the Nansen LEGACY

Annual report
2018

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Statement from the Board

The Nansen Legacy project idea was launched in 2011. During the subsequent six-year period, a dedicated and joint effort by Arctic marine scientists across Norway lead to an ambitious science and implementation plan, and secured necessary funding to meet the urgent needs for knowledge of the changing climate and ecosystem in the northern Barents Sea. In 2018, 130 scientists from ten institutions embarked on this ambitious quest to obtain new insight into the changing Arctic. The same year, the Nansen Legacy initiated the first research cruises with the new Norwegian research icebreaker RV *Kronprins Haakon*.

At the end of the first year of the project, it is clear that the efforts have paid off. The project has already provided new scientific advances relevant to and important for both Earth system science and society. This includes understanding the impact of Atlantic water on the sea ice formation north of Svalbard and the Pan-Arctic trends in sea ice extent, the importance of reliable data on the amount of open water in the seasonal ice zone for wind conditions far away from the ice edge, and how technological developments can improve our observational capabilities and the quality of our data.

A new generation of polar researchers have started their education in this collaborative and interdisciplinary community, and will through research and education develop competence and networks to meet the future need for a more holistic understanding of Arctic ecosystems.

The Nansen Legacy project is unique both with respect to size, structure and research ambitions. The Board appreciates the work carried out by the scientists and technicians, the project administration and the project leaders, managing to develop and coordinate a project bridging disciplines and institutions to unite the Arctic marine expertise into one project with a common overarching research goal. Knowledge of how the Arctic ecosystem responds to the changing physical climate and increased human impact, together with an improved predictive capability, is crucial for the future sustainable management of the high latitude seas and Arctic Ocean.

The Board is pleased to see that this exciting journey has had an excellent start.

Photo: Rudi J. M. Caeyers

The Nansen Legacy sets sail



From left to right: PI Marit Reigstad, co-PI's Tor Eldevik and Sebastian Gerland.
Photo: Magne Velle

The first year of the Nansen Legacy is successfully completed. Activities and achievements include both a kick-off and an annual meeting, four research cruises, two workshops, more than 50 meeting presentations, and our first peer-review publications are already appearing. The "smooth sailing" results from the collaborative will and effort of the 130 Nansen Legacy scientists, and the increasing number of PhDs and postdocs (19 in 2018). Scientific collaboration has already in the first year transgressed disciplinary, methodological and institutional boundaries of the Norwegian research landscape – largely accommodated by the timely arrival of the new icebreaker RV *Kronprins Haakon*.

Climate change is particularly pronounced in the Arctic. Ongoing sea ice decline is a key indicator of how the Arctic environment is undergoing severe changes. Research from the Nansen Legacy project documents how the poleward reach of Atlantic water constraints sea ice and oceanographic conditions in the northern Barents Sea and beyond. Furthermore, improved Arctic weather forecasts are made possible as the impact of open water areas within the marginal ice zone on larger-scale wind conditions are being clarified.

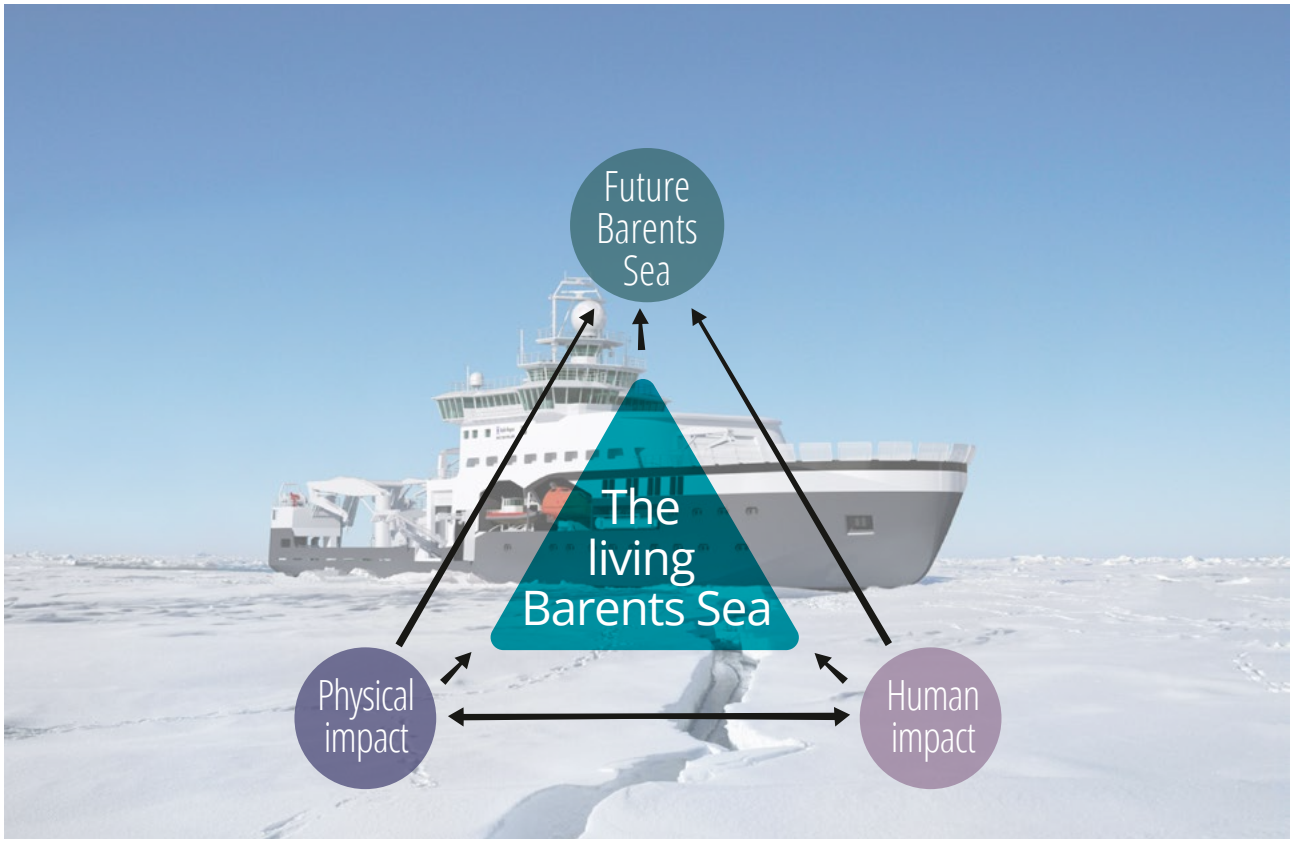
Research collaboration can be challenging, but is nevertheless a prerequisite for a holistic understanding of ongoing and future climate and ecosystem changes. Collaboration implies the sharing and integration of visions, a common appreciation of key processes and interactions, development of conceptual and logistic priorities – including common protocols to enable the integration of results. This should include fieldwork and empirical data, as well as numerical modelling and model data. Nansen Legacy coordination and integration should even bridge disciplines across geological time scales and into the future; spatial scales involving the details of the water column to sea ice drift across the Arctic Ocean; and ecosystem processes involving organisms from the sizes of bacteria up to whales. New results on adaptive technology help us investigate the scales and distribution of algal food patches and provide new insight to the world experienced by marine organisms.

It has taken – and will still take – time and effort to establish the common protocols and labeling of samples, to employ a large pool of new PhD fellows and postdoctoral scientists, to link models across scales and disciplines, and to make good use of a brand new research vessel. Taking up this challenge is not a task for an individual (nor for three people). It is becoming the mode-of-operation for both our project office and some 100 people: from the leaders of our different research foci and activities, via task and sub-task leaders, to the scientists and administrators involved in general all across Norway. We are confident that the time and effort invested by the Nansen Legacy team has contributed to the success in achieving all substantial milestones in 2018. As the project PIs, we are proud of the spirit and expertise of this research team.

It is increasingly important to communicate knowledge and contribute to discussions on the Arctic marine system and the development of this region. Project leadership, as well as many of the scientists and students, have contributed in social media, in panel debates, with presentations, workshops, with activities for children and youth during e.g. research days – all efforts to raise attention to climate change and engage with society.

