arctic Ocean with Greenland, Barents Seas and areas north of the Svalbard Archipelago. The model systems offered a comprehensive system differing in hydrology, $CaCO_3$ saturation and productivity providing an ideal test system for addressing our research questions. For example, the western part of the Greenland Sea is influenced to a much larger extent by cold Arctic Ocean water masses than the eastern part, which is overwhelmingly influenced by warm water masses of Atlantic origin.
The work was carried out aboard r/v Oceania, r/v Johan Hjort and r/v G.O. Sars.
In addition, several land-based expeditions were conducted in order to obtain shallow water samples not obtainable from larger research vessels. During those cruises and the land-based expeditions extensive physical and biological parameters of the water masses were measured and biological samples collected. The physical parameters measured included temperature, salinity, carbon dioxide system parameters (Ct, At, $pCO_2$, pH) and nutrients. Biological samples included quantitative samples of mostly calcifying benthic fauna.

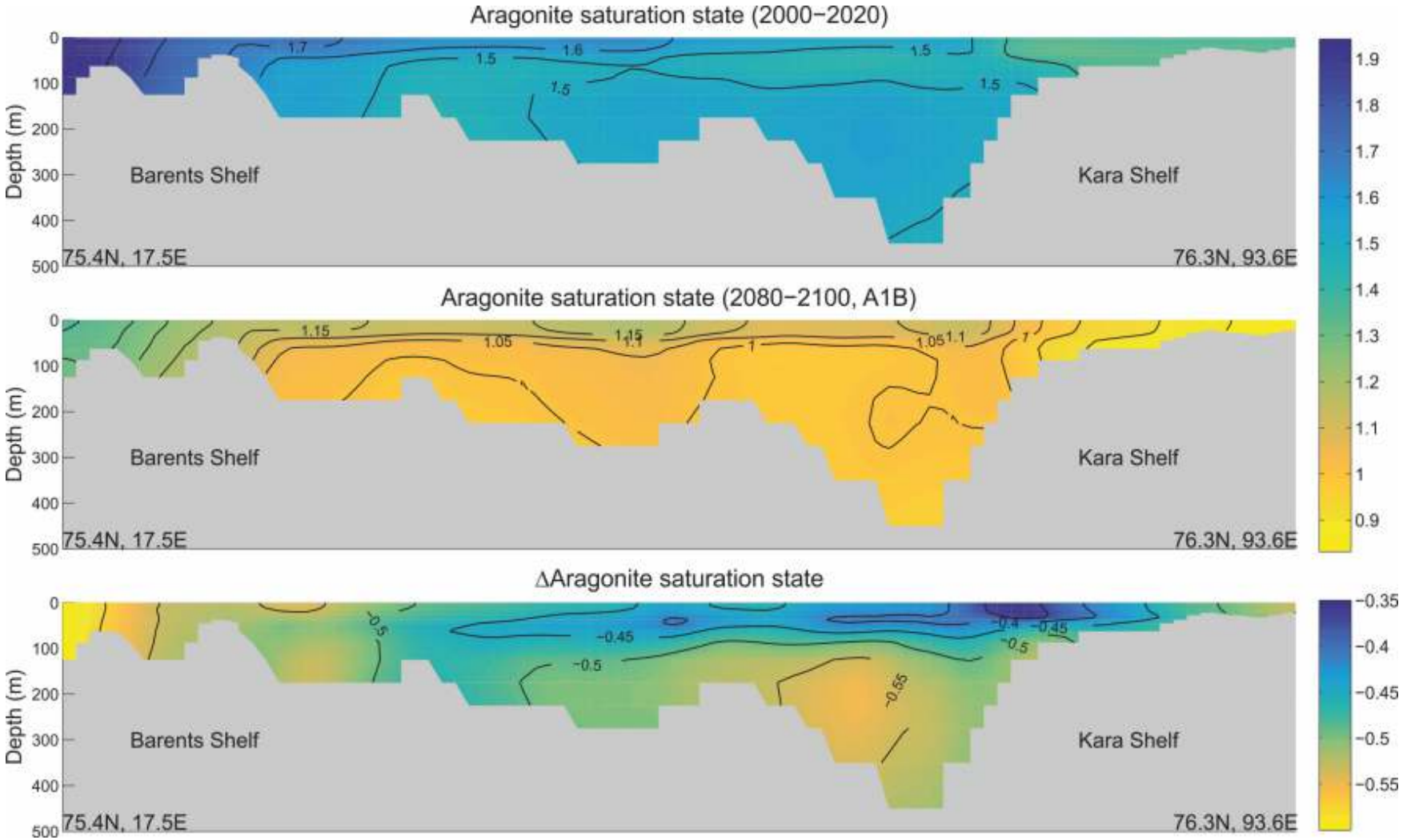



Collection of samples for POLNOR.

