FRAM CENTRE

FRAM FORUM

2013

CONTENTS

FRAM Forum is published once a year on behalf of FRAM – the High North Research Centre for Climate and the Environment. Its aim is to inform the general public about the wide range of activities that take place within the Fram Centre. It is available free of charge to any and all who are interested in topics related to climate, environment, and people in the High North.

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AN ARMADA OF FLAGSHIPS?

To live up to the expectations in the mandate from the Norwegian Ministries, the Fram Centre must achieve broad expertise, top-notch research and cross-disciplinary cooperation. As a means toward this goal, the activities at the Fram Centre are organised around five Flagships: Fjord and Coast, Sea Ice in the Arctic Ocean, Ocean Acidification, Terrestrial Systems, and Hazardous Substances. An interdisciplinary approach is central to the Flagships. The intention is that the “crew” of each Flagship should represent a wide range of disciplines and have extensive networks at home and abroad, bringing together different types of competence and different perspectives.

But the Flagship concept has not previously been tested. Does an interdisciplinary approach actually work? Is it possible to address themes as complex as the ones each Flagship encompasses in a single coordinated effort? At the outset, some critics voiced scepticism about the prospects for successful collaboration within the Fram Centre Flagships.

Well aware of the potential benefits of continuous follow-up, the Fram Centre’s Research Leader Group approached the Research Council of Norway and requested an independent evaluation of how the work is progressing. The Research Council agreed, and its first report became available in November 2012. This evaluation focused on the scientific relevance and originality of the research within each Flagship, the competence of the researchers involved, the project’s feasibility, international collaboration and support networks, and the Flagship’s organisation.

The experts are impressed with the progress the Flagships have already made. Highly important research questions have been formulated, and complex collaborative networks have been established, fulfilling the mandate’s demand for cross-disciplinary cooperation. As stated in the Research Council’s summary, this approach should facilitate identification of environmental and societal challenges and ultimately produce results that can influence policy-makers, both within Norway and internationally.

But the report also highlights aspects where some of the Flagships fall short of the high expectations. One weak area concerns international networking. For some Flagships, the focus is still too regional (Arctic Norway), or bilateral (Norway-Russia). The experts feel that these Flagships would benefit from cultivating international partnerships to gain access to resources that are not available within the current collaborative networks.

Funding is another weak point, and though this is true for all Flagships, some are managing better than others. The report reminds the Flagships that the modest funding they received from the Norwegian government was intended as “seed money” to encourage establishment of first-class international research networks. International collaboration is - again - a key factor for success. Strong international networks stand a much better chance of securing funds from Norwegian, European and international funding agencies.

Overall, however, the Flagships appear to be sailing on an even keel and making good headway. Two Flagships stand out by virtue of their already strong international and transdisciplinary ties: Hazardous Substances and Terrestrial Systems were described as “good” or “very good” on all assessment criteria. And the funding situation for another Flagship is better now than when the assessment was done: a project within the Arctic Ocean Flagship was granted 12.5 million NOK just before Christmas.

The doubts expressed early on concerning the Flagship model have to some extent been assuaged. Nonetheless, more could be done, particularly in the contexts of outreach, joint use of infrastructure, and overarching research themes. The Research Council encourages the Flagships to cooperate with each other and - not least - to learn from each other’s successes. Networking and collaboration are beneficial not only in international contacts, but also within the Fram Centre itself.

Janet Holmén, Editor

Jan-Gunnar Winther // Chair, Committee of Institutional Directors of the Fram Centre

A hectic year for the Fram Centre

The Fram Centre is only two years old, but has already amassed a great many tasks and expectations. The Centre will acquire basic knowledge for use in national management, international processes such as the Arctic Council and the UN's climate panel, and knowledge-based policy development. It is inspiring to contribute to developments in the North. This is especially true in a time when climate change is dramatic and business interests follow in the wake of the melting ice. The changes in the Arctic have global consequences, and the Arctic has consequently made it onto the international agenda.

This year's Fram Forum covers many of the activities that have taken place in 2012, although there is simply not room for all of them. The main part of the work of the Centre is geared towards five flagship initiatives: the effects of environmental contaminants, climate change in fjords and along coastlines, climate change on land, ocean acidification, and developments in the Arctic Ocean. Additionally, funds from the Ministry of the Environment are used to strengthen interdisciplinary research across the flagship initiatives. The Centre's administrative bodies, the Centre meeting and the Senior Scientist Group, also prioritised education, communication and internationalisation over the course of the past year.

In 2012, the new building has taken shape on the drawing board. Countless meetings have been held with the builder, Statsbygg, the Fram Centre as the user, architects, the main contractor and Tromsø municipality. Construction is expected to commence early in the spring of 2013, with a construction period of about 2 years. When the new building is complete, 550 experts from over 20 institutions will be housed under the same roof. As interest in the Arctic continues to grow, we predict that the Fram Centre will require a third addition in 6-8 years' time. The Fram Centre's vision is that our local area will develop into a knowledge centre made up of institutes and organisations working with the High North.
The government budget for 2013 contained an initiative that is particularly exciting and important to the Fram Centre, Norwegian polar research, and Norway as a knowledge nation. The Government gave the go-ahead for building a new national ice-breaking vessel. The vessel will be a state of the art research platform, giving us the opportunity to answer the many and complex research questions the Arctic poses. The vessel will be owned by the Norwegian Polar Institute, operated by the Norwegian Institute of Marine Research, and it will have the University of Tromsø as its main user. Even though these three institutions will be using it the most, the whole research community will benefit from this advanced vessel, which will have Tromsø as its home port. The vessel will be ready for its first research expedition sometime in late 2015/early 2016.
We have also received many prominent visitors this year, the most notable being the US Secretary of State, Hillary Rodham Clinton, and the Finnish President, Sauli Niinistö. It is a privilege and an acknowledgement to be able to inform state leaders on official visits to Norway of the important work that we do.
The Fram Centre's mandate states that we shall acquire knowledge geared towards the needs of the public administration and society in general. The same quality requirements apply to this type of research as to any other. We must and will be measured against the toughest requirements of the international research community. Therefore, the Fram Centre decided early on that an independent and critical evaluation was necessary, in order to be advised of any improvements or changes of course we should be making. At the end of the year, our five flagship initiatives were evaluated professionally by the Norwegian Research Council. In general, the evaluation was positive, but scope for improvement was also identified. In 2013, the Fram Centre will be using these evaluations to fine-tune and improve the quality of its operations even further.

PICTURE OF THE YEAR

Tromsø professor Audun Rikardsen captured this image off the coast of Nuuk in Western Greenland. It earned him the title of Nordic Nature Photographer of the year in the Nordic Nature Photo Contest of 2012.

When he's not out chasing whales with Greenlanders, Rikardsen does research on salmon at the Institute of Arctic and Marine Biology at the University of Tromsø. He is also the recipient of this year's Fram Centre Communication Award (see page 73).

"In 2011 I spent three days on a whaling vessel. When Greenlanders are looking for whales, they often search near icebergs. This time we didn't find any whales, but we did find a whole flock of harp seals. An iceberg had washed aground and several harp seals had managed to get up onto it with the help of big waves. As we watched, the iceberg suddenly rocked. One seal lost its grip and started sliding off at great speed. Fortunately, I had my camera ready and caught the descent on my memory chip," says Rikardsen.

Ole Magnus Rapp

Reindeer rover

This article could have been called “The Svalbard Chick”, or I could have made a pun about a terrestrial ecologist with both feet on the ground. But for Åshild Ønvik Pedersen, researcher at the Norwegian Polar Institute, the plump reindeer of the far north are part of everyday life. She doesn’t get sentimental about them, though.

Photo: Ole Magnus Rapp

MORE THAN ANYTHING, Åshild Ønvik Pedersen wants to talk about going hiking. She does it often and with pleasure, both as part of her job and in her spare time. The 43-year-old often walks to work, parking her car by Prestvannet in order to enjoy a stroll first thing in the morning, and then walking back up all the hills again in the afternoon. A quick walk gives her a chance to think, reflect and get the working day off to a good start.

“More people should go walking more often. It energises you and makes you happy,” she says.

Her children are happy to come along, and seize the opportunity to share in their mother’s knowledge about the connections in nature, about all the fine-tuned mechanisms, and about the Svalbard reindeer’s important role for other life forms in the archipelago.

Personally, she really enjoys good old-fashioned fieldwork. A long working day in Svalbard can entail 40 kilometres on foot with binoculars and a notebook. She observes the reindeer herds, checks if they’re doing alright, and looks to see what they’re eating. Based on fixed rules, she then determines herd size.

When an unpredictable climate brings a mild spell in winter, and the grazing areas freeze over, her animals face a hard time. But that’s just part of life in the Arctic: survival of the fattest.

Åshild comes from Lyngdal, north of Kongsberg, and had accomplished quite a lot before she got what her father called her first “real” job, as an ecologist at the Norwegian Polar Institute, responsible for monitoring the Svalbard reindeer. Her interest in what happens up north was sparked by polar bear researcher Thor Larsen. Åshild heard him lecture when she was at university doing her master’s degree on the topic of vegetation ecology in Africa. (Larsen knew a lot about the tropics as well.) The young student needed advice, and Larsen emphasised that if she wanted to focus on something truly exciting, she should look north.

And so she did. Further and further north. What was originally intended to be a short stay in Svalbard in 1996 ended up lasting two years. Then she had a stopover in Oslo, at the WWF’s Arctic division and as Oslo municipality’s first nature manager, dealing with moose, skiers, forest boundaries and vast spruce forests. Young Åshild was addicted to nature in general, and the Arctic in particular, and ended up on the polar merry-go-round that many will recognise.

However, she kept her feet on the ground, on the terrestrial, and focused her efforts on reindeer, ptarmigan, arctic fox, and geese.

“Not polar bears?”

“No, why polar bears? Reindeer are really interesting; geese too. Not to mention the ptarmigan! And everything is connected to everything else. A reindeer’s most important task in a bad year is to die, so the arctic fox can find an edible cadaver and produce lots of puppies.

“And an arctic fox with lots of puppies needs lots of food, and will feast on birds and the eggs in their nests on the

ground. So what happens to the animals and the climate in winter has impact on the next summer's production of eggs and chicks on the tundra. And so life goes on," she explains.

Åshild Ønvik Pedersen has published her knowledge in a children's book on the Svalbard rock ptarmigan, and hopes to write another one in the future, this time on the chubby and trusting reindeer of the tundra. Simultaneously, her research has lately passed through the narrow eye of the needle at the prestigious journal *Science*. But the professional pride this evokes doesn't make her forget that children's books are also communication.

Her daughter Sigrid, aged 7, acted as adviser on the ptarmigan book, and her younger daughter Synne, 4, could have a part in a planned book about reindeer. The children are eager walkers and each has her own husky: the dogs pull both the girls and their lunch boxes on trips.

The girls attended an outdoor nursery on Kvaløya until Sigrid started school. They enjoy the outdoors, which makes their mother smile.

All three are active in a children's walking society, where Åshild the researcher often applies her knowledge of nature and where she has learned to communicate excitingly, using simple words.

"Life is all about being outdoors," says Åshild.

From her office window she can see bare mountains to the north, and her thoughts wander happily away from impressive ring binders with titles such as "Ptarmigan habitat models" and thick folders that only those with a PhD in ecology would understand.

She sees our quizzical look and is happy to explain.

"For a long time researchers only concerned themselves with individuals. In the ocean we studied cod, in the mountains, ptarmigan, on the ice, the polar bear. Now I look at everything, and look for connections. It's called ecosystem thinking. Using it, researchers can provide administrators with a better tool for protecting nature."

Climate and global warming also have an impact on the research. Changes are noticed first in the north. Monitoring is becoming more and more urgent now that spring comes earlier than ever and long periods of mild weather occur in an otherwise stable, ice-cold winter.

"Svalbard provides opportunities for research in an ecosystem that's easy to get a good overview of. Much of what we discover here about cause and effect can be important both nationally and internationally," she says.

She goes to fetch some freshly-brewed coffee in stout mugs and looks a bit puzzled. Really, she would like to talk about her dream of becoming a hunter. But is an ecologist actually allowed admit that she would like to shoot - and maybe even eat - the organisms she studies? Certainly!

"I don't have any romantic notions concerning my research. I don't get lost in the animals' deep, dark eyes," she says. Enough said on that topic, then.

"What about reindeer and ptarmigan on your dinner plate?"

"I'm a bit slow when it comes to good food and a suitable wine. It's better letting others deal with that. If I were to choose a favourite dish, it would have to be home-made fish cakes, something we make often," she smiles.

Smiling is another thing Åshild does often, and it's contagious. Over the course of a year on the Fram Centre's fourth floor, everyone has become familiar with her quiet sense of humour and motherly concern.

Photo: Ole Magnus Rapp

Agneta Fransson // Norwegian Polar Institute
Melissa Chierici // Institute of Marine Research
Mats Granskog // Norwegian Polar Institute

Understanding ocean acidification – Is the Arctic turning acid?

EVERYONE WHO WATCHES the evening news is undoubtedly aware that carbon dioxide levels in the atmosphere have increased. But fewer know that carbon dioxide (CO_2) is increasing in the ocean as well. This phenomenon is called ocean acidification (OA), and it has raised a number of questions regarding the effects on organisms and the marine ecosystem. What are the consequences of the increased acidity and decreased carbonate ion concentration? The cold, relatively fresh waters of the polar oceans are particularly sensitive to changes, since they already have low carbonate ion concentrations and cold water can take up more atmospheric CO_2 than warm water. This is why polar seas are the first to show a significant increase in acidity, with consequences particularly for calcifying organisms such as corals, shellfish and molluscs.

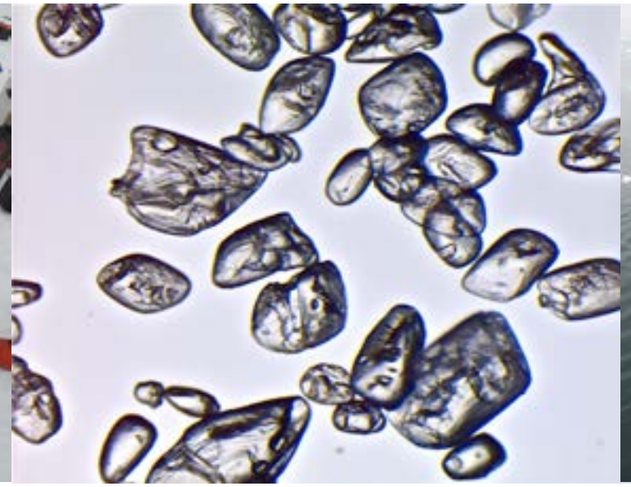
When CO_2 dissolves in water it becomes carbonic acid (a weak acid), which rapidly turns into bicarbonate due to a chemical reaction. Hydrogen ions are released, causing a decrease in pH. (pH is a measure of acidity: the lower the pH, the greater the acidity. Solutions and molecules with a high pH are called "basic".) To compensate for the acidic hydrogen ion, basic carbonate ions are consumed. This regulating system is called the ocean carbonate system, and it buffers the ocean against acidic compounds. However, since ocean CO_2 has increased rapidly on a short time scale, the ocean chemistry has shifted to a more acidic state, although still basic. Carbonate ions are essential for marine organisms that produce calcium carbonate ($CaCO_3$) to build hard parts such as skeleton and shells.

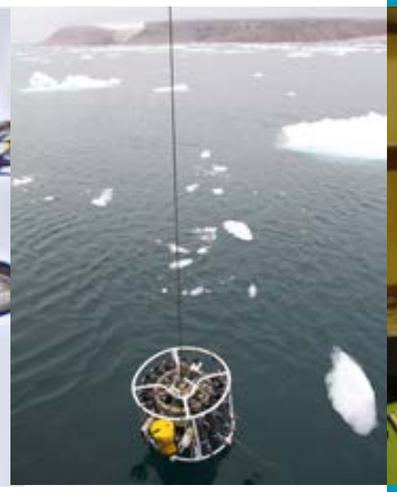
Simultaneously, the Arctic climate system is rapidly changing as atmospheric CO_2 increases. This is most evident in the thinning of Arctic sea ice, in warming, and increased river runoff, which also increases the transfer of carbon from terrestrial ecosystems to the ocean. These factors will likely modify several processes relevant for the carbon budget of the Arctic Ocean, which will affect OA in a complex and not well understood way. Observations from the Arctic Ocean are scarce relative to other oceans due to the challenging conditions, with seasonal sea-ice cover and polar night. Consequently, we have very little background information on the natural baseline of the Arctic Ocean carbonate system and the OA state.

From earlier work in the Arctic Ocean, we know that the $CaCO_3$ saturation (estimate of $CaCO_3$ dissolution) in the surface water depends on location and season, and is closely related to changes in biogeochemical processes, in particular biological primary production and respiration. Sea-ice melt results in naturally low $CaCO_3$ saturation in some areas, and an increase in fresh water input could result in enhanced OA.

Sea ice is important for OA since it can concentrate alkalinity (buffer acid). As ice melts, alkalinity is released to the surface water and the potential for CO_2 uptake increases. When more CO_2 is taken up in the surface water, the $CaCO_3$ saturation state decreases, reducing the number of carbonate ions available for the marine organisms to build their calcareous shells and skeletons. These changes will in turn also affect the high-latitude marine ecosystems.

Authors Agneta and Mats collect newly-formed sea ice. Photo: P. Dodd, Norwegian Polar Institute



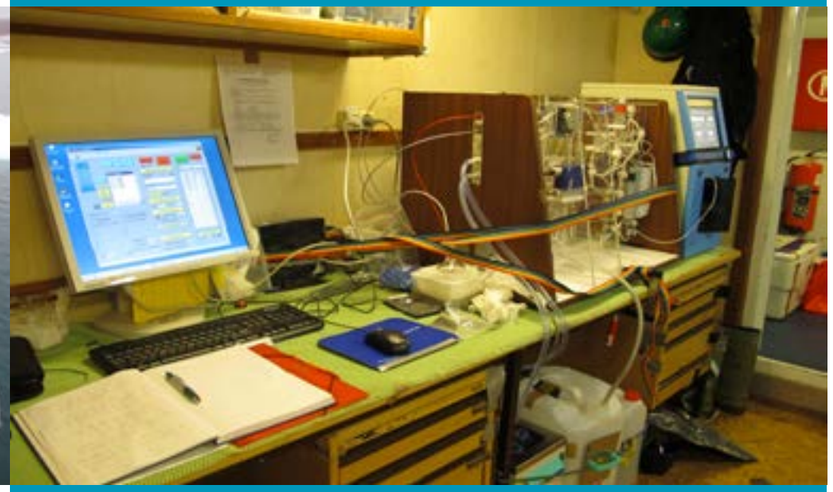


Within the Ocean Acidification Flagship at the Fram Centre, two projects aim to examine the current status and baseline of OA, the role of biogeochemical processes on OA state, and air-ice-water carbon transport in the Norwegian Arctic. One is called OA^{state} (*Establishing the Current Status of Ocean Acidification in the Norwegian Arctic*). The main aims of the other project, SICCA (*The role of Sea Ice processes on CO_2 exchange and Calcium CArbonate saturation levels*), are to investigate how sea-ice processes (especially formation and melt) affect the ocean carbonate system, air-sea CO_2 fluxes and OA state. These studies are done on expeditions and field work in and around Svalbard. The demanding task is to collect various samples (sea ice, seawater at several depths, snow, brine, and frost flowers), and analyse these samples in the field or back home in the laboratory.