The Nansen Legacy is an ambitious project. We will provide scientific knowledge for a sustainable management of the ice-free areas that emerge with the ongoing and future changes in the Arctic. The changes are rapid, and the Barents Sea region is both in the forefront of regional change, but also closely interlinked with the global system. The international connections and collaborations established are therefore crucial to link processes and responses in the Barents Sea to lower latitudes as well as throughout the Arctic. Also guided by our scientific advisory board and through established project collaboration, we have now set sail for the Nansen Legacy and the holistic understanding of a changing Arctic marine system in the Barents Sea.

Vision and objectives



The four research foci of the Nansen Legacy. Physical and human impacts on the living Barents Sea will determine the state of the future Barents Sea.

Illustration: Tor Eldevik, Rudi J. M. Caeyers

The Nansen Legacy is a novel and holistic Arctic research project. It provides integrated scientific knowledge for sustainable management of the marine environment and resources of the Barents Sea and adjacent Arctic Basin through the 21th century. The Nansen Legacy has the following objectives:

1 Improve the scientific basis for sustainable management of natural resources beyond the present ice edge

2 Characterize the main human impacts, physical drivers, and intrinsic operations of the changing Barents Sea ecosystems in the past, present and future

3 Explore and exploit the prognostic mechanisms governing weather, climate and ecosystem, including predictive capabilities and constraining uncertainties

4 Optimize the use of emerging technologies, logistic capabilities, research recruitment and stakeholder interaction to explore and manage the emerging Arctic Ocean

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Fridtjof Nansen as seen by the artist Hege Holen Paulsrud, on the deck of RV *Kronprins Haakon* in the Barents Sea.
Photo: Hege Holen Paulsrud

Nansen Legacy meteorologists mounting a wave sensor on the sea ice north of Svalbard.
Photo: Inger Lise Næss

Four times out, four times back with success

Have you ever simultaneously planned four long journeys together with dozens of people from all over the country? The Nansen Legacy took on the challenge, conducting four inter-institutional research cruises in 2018 alone.

Scientists from all over Norway joined forces, aligned their scientific methods, agreed on sampling strategies, packed tons of equipment, and headed northwards to study the northern Barents Sea in a coordinated and holistic manner. Four times out, four times successfully back with piles of new data and thousands of samples.

Out with a new boat

In August, the Nansen Legacy had the honor of taking the new Norwegian research icebreaker RV *Kronprins Haakon* on its first scientific mission. Although a large ship, the Nansen Legacy project managed to fill about every inch of laboratory space on board RV *Kronprins Haakon*, and to challenge most of the ship's scientific equipment. Correspondingly, the 32 scientists on board were able to take more samples than expected. Once analysed, these samples will increase our understanding of the physical-biological conditions of the central and northern Barents Sea, laying the foundation for a sound sustainable management of the region.

Currents, waves and atmosphere

Two of the four research cruises focused on the physical environment of the northern Barents Sea and the area north of Svalbard, where warm Atlantic water currents encounter cold Arctic water masses. Here, Nansen Legacy scientists deployed oceanographic moorings and gliders to map water masses, current flows and mixing processes, in order to increase our understanding of the increasing "Atlantification" of the region. Deployment of remote-controlled meteorological balloons generated important data of the near sea-ice-atmosphere interface, which will help increase the accuracy of weather forecasts in these high latitude regions.

Norway's longest mud core

Understanding the present and predicting the future requires a thorough understanding of the past. Consequently, the fourth Nansen Legacy cruise in 2018 focused on collecting sediments from the past 12,000 years, using dedicated coring systems onboard RV *Kronprins Haakon*. The cruise managed to extract Norway's longest sediment core of 26.5 m from the sea floor. The core will be carefully analysed for proxies characterising key components of the physical, chemical, and biological systems, including a detailed calibration exercise connecting the modern situation with the historical proxies studied.

Scientific highlights

High sea ice resolution increases accuracy of weather forecasts

Modern weather and climate models tend to be less accurate in polar regions. One of the issues is the representation of the spatial structure of sea ice, and its interaction with the ocean and atmosphere. In most of contemporary atmospheric modelling systems, sea ice cover is represented as a relatively smooth field, which does not reflect reality. A model experiment was carried out to test the sensitivity of an atmospheric model to kilometer scale modifications of the sea ice cover. In the experiment, sea ice cover was altered by merging a low-resolution sea ice concentration field with a dedicated sea ice lead product. It was shown that the presence of small-scale structures in the sea ice cover impacted impacted air-sea heat fluxes. The resulting changes in near-surface temperatures and winds could be traced all the way to areas 500-1000 kilometers away from the ice edge, indicating the importance of accurate representation of the sea ice structure.

Reference
Batrak, Y. and **Müller, M.** (2018). Atmospheric response to kilometer-scale changes in sea ice concentration within the marginal ice zone. *Geophysical Research Letters*, 45: 6702-6709. https://doi.org/10.1029/2018GL078295

Large inflow of warm Atlantic water keeps the ocean north of Svalbard ice free well into winter

A recent study, based on timeseries of hydrography and velocity of the Atlantic water current north of Svalbard, documents large inflow of warm water in autumn and early winter, which prohibits sea ice from forming. Combined with recent years' reduction in sea ice coverage and thickness in the Arctic Ocean, resulting in less freshwater input from the north, the isolating colder meltwater layer in the surface is weakened. The result is that the warm Atlantic-origin water extends all the way up to the surface for major parts of the year, providing a large ice-free area north of Svalbard. Only when the wind blows more sea ice and fresh water from the interior Arctic Ocean or from the east, a proper sea ice cover may establish over the Atlantic inflow area.

Reference
Renner, A.H.H., Sundfjord, A., Janout, M.A., **Ingvaldsen, R.B.,** Beszczynska-Möller, A., Pickart, R.S., and Pérez-Hernández (2018). Variability and redistribution of heat in the Atlantic Water boundary current north of Svalbard. *Journal of Geophysical Research: Oceans*, 123: 6373-6391. https://doi.org/10.1029/2018JC013814

Upstream regulation of inflow to the Arctic Ocean

The inflow of warm Atlantic water to the Arctic Ocean is relevant for what happens to the sea ice and the ecosystem, and studying the processes that regulate Atlantic water inflow is therefore important in order to understand the observed changes. A sea ice and ocean model that resolves eddy (circular current of water) formation was used to investigate oceanographic conditions that promote flow over the Yermak Plateau, a topographic obstacle which warm water in the West Spitsbergen Current must pass on its way to the Arctic Ocean. The results of the study show that strong pulses of inflow were associated with a warmer, faster West Spitsbergen Current. This increases the potential vorticity in the outer part of the current, which acts as a barrier and guides the flow onto the Plateau. This implies that if the temperature of the current flowing toward the Arctic Ocean increases, a larger fraction of the ocean current is likely to be steered into the Arctic Ocean.

Reference
Crews, L., **Sundfjord, A.** and Hattermann, T. (2019). How the Yermak Pass Branch Regulates Atlantic Water Inflow to the Arctic Ocean. *Journal of Geophysical Research: Oceans*, 124, 267–280. https://doi.org/10.1029/2018JC014476

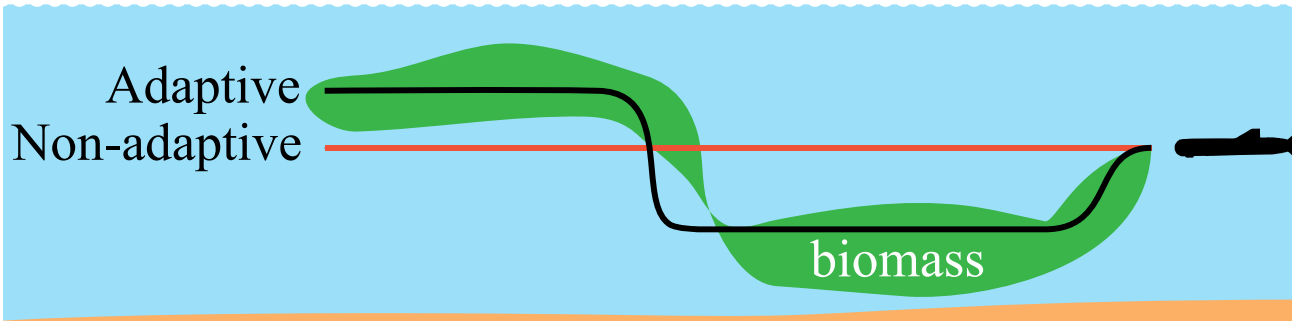
Increasing winter sea ice loss

One of the clearest indicators of ongoing climate change is the rapid decline of Arctic sea ice. Based on sea ice concentration observations since 1950, Arctic sea ice variability and trends have been assessed regionally and seasonally in a recent study. Onarheim et al. (2018) show that the highest recent ice loss is in the summer season, and is found in the Siberian sector of the Arctic Ocean. These Arctic shelf seas are still fully ice covered during winter, and ice growth happens very rapidly in autumn. However, as the summer ice continues to diminish, further sea ice loss must increasingly be taking place in winter – which is presently dominated by sea ice retreat in the Barents Sea. The authors explain the high ice loss in winter with increasing "Atlantification" of the Barents Sea, e.g., that the inflow of warm Atlantic water reduces the ice production. They furthermore suggest that further winter ice retreat is now progressing downstream with Atlantic heat to the Kara Sea, then subsequently the Laptev Sea and possibly beyond.