# POLNOR

**Results**

The main results of the project indicate that the properties of water, including alkalinity and pH, in the studied area of the Arctic Ocean have no impact on the distribution and diversity of calcareous fauna. Currently available results suggest that the major factors responsible for the survival of fauna with calcareous skeletons are productivity and the availability of a suitable substrate. Nonetheless, the vast dataset gathered during this project is still being analysed and we cannot rule out the possibility that additional patterns will appear in the near future.
More detailed analyses of particular organisms or groups of them at both temporal and spatial scales indicated that although biological control is the major force behind the chemical and mineralogical structure of the skeleton, environmental parameters (most likely temperature and pH) also have an impact on them. The POLNOR project demonstrated that the skeleton of every Arctic species has a specific chemical and mineralogical composition. This further confirms that the properties of the skeletal structure are closely controlled by the biological "programming" of the organisms.




Modelled aragonite saturation state vs. depth and along a horizontal transect across the northern Barents and Kara seas, showing bidecadal averages over a present day period (2000-2020) (top), over a future period (2080-2100) (middle), and the difference (future – present day) (bottom).

# POLNOR

**Outreach**

Communication with the general public made up a large part of the project. Several approaches were taken into account. First of all a website (*http://www.iopan.gda.pl/projects/PolMNor/*) containing all the information about the project's aims, participants and all the activities during the duration of the project was designed. The site was regularly updated throughout the project's duration. In addition to this web activity, a fun page of the project was established on Facebook (*https://pl-pl.facebook.com/POLNOR/*). It contains very similar information to the website, but with this active tool we were able to target a large number of end users. At the end of its existence the fun page had over 500 followers.

For the purpose of the project a short film was made to introduce to the general public the details of the work involved in the project. The film was publicised in all the media used by the project, including the website, Facebook and YouTube.

Another means of communication, targeting a more professional audience, was the organization of a series of lectures. A number of talks by scientists involved in the project were given to students, other scientists and to the public at the University Centre on Svalbard (Norway). The lectures were well attended.

We also engaged a number of artists. The aim of this interaction was to disseminate some of the important issues addressed by the project to the general public using artistic language.

The project members were involved in several of the Science festivals organized annually at Sopot (Poland).

Artists were invited to take part in POLNOR activities – here is one of the results – "Polar bears" oil on canvas by Aleksandra Fronc.

# POLNOR

**Conclusions and future perspective**

The role of organisms that produce calcium carbonate skeletons, which in the Arctic Ocean include such important groups as molluscs, brachiopods or bryozoans, is beyond question. These organisms not only create habitats for other biota but are also important functional groups, not to mention the fact that some of them are commercially important as they provide high quality food for humans. That is why understanding the impact of the rapid changes observed in the Arctic Ocean on these organisms is so important. The POLNOR project showed that these organisms can, to a large extent, control the formation of their skeletons biologically: in other words, organisms are programmed to build skeletons of a certain mineralogical and chemical composition. Nevertheless, it appears that environmental parameters, including the saturation of calcium carbonate in the water, also play a role in governing skeletal parameters. Therefore, future challenges will be to define precisely the threshold values of environmental parameters that appear to be changing rapidly (e.g. temperature, pH), at which organisms will no longer be able to build their skeletons according to their internal "programme". The POLNOR project aimed to establish those values, but at the current state of its development, this knowledge has yet to be acquired.

Summer in glaciated fjord – view from OCEANIA.

# POLNOR

**Project participants**

**WP 1 Baseline ocean observations and contemporary modeling**
**leader Richard Bellerby**

**WP 2 Marine Biodiversity and Ecological Function**
**leader Paul E. Renaud**

**WP 3 Recent and subfossil biomineral skeletons of Arctic carbonate sediments and organisms\as (paleo)environmental archives: a critical assessment**
**leader Jarosław Stolarski**

**WP 4 Future Arctic Ocean Change and Society**
**leader Richard Bellerby**

**WP 5 Synthesis of the Results, Transfer of Knowledge and Public Outreach**
**leader Joanna Piwowarczyk**


Polnor meeting in Sopot.

Kittiwakes feeding at the glacier cliff on krill aggregations.


Washing the WP-2 mesozooplankton net onboard OCEANIA.