Preliminary findings from the western Fram Strait (i.e. Arctic outflow) showed a layer with low pH and low $CaCO_3$ saturation (high CO_2). This coincided with high organic matter content and high brine fraction, which we believe was caused by a combination of bacterial respiration and surface CO_2 being transported to deeper layers along with the brine that is created when sea ice forms.

We found crystals of ikaite ($CaCO_3$) in the sea ice north of Svalbard, and at the same place we could directly measure CO_2 fluxes from sea ice to air. When ikaite crystals are formed in the ice, CO_2 is released to the brine and sinks to deeper water along with the brine or escapes to the air. During ice melt, excess alkalinity caused by the $CaCO_3$ crystals is added to the surface water, facilitating CO_2 uptake. We also found that ice brines affect the $CaCO_3$ saturation state in the underlying waters, with a decrease in winter as an effect of release of CO_2 and an increase in spring due to the alkalinity-enriched ice melt. This knowledge is important for the understanding of the OA state.

We investigated the influence of glacier and sea-ice melt water on the OA state in the water column of a Svalbard fjord. Here, we found elevated alkalinity, increased pH and decreased amounts of CO_2 in the surface water close to a glacier. We assume this was due to glacier melt water entering the fjord. This means that the glacier melt water may have the potential to limit OA and affect CO_2 fluxes between air and sea.



From left to right

– Ice core sampling. Photo: M. Chierici, Institute of Marine Research

– Crystals of calcium carbonate (ikaite) found in the sea ice. Image taken with confocal Raman microscope. Photo: P. Assmy, Norwegian Polar Institute. From Nomura et al. (2013). Characterization of ikaite (CaCO32 •6H2O) crystals in first-year Arctic sea ice north of Svalbard. Annals of Glaciology, 2013: 54(62). Used with permission

– Rosette with CTD (conductivity-temperature-depth) for seawater sampling from surface to bottom. Photo: A. Fransson, Norwegian Polar Institute

– Laboratory setup for carbonate-system analyses. Photo: A. Fransson, Norwegian Polar Institute

FURTHER READING

Chierici M, Fransson A, Lansard B, Miller LA, Mucci A, Shadwick E, Thomas H, Tremblay J-E, Papakyriakou T. (2011) The impact of biogeochemical processes and environmental factors on the calcium carbonate saturation state in the Circumpolar Flaw Lead in the Amundsen Gulf, Arctic Ocean. JGR-Oceans. 116, C00G09, doi:10.1029/2011JC007184

Chierici M, Fransson A. (2009) $CaCO_3$ saturation in the surface water of the Arctic Ocean: undersaturation in freshwater influenced shelves. Biogeosciences, 6, 2421-2432

Gattuso J-P, Hansson L (eds). (2011) Ocean Acidification, Oxford University Press Inc., NY, USA, ISBN 978-0-19-959108-4, pp 326

Nomura D, Assmy P, Nehrke G, Granskog MA, Fischer M, Dieckmann GS, Fransson A, Hu Y, Schnetger B. (2013) Characterization of ikaite (CaCO32 •6H2O) crystals in first-year Arctic sea ice north of Svalbard. Annals of Glaciology, 54(62) doi:10.3189/2013AoJ62A034

Torstensson A, Chierici M, Wulff A. (2011) The influence of increased temperature and CO_2 levels on the benthic / sea ice diatom. Polar Biology, DOI 10.1007/s00300-011-1056-4

Partners: NIVA, UNIS

Anita Evenset, Marianne Frantzen, Guttorm N. Christensen // Akvaplan-niva

“Contaminant cocktails” – a threat for Arctic fish populations?

Mature Arctic charr from Lake Ellasjøen (left), fertilised eggs (middle) and an egg that has just started to develop.

ARCTIC ANIMALS are exposed to a range of environmental contaminants ("contaminant cocktails") that reach the Arctic mainly through long-range transport. The levels of these contaminants in many top predators are high enough to have negative effects on health.

During recent years, researchers from several disciplines have worked together on Bjørnøya (Bear Island, Norway), studying the presence and fate of persistent organic pollutants (POPs) in this apparently pristine Arctic environment. They have found high concentrations of POPs in sediment and organisms from Ellasjøen, a lake located in the southern part of Bjørnøya. In other lakes on Bjørnøya, such as Lake Øyangen and Lake Laksvatn, levels of POPs are considerably lower than in Ellasjøen. The main reason for the high contaminant levels in Ellasjøen is the large population of seabirds at the southern end of Bjørnøya. The birds transport POPs from the marine to the freshwater ecosystem because they feed on contaminated organisms in the ocean and then deposit droppings - guano - into the lake. This biological transport mechanism explains why the POP levels in Arctic charr are about ten times higher than in other Arctic top predators.

Laboratory studies have clearly demonstrated that a range of disorders in fish may be associated with exposure to POPs. But even though we are rapidly gaining an understanding of how individual contaminants affect communities, very few studies probed the effects of mixtures (cocktails) of diverse contaminants in aquatic communities. This means we still do not know for certain if the contaminant cocktail present in charr from Ellasjøen has any negative effects on the health status of the fish.

Bjørnøya, where lakes with comparable species composition but with substantially differing contaminant loads lie in close proximity, provides a unique opportunity to study the possible effects of contaminants. This makes Bjørnøya an ideal natural field laboratory.

In 2012 the Fram Centre Flagship "Hazardous substances - Effects on ecosystems and human health" funded a pilot study, where the aim was to investigate if the contaminant cocktail in fish from Ellasjøen has any effects on the reproduction of the fish. In addition, the Norwegian Research Council (Miljø 2015 program) recently funded a 3-year project where the results from the pilot project will be followed up.

PILOT PROJECT 2012

In early September 2012 a total of 20 fish were caught in two lakes on Bjørnøya: Ellasjøen and Laksvatn (a reference lake with low contaminant levels). Samples of blood, liver, muscle, brain, gills, kidney and gonads were collected for analyses of various biomarkers for contaminant exposure and effects.

In addition, eggs and sperm were collected from mature individuals and a small fertilisation experiment was carried out. Eggs from four and three females from Ellasjøen and Laksvatn, respectively, were fertilised with sperm pooled from males from the corresponding lake. The fertilised eggs were allowed to develop to an early cell cleavage stage, when 300 eggs per female were sampled to assess fertilisation rate and the ratio between normal and abnormal cell cleavage. In addition, egg volume and egg size was recorded.

Muscle and gonad samples are currently being analysed for selected POPs, and steroid hormones are being determined in blood samples. The results from egg analyses show that the relative fecundity (number of eggs/fish weight) is higher in fish from Ellasjøen than in fish from Laksvatn, but that the eggs from fish from Ellasjøen are significantly smaller. Nonetheless, the pilot fertilisation experiment indicates that eggs from Ellasjøen develop just as well as those from Laksvatn. However, a larger number of fish must be investigated before any conclusions can be drawn. New experiments are planned for 2014.

All together, the results from this study will give new and valuable insight into how the cocktail of contaminants that is present in Arctic animals affect their health status.

Therese Larsen // Department of Geology / University of Tromsø

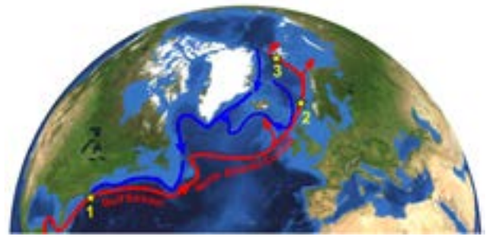
Gulf Stream warming and its impact on Norwegian and Arctic continental margins – methane release and instable slopes?

THE RELATIONSHIP BETWEEN ocean warming and methane escape from the seabed is one of the most pressing issues in the field of global climate change. Observations over the past years reveal that methane release in the oceans is increasing, but its immediate effect on oceanic and atmospheric environments is still uncertain. Resolving that uncertainty is one of the aims of CAGE, the Centre for Arctic Gas Hydrate, Environment and Climate at the University of Tromsø.

The Gulf Stream is in contact with thousands of square kilometres of seabed, and the methane hydrate that exists beneath the seabed is evidently very sensitive to changes in bottom-water temperature. Recent findings imply that pools of gas hydrate in ocean sediments are destabilising, and might release gigatons of methane.

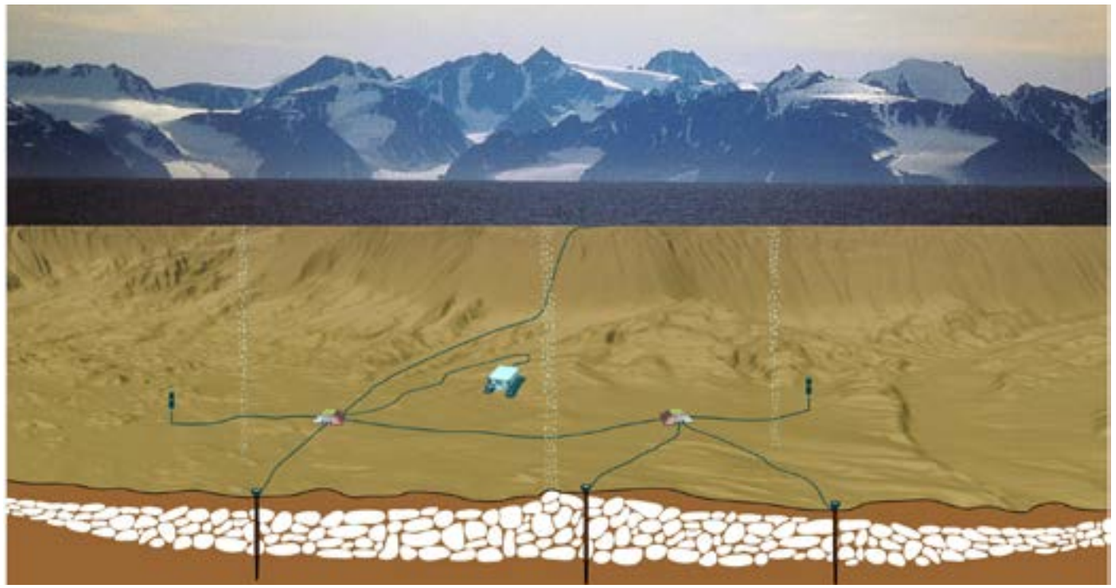
Professor Jurgen Mienert, Head of the Department of Geology at the University of Tromsø and leader of CAGE, predicts that methane will have a major impact on the future climate. Methane release will be a highly relevant theme in climate debates in the years to come.

"We now observe a global warming caused by the release of CO_2 in the atmosphere. These are anthropogenic emissions, and can be adjusted with political means. At the same time, we are experiencing an increase in methane emissions from polar regions, and this is incontrollable", says Mienert.

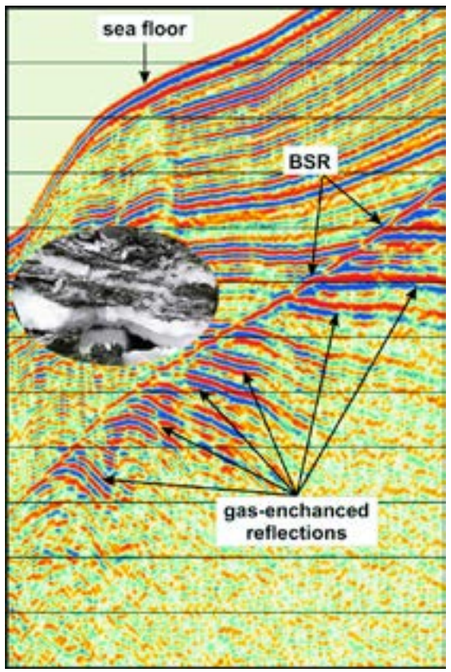


The Gulf Stream and the North Atlantic current are in contact with thousands of square kilometres of the seabed in which three major known submarine slides have occurred in sub-seabed gas hydrate provinces (1: Cape Fear slide; 2: Storegga Slide; 3: NW-Svalbard slide)

Jurgen Mienert, head of both the Department of Geology and the new Centre of Excellence named CAGE: Centre for Arctic Gas Hydrate, Environment and Climate.



Sub-seabed gas hydrates on Arctic continental margins and long-term observatories to study their dynamics. Systematic monitoring and understanding of hydrate dynamics in a warming Arctic is of key importance because melting gas hydrates could contribute to ocean acidification and accelerate global warming if methane is released to the atmosphere.



This seismic section from offshore NW-Svalbard shows the base of the gas hydrate stability zone, which is evident from the seismic detection (~200 m beneath the sea floor) of a bottom simulating reflector (BSR). The BSR more or less mimics the seafloor (water depth ~2000 m). Free gas accumulates beneath impermeable gas hydrate, causing gas-enhanced reflections. The inset figure shows what methane hydrates can look like in sediments above the BSR. Methane hydrate is only stable at low temperature and high pressure and will start melting, releasing methane from the seafloor, if ocean temperatures increase.

NEW CENTRE OF EXCELLENCE

The Centre for Arctic Gas Hydrate, Environment and Climate (CAGE), at the Department of Geology, University of Tromsø, was recently awarded the status of a Centre of Excellence by the Norwegian Research Council. The Centre aims to elucidate how the methane in subsea reservoirs in the Arctic might influence sea environment and global climate in the future. CAGE was selected – in fierce competition – from among 139 research environments in Norway. For 10 years, starting in 2013, CAGE will receive research funding amounting to 14 million NOK per year.

POTENTIAL CAUSE OF ENVIRONMENTAL CHANGE

Methane hydrate is an ice-like structure, which fills the pore space of sediments in the seabed and subseabed. Large amounts of natural gas, mainly methane, are stored in the form of hydrates in continental margins worldwide, particularly in the Arctic. Gas hydrates are stable when the temperature is low and the pressure is high.

Gas hydrate consists of ice-like crystalline solids of water molecules encaging gas molecules, and is often referred to as “the ice that burns”. Some see it as a potential unconventional energy resource, but methane released from hydrates will also accelerate climate change because it is a major greenhouse gas. It has a much higher Global Warming Potential than carbon dioxide, CO_2. If more methane is introduced into the atmosphere, even more heat will be trapped, accelerating global warming.

There are two big stories related to methane in the environment. One is about the potential warming effect of increasing methane levels in the atmosphere. The other is about large scale collapses of continental slopes, which may cause tsunamis.

SIGNS OF INSTABILITY

Research done by Benjamin Phrampus and Matthew Hornbach, presented in a recent article published in *Nature* (October 2012), suggests that changes in the Gulf Stream are rapidly destabilising methane hydrate along the North American continental margin. This destabilisation is happening where the deep ocean meets the shallow continental shelves, the transition zone between continental and oceanic crust. The researchers’ findings strengthen the assertion that there is a substantial risk of rapid future methane emissions from the seabed, suggests Mienert in a related article in the same issue of *Nature*.

The ocean temperatures in shallow areas appear to have an effect on the stability of gas hydrate. Researchers from the Department of Geology at the University of Tromsø have analysed data from the Norwegian-Svalbard continental margin from the past 60 years, and concluded that the bottom-water temperature has increased rapidly since 1980. Before then, there was a period of significant cooling, but since 1980, bottom-water temperatures have increased by approximately 2°C both in the shallow areas of the Barents Sea and near Prins Karls Forland, and by 0.5°C in deep water. At the same time, measurements conducted on air samples show that the increase in methane emissions over the past decades is much larger than the variations seen in ice core records covering over 800 000 years.

Phrampus and Hornbach estimate that the changes in the Gulf Stream will ultimately warm the western North Atlantic margin by as much as 8°C, which will trigger the destabilisation of 2.5 gigatonnes of methane hydrate.

Another important indication that the Gulf Stream and its continuing northward-flowing currents affect the stability of gas hydrates from northern Atlantic to Arctic continental margins is the occurrence of subsea slides in the zone of ocean floor where warming ocean water masses are in contact with the seabed.

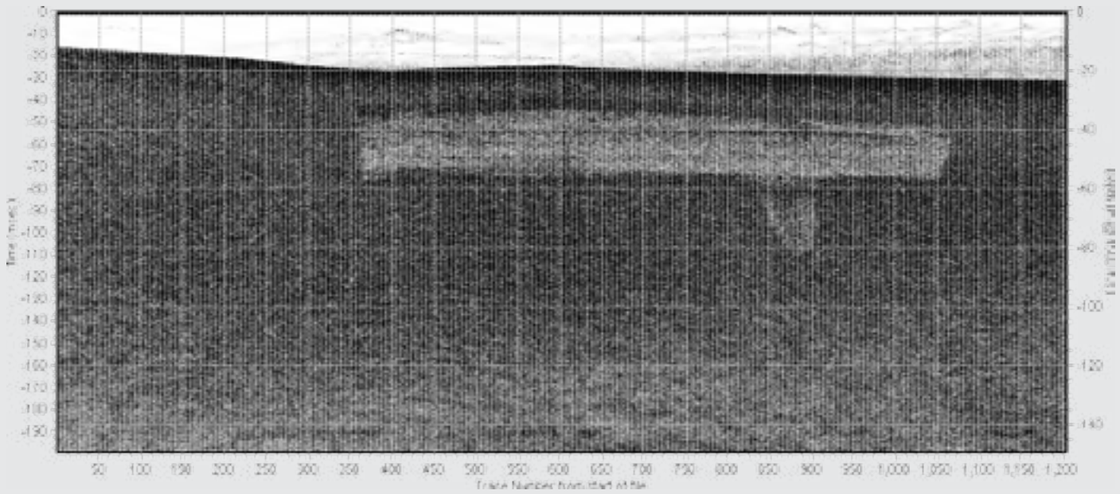
The correlation between slope failure and hydrate dissociation has not yet been proven, but a number of observations support this potential relation. The Storegga slide is a striking example of this: an enormous slide at the mid-Norwegian margin, dated 8 200 years ago, where the decomposition of gas hydrate contributed to the instability of slopes. The slide involved the displacement of 3 500 cubic kilometres of sediment and caused a ten metre high tsunami wave that hit coastlines from Southwest Norway, Scotland, the Shetland Islands and way up to the Faeroe Islands.

Geophysical data from the same area document a long-term history of slope instability covering the last 500 000 years.

Both the ocean warming and the methane escape from the seabed are apparent, but the correlation between them is the subject of lively debates in the international scientific community. The big unknowns of this century’s ocean temperature shifts are *if*, and *how rapidly*, these shifting temperatures are reducing the stability of methane hydrate in Arctic continental margins.