Reference
Onarheim, I.H., **Eldevik, T., Smedsrud, L.H.** and **Stroeve, J.C.** (2018). Seasonal and regional manifestation of Arctic sea ice loss. *Journal of Climate*, 31: 4917-4932. https://doi.org/10.1175/JCLI-D-17-0427.1

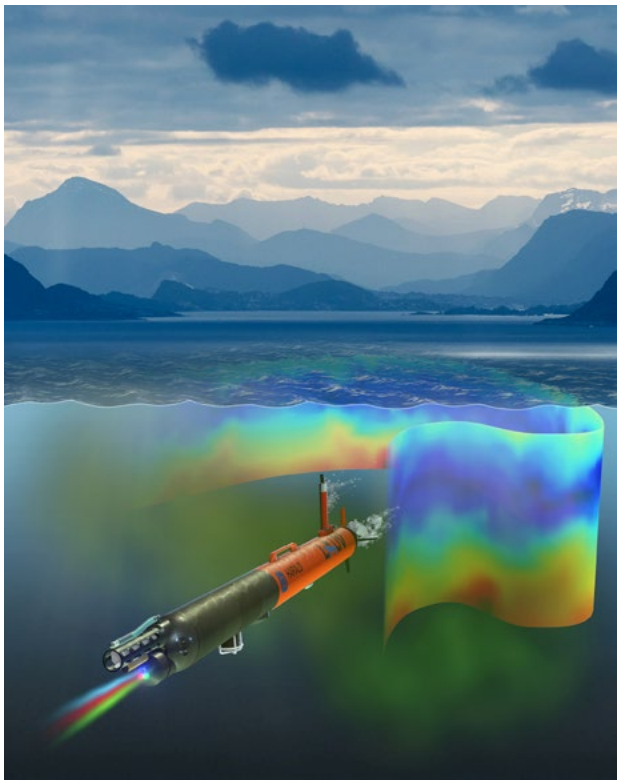
Data-driven sampling

Oceanographic sampling has traditionally been based on pre-planned or deterministic sampling stations and depths, offering little possibility to track instantaneous and local conditions; this can in turn lead to under-sampling of important features in the water column.



Adaptive sampling strategies can react to immediate changes in the environment and adjust data collection accordingly, increasing the resolution and coverage of important features in the water column.
Graphic by Trygve Olav Fossum.

Autonomous underwater vehicles, AUVs, are propeller-driven unmanned vehicles, and they offer the potential to deliver high-resolution targeted samples of the ocean interior. Normally, AUV trajectories are pre-scripted missions, where the vehicle follows a deterministic path. In adaptive path planning, the mission is continuously updated based on what the vehicle is sensing.



The AUV *Harald*, measuring the concentration of chlorophyll a in the ocean as an indicator of phytoplankton.
Illustration: David Fierstein and Arild Hareide

Programming underwater robots to continuously adapt their sampling strategy to local features will render a more accurate representation of the ocean and the processes therein. In the work by Fossum et al. (2018), it is demonstrated how marine data from AUV s, model forecasts, and measurements from remote sensing satellites, buoys, and ships are combined and correlated towards this end using stochastic modelling and machine intelligence. Gathering marine data across a number of heterogeneous sources enables cross-validation and augmentation across platforms and scales, resolving upper water-column interactions with improved coverage and accuracy.

Reference
Fossum, T.O., Eidsvik, J., Ellingsen, I., Alver, M.O., Fragoso, G.M., Johnsen, G., Mendez, R., **Ludvigsen, M.** and Rajan, K. (2018). Information-driven robotic sampling in the coastal ocean. Journal of Field Robotics, 35: 1101-1121.
https://doi.org/10.1002/rob.21805

Data Matrix codes for Barents Sea water

During the legendary Fram expedition in 1893–96, Fridtjof Nansen and his team obtained thousands of unique measurements and samples, well recorded in handwritten journals and logs. 125 years later, technological development has led to an explosive augmentation of scientific data recorded during cruises.

Data Matrix codes for Barents Sea water. A new system of unique identifiers helps Nansen Legacy scientists to keep track and overview over their many thousand samples.
Photo: Pål Gunnar Ellingsen

One terabyte a day

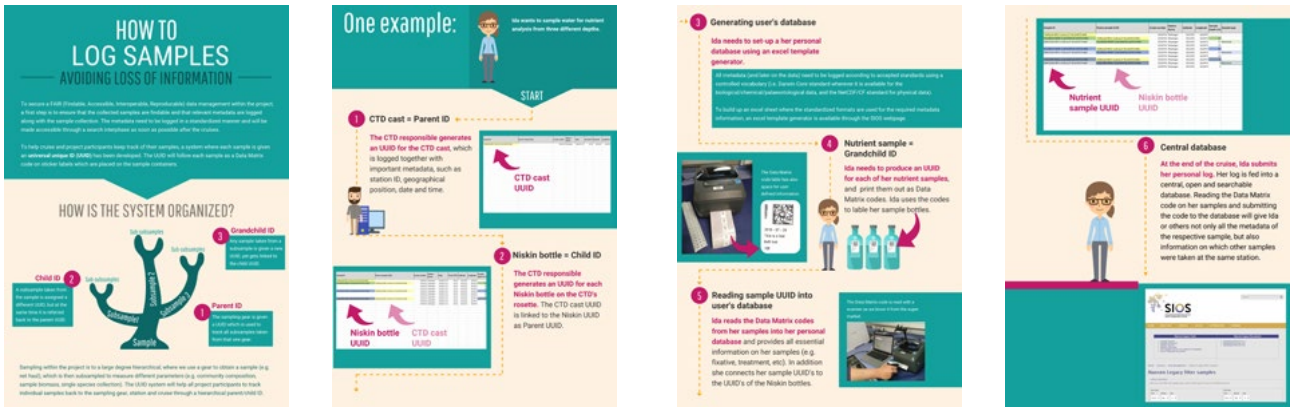
Shipborne instruments on the RV *Kronprins Haakon* can daily produce one terabyte of scientific data. In addition, data and samples are manually obtained by scientists on board. Only within the project's first year, Nansen Legacy scientists collected over 15,000 samples and measurements from the sea floor, water column, and sea ice in the Barents Sea. When brought back home, many of these samples get split into sub-samples, in order to investigate a multitude of different parameters. The results are data sets of such size and complexity that handwritten records alone can no longer keep track of the work done. A major goal for the Nansen Legacy was therefore to develop a sample and data logging system, which secures FAIR (Findable, Accessible, Interoperable, Reusable) data management.

Data Matrix codes for all samples

A first step towards this goal was to ensure that all collected samples are findable, and that relevant metadata are logged in a standardized manner along with the sample collection. For that, the project's data managers developed a system where each sample is given an unique identifier, which follows each single sample through a Data Matrix code on the sample containers. The identifier ensures preservation of context for individual samples. A full overview of Nansen Legacy samples and metadata is publically available via the SIOS portal (https://sios-svalbard.org/reports/aen_multi).

Making data accessible

Nansen Legacy data managers are now preparing for a joint data storage on SIGMA2 and publication of data, which will not only allow all Nansen Legacy scientists to access all data, but also ensure public accessibility, interoperability and reusability of the data, and hence the legacy of the project.



How to convince 130 scientists to embrace a new sample logging system? Colorful dispatches were designed to help people get started.