**Norwegians and Poles on Svalbard – Svalbard connection.**

I feel honored that professor Stanisław Siedlecki, founder of Polish Polar Station in Hornsund considered me (two generations younger) his friend, and during nearly two years that we spent together on Svalbard, I heard his stories about Norwegians and Poles on Svalbard. Now, thirty years after those long talks, I have collected my own observations to complete the history that started in 1930 on Bjornoya. It is funny to realize how different were the relations then and now. Siedlecki, after his wintering as meteorologist and geophysicist on Bjornoya, organized a team of young climbers and mountaineers from his alpine club in Warsaw. Three Polish students, raised funds and went to Tromso to get transport to Spitsbergen – which they were going to cross on ski. With no problem they got a fishing boat, that was willing to give them lift, and the student's money were highly appreciated by Norwegian fishermen, who were happy to get additional income. It was poor Norway long before the oil boom, and relatively rich, agricultural Poland.

Next scene was in 1957, when Siedlecki started Polish Polar Station in Hornsund – it was both not long after World War II and just after the most oppressive communist regime started to melt. Norwegian friends of Siedlecki from the 30-ties were essential in helping to get permissions, logistics and practicalities. Number of them were serving in the Resistance and in the Navy, and felt close bonds to Polish researchers, many of whom were combatants.

When in early 80-ties we started the marine research on Spitsbergen, it was a political crisis again, and immediate wide ranging help and support from Norwegians was overhelming. At that time they were poor Poles and rich Norwegians – still the sense of solidarity and support was the most important. That was the time we developed some long lasting friendship bonds that are still valid.

The book that we have completed represents entirely new period of our mutual relations. Advanced international research programs, relief from political pressure, and focus on skills and scientific outcome. This is the reality, that Adam Wajrak experienced and observed (see the introduction), and one of our Norwegian friends – Birger Amundsen reminds the feeling of the former time in his historical note on page 84.

**Jan Marcin Węsławski**
researcher

Saxifraga - flowers on the tundra in July, Hornsund.

**Cold years, warm people**

After several days in a Zodiac we reach Dunøysundet just north of Hornsund. The plan is to continue to the old hunting cabin in Hyttevika. To our surprise, the sound is filled with heavy drift ice forming what looks like an impenetrable wall between us and land. A barely five meter long vessel of canvas and air, with a 35 horsepower outboard motor, is not much to cope with that kind of obstacle. But nothing ventured, nothing gained. I turn into the ice and press on. It's early August 1983 and nothing is going to stop us.
Two weeks earlier, a Russian helicopter had crashed just north of Hyttevika. The accident happened when landing at the Polish Baranówka hut, a scientific field station below the moraine of the Werenskiold Glacier. On board had been a group of Polish students, but nobody died or was even injured. The incident did, however, start a Norwegian-Soviet tug of war. The Russians had been accustomed to taking the law into their own hands on Svalbard, and wanted immediately to remove all traces of the wreckage. They had once done this in an earlier incident – much to the annoyance of the Norwegian authorities.
The Governor of Svalbard (Sysselmannen på Svalbard) had sent his people to stop the Russians removing the wreckage until it had been investigated by Norwegian experts. This was, however, at a time of deep conflict in Poland with Solidarność and a growing resistance towards the Soviets. The Norwegian crew had been welcome to cross the small bridge to Baranówka, whereas the Russians were denied access. The years of martial law and Soviet pressure had struck a spark in the Poles that spread even as far afield as a moraine landscape on an island just below the North Pole. The year before, a wooden cross had been raised on Wilczekodden as a political statement against Russian interference. In addition, a notice on the wall near the front door made it clear that the station was under the governance of the Sysselmannen på Svalbard.
It took us several hours to push our way through the ice and it was early morning when we could finally stretch our legs on land not far from the cabin. Students who had been involved in the accident were housed in the cabin, and we put up our tent nearby. Nailed to a big piece of driftwood raised up against the cabin wall was a Polish book with a picture of Leonid Brezhnev on the front cover. An axe had been driven into the log just below the Soviet head of state. The students smiled and said that the book was propagandistic rubbish and by using the biggest nails they could find, they had made certain that the book would never be opened again. One of them stuck his hand under the cabin and pulled out bits of rotor blade and fuselage – trophies of symbolic power that they wanted to keep hidden from the Russians. One piece of the rotor blade was nailed to the cross, with crash date 15.07.83 painted on and the names of the students.
Since my first visit to Hornsund in summer 1977, I have stayed at the Polish station many times. Almost nowhere else is the Polish-Norwegian bonding closer and friendlier than in Hornsund. One of the finest qualities of Svalbard is that the darkness and cold cause people to reach out to each other.

**Birger Amundsen**
journalist and author

Large iceberg anchored on the shelf at Spitsbergen coast.


OCEANIA
GDAŃSK