Justin P. Gwynn // Norwegian Radiation Protection Authority (Fram Centre)
Hilde Elise Heldal // Institute for Marine Research (Bergen)
Bjørn Lind // Norwegian Radiation Protection Authority (Østerås)

Joint Norwegian-Russian mission to investigate dumped atomic waste in the Kara Sea



Sonar image of the dumped nuclear submarine K-27. Image: Norwegian Radiation Protection Authority

In the autumn of 2012, a joint Norwegian-Russian expedition to the Kara Sea investigated an area where radioactive waste had been previously dumped. The purpose of the mission was to obtain up-to-date information about radioactive pollution in the area and assess the condition of the dumped items.

The practice of dumping radioactive waste at sea was halted by most countries in 1985, but the former Soviet Union and later Russia continued dumping radioactive waste in the Kara and Barents Seas until 1992. According to the Russian authorities, a range of dumped materials can be found in arctic seas, including nuclear-powered submarines, reactor compartments and more than 17 000 containers of radioactive waste.

R/V *Ivan Petrov*. Photo: Norwegian Radiation Protection Authority

POTENTIAL SOURCE OF RADIOACTIVE POLLUTION

Dumped radioactive waste is a potential source of pollution in the northern areas. This applies in particular to the spent nuclear fuel that has been discarded at sea. According to the Russian authorities, some of this fuel waste is so highly enriched that the possibility of a nuclear chain reaction under certain circumstances could not be excluded. Three Norwegian-Russian missions to the dumping sites in the Kara Sea took place in the early 1990s. The conclusion at that time was that radioactive pollution in the area was low, but that there was a risk of future leaks from the dumped items. This autumn's mission aimed to follow up on that risk.

THE EXPEDITION PARTICIPANTS

The expedition lasted for four weeks and was carried out on the Russian research vessel *Ivan Petrov*. Norway was represented by participants from the Norwegian Radiation Protection Authority, the Institute of Marine Research, the University of Life Sciences, and the Institute for Energy Technology. From Russia, there were participants from the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet), the Kurchatov Institute, and the Yuzhmorgeologiya research centre. The International Atomic Energy Agency (IAEA) was also represented.

INVESTIGATING THE MARINE ENVIRONMENT

The expedition focused its efforts on Stepovogo Bay on the east coast of Novaya Zemlya where the nuclear submarine K-27 containing two reactors with spent uranium fuel was dumped in the outer fjord at a depth of 30 metres in 1981. In addition, some 2 000 containers of radioactive waste have been dumped in the inner fjord. The condition of K-27 and some of the dumped containers was inspected using a remotely operated vehicle, while seawater, sediment and biota samples were taken to determine the radiological status of the marine environment.

NO LEAKAGE FROM K-27

Preliminary measurements on surface sediments and water samples showed that the level of contamination with caesium-137 was generally low. However, slightly enhanced levels of caesium-137 were detected in bottom seawater and sediment collected in the area where containers had been dumped. Measurements taken around K-27 revealed no signs of leakage from the submarine. The level of radioactive contamination in Stepovogo Bay was similar at the time of the Norwegian-Russian expedition in 1993-94. Further analyses of the samples collected will be performed in both Norway and Russia through close collaboration.

IMPORTANT FOR FUTURE WORK

"It's reassuring that the preliminary results show that the radioactivity in the environment has not increased. The expedition was important for future work and is the first step towards having good knowledge on the environmental condition in the Arctic," said Per Strand, director of the Department for Emergency Preparedness and Environmental Radioactivity at the Norwegian Radiation Protection Authority.

A final report based on the findings of the 2012 joint Norwegian-Russian expedition will be published by the end of 2013. An important task for joint future work will be to carry out environmental assessments of different potential remediation options for the various dumped materials, including the possible raising of the nuclear submarine K-27.

Researchers sampling fish during the cruise. Photo: Norwegian Radiation Protection Authority

Nicholas A. Warner // NILU – Norwegian Institute for Air Research

Low levels of siloxanes in pregnant and postmenopausal Norwegian women

RESEARCHERS FROM the University of Tromsø, McMaster University in Ontario, Canada and NILU - the Norwegian Institute of Air Research at the Fram Centre, have quantified cyclic volatile methylsiloxanes (cVMS) in blood plasma of pregnant and postmenopausal women to identify the potential risk of exposure to this class of chemicals. They conclude that the risk is low, both for human adults exposed directly and for the fetus exposed through maternal transfer.

Nicholas Warner, scientist at NILU and project participant. Photo: Kurt Jacobsen / Fram Centre

COMMON CHEMICALS

cVMS are classified as “high production volume” chemicals in the European Union; this means that the annual production or import of cVMS exceeds 1000 tonnes per year. Although they are used in various industrial applications and consumer products, cVMS are most heavily used in the personal care product and cosmetic industry. Elevated levels of these chemicals have been detected in air, water, sediment and biota, prompting concern among international regulatory agencies about cVMS persistence in the environment and the risk of accumulation in living organisms.

GENERALLY LOW LEVELS FOUND IN HUMANS

To our knowledge, this was the first study to report cVMS in humans from a randomly selected population cohort. The cVMS concentrations were generally low; only D4 (octamethylcyclotetrasiloxane) was consistently above detection limit, and was found in 85% of the plasma samples we had collected from postmenopausal women. Another cyclic siloxane, D5 (decamethylcyclopentasiloxane), which is more abundant in personal care products and is the predominant form of siloxane in the natural environment, was found at much lower concentrations than D4, and was detected in only 18% of the plasma samples. These findings may be attributed to D5 being absorbed more slowly than D4 into the skin. D5 may also have higher affinity to fatty tissues than D4, which means that D5 will more readily move from blood and plasma to tissues with higher fat content.

Based on the findings of this study, cVMS exposure poses little risk to human adults. The risk to the fetus through maternal transfer is also low.

In blood samples we had collected from pregnant women, we found cVMS even less frequently. D4 was detected only in 12% of the samples, and D5 was not detected at all. One possible reason for the concentration difference in blood compared to plasma may be that the samples were collected at different times. Plasma samples were collected in 2005, whereas blood samples were collected in 2009. The low concentrations in blood may reflect higher usage of D4 in products in earlier years. In addition, restrictions have been imposed on use of D4 in recent years due to concerns about toxic effects in mammals and aquatic systems, and industry has shifted production: D5 is now the dominant cVMS in personal care product formulations.

The negative correlation between personal care product usage and the concentration of D4 in plasma may also be a result of humans being able to eliminate these chemicals efficiently. The findings presented here, together with results from earlier inhalation studies, indicate that air-breathing organisms can efficiently eliminate most of the siloxane in their bodies through respiration. This is also indirectly supported by the high siloxane concentrations previously reported in fish, which lack access to this route of elimination.

FURTHER STUDIES OF CVMS IN TISSUES WITH GREATER FAT CONTENT NEEDED

Based on the findings in this study, cVMS exposure poses little risk to human adults and fetuses. Cyclic siloxanes absorbed into the body after application of personal care products appear to be eliminated efficiently. However, it is important to consider that due to their hydrophobic nature, cVMS will partition out of plasma/blood and into tissues with greater fat content once they have entered the body. Concentrations within such tissue compartments are expected to be higher and elimination slower compared to plasma and blood compartments. Future research on human exposure to cVMS should focus on fatty tissue compartments.

FURTHER READING

Hanssen L, Warner NA, Braathen T, Odland JØ, Lund E, Nieboer E, Sandanger TM. (2013) Plasma concentrations of cyclic volatile methylsiloxanes (cVMS) in pregnant and postmenopausal Norwegian women and self-reported use of personal care products (PCPs). Environ Int 51:82-87

THE RESEARCHERS INVOLVED IN THIS STUDY ARE AFFILIATED WITH

— The Department of Community Medicine, University of Tromsø (Linda Hanssen, Tonje Braathen, Jon Ø. Odland, Eiliv Lund, Evert Nieboer, Torkjel M. Sandanger)

— NILU – Norwegian Institute for Air Research, FRAM Centre, Tromsø (Linda Hanssen, Nicholas A. Warner, Torkjel M. Sandanger)

— The Department of Biochemistry and Biomedical Sciences, McMaster University, Hamilton, Ontario, Canada (Evert Nieboer)

Ingjerd Sunde Krogseth // NILU – Norwegian Institute of Air Research

Chemicals from your deodorant fly to the Arctic

PhD candidate Ingjerd Sunde Krogseth from NILU is worried about the finding of siloxanes in the air at Zeppelin Mountain, Ny-Ålesund. The new study proves that siloxanes can be transported over great distances in the atmosphere, which in itself is a reason for concern. Photo: NILU

Do you ever wonder what actually happens to all of the deodorants and skin lotions and makeup that you put on every day? Does it all just disappear? Maybe not! New research has for the first time shown siloxanes in air samples from the Arctic. These chemicals come from sources much further south, which gives reason for concern.

LATELY THERE HAS BEEN an increasing focus on substances in personal care products that can potentially be harmful for human health and the environment. Siloxanes are chemicals that are used in large volumes in personal care products, such as deodorants, skin lotions and shampoos. They are released to the environment mainly through volatilisation to the atmosphere and with wastewater.

HIGHER LEVELS THAN PCB

NILU - the Norwegian Institute for Air Research, in cooperation with Stockholm University and Aarhus University, have carried out an extensive study that confirms the presence of siloxanes in Arctic air. A previous study had detected the same substances in a few individual samples, but not with enough certainty to say affirmatively that they were present and at which levels. The new results show that the siloxanes D5 and D6 are indeed present in the Arctic atmosphere. The concentrations might seem low - about 1 nanogram per cubic metre of air (1 nanogram = 0.000 000 001 gram) - but this is still about 100 to 1000 times higher than typical concentrations of the classical pollutants PCBs in air at the same site.

There are currently no regulations on the use of siloxanes, but two siloxanes - D4 and D5 - are on the Norwegian government's priority list of chemicals that should be phased out by 2020 due to their threat to human health and the environment. The knowledge about any potential effects of these chemicals on human health and the environment is still very limited. Siloxanes are highly volatile, and hence it is not expected that they can be deposited from the Arctic atmosphere to the terrestrial and aquatic environment as efficiently as other pollutants. However, the new

In personal care products, siloxanes are used for a wide range of different reasons, such as making the products feel soft and silky, and as fragrance carriers.

FURTHER READING:

Krogseth IS, Kierkegaard A, McLachlan MS, Breivik K, Hansen KM, Schlabach M. (2013) Occurrence and seasonality of cyclic volatile methyl siloxanes in Arctic air. Environ Sci Technol 47(1): 502-509. DOI: 10.1021/es3040208

In Norwegian:

http://www.miljostatus.no/no/Tema/Kjemikalier/Noen-farlige-kjemikalier/Siloksaner/

study by NILU proves that they can be transported over great distances in the atmosphere, which in itself gives cause for concern.

LONG-RANGE TRANSPORT LIKELY

Our measurements were performed at the Zeppelin observatory, which is located on a 400-metre high mountain next to the settlement of Ny-Ålesund in Svalbard. The settlement is so small that it is not expected to have had any influence on the measurements. With support from computer models, we can with a high degree of certainty conclude that the siloxanes we detected have been transported with atmospheric currents from source regions further south, like Scandinavia and Europe. The ability to be transported over long distances is an important criterion (together with others) to classify a chemical as a pollutant.

The concentrations of siloxanes in Arctic air are higher in the winter season than in the summer season. In summer, the siloxanes are degraded by atmospheric radicals produced in the presence of sunlight. In the Arctic winter, when the sun stays below the horizon for several months, the siloxanes are not degraded to the same extent, and the concentration in the atmosphere increases.

DIFFICULT TO MEASURE

Siloxanes are very challenging to measure in air. First, the chemicals are highly volatile, which means that the traditional air sampling methods are not necessarily applicable to siloxanes. Second, siloxanes are ubiquitous in our surroundings, not only in laboratory equipment and indoor air, but also on us (e.g. hand creams). Hence extreme caution is necessary to avoid any contamination of the samples. The new measurements were carried out between August and December 2011, using a new method that was developed at Stockholm University a couple of years ago, and has since been further developed. The study was financed by Miljø2015 (the Norwegian Research Council), and the results from the study were recently published in the well-respected journal Environmental Science & Technology.

FACT BOX

Siloxanes have previously been measured in fish in Mjøsa, the largest lake in Norway, where NIVA – the Norwegian Institute for Water Research determined that the concentrations increased higher up in the food chain (http://www.forskning.no/artikler/2012/mai/321036).

Siloxanes are chemicals that consist of a skeleton (rings or chains) of oxygen and silicon with organic side groups attached. The most hotly debated siloxanes are D4 (octamethylcyclotetrasiloxane), D5 (decamethylcyclopentasiloxane), and D6 (dodecamethylcyclohexasiloxane).

Siloxanes are used in the production of silicone polymers, in personal care products, and in various technical products. In the European Union the consumption of D4, D5, and D6 has been estimated to be about 9 500, 19 000, and 2 000 tonnes per year (numbers for 2004, includes personal care products and polymer production only). In personal care products siloxanes are used for a wide range of different reasons, such as giving the products a soft, silky feeling and as fragrance carriers.

The siloxane content in cosmetics is usually only a few percent, but certain products can contain more than 50% siloxanes, and in extreme cases close to 100%. Uptake of siloxane through the skin is minimal, and most of it volatilises to the air or is washed off. In the list of ingredients on personal care products, siloxane substances have names that end with –siloxane or –methicone.

D4 has been classified as harmful for reproduction and for aquatic organisms, but it is still unclear whether D5 and D6 have any harmful effects. The reason for concern about siloxanes is primarily their environmental effects, especially for aquatic organisms, and not their effects on human health.

Warner NA, Evenset A, Christensen G, Gabrielsen GW, Borga K, Leknes H. (2010) Volatile siloxanes in the European Arctic: Assessment of sources and spatial distribution. Environ Sci Technol 44(19):7705-7710

News items

LAUNCH OF FRAM SHORTS

On 9 March 2012, the Fram Centre launched a completely new research dissemination concept - Framshorts.com.

Fram Shorts is a series of short films in which researchers at the Fram Centre's institutions talk about their work and illustrate their projects. It is hoped these films will give the general public an insight into the research being done and how the environment and climate in the High North are being monitored. And there are plenty of topics to choose from: polar bears, seals, ice, climate change and environmental toxins, to name just a few. All the films are in English and are designed to be used by everyone, including schools, and also as a general information service. The page is adapted for use on traditional computers, e-book readers and smartphones.

IPY – MONTREAL

The Fram Centre's presence at the IPY Conference in Montreal from 22 to 27 April 2012, which attracted some 3 500 participants, was the biggest international promotional event for the Fram Centre to date. The Fram Centre was visibly present with a large exhibition in the conference hall, where there were 150 exhibitors and 3 500 poster presentations. Together with APECS (Association of Polar Early Career Scientists), the Fram Centre held a large reception in the Montreal Conference Centre, which was attended by 550 guests who were informed about the research done at the Fram Centre and about its institutions. The Centre was also promoted through a Norwegian-Canadian workshop.

Sebastian Gerland and Edmond Hansen // Norwegian Polar Institute
Torbjørn Eltoft // University of Tromsø

Combining satellite remote sensing and field work to characterise Arctic sea ice properties

Figure 1

Sea ice thickness and surface topography are surveyed from helicopter with an instrument called an "EM-bird" and an automated camera system. This image is from sea ice surveying in Fram Strait during the most recent expedition of the Norwegian Polar Institute in August 2012. The helicopter operates from the Institute's research vessel *Lance*. Photo: Sebastian Gerland / Norwegian Polar Institute

The Fram Strait is the approximately 500-km wide passage between Greenland and Svalbard. Its status as the main oceanic passage between the North Atlantic and the Arctic Ocean makes Fram Strait important in the context of Arctic climate change. Most of the drifting sea ice that leaves the Arctic Ocean escapes here; roughly ten percent of the total Arctic sea ice area is exported through Fram Strait each year. The Norwegian Polar Institute has been monitoring ocean and sea ice properties in this region since the early 1990s. As a part of the project "Characterization of Arctic sea ice properties from remote sensing observations - CASPER", scientists from the Norwegian Polar Institute, the University of Tromsø, and Norut are now studying the sea ice in the western Fram Strait in detail using satellites and airborne remote sensing instruments, in combination with direct ground-based measurements. CASPER is one of the projects organised under the Fram Centre flagship "Sea ice in the Arctic Ocean, technology and systems of agreements".

HOW CAN REMOTE SENSING HELP US UNDERSTAND SEA ICE PROCESSES?

The sea ice that we find in Fram Strait has travelled a long way before arriving there. In terms of ice dynamics, Fram Strait is at the end of the so-called "trans-polar drift". This relatively stable drift pattern was perhaps first exploited by Nansen's *Fram* Expedition, which drifted from north of Siberia to Fram Strait between 1893 and 1896. Later, Russian drifting stations and the Tara Expedition (during the International Polar Year 2007-2008) drifted in a similar fashion. By systematically surveying different sea ice types as they show up in Fram Strait, we aim to better understand the processes that have operated on the ice during its travel across the Arctic Ocean.

In the CASPER project, we measure sea ice properties on the ice itself, from above using helicopters and satellites, and from below with upward looking sonars permanently moored on the seabed. During the scientific cruises, ships transport instruments, a helicopter and scientists to pre-selected regions. High-resolution synthetic aperture radar (SAR) satellite images of these regions are downloaded at the same time as measurements are being made in the field. This means we have data from several sources about ice thickness, snow distribution, melt ponds, and the degree of dynamically caused deformation. The information on deformation can be retrieved from the statistical distribution of sea ice pressure ridges and other signs of deformation within the ice. The combination of two SAR systems (Radarsat 2 and TerraSAR-X) allows for multiple frequency observations. In addition, both radar systems have multiple polarisation capabilities, which enables us to measure more surface properties than is possible with conventional SAR systems.

The intercomparisons of the different measurements help us assign features discovered in the SAR images to properties of certain ice types. In other words, these comparisons tell us what different types of ice look like in SAR images.