Testing the sensitivity of polar cod

Polar cod is a hardy little fellow, growing up right underneath the Arctic sea ice, and reproducing during the harshest winter months with little access to food. But, is polar cod hardy enough to cope with potential pollution in the wake of increasing human activity in Arctic seas?

Photo: Peter Leopold

Increased human activity may put polar cod at risk

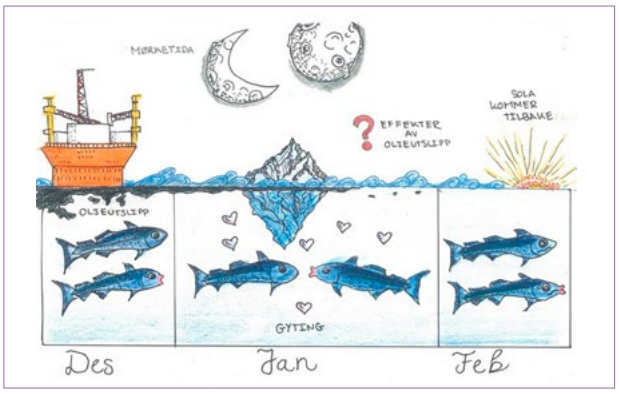
Polar cod is a key component of Arctic marine food webs, connecting lower levels of the food web with those at the top by being an important food for sea birds and marine mammals. From a management perspective, it is therefore important to understand how sensitive polar cod is to potential pollution, which would provide us with an idea of the consequences an oil spill would have for the marine food web in the Arctic. The dramatic accident of the fish trawler *Northguider* in Hinlopen after Christmas 2018 demonstrated that darkness, temperatures well below zero and winter storms create challenging conditions for ship navigation in the Barents Sea during the darkest time of year. Ship accidents can lead to vast emissions of chemicals that are likely to have negative consequences for the Arctic marine ecosystem. With less sea ice opening up for new areas for oil exploration and maritime transport in the northern Barents Sea, the risk for accidental oil spills in Arctic waters is also rising.

Are the fish's energy reserves large enough to combat pollution?

Recent research shows that polar cod eggs and larvae are sensitive to very low levels of crude oil, and an oil spill would have major consequences for the early life stages of polar cod. We hypothesize that oil spills can affect polar cod recruitment well before eggs and larvae are exposed, which is related to adult fish investing a huge amount of energy into their reproductive development during the winter months. Adult polar cod have been shown to efficiently break down toxic oil components and tolerate certain levels of oil exposure. However, in the event of an oil spill during the polar night, fish have depleted the majority of their energy reserves in order to produce good quality eggs and sperm, leaving little energy for the fish to combat the toxicity of oil compounds and withstand a major oil spill. For polar cod, additionally deprived of food during winter, this could lead to adverse effects on the survival of fish and the fish's recruitment.

Large-scale and long-term experiment

To test the effects of a winter oil spill on polar cod reproduction, Nansen Legacy postdoctoral fellow, Ireen Vieweg (UiT), brought many hundreds of live polar cod to Tromsø from a cruise in Hinlopen. In the aquarium facilities of UiT, the fish have been held in several large tanks under cold, dark and food deprived conditions since December, when they were exposed to low levels of crude oil. Since then, Nansen Legacy researchers have closely followed the fish's physiological responses to the crude oil exposure, as well as their energy investment into reproduction. The experiment will run for five months and first be terminated around Easter.



Nansen Legacy researchers are experimentally investigating the effects of crude oil exposure on polar cod in the spawning period during the Arctic winter.

Illustration: Leah Strople

Workshop on best practices for ecological models

Ecological models are essential tools for studying complex marine food web structures, and for evaluating potential impacts of climatic changes and human activities in the past, present and future. The Nansen Legacy therefore uses five different ecological models, in order to provide the most complete knowledge of the Barents Sea ecosystem. But how to compare and evaluate the outcome from these different models in a scientific and sound way?

This question was the motivation for a two-day workshop in Tromsø in November, attended by 13 participants from four institutions (IMR, UiT, UiB, UiO). The objective of the workshop was to develop recommendations for best practice in evaluation of the performance of Barents Sea food-web simulation models used in the Nansen Legacy project. Current practices in model evaluation for the five ecological models were reviewed, and workshop participants engaged in open discussions around specific topics related to model evaluation methods. Finally, an attempt was made to develop a protocol for the standard reporting of model evaluation procedures. Two important recommendations from the workshop are: 1) the definition of clear objectives for specific applications of a model are a pre-requisite for model evaluation. These clearly stated objectives are often lacking and will need to be specified; 2) a standard protocol for describing model evaluation will significantly contribute to standardisation, transparency, communication and quality of the evaluation of the ecological models used in the Nansen Legacy.

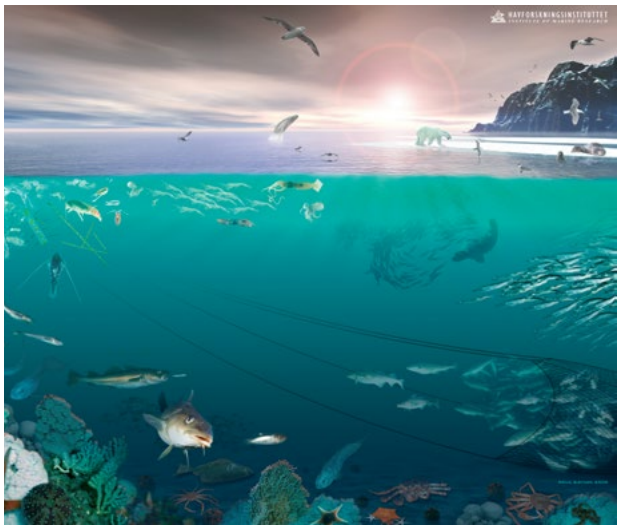


Illustration: Institute of Marine Research

Workshop on Arctic microalgae taxonomy

Minute microalgae are the grass of the sea, forming the nutritional basis for most of the marine life. Since consisting of a single cell only, these algae are only to be seen through a microscope and correspondingly difficult to identify to species level. Nansen Legacy researchers met therefor with other experts in order to establish a common identification strategy for Barents Sea algae.

The workshop took place at the Biological Station in Drøbak of the University of Oslo during two days in October. A total of 19 participants were gathered from six institutions (UiO, UiB, UiT, NTNU, NPI and IMR). In addition, international taxonomists participated from Canada, Poland, France, Germany and Norway. The aim of the workshop was to jointly analyse samples from the northern Barents Sea and sea ice, in order to hands-on discuss species identification and to agree on a common taxonomy to be used within the Nansen Legacy. Such an agreement is essential for the success of the project as scientists from many Nansen Legacy institutions will work with the identification of marine microalgae, and a common and sound taxonomy is therefore of utmost importance to ensure coherence in the project's final data set. Participation of international experts in the workshops contributed further to an integration of the taxonomic work by the Nansen Legacy into a larger pan-Arctic picture..

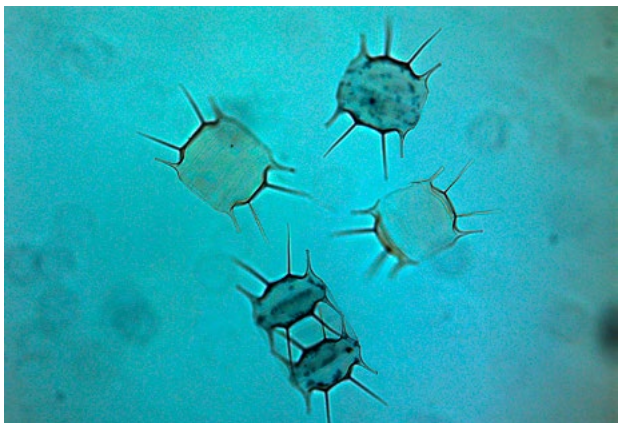


Photo: NFH marine microalgae group

Recruits

A new generation of polar researchers is needed to face and solve the challenges of a rapidly changing Arctic. The Nansen Legacy has dedicated funding for ca. 50 PhD students and postdoctoral fellows, of which the first 19 young researchers joint the project in 2018. The Nansen Legacy will take advantage of it's cross-disciplinarily and multi-institutional structure, and educate its young researchers through workshops and summer schools in a multidisciplinary manner, giving highly needed crossover competence.