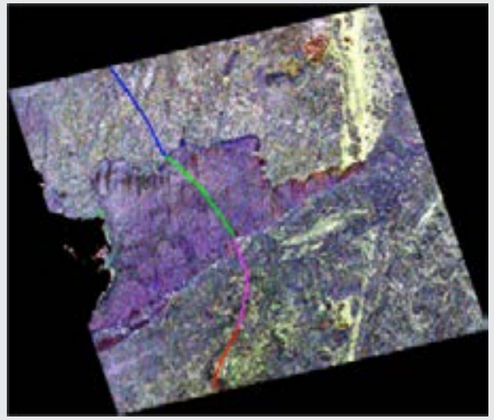


Figure 2

Geocoded C-band Polarimetric (Pauli) image of sea ice in the Fram Strait from Radarsat 2. In this RGB image, the red channel (R) represents double bounce scattering, the blue channel (B) represents surface scattering (single bounce), and the green channel (G) is volume scattering. The line crossing the image from top to bottom is the helicopter track, and shows where thickness measurements were obtained from the EM-bird. Processed by Ane Fors / University of Tromsø

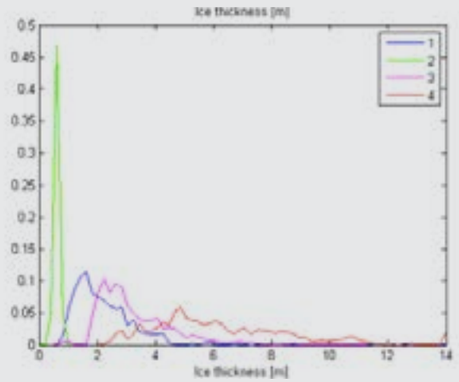


Figure 3

Diagram showing sea ice thickness along the helicopter track in figure 2. The colours correspond to the colour segments of the track. Processed by Angelika H.H. Renner /Norwegian Polar Institute and Ane Fors /University of Tromsø

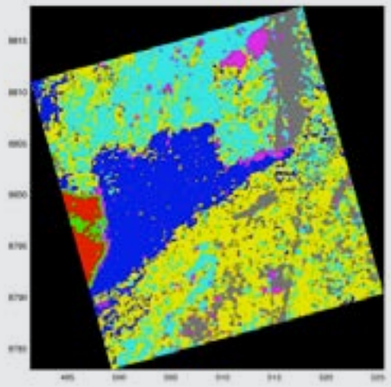


Figure 4

Here the PolSAR data shown in figure 2 have been analysed with a statistically based segmentation algorithm. The resulting image shows six different classes: red is open water, blue is first-year ice, cyan and yellow are two types of multi-year ice, grey is ridged ice, and the two purple dots in the upper right corner are icebergs. Processed by Anthony Doulgeris / University of Tromsø

HOW DOES THE FIELD WORK CONTRIBUTE TO MAPPING SEA ICE TYPES AND ICE THICKNESS?

In late summer 2011, during an expedition with R/V *Lance*, a subarea in Fram Strait was investigated close up, and ice thickness was measured with an electromagnetic sounder instrument, the "EM bird" seen hanging below the helicopter in figure 1. The idea was to compare these data with satellite images taken at the same time. Figure 2 shows a geocoded, full polarimetric SAR (PolSAR) image from that subarea, displayed as a RGB colour image, where the colours represent different scattering types (i.e. the physical mechanisms responsible for the radar echoes). The line crossing the image from top to bottom is the helicopter track, and shows where thickness measurements were obtained. The track's different colours correspond to the lines in the ice thickness graph (Figure 3).

From this image, we make the following interpretations:

1. *The purple area in the middle of the image is relatively smooth, thin, first-year ice. This is verified by the green line in figure 3.*

2. *On either side of this area, we find rougher, thicker, multi-year ice. We can clearly see differences in the appearance. The lower side has more inclusions of deformed ice (more white, greenish colour), and this ice type is on the average thicker, as can be seen by comparing the blue with the red and purple lines in figure 3.*

3. *The white structure in the upper right corner is ridged ice.*

The on-going analysis in the CASPER project focuses on detailed characterisation of the radar signals within image segments. Figure 4 shows a version of the image in figure 2 where a statistically based segmentation algorithm has been applied to the PolSAR data. We hope this work will ultimately lead to methods for automatic retrieval of geophysical quantities (ice type, thickness) from PolSAR images.

WHAT DOES ICE IN FRAM STRAIT TELL ABOUT ICE IN THE ARCTIC BASIN?

The Fram Strait is well suited for long-term monitoring of Arctic sea ice thickness because steady stream of ice passing through the strait comes from many sites across the Arctic Ocean. Ice thickness and other ice features observed here represent a summary over time of ice status in the regions of the Arctic Ocean that deliver ice to the Transpolar Drift and Fram Strait. In analysing variability, it is particularly important to distinguish between variations in ice thickness that are due to differences in drift patterns and variations due to any other cause. In other words, we must know where the sea ice came from. For this purpose we perform backtracking based on a combination of passive microwave satellite data, and wide swath radar satellite images (QuickSCAT/ASCAT or Radatsat2 ScanSAR) .

RECORD LOW SEA ICE EXTENT IN THE ARCTIC IN SEPTEMBER 2012

Since continuous satellite monitoring with passive microwave sensors began in 1979, September 2012 was the month with the smallest sea ice extent observed in the Arctic. The strongest decline in ice extent is seen in the summer, but winter sea ice is also declining. And the changes are not limited to ice extent. The ice is also becoming thinner, and sea-ice-free seasons in many Arctic regions are lasting longer. Around Svalbard and in the Barents Sea, recent winters have had less sea ice than earlier, and landfast sea ice has formed late or not at all. Arctic sea ice on average is getting younger: more and more old ice is being replaced by first or second year sea ice. As mentioned above, the sea ice drifting through Fram Strait summarises the ice status over time, and here too we see the ice changing, becoming thinner and younger. The improved possibilities to analyse remote sensing data from satellites enable scientists increasingly to use data with high spatial and temporal resolution, also in winter, when there is little opportunity to take measurements on site. The Norwegian Polar Institute's long-term monitoring program of sea ice and ocean parameters in Fram Strait provides an important baseline dataset, also to distinguish year-to-year variability from climate-related changes.

Aleksey Marchenko // The University Centre in Svalbard, and Sustainable Arctic Marine and Coastal Technology (SAMCoT), Centre for Research-based Innovations, Norwegian University of Science and Technology, Trondheim
Beate Kvamstad and Kay Fjørtoft // MARINTEK e-Maritime, Trondheim
Janet Holmén // Fram Forum

Characteristics of ice drift in the western Barents Sea

A CENTURY AGO, the Russian navigator Valerian Albanov signed onto the vessel *St. Anna*. The ship's captain intended to sail through the Northeast Passage to Vladivostok, hunting along the way, but the expedition was ill-fated. In October 1912, the vessel froze into the ice of the Kara Sea, and remained ice-locked for well over a year, drifting slowly northward. Despairing of the ship thawing free before they died of starvation, Albanov and several other crew members set off across the ice, hoping to reach Franz Josef Land. Only Albanov and one other man survived.

Throughout the sea voyage, the drift with the trapped *St. Anna*, and the perilous journey across the ice, Albanov kept a diary. It describes hardship and survival in the Arctic, but also contains an eye-witness report of Arctic ice drift into the Barents Sea between Spitsbergen and Franz Josef Land. In March 1914, when he first sighted Franz Josef Land, Albanov calculated that the ice was drifting at 8.5 nautical miles/day. He wrote that this speed was too high to be explained by wind action only.

The ocean current running through the strait between Svalbard and Franz Josef Land to the southwest was later named the East Spitsbergen current. The huge amount of driftwood observed on the beach of Edgeøya and marked on the Peterman map from 1865 (and in Figure 1) can be explained by this current transporting driftwood from Siberia.

In 1988 M/V *Polarbjørn* drifted from the Arctic Ocean into the Barents Sea together with ice between Kvitøya and Nordaustlandet. The objective was to study the properties of sea water and take conductivity-temperature-density (CTD) profiles below continuous ice and in the marginal ice zone of the Barents Sea. On the way south, *Polarbjørn* passed east of Hopen Island before emerging at the ice edge. The trajectories of *St. Anna* and *Polarbjørn* demonstrate that is possible for sea ice to drift from the coastal zone of the Kara Sea to southeastern Svalbard in two years.

The influx of Arctic water to the Barents Sea takes place along two main routes: between Spitsbergen and Franz Josef Land and through the opening between

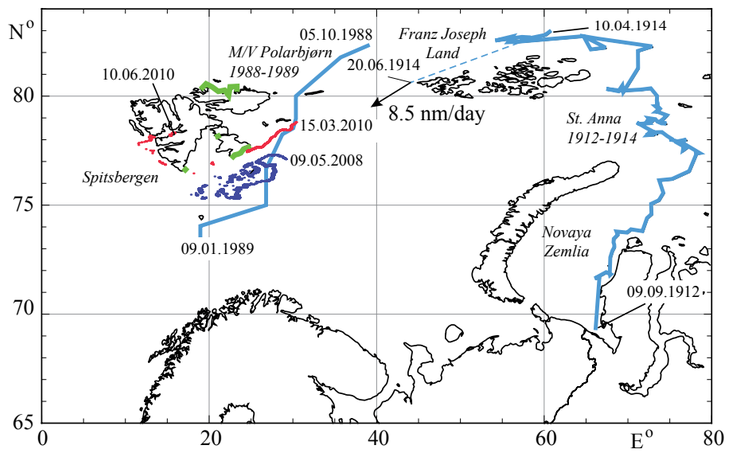


Figure 1

Drift trajectories of *St. Anna* (1912-1914) and M/V *Polarbjørn* (1988-1989). The dark blue line shows Albanov's route to Franz Joseph Land. Green marks the locations of driftwood on the beach. The dashed blue line shows Albanov's route to Franz Joseph Land. Green marks the locations of driftwood on the beach. The dark blue dots show the trajectory of an ice tracker from 9 May to 17 September 2008. The red dots show the trajectory of another ice tracker from 15 March to 10 June 2010. This tracker transmitted signals only sporadically for the last two months

Franz Josef Land and Novaya Zemlya. Prevailing water drag forces tend to make the ice drift from the northwestern Barents Sea in a southwesterly direction. At the same time, Atlantic water flows northward into the Barents Sea with branches of the Atlantic Current. When these water masses meet, the warm, salty Atlantic water dives under the cooler, fresher Arctic water, and a clockwise current loop is formed above Spitsbergenbanken (see map in figure 2). The branch of Arctic water flowing southward north of Hopen turns west along the southern edge of the Svalbard archipelago and joins the Atlantic Current branch flowing along the west coast of Spitsbergen to the north. The North-West Spitsbergen current carries warm and saline Atlantic waters northwards along the western coasts of Svalbard. The velocity of this northward current exceeds 41 cm/s at the latitude of 76.5°N and 55 cm/s at 78ºN.

In the northwestern Barents Sea in wintertime, the wind usually blows from the northeast. The wind rose in figure 2 shows the wind directions measured at the meteorological stations of Hopen Island from January to June over the five-year period from 2007 to 2011. One can see that the prevailing winds on Hopen are from the north and northeast. Given this pattern of sea currents and winds in the West Barents Sea, the ice should drift to the southwest along eastern Svalbard. Then it can melt, be captured in the current loop above Spitsbergenbanken or drift to the north along the west coast of Svalbard.

We monitored ice drift in the West Barents Sea in 2008 and 2010 with Iridium Ice tracking buoys (IT) Oceanetic Model 703. The ITs were deployed on drifting ice in the Barents Sea (see figure 3). The buoys were equipped with GPS and gathered data about their positions with a sampling interval 20 min. Every two hours, the IT automatically e-mailed these data via the Iridium SBD data service. For optimal communication with the satellite, the tracker's antenna must be vertically oriented. Therefore, each IT had a stick going through the ice and a plastic foam ring to support it in a vertical position. Before deployment, the ITs were painted white to mask them from inquisitive polar bears.

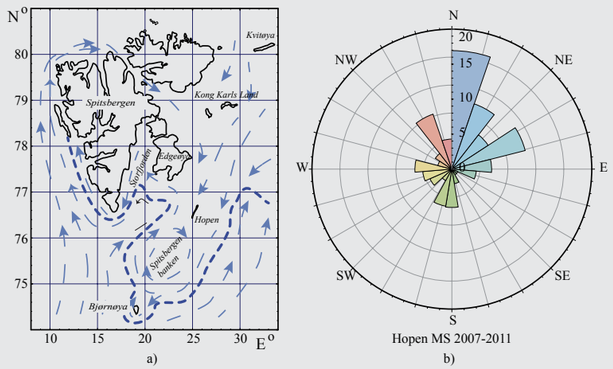


Figure 2

Currents in the Barents Sea (a). Wind rose reconstructed from data from meteorological stations on Hopen Island (b).

Figure 3

Installation of the ice tracker on drifting ice in the Barents Sea on 15 March 2010. Photo: Kåre Johansen / UNIS

In 2008 an IT was deployed on 9 May in the marginal ice zone (MIZ) of the Barents Sea during an expedition with R/V *Lance*. It drifted with the ice until mid-June and later floated on the water surface. This tracker sent its last signal on 17 September 2008. Figure 4 shows ice conditions in the Barents Sea and drift trajectory of the IT when it was drifting with ice. The place of deployment is shown by white spot on the ice map from 9 May (Fig. 4). It is clear that the IT was drifting in the MIZ and its trajectory repeats the shape of the MIZ shown in the ice charts.

In 2010 five ITs were deployed on the drifting ice east of Kong Karls Land. This time the trackers were deployed well into the ice pack, over 200 km from the MIZ. Representative ice floes in the area were estimated to have a diameter of about 3 km and the ice at the points of deployment was 60-70 cm thick. Two ITs were deployed at different points on a single floe. The surfaces of the floes were flat and the snow thickness was 10-15 cm.

From this experiment, we learned that the ice was drifting at a speed of 0.18 m/s, corresponding to about 240 nautical miles in one month. This speed matches well with Albanov's calculated drifting speed of 8.5 nautical miles per day. We also reconstructed velocities using data from remote sensing systems and by studying satellite images of the ice belt and found that ice from the Barents Sea is entering Isfjorden. Together, these findings indicate that in the event of oil spill in the Barents Sea east of Spitsbergen, oil could very well reach Longyearbyen within a few months' time.

From 15 March to 20 April all ITs drifted southwest as shown in figure 5. Between 5 and 15 April, wind conditions clearly influenced ice drift: for several days, all the ITs drifted northeast, and then resumed their drift in a southwesterly direction (see the multiple lines in the lower right of figure 5). During this event the ice was deformed and the communications with four ITs failed. From 15 April only one IT was still functioning. Its trajectory is shown by the yellow line in figure 5. It continued to send signals until April 20 and then disappeared in Tusenøyane. In an interesting twist to this tale, the IT shown in blue in figure 5 began to send signals again later and eventually drifted almost all the way home to Longyearbyen. It was picked up in Sassenfjorden and delivered to the University Centre in Svalbard on 10 June 2010.

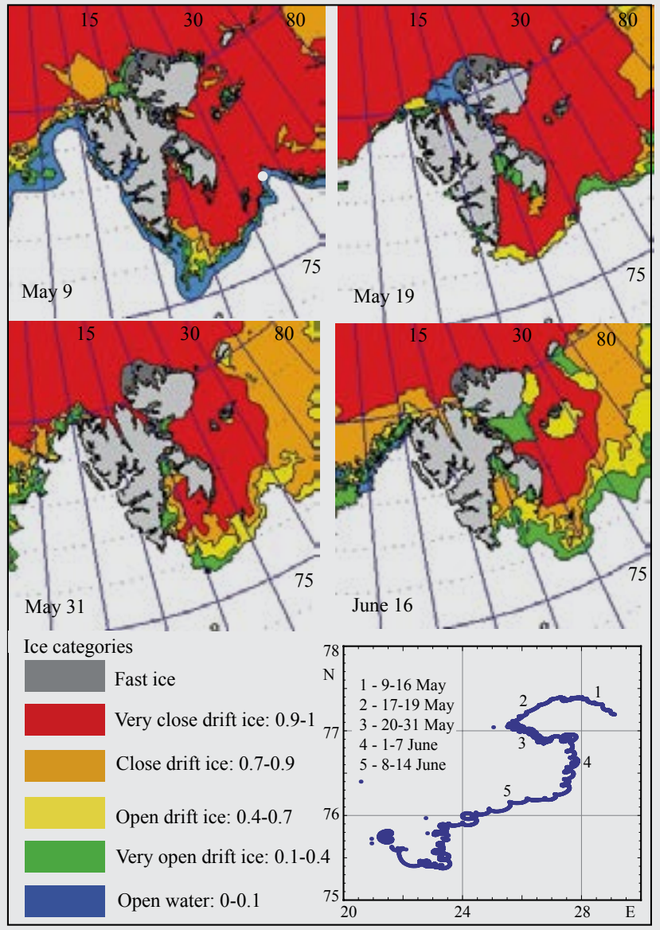


Figure 4

Ice conditions in the Barents Sea and the ice tracker trajectory.

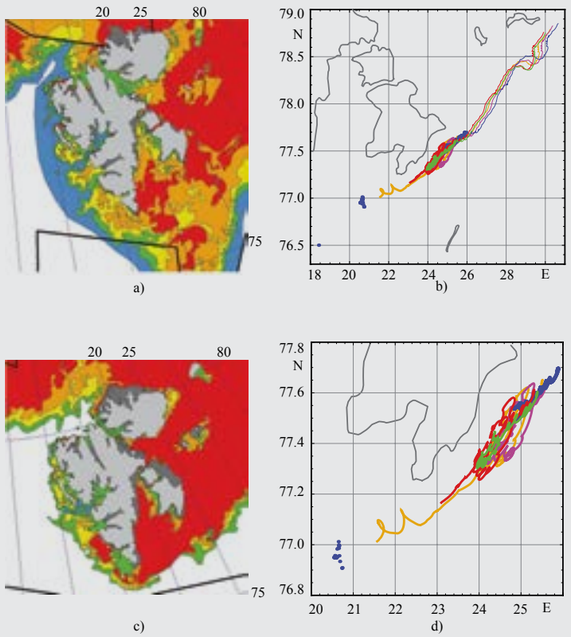


Figure 5

Winds can have a significant local influence on overall ice drift trajectories. Here we see ice charts for 15 March (a) and 15 April (c) 2010, along with the trajectories of the ITs from 15 March to 20 April 2010 (b) and 1-20 April 2010 (d).

The fate of Albanov's lost companions was completely unknown until the summer of 2010, when a Russian expedition found several artefacts and the remains of one man not far from where Albanov and the other survivor were rescued (see www.aolnews.com/2010/08/14/russians-find-traces-of-ill-fated-1912-arctic-expedition/). And what became of the crew members who remained with the ship? Chances are they drifted with the ice - alive or dead - until the *St. Anna* reached open water and sank. But given the drift trajectories of M/V *Polarbjørn* and the ice tracking buoys, it is not inconceivable that some of the wreckage may have washed ashore in the eastern part of the Svalbard archipelago.

FURTHER READING

Albanov VI. (1917) Southward, to the Franz Josef Land. Petrograd, Tipografia Morskogo Ministerstva, 194 pp. (in Russian)

Barr W. (1975) South to Zemlya Frantsa Iosifa! The cruise of Sv. Anna and Al'banov's sledge journey, 1912-14. Canadian Slavonic Papers, 17(4): 567-595

Marchenko A, Kvamstad B, Fjørtoft K, Høyland K, Brazhnikov D. (2011) Characteristics of ice drift in the Western Barents Sea reconstructed by the data of ice trackers deployed on drifting ice in 2008 and 2010. Proceedings of the 21st International Conference on Port and Ocean Engineering under Arctic Conditions, 2011. Montreal, Canada, POAC11-147, 484-509

Steele M, Morison JH, Curtin TB. (1995) Halocline water formation in the Barents Sea. Journal of Geophysical Research: Oceans, 100(C1): 881-894

News items

CLOSER COOPERATION BETWEEN UNIS AND IMR

The Institute of Marine Research (IMR) and the University Centre in Svalbard (UNIS) entered a formal agreement of cooperation in November 2012, when a new IMR office was opened in the Svalbard Science Centre.

"By having an office in Longyearbyen, the IMR hopes to strengthen its presence in Svalbard," says Harald Loeng, research director at IMR.

As he points out, climate change means that the Arctic Ocean is an increasingly important element in the management of the ecosystems. UNIS students learn about the Arctic Ocean within a number of fields.

"They study oceanography, marine biology and fish biology - all important fields for the IMR. With an office in Longyearbyen, it will be easier for IMR scientists to contribute to the teaching at UNIS, not to mention the added benefits of research cooperation and data exchange," says Loeng.

"This will open up new possibilities for us," says UNIS director Ole Arve Misund.

Misund highlights the potential for developing new courses within the framework of the cooperation agreement with IMR.

"We see possibilities in Arctic biology, especially within ecosystem-based research, management and industry," he says.

ARCTIC FRONTIERS 2013

The Arctic Frontiers conference was organised for the seventh time, and with record attendance figures. As many as 1007 participants had signed up, making Arctic Frontiers manifestly one of the most important Pan-Arctic conferences. Politicians, research scientists, entrepreneurs and industrialists, students and others came together this year under the theme of "Geopolitics & Marine Production in a Changing Arctic" (see also page 68 about the Arctic Council). The theme for the 2014 conference will be "Working in the Arctic - Health, Environment and Technology."

FRAM DAY

Fram Day is an annual event aimed at contributing to interdisciplinary cooperation and increased professional and social contact, and at inspiring better and broader dissemination of research activities. The target group for the event are the members of the Fram Centre, its partners and selected media representatives. In 2012, the second Fram Day was held at the Fram Centre on 16 November, 160 participants in attendance.

RESEARCH DATABASE

The research database at www.iframm.no was launched in 2012. The site provides a searchable and dynamically updated database containing information (including graphics) on all the Flagship research programmes at the Fram Centre.

Jan-Gunnar Winther // Director of the Norwegian Polar Institute
Tore Nepstad // Director of the Norwegian Institute of Marine Research
Jarle Aarbakke // Rector of the University of Tromsø

New ice-breaking research vessel provides new knowledge

A new Norwegian ice-breaking research vessel will provide new opportunities for polar research, and increase security in the North.

In their day, Nansen's *Fram* and Amundsen's *Maud* cleared a path for new insight into the polar regions. In the suggested government budget, a grant for a new ice-breaking research vessel has been included. This is an important continuation of the proud Norwegian research tradition in the polar regions.

Up until now, the polar regions have been difficult to access, even in summer. Consequently, we lack important knowledge about both ecosystems and the natural physical environment. We also lack significant insight into the northern Barents Sea and the Arctic Sea. The new vessel will give us the opportunity to acquire more data on the oceans in the Arctic and around Antarctica. This will provide a stronger basis for decision-making concerning management of natural resources and the environment in these areas.

An ever more rapid reduction of the Arctic ice mass will cause great changes in the ecosystems, both in ice and water. We need more knowledge in order to understand what consequences this will have. With little data and knowledge about the status "before", it is difficult to understand and predict changes in the ecosystems and to plan strategies for how we as a society should face the status "after". Many of the biological resources we manage and exploit are directly or indirectly connected to the sea ice. The rich biological production along the edge of the ice is fundamental to many species, and important to the rich fishing resources of the North.

Norway wants to protect the biodiversity of the polar regions, but little research has been done on this topic. We need more knowledge about non-commercial species and about how organisms live in such extreme surroundings. Organisms adapted to extreme natural conditions may also carry secrets that could be exploited commercially. Discoveries based on marine bioprospecting in organisms from polar regions may potentially find uses in the pharmaceutical industry and foodstuffs industry, among others.

Norway has significant research interests connected to the natural physical environment. Norwegian researchers have a long and strong tradition, not least in the fields of meteorology and oceanography. Still, there are significant knowledge gaps when it comes to the balance of energy and mass between the atmosphere, the ice and the ocean; we need additional insight into conditions in the depths and the seabed of the Arctic Ocean. Fridtjof Nansen was a pioneer in the exploration of this ocean. The new vessel will provide better opportunities for taking new measurements from new areas, measurements that will be important in understanding the natural environment and improving models. This knowledge should be put to use in international climate initiatives, such as the UN's climate panel and the Arctic Council.

Another important topic is improving our knowledge of the geological layers beneath the seabed. They may turn out to be natural archives of prehistoric climate and bioproduction. They may also pose geohazards such as underwater landslides, and (greenhouse) gas and fluid emissions. They may represent sources of energy in the form of conventional oil and gas, gas hydrates, or geothermal heat. Studies of the sea and ice can help improve the climate models used to predict possible climate developments both regionally and globally. Knowledge of the polar regions is important in the management of resources in widely different locations on Earth.

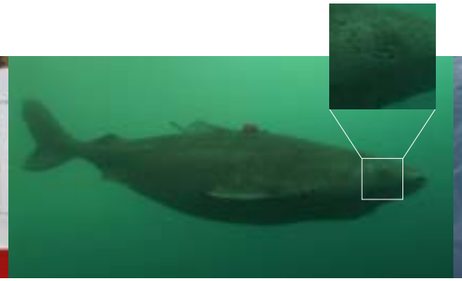
Significant business interests are connected to fisheries, petroleum, rocks, minerals and shipping in Northern waters. The new ice-breaking vessel will play an important part in acquiring new knowledge of these areas and the management of these resources. All these elements, in addition to tasks outlined in the management plan for the Barents Sea, will require increased research investment, presence and monitoring of our Northern regions. In addition, the vessel can be used as a resource when required, such as for search and rescue. During construction, we will be striving to ensure that the research vessel, together with other Norwegian marine infrastructure, such as the Coast Guard, will become an integral resource in the High North. The vessel will have Tromsø as its home port.

The new ice-breaking vessel will strengthen Norway's position as a leading nation when it comes to acquiring knowledge about these regions, both by significantly expanding our access to those parts of the seas in the Arctic that are covered by ice, and by being an all-year presence there.

Christian Lydersen and Kit M. Kovacs // Norwegian Polar Institute

Greenland sharks as predators of seals in Svalbard

Landing a Greenland shark. Some sharks were harvested in this study to assess pollution levels, for anatomical studies, and to examine their stomach contents. Although the shark dwarfs its captors, it is not yet fully grown. None of the sharks captured in this study had attained sexual maturity.



Greenland shark with tags attached to its back and the base of its dorsal fin. Many sharks were captured and then released after being tagged to allow tracking and measurement of their swimming performance. The string-like object trailing from the shark's eye is a copepod parasite that attaches to the eye surface. Almost all Greenland sharks carry one such copepod on each eye (see insert for a close-up).

Landing ... just a head! The body of this shark was eaten by other sharks after it was hooked.

GREENLAND SHARKS ARE VORACIOUS, generalist predators that eat fish and marine mammals. Additionally, an astounding variety of marine debris has also been found in the stomachs of these sharks and they are known to turn into cannibals when they come across members of their own species caught on fishing lines. We initiated an investigation a few years ago to assess the potential role of this little-known shark as a predator of seals in Svalbard. We conducted fieldwork in June 2008 and 2009 in Kongsfjorden. During these excursions, we collected 45 sharks for studies of diet, pollution levels, and anatomy. We also captured and released an additional 21 sharks carrying instruments. Most of these sharks were fitted with pop-off satellite tags for tracking studies, but some of them were equipped with accelerometers that document swimming and diving behaviour in detail. Some highlights of the results of our studies are presented below.

Greenland sharks are big fish. Those we captured weighed 136-700 kg, but even the largest individuals were not yet sexually mature. Stomach contents showed that more than one third of the sharks had fed on seals and 20% had eaten whale blubber. With the help of a DNA register maintained by the Institute of Marine Research, we found out that the sharks had scavenged all of the whale blubber from minke whales killed in the fishery. During the butchering process minke whale blubber is thrown overboard; some of it clearly ends up as shark food. The dominant seal species in the diet was ringed seal. We also found pieces of bearded and hooded seals. Many of the shark stomachs also contained fish, including Atlantic cod, wolffish and haddock. Most fish had been swallowed whole, including a cod that weighed 4.2 kg and a wolffish that weighed 8.6 kg.

Our satellite tracking showed that the dominant movement direction was northward, though there was no clear migration path. Most of the tags popped off within 500 km from the tagging site but two of our sharks travelled 725 and 980 km, respectively, representing the most northerly (82.4°N) and easterly (40.8°E) locations documented for this species. The sharks occupied waters from the surface down to below 1 500 m. They travelled in water with temperatures ranging from -1.5°C to 7.4°C. Data from the accelerometers showed us that the average travel speed was only 1.2 km/h which is about 10% of what would be expected based on the body size of these sharks. Everything about the swimming performance of these sharks is SLOW. Maximum speed was 2.7 km/h making the Greenland shark the slowest fish (for their size) ever studied.

Greenland sharks are known to scavenge marine mammals, but we think they also actively hunt live seals. There is a lot of circumstantial evidence for this conclusion - first and foremost, the condition of the seals that we found in the shark stomachs. There were no carnivorous amphipods associated with them. These little carrion-eating crustaceans would definitely have been there if the seals had been dead when the sharks ate them. The seals we found in the shark stomachs all belong to the "true seals". Species within this group sleep in the water, and have bilaterally symmetrical sleep similar to terrestrial animals - which means that when they are asleep they are immobile; they have their eyes closed; and both sides of their brain rest simultaneously. Because Greenland sharks are such extremely slow swimmers, we think that the only way that they could catch seals would be using a cryptic approach targeting sleeping seals.

Greenland sharks were fished for liver and oil until around the time of WWII. Records show that more than 100 000 sharks were caught annually in Greenland and Norway for many decades without any apparent effect on population size. In the 1950s other oils took over the market and the Greenland shark fishery was dramatically reduced. This fact, in combination with the ease with which we captured a large number of sharks in a small area in a short time, suggests that this species is numerous in our part of the Arctic. In combination with the high occurrence of seals in their diet, it appears that the Greenland shark is likely a significant source of mortality for seals in Svalbard.

SOURCES/FURTHER READING:

Fisk AT, Lydersen C, Kovacs KM. (2012) Archival pop-off tag tracking of Greenland sharks (*Somniosus microcephalus*) in the High Arctic waters of Svalbard, Norway. Mar Ecol Prog Ser 468: 255-265

Leclerc L-M, Lydersen C, Haug T, Glover KA, Fisk AT, Kovacs KM. (2011) Greenland sharks (*Somniosus microcephalus*) scavenge offal from minke (*Balaenoptera acutorostrata*) whaling operations in Svalbard (Norway). Polar Res 30, 7342, doi: 10.3402/polar.v30i0.7342

Leclerc LM, Lydersen C, Haug T, Bachmann L, Fisk AT, Kovacs KM. (2012) A missing piece of the Arctic food web puzzle? Stomach contents of Greenland sharks sampled in Svalbard, Norway. Polar Biol 35: 1197-1208

MacNeil MA, McMeans BC, Hussey NE, Vecsei P, Svavarsson J, Kovacs KM, Lydersen C, Treble M, Skomal GB, Ramsey M, Fisk AT. (2012) Biology of the Greenland shark *Somniosus microcephalus* Bloch & Schneider 1801. J Fish Biol 80: 991-1018

Molde K, Ciesielski T, Fisk AT, Lydersen C, Kovacs KM, Sørmo EG, Jenssen BM. (2013) Associations between vitamins A and E and legacy POP levels in highly contaminated Greenland sharks (*Somniosus microcephalus*). Sci Total Environ 442: 445-454

Watanabe YY, Lydersen C, Fisk AT, Kovacs KM. (2012) The slowest fish: swim speed and tail-beat frequency of Greenland sharks. J Exp Mar Biol Ecol 426-427: 5-11

Knut Sunnanå // Head of the Barents Sea Ecosystem Programme / Institute of Marine Research

Why all the cod in the Barents Sea?

This year's cod quota for the Barents Sea is one million tonnes, the highest quota ever set by the Joint Russian–Norwegian Fisheries Commission. Here are some possible explanations for why the north-eastern arctic cod population is so large.

Chief Engineer Kay Jørgensen with a large cod on the deck of the Johan Hjort, research vessel of the Institute of Marine Research. Photo: Gunnar Sætra / Institute of Marine Research

In recent years, all vessels fishing for cod in the Barents Sea and along the coast of northern Norway have had large catches. The cod quota that has been set for the coming year is the largest since the system was introduced in the late 1970s. Photo: Gunnar Sætra / Institute of Marine Research

THE LAST 30 YEARS have seen a significant rise in the water temperature in the Barents Sea, albeit with great variations on the scale of a few years. Simultaneously, we have seen the numbers of cod increase sharply, and the variations in cod spawn numbers mirror the temperature variations fairly well.

There are many reasons for such a correlation, and most of them have to do with the fact that increased temperature equals increased biological activity. When the ocean temperature rises, the cod's body temperature also rises. Consequently, it will grow faster, but will also require more food to support the growth and maintain its activity levels.

Food production also increases in the ocean when the temperature rises, just as grass grows thick on hot summer days after being watered and fertilised. The grass of the ocean, plankton, also needs fertilisation (nutrient salts) to achieve optimal growth, and the nutrient salts are introduced by water flowing in from the Norwegian coast and the Atlantic to the Barents Sea. The temperature in the Barents Sea is also regulated by the amount of water flowing eastward and northward from the Atlantic, so there are factors in the physical part of the ecosystem that lead to an increase in production.

Another effect of large amounts of warm water flowing eastward and northward into the Barents Sea is less ice in the Barents Sea in both winter and summer. This provides the cod with a much larger area in which to live, and also provides good growing conditions for a large stock. The cod itself does not eat phytoplankton, but *Calanus finmarchicus*, krill and other zooplankton feast on the grass of the ocean, and consequently, capelin and other small fish can stuff themselves with these organisms. Capelin is the main source of food for cod in the Barents Sea, and there is evidence that we now have a stable stock of capelin in the Barents Sea. This undoubtedly explains - at least in part - why we have such a large stock of cod as we do today.

However, it is important to remind ourselves that fisheries have often overtaxed the ocean resources in the past, and that we from time to time have difficulty managing the ecosystem and fisheries well. Today's fisheries management relies heavily on data from expeditions and complicated calculations carried out by competent researchers and technicians at the Norwegian Institute of Marine Research. A scheme for establishing quotas and audits of fisheries has also been developed and is working well, ensuring that almost no unauthorised fishing is done by either Norwegian or foreign fishing boats in the Barents Sea. Norwegian researchers have been working hard to develop methods for calculating quotas and giving management advice, and in recent years they have tested several harvesting rules to check that they are consistent with sustainable management.

This is why it is possible, with a high degree of certainty, to recommend a total cod fishing quota of about a million tonnes. In the future we will have to be prepared for fluctuating cod numbers, both on the short term and as a result of temperature variations in the long term. Nevertheless, modern marine research and management schemes will ensure that fisheries continue to harvest responsibly within the production potential that nature provides.

Susanne Kortsch and Raul Primicerio // University of Tromsø
Paul E. Renaud // Akvaplan-niva and University Centre in Svalbard

Climate-driven regime shifts in Arctic communities

The ocean floor communities of two fjords in Svalbard, Kongsfjorden and Smeerenburgfjorden, have changed dramatically during the last 30 years. The large and abrupt changes in rocky-bottom community structure are consistent with a climate-driven ecological regime shift.

The authors (left to right) Raul Primicerio, Susanne Kortsch, and Paul E Renaud. Primicerio is Associate professor at the Faculty of Biosciences, Fisheries and Economics, University of Tromsø. He coordinates the Fram Centre Forum for Ecological Modeling. Kortsch is a PhD candidate at the same faculty. The title of her thesis is “Structural properties of Barents Sea food webs”. Renaud is Senior researcher at Akvaplan-niva and Professor II at UNIS. He is deputy leader of the Fram Centre Fjord and Coast Flagship.

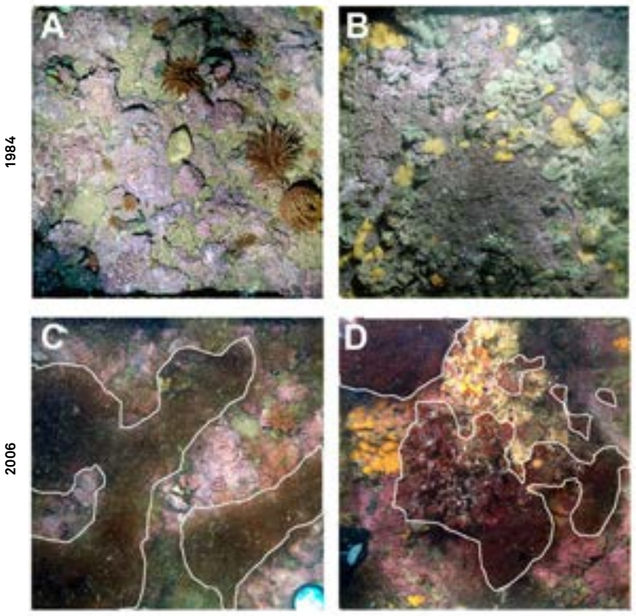
Bjørn Gulliksen, who initially designed and performed the research.

THE ARCTIC IS CHANGING. Over the past 30 years, as the global surface temperatures have become warmer by about 0.2°C per decade, water temperatures in the Arctic have increased at twice the global average. Meanwhile, the sea ice coverage at the end of the summer has decreased by 30%. These changes modify Arctic marine habitats in terms of light and temperature regimes, which in turn impact local biological communities. Despite the considerable interest in understanding how marine ecosystems respond to rapid sea-ice loss and higher temperatures, few long-term studies are addressing these issues.

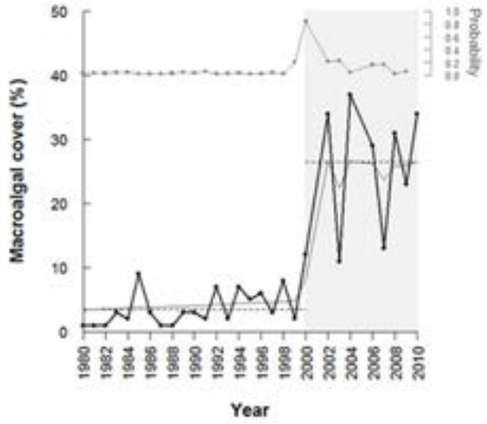
Our study is unique in a marine Arctic perspective, because it spans three decades of observations. Such time-series are necessary to understand long-term ecosystem change. The survey was initiated in 1980 by Professor Bjørn Gulliksen at a time when climate warming started to accelerate. Between 1980 and 2010, the region’s summer ice-free season has expanded by an average of 3.3 days per year. Sea surface temperatures have risen by 0.5°C.