The first gathering of the Nansen Legacy Recruit Forum took place in connection with the Annual project meeting that was held in Bergen in November 2018. The Recruit Forum is a meeting place for all PhD students and postdoctoral fellows in the project, including associated members. In addition to facilitating networking amongst the recruits, the forum will be a frame for attending workshops on soft skills as well as summer schools on multidisciplinary scientific themes relevant for the project.

Photo: Gunnar Sætra

Nansen Legacy PhD students and postdoctoral fellows that started in 2018 were recruited from both Europe and America. Numbers indicate number of recruits for each country.

Illustration: colourbox

Studying the genetic structure of Barents Sea fish

PhD student Siv Nam Khang Hoff (UiO) In her PhD project, Hoff will investigate the role of spatiotemporal population structure and possible local adaptations in Atlantic cod, capelin and polar cod in the northern Barents Sea ecosystem. The motivation for this work is to study if local adaptations are important for population dynamics and responses to climate change, as this could impact fishery management decisions in order to maintain intact spatial and genetic structure of the fish stocks in the northern Barents Sea.

Exploring possible future states of the Barents Sea

PhD student Elliot Sivel (IMR) In his PhD work, Sivel attempts to explore the possible future states of the Barents Sea under a range of climate and fisheries scenarios. As a tool, Sivel uses the Non-Deterministic Network Dynamic (NDND) model, in which he is implementing climate and fisheries modules in order to run forecast simulations. A major aim in Sivel's work is to investigate the impact of climatic changes and fisheries on the Barents Sea food web, including potential changes in primary productivity.

Tidal currents and sea ice loss

Master student Aleksander Dürr Libæk (UiB) Libæk was the first Master's student to join a Nansen Legacy research cruise. He will use the observations from the cruise, as well as idealized numerical model experiments, to quantify tidal forcing north of Svalbard. Tidal currents over variable bottom topography can lead to internal motions in the water column, potentially increasing vertical mixing of the water column. This in turn may increase heat fluxes from the warm Atlantic Water, leading to increased sea ice melt. Libæk's Master thesis will therefore contribute to a better understanding of the processes leading to sea ice decrease north of Svalbard.

Tracking changes in the Arctic seawater front

Postdoctoral fellow Marika Marnela (UNIS) Warm Atlantic water meets colder Arctic water masses north of Svalbard. An oceanic front is formed where these water masses meet, which impacts sea ice distribution and the heat exchange mechanisms (or just the heat exchange) between the ocean, sea ice, and air. The objective of Marnela's project is to investigate the profound changes this front has undergone north of Svalbard during the last decades. Marnela's work will contribute to a better understanding of processes connected to the progressing 'Atlantification' of the European Arctic seas.

Improving AUV navigation under drifting sea ice

Postdoctoral fellow Petter Norgren (NTNU) Automated underwater vehicles (AUVs) are an essential asset in marine research. Yet, the harsh environmental conditions and especially drifting sea ice, impedes the use of AUVs in the Arctic. Norgren is therefore developing and testing a robust navigation system specially designed for under-ice AUV operations, including an embedded support for navigation under drift ice. Norgren's project also aims at developing acoustic navigation and communication buoys, which can provide aid for AUVs in Arctic under-ice operations.

Do cold seeps feed Barents Sea animals?

Associated postdoctoral fellow Emmelie Åström (UiT) A multitude of natural methane seeps, deriving from petroleum and gas reservoirs in the seabed, was recently discovered in the Barents Sea. Åström's research focuses on quantifying the extent to which methane-derived carbon from cold seeps is incorporated into higher trophic level predator animals in the Barents Sea. Åström is financed through VISTA, but joined forces with the Nansen Legacy as an associated member of the project, closely working together with Nansen Legacy scientists. Åström joined the Nansen Legacy cruise in August.

Nansen Legacy biologists, chemists and ice physicists set out for a long day's sampling effort on the ice northeast of Svalbard.

Photo: Luka Supraha

Outreach

Nansen Legacy scientists used the project's first year to communicate their research and the Nansen Legacy vision to a large audience, ranging from school kids to European ministers. Nansen Legacy scientists appeared in media, contributed with a number of newspaper chronicles, a research blog on Forskning.no, and a large variety of public talks.

Nansen Legacy co-PI Tor Eldevik and chairman of the Board Kenneth Ruud, member of the Board Nalân Koç and researcher Maria Fossheim, joined the 2nd Arctic Science Ministerial.
Photo: Rune Vistad

2nd Arctic Science Ministerial

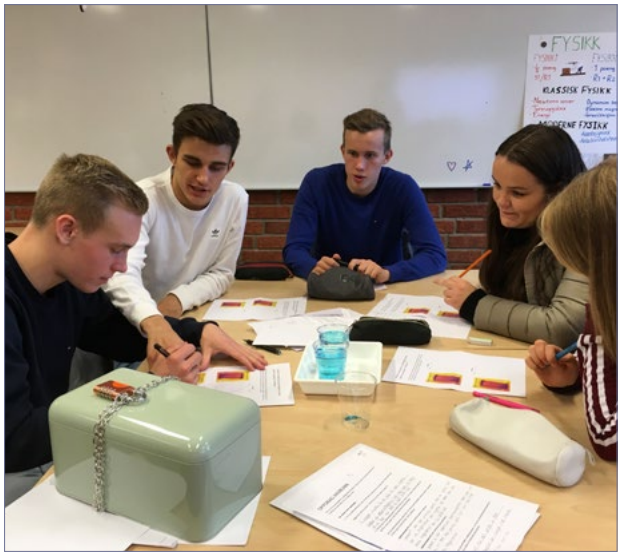
Cooperation is a cornerstone for exploring and living in the Arctic. The sound management of the Arctic requires a common vision and collective effort to step up international scientific cooperation, not only between the Arctic Council states, but generally including the many "Arctic-minded" countries of the global community.

The 2nd Arctic Science Ministerial (ASM2) meeting was accordingly held in Berlin 25-26 October 2018, jointly hosted by the EU, Germany, and Finland, with 29 countries represented and the Nansen Legacy well on board. The Research Council of Norway led the Norwegian delegation of 20 persons, including Nansen Legacy co-PI Tor Eldevik and chairman of the board, Kenneth Ruud. Ruud addressed the ASM2 science plenary on Arctic observational capacities and needs. Eldevik and Ruud jointly gave an in-depth presentation of the Nansen Legacy at RCN's "side event" at the Royal Norwegian Embassy. The ASM2 was concluded with government ministers and Arctic indigenous organizations discussing the main scientific issues and the endorsement of cooperation through the "Joint Statement of Ministers".

Contributing to a ship's mission

One hundred and twenty-five years after RV *Fram* left for its historic Arctic expedition, the new Norwegian research icebreaker RV *Kronprins Haakon* left Tromsø on August 6, for its first scientific expedition to the Barents Sea. Onboard were 32 Nansen Legacy scientists ready to use the ship for everything it is worth, contribute to the scientific mission of the new vessel, exploring the little known waters of the ice-covered Arctic Ocean. Cruise leader Randi Ingvaldsen (IMR) reported live from the sea ice about the Nansen Legacy work during the main evening news on Norwegian national TV. Four months later, on November 17, the icebreaker returned to Tromsø for its baptism by H.R.H. Princess Ingrid Alexandra. Nansen Legacy members were present, reporting live on national TV on the essential role RV *Kronprins Haakon* plays for the success of the project.

Nansen Legacy scientists eagerly awaiting school classes to arrive to their laboratory.
Photo: Ellen Katrine Bludd



At the high school in Senja, pupils try to solve Arctic science riddles in order to break the code lock around the Nansen Legacy treasure box.
Photo: Ellen Katrine Bludd

Arctic science for schools

Can Arctic research be fun? Nansen Legacy members think so, and met about one hundred 12–18-year-olds at their schools, or invited them to their research laboratory during the National Research Days. Here, pupils could hunt with scientific equipment for the age of copepods and fish, detect the growth rate of microscopic algae, or study the development of the Barents Sea by studying the layering and composition of a sediment core. Other pupils were challenged to solve a variety of scientific questions with the help of small experiments or literature search, in order to obtain the right number combination to open the code lock to a treasure box. Yet other pupils investigated the effects of climatic changes on the Arctic marine ecosystem by case studies and examples from around the Arctic Ocean.