The study is based on photographic surveys of fixed bottom transects from Kongsfjorden and Smeerenburgfjorden. Analyses of the photographs revealed nearly simultaneous shifts in the subtidal (15 m of depth) rocky-bottom communities of both fjords. The most striking component of the community shifts was the abrupt and persistent increase in the abundance of macroalgae - a group that includes many types of seaweed and kelp - at both sites. In Kongsfjorden, algae composition remained stable for 15 years. Then, between 1995 and 1996, brown algae went from covering 8% of the seafloor to a whopping 80%.

Macroalgal cover has since stabilised around 40%, or five times more than originally observed. Sea anemones, which were previously the fjord’s dominant species, have declined by 80% after the shift. In Smeerenburgfjorden, the jump occurred in 2000, with brown and red algae cover rising from 3 to 26%. The fjord’s community had been dominated by barnacles (small sessile crustaceans) and sea squirts. These have been replaced by invertebrates called bryozoans.
Such changes are not simple, local tweaks. They are what we call “regime shifts”, in which both the structure and functioning of ecosystems change substantially and suddenly. They are also not limited to two fjords. The observed increase in macroalgal cover is



Photographs of the rocky-bottom communities before (1984) and after (2006) the regime shift. Previously published in the Proceedings of the National Academy of Sciences of the United States of America, 2012: 109 (35) 14052-14057



This diagram shows the abrupt shift in macroalgal abundance in Smeerenburgfjorden.

Previously published in the Proceedings of the National Academy of Sciences of the United States of America, 2012: 109 (35) 14052-14057

likely representative of a regional trend toward increased macroalgal biomass, as supported by a separate study in Hornsund, in the south of Svalbard, where a threefold increase in macroalgal biomass was recorded between 1988 and 2000. In addition, a study from West Greenland documented substantial increases in the productivity and depth extension of macroalgae (kelp beds) in relation to the retreat of sea ice and prolongation of the open water period.

The observed local increases in erect macroalgal cover are predicted to occur throughout the Arctic as a response to changing environmental conditions. How these changes will ripple through the food chain remains to be seen, but such a structural change is expected to have implications for the functioning of rocky-bottom ecosystems.

The new coastline ecosystems could be more productive and diverse than before. The observed changes indicate that the Arctic flora and fauna is being supplemented, and in some cases replaced, by boreal species advancing up the Svalbard coast. Macroalgae will also provide shelter and more food for herbivores (plant eaters) and detritivores (e.g. bacteria), substantially altering feeding pathways. Management of Arctic ecosystems, thus, faces the challenge of novel communities and changing ecosystem functioning. An additional challenge is that these changes may come as sudden and substantial structural shifts.

This study was a collaboration between researchers from the University of Tromsø, the University Centre in Svalbard, Akvaplan-niva and the University of Cambridge. The work is a contribution to the “Arctic Tipping Points” and “Barents Sea Ecosystem Resilience” projects funded, respectively, by the European Union and the Norwegian Research Council.

FOR FURTHER READING:

Beuchel F, Gulliksen B. (2008) Temporal patterns of benthic community development in an Arctic fjord (Kongsfjorden, Svalbard): results of a 24-year manipulation study, Polar Biology, doi: 10.1007/s00300-008-0429-9

Kortsch S, Primicerio R, Beuchel F, Renaud PE, Rodrigues J, Lønne OJ, Gulliksen B. (2012) Climate-driven regime shifts in Arctic marine benthos, Proceedings of the National Academy of Sciences, doi: 10.1073/pnas.1207509109.

Krause-Jensen D, Núria M, Olesen B, Christensen PB, Rodrigues J, Renaud PE, Balsby TJS, Rysgaard S. (2012) Seasonal sea ice cover as principal driver of spatial and temporal variation in depth extension and annual production of kelp in Greenland, Global Change Biology, doi: 10.1111/j.1365-2486.2012.02765.x

Weslawski JM, Wiktor J, Kotwicki L. (2010) Increase in biodiversity in the arctic rocky littoral, Sorkappland, Svalbard, after 20 years of climate warming. Marine Biodiversity, doi: 10.1007/s12526-010-0038-z

Arctic tipping points (ATP) project: www.eu-atp.org

Barents Sea Ecosystem Resilience (BarEcoRe) project: www.imr.no/forskning/prosjekter/barecore/en

Anders Skoglund // Norwegian Polar Institute

TopoSvalbard

TopoSvalbard is an interactive topographic map of Svalbard which is quick, clear and easy to use. The portal’s main focus is topography, but it also displays geographic names, map sheet division in the S100 series, updated glacier fronts from recent satellite images and nature reserve boundaries. The portal includes many aerial views and landscape images, in addition to information on the story behind each geographic name on the archipelago. Map users may also input their own geographic data lists and GPS tracks.

In 2012, TopoSvalbard’s maps literally gained a new dimension. Two different 3D visualisations now give users the opportunity to view the map and surrounding terrain from a bird’s-eye view, making it possible to go “flying” and looking around, in several directions and at several angles.

One of the next new features for TopoSvalbard will be orthophotos, allowing users to choose between traditional topographic maps and one large aerial view, also in the form of an additional layer in 3D visualisations.

TopoSvalbard is meant for scientists, environmental managers, and the general public. One day in November 2012, the portal had around 150 visitors, of which a third were foreigners. Over the past year, the portal has had roughly 40 000 visits.

The Norwegian Polar Institute has national responsibility for the topographic mapping of the Arctic and Antarctic, including Svalbard, and TopoSvalbard has mainly been developed by the Institute’s map department.

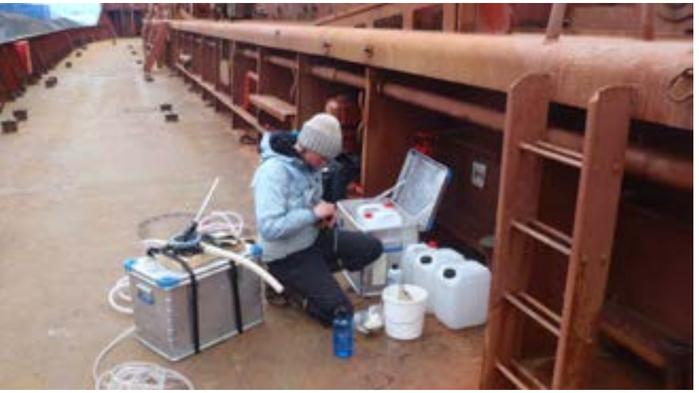
The portal’s address is http://toposvalbard.npolar.no

Eva Therese Jenssen // University Centre in Svalbard

Arctic hitchhikers

A novel study is investigating the potential for non-native organisms to “hitchhike” with marine vessels and invade Svalbard waters. The results will have impact on the future management regime for the marine environment of the High Arctic.

This project has received funding from the Svalbard Environmental Protection Fund, Tromsø University Museum and the Fram Centre.



Ballast water sampling in Barentsburg. Photo: Chris Ware

In 2011 researchers from the University Centre in Svalbard (UNIS), Tromsø University Museum, the Institute of Marine Research, and the University of Tasmania started investigating the potential for shipping to facilitate species introduction to Svalbard, and the risk that introduced species would have have impact on this vulnerable High Arctic region.

So far only two studies have investigated shipping as a pathway for species introduction to the Arctic and both focused on the North American Arctic. The Svalbard project, entitled “Arctic Stowaways”, is the first study ever to focus on the European Arctic.

PREVENTION OVER ERADICATION

One of the most serious pressures on the natural environment today is the impact caused by introduced species. In the marine environment it is almost impossible to eradicate non-native species once they have been introduced.

Shipping to Svalbard has expanded significantly over the last couple of decades, according to the Governor of Svalbard. No true alien marine species have been recorded as established in Svalbard waters. But with the expected climate warming researchers fear that a range of southerly species might establish themselves in the High Arctic. The challenge is that alien species are often introduced to new environments by human activities. In the ocean the dispersion of non-native species is often facilitated by ballast water or “hitchhiking” on the ships’ hulls. In other words, marine species may “stowaway” on ships and invade new habitats. From other parts of the world we know that shipping is responsible for the introduction of several particularly invasive alien species. So according to the scientists, the best and most effective way to prevent invasion in High Arctic waters is to implement management regulations that prevent ships from introducing new species.

Sampling in Svea. Photo: Chris Ware

HIDDEN INVASION

Chris Ware, PhD student at the Tromsø University Museum and the University of Tasmania, is lead investigator in “Arctic Stowaways”. Ware has investigated the potential for “alien” invasion of the Svalbard environment before. Previously, as a student at the University Centre in Svalbard (UNIS) he set up a free shoe-cleaning service at the airport in Longyearbyen.

The soil he collected from travelers’ shoes was inspected for non-native seeds, and those found were planted and monitored under Svalbard summer weather conditions. The result was that 26% of the seeds managed to germinate. (See “Aliens with latitude” in Fram Forum 2012 for details.) Now, his PhD project focuses on the hidden invasion threat posed by marine vessels travelling into Svalbard waters.

In the Arctic Stowaways project, Ware and his colleagues focused on the two main carrier elements for marine organism dispersal: ballast water and biofouling.

The research team worked on coal ships arriving to the ports of Svea (Svalbard’s main coal mining community), Longyearbyen and the Russian settlement Barentsburg. They also inspected other kinds of vessels that docked in Longyearbyen during the summer of 2011 for the presence of biofouling.

The samples and associated data were collected in order to determine the diversity and composition of species transported by these vessels, and by doing so evaluate associated potential hazards and risks.

BALLAST WATER

The research team sampled ballast water from eight coal ships docking in Svea, Barentsburg and Longyearbyen in the summer of 2011. The vessels, sailing from the Netherlands, Portugal and the United Kingdom, took on ballast water in the port of origin before sailing northwards. Nearly any small thing in the water column can be transferred to the ballast tanks, including organisms as minute as viruses, bacteria and phytoplankton, and bigger organisms such as juvenile crabs or shrimp.

Some of the ships bound for Svalbard exchanged ballast water in the open ocean en route to the High Arctic as a way to limit the likelihood of species introduction to the local Svalbard ports. When ships discharge ballast water collected from the coastal port of origin and take on oceanic ballast water, many of the original organisms are either discharged or killed.

The scientists collected samples to assess the number of organisms that can survive transport in ballast water tanks, and the types of organisms collected. The team decided to focus on the larger zooplankton, but also collected data on the amount of ballast water discharged, locations where ballast water was sourced and exchanged (if done so) and the voyage duration.

“We still haven’t identified and counted all the species collected in the ballast water samples, as we are still awaiting results from DNA barcoding of the organisms,” Ware explains.

The sailing time from the port of origin up to Svalbard has great impact on the survival rate of organisms in unchanged ballast water. One of the sampled vessels started its journey from Portugal and did not exchange ballast water before docking in Longyearbyen.

“The survival rate of the organisms in the ballast water was low. The 8-10 day long transit made sure that many of the organisms did not make it alive up to Svalbard,” says Ware.

Two coal ships, originating from the Netherlands and the UK, arrived in the Russian mining settlement of Barentsburg after a journey of approximately 6-8 days. Neither exchanged ballast water en route to Svalbard. Here the scientists found a higher proportion of live organisms.

The five ships sampled in Svea all originated from the Netherlands, but all five had exchanged ballast water mid-ocean before arriving in Svalbard.

“Exchanging ballast water before arrival in Svalbard is at present a voluntary measure,” explains co-investigator Inger Greve Alsos of Tromsø University Museum. “And the evidence suggests that the organisms collected mid-ocean often are used to living conditions similar to what we find in Svalbard, thus the preventive measure of exchanging ballast water is perhaps not as effective as previously assumed,” she says.

“The amount of surviving coastal organisms in our samples indicates that the effect of ballast water exchange was limited. Therefore, the rationale for ballast water exchange to be undertaken between all ports and Svalbard should be thoroughly evaluated,” say Ware and Alsos.

BIOFOULING

The researchers also looked at “biofouling”, the accumulation of microorganisms, plants, algae or animals on the wetted surfaces of vessel hulls. As a source of introducing non-native species, biofouling has been neglected relative to ballast water. However, in recent years there has been a growing concern for biofouling in the sub-Antarctic waters. Today, some countries are moving towards requiring biofouling inspections on vessels before sailing to the sub-Antarctic region. ut no such standard exists for Svalbard or the High Arctic - yet.

Inspection of vessel hulls is usually done by divers, but in the extreme conditions of Svalbard, the team decided to use an underwater remotely operated vehicle (ROV) with a mounted camera to get a clearer underwater view of the vessel hulls. The team surveyed several cruise and expedition ships in addition to research, cargo and private vessels. For each of the surveyed vessels they also identified the age of antifouling paint, the duration of previous port layovers and the average speed of the vessels.

“Our survey shows clear evidence of a positive association between biofouling and older antifouling paint, slower vessel speeds, and longer layover periods in ports. The one recreational vessel surveyed had extensive biofouling, probably due to overwintering in a mainland Norwegian port. Recreational vessels are the most common type of boat visiting Svalbard and they also visit many locations around Svalbard; their potential to introduce species to Svalbard is high, according to Ware and Alsos.

As with the ballast water issue, the scientists point out that there is no perfect solution to prevent the alien hitchhikers from attaching to the vessel hulls.

“Antifouling paint is a widely used measure; however, it does not completely prevent organism dispersal. It is like brushing your teeth once a week and expecting them to stay clean,” Alsos explains.

MANAGEMENT RECOMMENDATIONS

The sampling and data analysis will permit the scientists to identify bioinvasion hazards. They have, among other things, employed a pathway analysis based on the regional shipping network and climate similarity, identifying a number of vessel types and pathways with the potential to transfer suitably adapted non-native organisms.

“We find that marine vessel traffic to Svalbard is highly connected to worldwide ports, many with environmental conditions similar to those in Svalbard,” says Ware.

Their analysis also indicates that predicted ocean warming will increase the similarity to over 100 ports worldwide which host large numbers of known invasive species, furthering the potential for establishment of dispersed alien species.

“This study is important in evaluating the environmental impact of introducing non-native species into Svalbard waters: a warmer climate will place Svalbard further south - climatically speaking - and will therefore render Svalbard increasingly vulnerable to ship-mediated species invasion,” says Alsos.

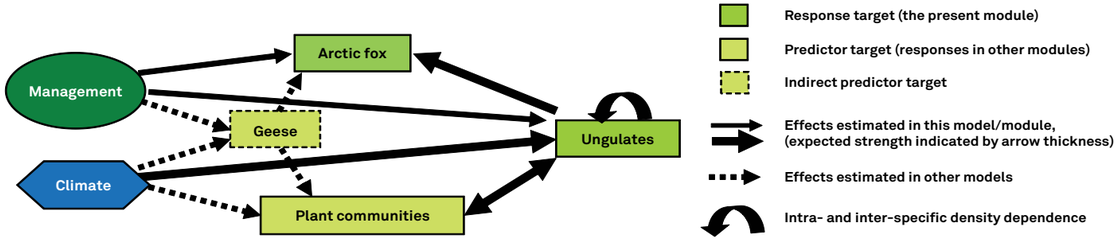
Coal freighter in Svea. Photo: Chris Ware

According to recent reports from the Norwegian authorities the number of ships sailing from Europe to Asia via the Northeast Passage has increased significantly over the past couple of years, thanks to a warmer Arctic climate and the receding sea ice cover. In 2010 only four ships sailed along the Northeast Passage; in 2012 the number had increased to almost 50.

The analyses are still a work in progress and the project’s conclusion will result in recommendations to the Governor of Svalbard about the effect of existing regulations and a discussion of the need for further development of management strategies to maintain a rigorous regime to protect the marine environment in and around Svalbard.

Eva Fuglei and Åshild Ø. Pedersen // Norwegian Polar Institute

Long term monitoring data provide knowledge of climate change in Svalbard



The reindeer module in COAT Svalbard. The main impact paths act through (1) warmer winters causing "rain-on-snow" leading to ground ice formation limiting access to forage and increasing mortality and (2) warmer and longer growth seasons improving survival and reproductive rates of the reindeer. Changed abundance of reindeer will have impact on the composition and structure of the plant community through changes in grazing pressure, which may contribute to vegetation state changes. The path model also addresses the potential modifying effect of geese on vegetation state changes (COAT Science Plan 2012). Similar climate impact modules have been developed for the Svalbard rock ptarmigan, Svalbard reindeer and arctic fox. From Ims et al. 2012

THE HIGH ARCTIC Svalbard archipelago harbours one of the northernmost terrestrial ecosystems in the world. Climate change is expected to be faster and more substantial in the Arctic than in any other areas on Earth. The expected changes will have profound effects on the terrestrial ecosystems and the species that inhabit it. The Norwegian Polar Institute monitors annually populations of the endemic Svalbard rock ptarmigan and the Svalbard reindeer, and the circumpolar predator and scavenger the arctic fox. The Svalbard branch of "Climate-ecological Observatory for Arctic Tundra" (COAT) will focus on these key species along with the pink-footed goose in four monitoring modules.

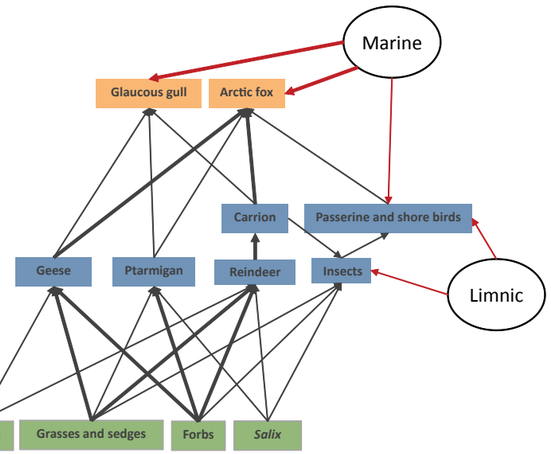
Long-term studies at levels from individuals to ecosystems are important to understand ecological patterns and processes. With its simple terrestrial food web containing only a few species on each trophic level, Svalbard provides an excellent opportunity to disentangle direct and indirect ecological effects of climate change by means of adaptive monitoring framework employed in COAT (see page 58). COAT-Svalbard will contribute new knowledge to the management of the Svalbard terrestrial ecosystem, where Norway has an ambition for Svalbard to be the best managed ecosystem worldwide.

The functionally most important herbivores in the food web are reindeer, ptarmigan and two migratory geese species (pink-footed goose and barnacle goose). The carnivores/scavengers in the food web are the arctic fox, the glaucous gull and the arctic skua, which also utilise resources from the marine ecosystem. In summer, migrating snow buntings and several species of shorebirds (e.g. purple sandpiper) add to the diversity and abundance of prey.