Artists on board

Artist Hege Paulsrud joined the Nansen Legacy's cruise on physical processes north of Svalbard, and was so fascinated by both the research and the ship, that she painted a homage to the projects eponym Fridtjof Nansen (see page 5). Hege was one of two artists invited by the Nansen Legacy to come along and experience Arctic science in the field. Artist Lena Gudd, who studies the relationship between people and the North at the crossroads of image-based art and anthropo-geography, explained after the cruise: „It was extremely inspiring to study the ocean landscape and the researchers' relation to it on the ice-breaker, this floating piece of space, locked into itself and to the same time part of the ocean's immensity". The two artists will be ambassadors for the Nansen Legacy, and contribute with their art to the legacy of the project.

Photo: Lena Gudd/Tuumult

International collaboration

Although a Norwegian research project, the Nansen Legacy is tightly connected to the international marine Arctic scene through collaboration with several other projects, as well as through dialogues with relevant comittees and organisations.

Research cruises and data sharing

The Nansen Legacy collaborates with several projects from the UK programme Changing Arctic Ocean, that made cruise data from their 2018 northern Barents Sea cruise available for the Nansen Legacy, and added sensors to a Nansen Legacy mooring on nutrient dynamics and mixing. There has also been an exchange of UK and Nansen Legacy researchers that participated in each others research cruises to the Barents Sea. Further, the Nansen Legacy collaborated with the Finnish Meteorological Institute, deploying for them a sea ice-avoiding ARGO profiler in the interior northern Barents Sea. The data from this profiler will complement Nansen Legacy moorings and ship-borne measurements.

Strengthening synergies with MOSAiC

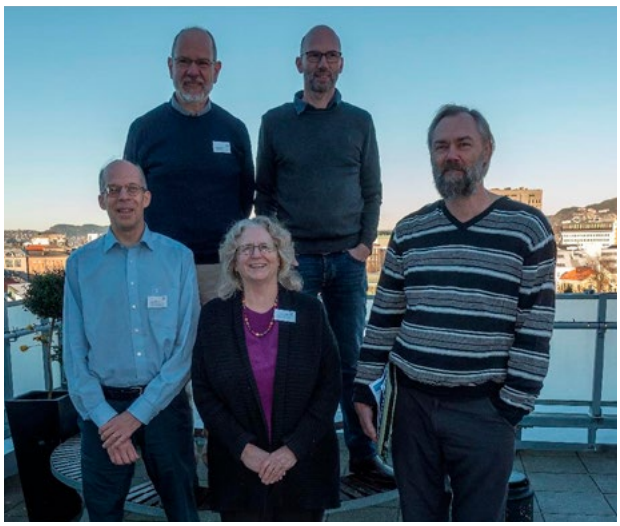
Seasonality in the Arctic constitute a knowledge gap, and the Nansen Legacy will carry out synoptic seasonal research cruises with the international drift experiment, the MOSAiC campaign, in 2019/2020. To ensure that the two projects obtain comparable and contiguous data, Nansen Legacy researchers participated in the MOSAiC Science Workshop in Postdam, Germany.

Nansen Legacy and the Pan-Arctic context

Dialogue and collaboration across the Arctic Ocean and neighbouring regions is a key to understand the changing Arctic Ocean and the role of the Barents Sea. Examples of integrating the Nansen Legacy in a Pan-Arctic context include presentations of the project at various conferences and dialogue meetings, such as the ICES/PICES conference "The effects of climate change on the world´s oceans", and and the National Academy of Sciences, both in Washington DC. The project has also been presented at the Pacific Arctic Group (PAG), the marine working group of IASC (International Arctic Science Committee), as well as to Arctic Science Partnership (ASP) which provide mutual information exchange and coordination with the Canadian, Danish and Greenlandic Arctic research communities.

Scientific Advisory board

The Nansen Legacy Scientific Advisory board consists of renowned international experts who will contribute advice in order to ensure the scientific quality and successful completion of the project. They are selected based on their scientific expertise, research activities and their geographic distribution to provide scientific advice on a broad disciplinary and geographic basis. Countries represented in the Scientific Advisory board include Germany, USA, Canada, Greenland, Finland, UK, and Denmark. The members' expertise span from physical drivers, through structure and function of Arctic marine ecosystems, to remote sensing and modeling.



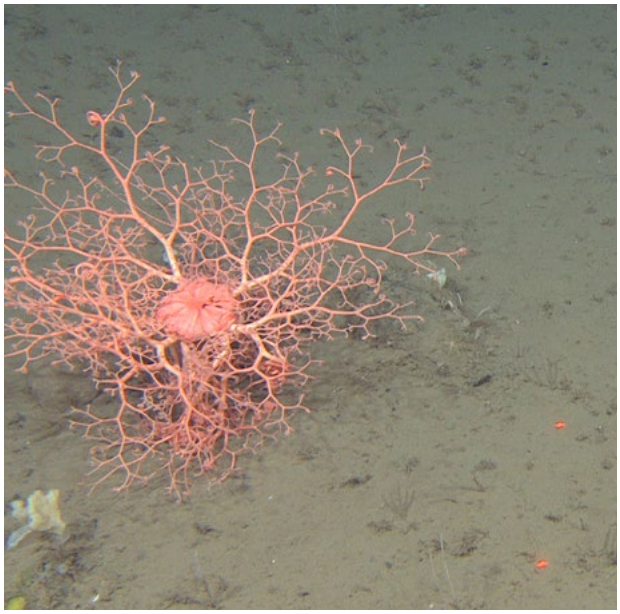
Representatives of the Scientific Advisory board present at the Nansen Legacy Annual meeting 2018 in Bergen. From the top left: Derek Muir (Canada), Michael Karcher (Germany), Timo Vihma (Finland), Jaqueline Grebmeier (USA) and Søren Rysgaard (Denmark).

Photo: Gunnar Sætra

Nansen Legacy physical oceanographers and technicians prepare a mooring for deployment.
Photo: Rudi J. M. Caeyers

Interaction with society

The Nansen Legacy is first and foremost a research project. But the full value of a successful research project depends on its overall impact on society. To what extent can the new knowledge help society overcome the challenges posed by the rapidly changing climate? The Nansen Legacy interacts with society in several ways, and works towards synthesizing and communicating its research findings in a way that facilitates dialogue with users also outside of the scientific community. Being the first of its kind as a cross-disciplinary, large national endeavour, the Nansen Legacy is also a pioneer with respect to synergies within national research infrastructures and technological development.



A marine basket star, *Gorgonocephalus* sp. at the seabed west of Isfjorden, Svalbard.
Photo: Institute of Marine Research/MAREANO

The Norwegian shrimp trawler *Northguider* stranded in Hinlopen, Svalbard, in December 2018.
Photo: Norwegian Coastal Administration

MAREANO

The governmental MAREANO programme has focused their seafloor mapping on the Barents Sea the past seven years, including areas in the northern Barents Sea overlapping with the sampling area of the Nansen Legacy.

It was therefore natural for both projects to join forces. Through four meetings in 2018, the two projects identified scientific topics and geographic regions of common interest. Further, the projects agreed to exchange information and data, to mutually optimize data collection and usage. So far, multibeam data for sea floor mapping have been shared and compared. A workshop is planned for more detailed discussions on data quality and extension of collaboration to include benthos, chemistry and core analysis. The Nansen Legacy will continue to contribute with multibeam data from transects, in particular from the deep Arctic Ocean region, whenever possible.

Reference Group

Efficent transfer of new scientific knowledge to a wider audience is crucial for ensuring sound environmental management.

For this purpose, the Nansen Legacy has established a Reference group, consisting of representatives from key sectors, including maritime-, petroleum-, fisheries-, biomarine- and the tourism industry as well as management organisations. The key needs identified by the Reference group include improved scientific knowledge for sustainable management, setting the Barents Sea in a pan-Arctic context, and helping society to adapt to changes and risks. The Nansen Legacy will use scenario workshops as one of several tools in the communication with the Reference group in order to address the points put forward by the group, and to address resource planning and development challenges in the Arctic.

Societal impact

Ice distribution and weather forecasts

One of the overarching goals for the Nansen Legacy project is to provide a better scientific basis for the sustainable management of the northern Barents Sea and the adjacent Arctic Ocean. New insights from Nansen Legacy researchers into the physical oceanography and sea ice dynamics are indicating how the declining sea ice and general "Atlantification" of the ocean are causing more open water, with possible ramifications for ecosystem function and fisheries, as well as future accessibility for ship traffic or other use. Open water versus sea ice also has an effect on the weather far away from the ice edge. Therefore, a combined use of remote sensing and ocean modelling work related to the changes in sea ice, shows how the project also will help improve weather forecasts for these areas.

Oil pollution

The experimental work on sensitivity of adult polar cod to crude oil exposure has direct societal relevance with regard to the risk of an oil spill during the polar night, when polar cod reproduce under the ice. The efforts allocated to surveillance, weather forecasts, rescue and regulation of human activity in the northern Barents Sea is scaled to the basic knowledge and current use of the area. The December 2018 incident with the Norwegian shrimp trawler that stranded in the Hinlopen strait is perhaps an early warning of what can happen more often around the Svalbard archipelago in the future. The parallel efforts in the Nansen Legacy on effect studies of pollutants on fish and other marine organisms, studies on sea ice dynamics, heat fluxes and water flow, as well as modelling for improved weather forecasts, are all important steps towards meeting these future challenges with better knowledge.

Robotics and biological dynamics

The development of automatic underwater robots that can "think for themselves" and follow gradients in, for instance, the concentration of chlorophyll, allows researchers to observe sub-surface blooms in 3D, and to follow the production dynamics in a completely new way. This is a giant step forward towards a better understanding of the smaller scale structures that influence plankton dynamics and production, which in turn impact harvestable biological resources in the northern Barents Sea, such as fish, shrimps and crab.

Inter-institutional coordination

In addition to these purely scientific advances, the highly successful pilot cruises with the new icebreaker RV *Kronprins Haakon* in the autumn of 2018 were a clear demonstration of the high potential for inter-institutional coordination of scientific infrastructure that lies within this project. The effort of "forcing" all institutions to use the same sampling protocols, and to cooperate in a joint data management using national and international structures such as the National Infrastructure for Research Data (NIRD), UNINETT SIGMA2 and Svalbard Integrated Arctic Earth Observing System (SIOS), is likewise a good example of the synergetic gain that is achievable with respect to a better use of marine Arctic research infrastructure within Norway.

A new generation of polar researchers

Many of Norway's polar researchers are approaching retirement age, creating a need for a new generation of well-trained polar experts. The Nansen Legacy has taken on the responsibility to educate 50 new PhD students and postdoctoral fellows in a cross-disciplinary manner to meet the challenges of a rapidly changing Arctic. This young generation of Arctic experts will not only serve in science, but potentially as much within national education and resource management.

International connections

Through collaboration with other international projects, via joint or parallel cruises, exchange of data and the participation of Nansen Legacy researchers in international organizations such as the Intergovernmental Panel on Climate Change (IPCC), the Arctic Monitoring and Assessment Program (AMAP), the International Arctic Science Committee (IASC), Conservation of Arctic Fauna and Flora (CAFF) and the World Meteorological Organization (WMO), the Nansen Legacy is also having a direct impact beyond national borders.

Nansen Legacy in the 6th IPCC report

Three Nansen Legacy scientists have been elected as authors to the 6th Assessment Report by the Intergovernmental Panel on Climate Change (IPCC), to be published in 2021 and 2022. Project co-leader Sebastian Gerland from NPI will be lead author for chapter 2 within IPCC Working Group 1, which assesses the physical scientific aspects of the climate system and climate change. In the same working group, Sebastian Mernild, director of NERSC, will be lead author for the Atlas, in which selected environmental data will be collected and interpreted. The third author is co-leader of the Nansen Legacy board, Nils Chr. Stenseth from UiO. He will be lead author on chapter 1 within IPCC Working Group 2, which will assess the vulnerability of socio-economic and natural systems to climate change, negative and positive consequences of climate change, and options for adapting to it. The scientific IPCC report is the most comprehensive and important basis for international climate policy.

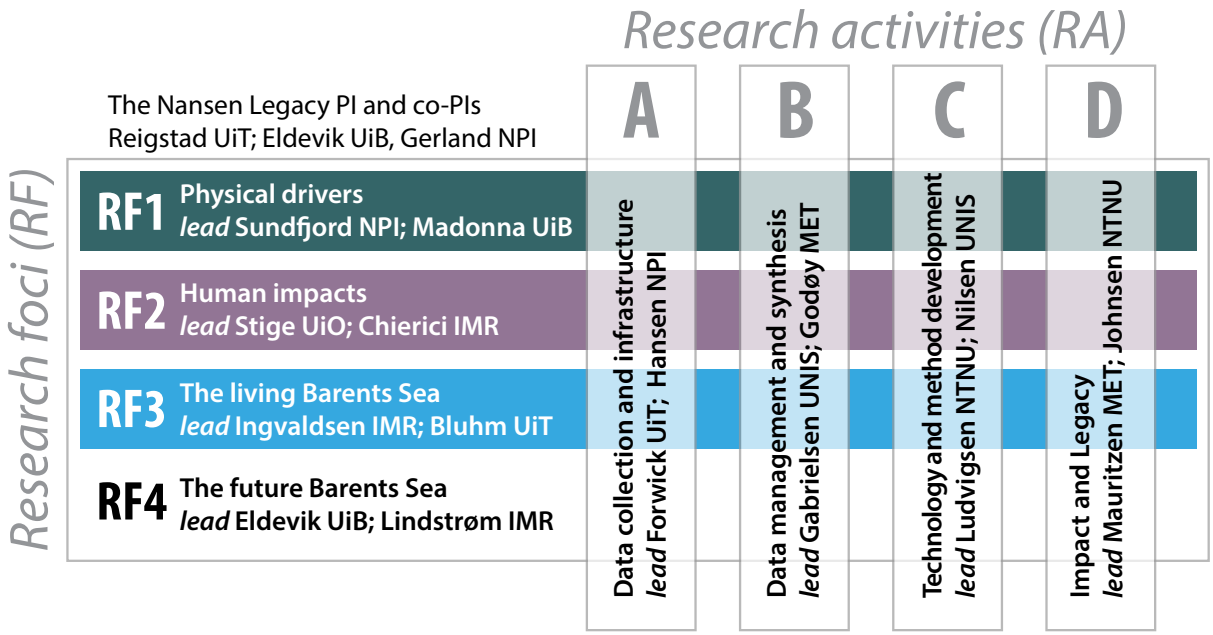

SEAONICS

We are living in times of fundamental changes in the physical and the ecological system of the Arctic. Documenting and understanding the interaction of the natural systems with human activity is the key to prediction and to a more sustainable use of ecosystem services. The Nansen Legacy offers the opportunity to take a significant step forward in this direction, focusing on the Barents Sea system with a full range of interdisciplinary observations and numerical modelling. We are convinced that the Nansen Legacy with its competent research groups, its embedding in the international science community, and the considerable support from the Norwegian state will provide long-lasting input to science and policy to achieve a more sustainable future of the Arctic Ocean.

Statement from the Scientific Advisory board

Organisation

The Nansen Legacy is a collaboration between ten Norwegian research institutions, currently involving over 200 project members. Members include PhD students, postdoctoral fellows, researchers, technicians, engineers and communication advisers. In addition to the scientific leadership, the project has a Board, as well as a Scientific Advisory board.



The Research Foci (RF1-4) represents "what" science the Nansen Legacy is investigating, and the Research Activities "how" (A-C), including impact and legacy in the public domain (D).

Project leaders

Marit Reigstad

Prof. Reigstad is the principal investigator (PI) of the Nansen Legacy. She is a marine ecologist interested in connectivity, including physics and biology, surface and deep waters, and regional connections. She has led several interdisciplinary projects and expeditions on Arctic marine ecosystems, and is active in science communication. Reigstad has been involved in international science planning since 2004, through ICARP and IASC. She serves on Liason- and evaluation panels and scientific advisory boards.

Tor Eldevik

Prof. Eldevik is co-PI and also leads the 'The future Barents Sea' Research Focus. Eldevik generally explores the northern seas' role in past, present, and future climate, using a combination of theory, observations, and numerical models. The combination is also Eldevik's approach in communicating his research and other aspects of climate change to students and the general public. Present commissions of trust include contributing to the European Academies' Science Advisory Council (EASAC) and JPI Oceans/ RCN.