The focal study species in COAT-Svalbard. Photos: Jason Roberts (arctic fox), Ann Kristin Balto (alpine bistort), Nicholas Lecomte (ptarmigan and reindeer), Thor S. Larsen (pink-footed geese)

A major aim of COAT is to identify pathways where climate change is expected to strongly impact key tundra species. In Svalbard the clearest ecological effect of climate warming is due to the increase of "rain-on-snow" events in winter. Rainfall on snow creates ground ice and ice layers in the snow, which have an impact on the entire vertebrate community. In particular, the ground ice locks the pastures for reindeer, thus increasing mortality. Reindeer carcasses improve food availability for the arctic fox in winter with subsequent positive effects on fox reproductive rates, and the increase in fox abundance has a negative impact on prey species such as geese and probably ptarmigan. Climate warming has increased plant productivity, which probably benefits the herbivore populations. However, the overall outcome of the interactions between earlier onset of spring and extended plant growth seasons and the relative roles of changes in winter versus summer climate/weather is complex, difficult to predict and needs to be monitored carefully.

The COAT approach involves development of conceptual models specifying climate and management relevant key- and conservation target species in the food web. The COAT science plan concerning Svalbard has developed four integrated "climate impact path models" focusing on the Svalbard reindeer, Svalbard rock ptarmigan, pink-footed goose and arctic fox as focal targets for monitoring and management. COAT-Svalbard will build on existing long-term data series but there is a need to expand the monitoring to include more species in the food web and more ecologically relevant climate parameters.



The plant based food web for high-arctic tundra in Svalbard where geese, Svalbard rock ptarmigan, Svalbard reindeer, and arctic fox have central positions in the interactions between carnivores and their prey and herbivores and their food plants. From Ims RA, Jepsen JU, Stien A, Yoccoz NGE. (2012) Draft science plan: Climate Ecological Observatory for Arctic Tundra. Fram Centre/University of Tromsø

FURTHER READING

Hansen BB, Grøtan V, Aanes R, Sæther B-E, Stien A, Fuglei E, Ims RA, Yoccoz NG, Pedersen ÅØ. (2013) Climate events synchronize the dynamics of a resident vertebrate community in the High Arctic. Science 339: 313-315

Stien A, Ims RA, Albon SD, Fuglei E, Irvine RJ, Ropstad E, Halvorsen O, Loe LE, Veiberg V, Yoccoz NG. (2012) Congruent responses to weather variability in high arctic herbivores. Biology Letter. doi: 10.1098/rsbl.2012.0764 Biol. Lett. rsbl20120764

Helge M. Markusson // Fram Centre

Fauna on the Svalbard tundra under the “climate whip”

Milder winters do not improve living conditions for the Svalbard fauna. On the contrary: rain falls, rather than snow, and the vegetation the animals live on is encased in an impenetrable shield of ice.

IN TWO NEW STUDIES published in the journals *Biology Letters* and *Science*, a group of scientists from the Fram Centre in Tromsø, collaborating with colleagues from Trondheim, Oslo, Ås and Aberdeen, show how Svalbard’s animals are affected by the winter climate on the archipelago. The most punishing aspect is periods of mild weather when precipitation falls as rain in the middle of winter. On such occasions, the numbers of Svalbard’s three herbivores - ptarmigan, reindeer and sibling vole - decline in proportion to the amount of precipitation. This is because rain freezes to ice on the ground, shielding the tundra vegetation these species survive on.

TOUGH TIMES

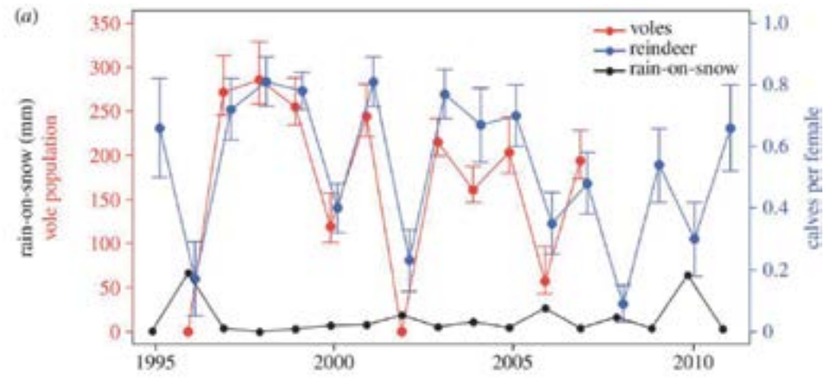
Only four warm-blooded species of animal winter on the High Arctic tundra of Svalbard. This hardy animal community consists of two endemic subspecies, the Svalbard reindeer and the Svalbard rock ptarmigan, sibling voles that accompanied the Russians to Svalbard, and the omnipresent Arctic predator, the arctic fox.

A lack of food results in higher winter mortality and poorer reproduction in spring. Reductions in the populations of the three herbivores are completely synchronised and follow rainy winters, whereas the dip in arctic fox population comes with a one-year delay. Scientists believe that this is mainly due to reduced access to reindeer carcasses, an important source of food for the arctic fox, especially in winter. High reindeer mortality one winter is usually followed by lower reindeer mortality and fewer carcasses the next winter, because weaker individuals have been eliminated from the stock.

FORCEFUL CLIMATE EFFECTS ON A SIMPLE ECOSYSTEM

“Previous studies have shown that icing of the tundra affects certain Arctic species. What is new, is how similar the effects of the winter climate are on the whole community of warm-blooded animals wintering on the tundra. The fact that species with such varying body sizes, mobility, life spans and reproduction reacted almost identically to the rainy periods was a surprise to us,” says scientist Audun Stien from NINA - the Norwegian Institute for Nature Research in Tromsø.

Stien analysed the connections between the size of the vole stock and the calf production in reindeer, and these findings were presented in the article published in Biology Letters.



Up and down at the same time. The number of sibling voles and calves per female reindeer fluctuates according to winter rainfall in Nordenskiöld Land in Svalbard. (Figure 1a from Stien A, Ims RA, Albon SD, Fuglei E, Irvine RJ, Ropstad E, Halvorsen O, Langvatn R, Loe LE, Veiberg V, Nigel G. Yoccoz NG. (2012) Congruent responses to weather variability in high arctic herbivores. Biology Letters 8:1002-1005, doi:10.1098/rsbl.2012.0764. Used with permission.)

“The very obvious covariation is probably because this type of climate effect is especially forceful and frequent in Svalbard, and because the simple, High Arctic ecosystem is controlled by only a few important factors,” Stien says.

THE VALUE OF LONG-TERM MONITORING

Eva Fuglei, a scientist at the Norwegian Polar Institute, studies the Svalbard rock ptarmigan and arctic fox and is in charge of the monitoring that provided data for the *Science* article. She says the studies show the value of long-term monitoring.

“It is particularly important that several species are monitored using scientifically robust methods, at the same time and in the same place, in order to document connections like these. Good cooperation between research groups with different skills is also important,” says Fuglei.

The *Science* study came about through collaboration between the Fram Centre scientists and ecologists and statisticians from the Norwegian University of Science and Technology, led by postdoc Brage B. Hansen.

COAT – A CLIMATE-ECOLOGICAL OBSERVATION SYSTEM FOR THE ARCTIC TUNDRA

The Fram Centre recently launched a comprehensive scientific plan for a climate-ecological observation system for the Arctic tundra (COAT). COAT is meant to extend the monitoring of the tundra ecosystem in Svalbard to encompass all parts of the food chain, from plants to predators. A similar system will be established for Low Arctic tundra on the Varanger peninsula. The director of COAT, Professor Rolf A. Ims at the University of Tromsø, emphasises that the new studies from Svalbard show that analyses that systematically combine different monitoring series give us new insight into the effects of climatic variations.

“However, it has become necessary to intensify and expand the ecosystem measurements due to the dramatic temperature increase expected to take place in the Arctic. Climate changes may quickly alter the tundra conditions to such an extent that yesterday’s data and insights will not provide a basis for tenable predictions of what tomorrow might look like in the Arctic ecosystems,” Ims explains.

Rolf A. Ims // University of Tromsø

COAT – Climate-ecological Observatory for Arctic Tundra

These photos from Varanger Peninsula in the Norwegian low-arctic exemplify three general issues that will targeted in COAT, namely (1) ecological change processes that may act to amplify global warming, (2) threats to arctic biodiversity, and (3) management actions potentially mitigating such undesired effects. Tall shrubs are expected to encroach on the low-statured vegetation over large tracts of the circumpolar Arctic tundra. In the late winter and spring, tall shrubs protruding over the snow surface reduce albedo (reflected sunlight) and absorb heat. More growth of tall shrubs in a warmer climate will thus act to amplify the warming (exemplifying issue 1). Arctic species like the snowy owl, adapted to breed in tundra landscapes with short vegetation, will experience shrinking of breeding habitats (exemplifying issue 2). Browsing reindeer can reduce the extent of tall shrub and thus prudent reindeer management may prevent shrub encroachment in tundra (thus exemplifying issue 3). Photos: R. A. Ims (left) L.A. Støvern (right).

THE ARCTIC TUNDRA is one of the earth's largest ecosystems. Owing to its remoteness, the tundra still harbours vast stretches of pristine wilderness with intact ecosystem functions and unique biodiversity of great fundamental and societal significance. Yet the arctic tundra is predicted to become more challenged by climate change than anywhere else on the earth's land surface. Models project an average temperature increase as large as 10°C by the turn of the century. Rapidly emerging new climate regimes are likely to give rise to ecosystems with entirely unknown properties, making science unable to predict the consequences. In turn, this will hinder society from responding to the changes by means of appropriate adaptive and mitigating actions. In this dire situation it becomes crucial to establish scientifically robust observation systems to enable real-time detection, documentation and understanding of climate impacts. Despite this pressing need, our observing capacity in the arctic tundra is presently very low. Scarcely any tundra site is devoted to long-term research targeting climate change with a genuine ecosystem perspective.

In response to these concerns, the Fram Centre has developed a comprehensive science plan for a Climate-ecological Observatory for Arctic Tundra (COAT). The plan has just been reviewed by an international expert panel that graded it as "Excellent".

The panel wrote:

> *"COAT will answer some critical questions that have a strong global value. The combination of an important topic and an original approach [...] will make a world-class contribution in the science of ecology".*

SCIENTIFIC APPROACH

COAT will first be implemented at two sites in the Norwegian Arctic - low-arctic Varanger Peninsula and high-arctic Svalbard. Later the COAT team also hopes to include Russian sites. The goal is to become the world's most comprehensive and management-relevant long-term research enterprise for arctic tundra. This is to be achieved by adopting a fully ecosystem-based adaptive monitoring system based on a food web approach. Food webs comprise communities of organisms that channel flows of matter and energy from plants to carnivores in ecosystems. Tundra food webs hold key regulatory functions of the climate system, important ecosystem services for local people and unique arctic species of conservation concern. These important attributes are now being subjected to climate change impacts which include (1) "Arctic greening" due to encroachment of forest and tall shrubs into the barren tundra with resultant feedbacks to ecosystem and climate, (2) changed abundance of arctic key-stone herbivores with cascading effects on other species in the ecosystem, and (3) outbreaks of new pest species causing devastation of vegetation, animal-borne diseases that can spill over to humans, and impoverish arctic biodiversity. The COAT plan develops models that predict such changes, outlines how they can efficiently be detected by monitoring, and proposes how undesired changes can be mitigated by management actions.

RELEVANCE TO MANAGEMENT AND SOCIETY

COAT prioritises those aspects of the ecosystem that are within the realm of realistic management options. The science plan outlines routines for involving policy makers and managers in order to provide a scientifically robust basis for decision making and implementation of actions. COAT is designed to be adaptive by repeatedly adjusting its focus and designs as new scientific knowledge and technologies become available. An outreach sub-program within COAT will regularly disseminate results to stakeholders and to the general public, to increase awareness of the consequences of climate change.

Arctic climate change is likely to be ongoing for a long while. Thus COAT must be organised, operated and financed as a long-term endeavour.

The panel reviewing COAT stated:

> *"Making this well-conceived and major initiative operational will simply rely on resources as all necessary components, particularly concepts and experience, are present".*

The substantial financing required to operate COAT is however still not in place.

Morten Smelror // NGU – Geological Survey of Norway

The first men on the last continent – Carsten Egeberg Borchgrevink and the *Southern Cross* Expedition, 1898–1900

The winter base at Cape Adare. Photo: NGU

24 JANUARY 1895. The tiny whaler *Antarctic* of Tønsberg is in the Ross Sea, east of Victoria Land in the Antarctic. At the tip of the lofty, precipitous cliffs at Cape Adare, Captain Leonard Kristensen and his crew discover a shingle beach where it is possible to get ashore. A launch is lowered and Captain Kristensen, the expedition leader, Henryk Johan Bull, a mate and some deckhands are on their way towards the beach to go ashore. The captain is standing in the bow, ready to jump ashore. This is a historic moment; the men are probably the first to set foot on the inhospitable Antarctic mainland. Then suddenly, one of the deckhands throws his oars aside, jumps into the water and dashes onto the stony shore. Carsten Egeberg Borchgrevink had claimed the sixth and last continent.

True enough, there are other versions of this historic landing. Perhaps Kristensen and Borchgrevink went up the beach simultaneously, and maybe other whalers had been ashore earlier. Captain Carl Anton Larsen and the crew of the *Jason* had discovered new land and several unknown islands on the other side of Antarctica the year before. They had been ashore on one of the islands and made a sensational discovery of fossils.

At Cape Adare, Borchgrevink found a stone with green moss growing on it, the first known find of terrestrial plants south of the Antarctic Circle. The men also collected birds for stuffing, eggs, guano, rocks and minerals. The landing at Cape Adare meant that the gateway to the new continent was finally opened and the interior lay there awaiting new expeditions and discoveries.

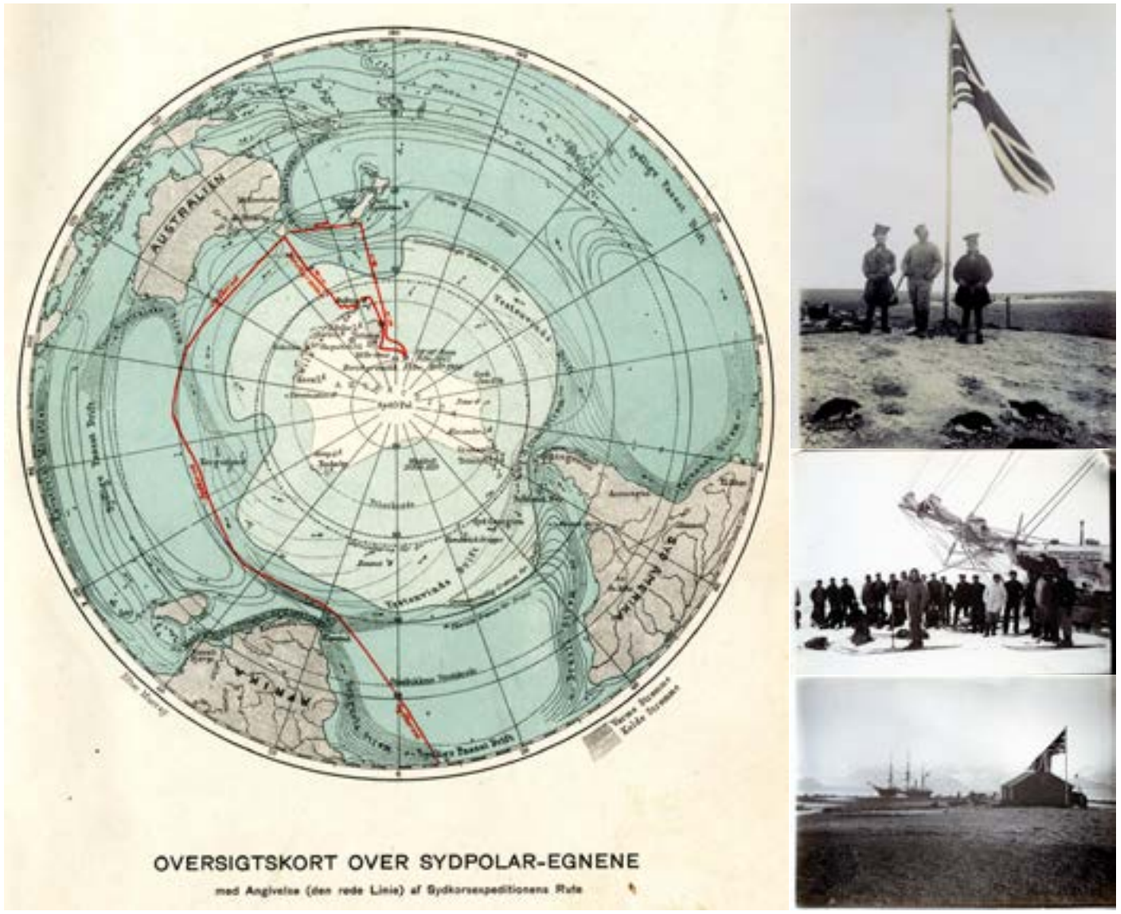
AN AMBITIOUS YOUNG MAN FROM OSLO SPEAKS BEFORE THE FOREMOST SCIENTISTS

In the years that followed, Carsten Borchgrevink came to play a major role in the exploration of the Antarctic. He enthusiastically addressed the Sixth International Geographical Congress in London later the same year. The British colonies were now well mapped and administered. It was now the Antarctic that was the *terra incognita*, full of unexplored opportunities.

Sir Joseph Dalton Hooker, Sir John Murray and Sir Clements Markham, who was President of the Royal Geographical Society at the time, were among the eminent scientists who listened to Borchgrevink's enthusiastic account at the conference. The 31-year-old did not hide his light under a bushel. The audience heard how he, at the request of Svend Foyn, had led the *Antarctic* expedition to the Ross Sea, how he from the crow's nest had discovered the beach at Cape Adare, and that *he*, as the first person in the world, had set foot on the Antarctic mainland. His great urge for self-assertion, and his frequently arrogant manner, would create great problems for this ambitious young man from Oslo, son of a Norwegian father and an English mother.

In the next two years, Borchgrevink travelled the world, lecturing in England, Germany, America and Australia. He thought the time was ripe for a new and larger expedition to the Antarctic. Sir Clements Markham, however, had other plans on behalf of the British Empire. He was not at all keen on allowing this penniless, rude, Norwegian social climber the honourable task of exploring the new continent. Such a task should be assigned to someone with a more appropriate background and greater authority. The Royal Geographical Society and Sir Clements wanted an expedition led by Captain Robert Scott. They thought, as The Times also put it, that "Scott has an absolutely decisive qualification for a polar effort - youth". The fact that Scott completed lacked insight into and experience of polar regions was brushed aside as "a bagatelle".

Carsten Borchgrevink, however, could not be stopped. He went from one rich man to another in his search for support, until he ultimately succeeded. The English newspaper and magazine tycoon, Sir George Newnes, gave him 35 000, a huge sum at that time. This enabled him to realise the first deliberate overwintering in the Antarctic. The Royal Geographical Society was still more irritated when Borchgrevink called this "The British Antarctic Expedition". Borchgrevink was told to take several hundred Union Jacks with him, and plant them on every vacant and undiscovered piece of land the expedition chanced upon.