Sebastian Gerland

Dr. Gerland is co-PI of the Nansen Legacy. He is currently working with sea ice physics research and monitoring in the context of Arctic climate research. Beyond his involvement in the Nansen Legacy, he is leading and participating in other national and international projects, including the Norwegian Polar Institute's long-term Arctic sea ice monitoring, and projects funded by the Research Council of Norway (e.g. HAVOC-MOSAiC and CIRFA SFI). Gerland is also active in climate assessments (currently IPCC's 6th assessment report and the NOAA Arctic report card).

RF1 Physical drivers

Arild Sundfjord

Erica Madonna

The Barents Sea is a significant gateway with inflow of Atlantic water to and Arctic water from the rapidly changing Arctic Ocean. A firm understanding of the physical climate system in this region is a fundamental building block for any sustainable management, and prognostic models for the Barents Sea and the adjacent Arctic. ***Objective:*** Determine contemporary and historical environmental conditions and internal regulation mechanisms, and based on this improve the understanding of physical system response to environmental changes.

RF2 Human impacts

Leif Christian Stige

Melissa Chierici

Arctic areas are exposed to climate change as well as other human influences, such as ocean acidification, pollution, and commercial fisheries. ***Objective:*** Improve our understanding of how human activities influence the northern Barents Sea ecosystem.

RF3 The living Barents Sea

Randi Ingvaldsen

Bodil Bluhm

Biodiversity, ecosystem functioning, and environmental forcing are inherently and intricately linked in any ecosystem, with their relationships shaped by region, habitat and temporal dynamic. ***Objective:*** Build critical understanding of how organisms in the northern Barents Sea ecosystem and adjacent slope respond to current and changing environmental conditions on the species and community levels by identifying characteristic communities, delineating the relevant environmental forcing factors that structure these communities across seasons and habitats, estimate their production and rate-limiting factors, and detail trophic and other ecosystem linkages.

RF4 The future Barents Sea

Tor Eldevik

Ulf Lindstrøm

The sustainable management of resources and environment is fundamentally about foresight. It depends critically on our capacity to observe, understand and eventually predict the transitions between past, present and future states of weather, climate, and the marine ecosystem. ***Objective:*** Assess the state, predictability, and associated uncertainties of the Barents Sea weather, climate, and ecosystem.

RA-A Data collection and infrastructure

Matthias Forwick

Håvard Hansen

The Nansen Legacy will carry out multi-disciplinary research using extensive ship-based field expeditions. This fieldwork is based on a coordinated use of the Norwegian research vessels, particularly the new Norwegian ice-going research vessel RV *Kronprins Haakon*. ***Objective:*** Facilitate, coordinate, and integrate the collection of new observational data, proxy data, and modeling output across the *Nansen Legacy* project.

RA-B Data management and synthesis

Tove Gabrielsen

Øystein Godøy

Structured data management is a pre-requisite for data exploitation; the act of exploration of the full potential of scientific data as individual datasets, in a discipline specific context, and in an interdisciplinary perspective. ***Objective:*** Ensure longterm preservation of all relevant data, with unified, open data access through services that provide for simplified data exchange and responsible data reuse, including proper attribution.

RA-C Technology and method development

Martin Ludvigsen

Frank Nilsen

Enabling technology for mapping and monitoring of extreme environments is essential for modern future management and sustainable utilization of the Barents Sea. Arctic conditions require a high degree of autonomy and integrated observation systems to reduce operation time and weather dependency, and to enable measurements in all seasons. ***Objective:*** Study and develop reliable and robust autonomous platform solutions for smarter measurements and sampling for detection and analysis, to improve modeling based on remote sensing with impacts on the ecosystem or human activity in the Barents Sea.

RA-D Impact and legacy

Cecilie Mauritzen

Geir Johnsen

A major task for the Nansen Legacy is to promote interest for and increase the general knowledge about Arctic marine systems. To accomplish this, it is necessary to reach out to the scientific community and the general public, to establish dialogue with users and stakeholders, to educate the next generation of scientists, and to enhance the focus on innovation as potential products of basic science. ***Objective:*** Ensure outstanding national and international impact from the research carried out, to ensure a lasting legacy of the project, and to enhance the benefit and relevance to society.

NANSEN LEGACY BOARD

Member	Substitute	Institution
Anita Evenset	JoLynn Carroll	Akvaplan-niva
Geir Huse, vice chair	Geir Lasse Taranger	Institute of Marine Research
Lars Anders Breivik	Jørn Kristiansen	The Norwegian Meteorological Institute
Johnny Johannessen	Anette Samuelsen	Nansen Environmental and Remote Sensing Center
Nalân Koç	Harald Steen	Norwegian Polar Institute
Ingrid Schjølberg	Tor Grande	Norwegian University of Science and Technology
Nils Gunnar Kvamstø	Ørjan Totland	University of Bergen
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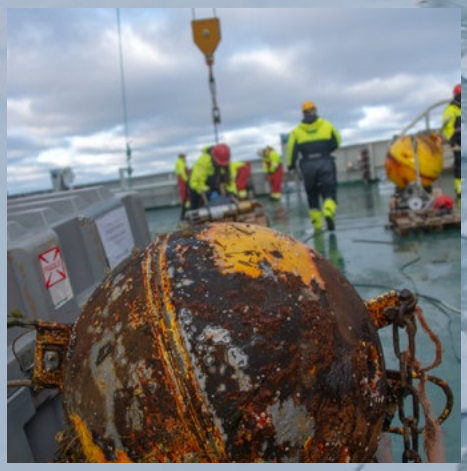
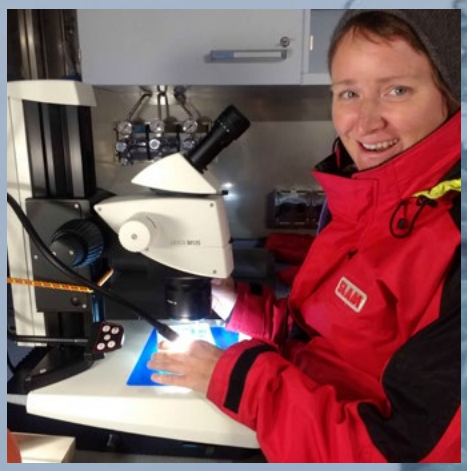
Søren Rysgaard	Aarhus University/Greenland Institute of Natural Resources/ University of Manitoba	Denmark/Greenland/Canada
Julienne Stroeve	University College London	UK
Timo Vihma	Finnish Meteorological Institute	Finland





Nansen Legacy at work.

Large photo: Vårin Trælvik Eilertsen
Small photos from the top: Vårin Trælvik Eilertsen, Rudi J. M. Caeyers, Bodil Bluhm
Cartoon: Hege Holen Paulsrud

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PHOTO: Name

A polar bear on the sea ice northeast of Svalbard in August 2018.
Photo: Ulrike Dietrich

The Nansen Legacy in numbers

6 years

The Nansen Legacy is a six-year project, running from 2018 to 2023.

200 people

About 200 scientists and technicians are involved in the project. By the end of the project period, the Nansen Legacy will have educated a total of 50 PhD students and postdoctoral fellows.

1 400 000 km² of sea

The Nansen Legacy investigates the physical and biological environment of the northern Barents Sea and adjacent Arctic Ocean.

10 institutions

The Nansen Legacy unites the complimentary scientific expertise of ten Norwegian institutions dedicated to Arctic research.

>10 fields

The Nansen Legacy includes scientists from the fields of biology, chemistry, climate research, ecosystem modelling, ecotoxicology, geology, ice physics, meteorology, observational technology, and physical oceanography.

50/50 financing

The Nansen Legacy has a total budget of 740 million NOK. Half the budget comes from the consortiums' own funding, while the other half is provided by the Research Council of Norway and the Ministry of Education and Research.

Norwegian Ministry of Education and Research

With funding from The Research Council of Norway

>350 days at sea

The Nansen Legacy will conduct 15 scientific cruises and spend more than 350 days in the northern Barents Sea and adjacent Arctic Ocean between 2018 and 2022. Most of these cruises are conducted on the new Norwegian research icebreaker RV *Kronprins Haakon.*

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