Map
Small-scale map of the "South Polar region" reproduced in Borchgrevink's book "Nærmest Sydpolen. Aaret 1900" [Closest to the South Pole. The year 1900]. From Borchgrevink 1905

Top
Carsten Egeberg Borchgrevink (centre), with Ole Must (to the left) and Per Savio at Camp Ridley on Cape Adare. Photo: NGU

Middle
The crew of the *Southern Cross* photographed just off the Great Ice Barrier on the coast of Victoria Land. Photo: NGU

Bottom
Camp Ridley on Cape Adare with the Union Jack in the foreground and the *Southern Cross* in the bay just behind. Photo: NGU

NORWEGIANS UNDER THE UNION JACK

The expedition was British, but the ship was Norwegian, and apart from a Swedish steward, the crew was Norwegian. Norwegians were also in the majority in the team that had been hand-picked to winter in the Antarctic. In addition to the leader, Carsten Egeberg Borchgrevink, the team included doctor Herulf Kløvstad, scientific assistant Anton Fougner, zoologist Nicolai Hanson, scientific assistant and cook Kolbein Ellefsen, and two dog-handlers Ole Must and Per Savio. The group's magnetic observer and cartographer William Colbeck was from England, as was the assistant zoologist Hugh Blackwell Evans. The astronomer and physicist Louis Bernacchi hailed from Australia. On 22 August 1896, they set sail from London bound for Tasmania.

The overwintering team had food and equipment for three years, as well as 70 dogs. It was a hard crossing to the Ross Sea in Antarctica. In mid-February, the *Southern Cross* anchored off Cape Adare, and the team bade farewell to the Colin Archer barque, which returned to Australia. Camp Ridley was set up on the ice-free spit, and it was here the team would spend nearly a year in two prefabricated huts. Twelve years later, Scott's South Pole Expedition erected its huts not far away.

The 1897-1899 Belgian Antarctic Expedition on the *Belgica*, led by Baron Adrian de Gerlache, endured a winter in the ice off the shore of the Antarctic continent, but the men from the *Southern Cross* were the first to winter on land.

Borchgrevink had always stressed the scientific aims as the most important aspect of the expedition. So it may seem odd that the group which overwintered consisted solely of young men without lengthy scientific experience. There was no lack of qualified applicants from all over the world, hundreds of them; but Borchgrevink chose only people who were younger than himself. He considered that a good disposition and a keen ability to observe things were most important. Experience of snow and ice was also important, and he originally wanted to have only Norwegians with him, but Sir George Newnes put his foot down and Colbeck, Evans and Bernacchi were included.

During the winter, the temperamental Borchgrevink fell out with the scientific personnel. As leader, he failed calamitously on several critical occasions. During a sledging trip, they were hit by a storm which broke up the ice beneath them. Borchgrevink left it to the others to salvage the equipment, food and dogs, while he himself found refuge on a rocky ledge. Following that experience, Bernacchi characterised the expedition leader in his diary in these words: "He is thoroughly incompetent and a pitiable coward." During the winter, loyalty was hard pressed. Borchgrevink showed lack of judgement, and many tense situations arose. One of the most serious was when he accused the others of mutiny and threatened them with 15 years' imprisonment.

GEOLOGICAL SPECIMENS FROM NEW LAND

As the southern winter waned, it was time to explore the terrain around Cape Adare. They embarked on a sledging trip across Robertson Bay and discovered a new island, which they named after the Duke of York. They explored the geology of the island and collected samples (basalt, granite, serpentine and schist). Borchgrevink found samples he was convinced contained gold, but Bernacchi thought it was pyrites. Typically, Borchgrevink stuck to his own opinion. Borchgrevink thought York Island was a good starting point for further expeditions and decided that they would build a stone hut that could function as an overnight stop and food store.

From the highest point on York Island, Borchgrevink discovered two large glaciers separated by a mountain ridge. The glaciers were named after his English friend, Frank Dugdale, and the Scottish oceanographer, Sir John Murray. The ridge was named Geikie Land, after the Scottish geologist, Sir Archibald Geikie, but has since been renamed Geikie Ridge. They made several sledging trips to Geikie Land from the stone hut, and investigated the mountains to a height of 1800 m, collecting feathers, eggshells and several species of lichen. They mapped the terrain in the mountains and along the coast of Robertson Bay. On one occasion, they were close to being killed in an avalanche of snow and rocks.

THE WORLD'S MOST BEAUTIFUL BURIAL SITE

They avoided the avalanche by a hair's breadth, but tragedy had already hit the expedition. The zoologist, Nicolai Hanson, died on 14 October after suffering stomach pains for a long time. Herulf Kløvstad undertook a post-mortem and determined that the cause of death was volvulus. On his death bed, the men took a poignant farewell with their friend. Hanson had chosen his final resting place himself, on a cliff above Camp Ridley. With him in his coffin lay a bouquet of pressed wild flowers, which his young wife had picked on Blåsenborg near Kristiansund just before the newly married couple separated when the expedition set sail.

Nicolai Hanson had systematically collected numerous bird skins and eggs during the expedition. Throughout the winter, he had looked forward to seeing the penguins return to their nesting site on Cape Adare. He did not live to experience this, but when he was buried on 20 October they were back. Hundreds of penguins clothed in black and white took part in the funeral. Borchgrevink said, "We moved around as in a dream. The penguins in their peculiar attire, observing us with interest, helped to make the ceremony even more solemn." The grave is situated where the trans-Antarctic mountain chain begins, on the edge of the cliff where the mountains and the sea meet. Nicolai Hanson's great-grandson, David Vogt, in his book about Carsten Borchgrevink and the *Southern Cross* Expedition, describes the spot as the most beautiful burial site in the world.

SEARCHING FOR THE SOUTH MAGNETIC POLE

Southern Cross was back in the Ross Sea on 28 January 1900. On 2 February 1900, the wintering party was ready to leave Cape Adare and the Union Jack was lowered. Two days later they heaved to off Coulman Island where they went ashore and collected geological samples and took photographs. One question they were seeking to answer was whether the geology on these islands in the Ross Sea was identical with that on the mainland. Borchgrevink thought it was.

They set course for the mainland once more and continued westwards along the coast of Victoria Land. They sailed past new land, which was named Cape Constance, after Borchgrevink's wife. Bernacchi and Colbeck went ashore on the ice in the bay beyond the cape, and achieved good results in locating the position of the South Magnetic Pole.

The coast of Victoria Land, showing the route sailed by the *Southern Cross*. From Borchgrevink 1905.

They continued sailing southwards and entered the bay which Sir James Clark Ross, who discovered the Ross Sea, called Wood Bay. When they went ashore, they found themselves in a volcanic landscape which they called Newnes Land after the expedition benefactor. On 6 February, they rounded Cape Washington, sighting Franklin Island on 8 February. Here they performed new magnetic measurements and trawled the seabed in search of life.

On the morning of 10 February, the *Southern Cross* passed Beaufort Island and the crew got a glimpse of the volcano, Mount Terror, on Ross Island. While they were collecting geological samples from a nearby mountainside, millions of tons of blue ice crashed into the sea setting up a huge wave that took Borchgrevink and Jensen in its undercurrent. When Colbeck and the deckhands reached them with the launch, they found them bloody and bruised, but alive. They had managed to clamber onto a rocky ledge at the very last minute.

The following day, they were closer to the South Pole than anyone had ever been, 78° 21' S. It was red-letter day and they congratulated each other on their achievement. Another record was set a few days later. At about 164° W, they discovered an open inlet in the Great Ice Barrier. This offered a good opportunity to get past the barrier, and on towards the south. Nine years later, this inlet was named the Bay of Whales by Ernest Shackleton, who used it as the starting point to reach further south than anyone else had achieved earlier, 88° 23' S. In 1911, Roald Amundsen anchored *Fram* in this bay, and his winter base camp, Framheim, was located there.

On 17 February, Borchgrevink, Colbeck and Savio sledged inland over the ice shelf with 12 dogs. They travelled about 16 km southwards before stopping at 78° 40' S. Borchgrevink was photographed at what was then "the furthest south ever reached by man". Borchgrevink had shown the world the way over what would be renamed the Ross Ice Shelf, and further on towards the South Pole itself.

HONOUR, DISGRACE AND ULTIMATELY A MEDAL

Roald Amundsen would later credit Borchgrevink with this achievement. After Amundsen and his men had won the race to the South Pole in December 1911, Amundsen wrote in his book *The South Pole* (1912): "We must acknowledge that in ascending the Barrier, Borchgrevink opened the way to the south and threw aside the greatest obstacle to the expeditions that followed".

Despite Amundsen's recognition, Borchgrevink was never received as he thought he deserved. On his return from the Antarctic, he was admittedly awarded some honours from the geographical societies in Scotland and the USA. In England, on the other hand, he was largely ignored and to some extent discredited by Markham and the Royal Geographical Society. Borchgrevink was quickly overshadowed by the attention directed at Robert Scott's Antarctic expeditions.

Carsten Borchgrevink was not received with open arms in Norway, either. After all, it was a British expedition he had led. His need for self-assertion, mixed with arrogance and high-handed methods did nothing to raise his stock in Norway. His life after his return from the Antarctic was marked by unemployment and ill-health. In 1929, five years before his death, he received rehabilitation in the shape of a Norwegian state stipend, and the following year he was finally awarded the Patron's Medal of the Royal Geographical Society. Shortly afterwards, he was created an honorary member of the Norwegian Geographical Society.

In his obituary, the geologist and polar researcher Adolf Hoel wrote: " ... his contemporaries did not fully understand the extent of Borchgrevink's feat." In a subsequent letter to Louis Bernacchi and Dr. H.R. Mill, Carsten Egeberg Borchgrevink's wife, Constance, quoted the following statement made by her husband: "It is often not before people are dead, that they receive the gratitude and reward due to them."

BIBLIOGRAPHY

Amundsen, Roald. The South Pole. John Murray, London 1912.

Bernacchi, Louis. To the South Polar Regions: Expedition of 1898-1900. Hurst and Blackett Ltd., London 1901.

Borchgrevink, Carsten E. Nærmest Sydpolen. Aaret 1900. Gyldendal, Copenhagen 1905.

Vogt, David. Vår glemte polarhelt. Carsten Borchgrevink og Southern Cross-ekspedisjonen. H. Aschehoug & Co (W. Nygaard), Oslo, 2008.

Helge M. Markusson // Fram Centre

VIP visitors and guests galore

In 2012, the role that Tromsø and the Fram Centre play in connection with research and monitoring of the climate and environment in the North was underlined by some prominent visitors.

The enormous security detail and the very thorough preparations in advance of the visit confirmed that someone significant was coming to Tromsø. The American Secretary of State is regarded as one of the most powerful people on the planet, and when Hillary Clinton visited Tromsø in June, it made headlines in international, national and local media. The host of the visit was the Norwegian Minister of Foreign Affairs, Jonas Gahr Støre.

ARCTIC ALLIES

During their summaries, both the American Secretary of State and the Norwegian Minister of Foreign Affairs, Jonas Gahr Støre (the Norwegian Labour Party), emphasised the importance of seeing with their own eyes what is happening in the North. The visit to Norway will bring the US and Norway closer as Arctic allies, the two said.

"It has been important to develop and deepen the cooperation between myself and Jonas, and the US and Norway. It is also important to send a clear signal. Even though it appears a insurmountable task for humanity to take the necessary steps to limit the consequences of global warming and climate change, everyone can do something. And it is our job to make that happen," Clinton said.

FINNISH STATE VISIT

Tromsø's role had been noted, and when Finland's President visited Norway on an official state visit, the message from the Finnish side and the Norwegian Ministry of Foreign Affairs was clear: We want to go to Tromsø!

On 12 November, the Finnish President Sauli Niinistö and his wife, Jenni Haukio, were welcomed at Tromsø Airport by Crown Prince Haakon, County Governor Svein Ludvigsen, and representatives from the regional and local political administration.
In his speech at the University of Tromsø, Niinistö emphasised the important role the Fram Centre plays in research in the North.

During a two-hour trip aboard the R/V *Helmer Hanssen*, the group was introduced to the Fram Centre by Jan-Gunnar Winther, Sidsel Grønvik (Chair of the Fram Centre's Research Leader Group) and Are Johnsen, administrative director of the Fram Centre. The Arctic Council and Kongsberg Satellite Services also introduced themselves aboard the research vessel.

GREAT INTEREST

Representatives from other countries also visited the Fram Centre in 2012. Their number and diversity bears witness to the international interest in researching and monitoring the climate and environment in the High North. The visitors included official and academic representatives from Belgium, Brazil, Canada, China, Denmark, Greenland, The Netherlands, South Korea, Sweden, the UK and the US.

Helge M. Markusson // Fram Centre

Victory in the Researcher Grand Prix

Kajsa Møllersen won both the regional and the national final of Forsker grand prix. From the award ceremony after the regional final. Photo: Stefan Amlie

In September, Kajsa Møllersen of Kirkenes won both the regional and the national final of the Researcher Grand Prix 2012.

THIS WAS THE SECOND TIME that the Fram Centre and the University of Tromsø, together with the Norwegian Research Council, hosted "Forsker Grand Prix" in Tromsø. The regional competition was held at Rica Ishavshotel, the same venue as last year, and was completely sold out. This year, the national final was also held in Tromsø, in the main hall of the Tromsø Cultural Centre.

The Researcher Grand Prix is a competition in research communication. The participants are PhD candidates who are well underway toward their degrees, but who have not yet presented their thesis. Participants are selected months in advance and given professional help with the content of their presentation, media training, performing on stage, and using their voice. Each participant presents his or her own research project within a given timeframe, and is then ranked on the basis of votes from the audience and the evaluation of a panel of judges.

Møllersen is a PhD candidate at the Department of Mathematics and Statistics at the University of Tromsø, and her subject area is statistics.

Møllersen's winning presentation was on the subject of melanoma, a form of skin cancer and the second most common cancer in adults. If the cancer is diagnosed early, it can easily be cured through removal of the melanoma, thus preventing metastasis. The objective of Kajsa Møllersen's research is help doctors spot melanoma. Suspected malignancies will be examined with a camera and a magnifying glass under polarised light, and the data fed into a computer program. The program will analyse the mole, collate pieces of information, and suggest a diagnosis, which may help general practitioners - non skin-specialists - diagnose the disease early, thus saving lives.

This the second year in a row that a PhD candidate from the University of Tromsø wins the national final. Audun Hetland was the winner in 2011.

Helge M. Markusson // Fram Centre

Arctic Council Secretariat in Tromsø opened by Arctic Ministers

THE ARCTIC FRONTIERS conference was held 21-22 January in Tromsø. Arctic Council Ministers figured prominently among the speakers in this year's policy section, where climate change and resource extraction in the Arctic were hot topics for discussion. The Standing Arctic Council Secretariat at the Fram Centre was also officially inaugurated.

Norwegian Minister of Foreign Affairs Espen Barth Eide held the keynote presentation, speaking about how the Arctic Council's importance grows in parallel with growing global interest in arctic regions. He also welcomed the Standing Arctic Council Secretariat to Tromsø and spoke about the important role the Secretariat will play in strengthening the activities of the Council.

Swedish Minister of Foreign Affairs Carl Bildt spoke of the need to resolve the geopolitical uncertainties that remain in the Arctic. He also expressed concern about the impact of coal-fired power plants on the climate.

Leona Aglukkaq, Minister of Health and the Canadian Northern Economic Development Agency, spoke about Canada's upcoming chairmanship of the Arctic Council. Aglukkaq emphasised that Canada's priorities will be shaped by her travel in the Arctic and dialogues with Arctic inhabitants. The main theme will be development for and with the people of the north.

After the conference the three Arctic Ministers gathered to formally open the Standing Arctic Council Secretariat. In previous years, the secretariat of the Arctic Council rotated between member states, but it will henceforth be located at the Fram Centre in Tromsø. The opening ceremony was well attended and many invited guests and journalists gathered to observe the signing of the Host Country Agreement between Norway and the secretariat's new Director. By signing the agreement Norway formally agrees to host the secretariat.

Elin Vinje Jenssen // Norwegian Polar Institute

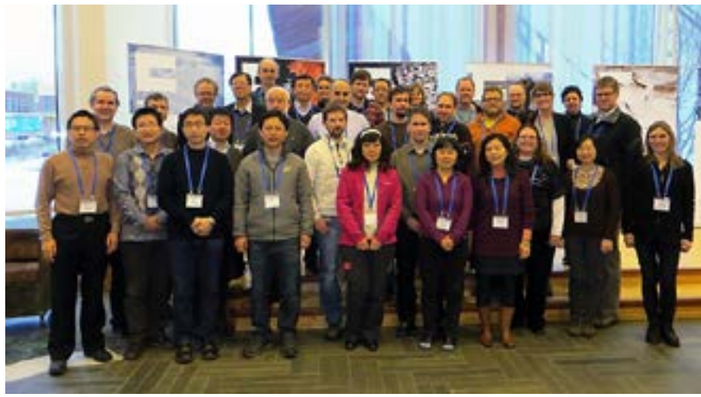
Intensifying research cooperation with China

AN INTERNATIONAL WORKSHOP was organised at the end of January 2013 aimed particularly at intensifying the research cooperation between Norway and China. It is a continuation of the existing cooperation agreement between the two countries. In 2010, the Norwegian Polar Institute and the Polar Research Institute of China signed a cooperation agreement for polar research. The agreement includes research into glaciers and sea ice, among other topics, as well as facilitation of research cruises in the Arctic.

Ongoing Norwegian-Chinese research projects include AMORA (observation and simulation of solar radiation on sea ice in the Arctic), LOTUS (studies of long-range transport of soot and its effect on albedo in northeastern China and the Arctic) and a project involving satellite remote sensing of atmosphere-surface systems and ground truth measurements, all of which are funded by the Norwegian Research Council.

"It is important to be here and to hear about the current status of the various institutions' research projects and also about what their needs will be in the time ahead," said Thomas Hansteen, the Research Council's special advisor for the research cooperation with China.

In recent years, China has become increasingly engaged in Arctic-related issues and research. Like Norway and several other countries, China has polar research scientists who are prominent in their fields and are internationally recognised. The workshop in Tromsø gathered research scientists from six countries, representing a number of international institutions, all of them working on projects relating to issues such as the development of Arctic sea ice, the transport of soot in the Arctic and its effect on albedo, satellite remote sensing and modelling of snow and ice.



Workshop participants at the Fram Centre.
Photo: Ann Kristin Balto / Norwegian Polar Institute

The workshop was organised by the Norwegian Polar Institute, CliC (Climate and Cryosphere), the University of Tromsø, ICE (the Centre for Ice, Climate and Ecosystems) and the Fram Centre. Most of the funding for the workshop came from the Fram Centre.

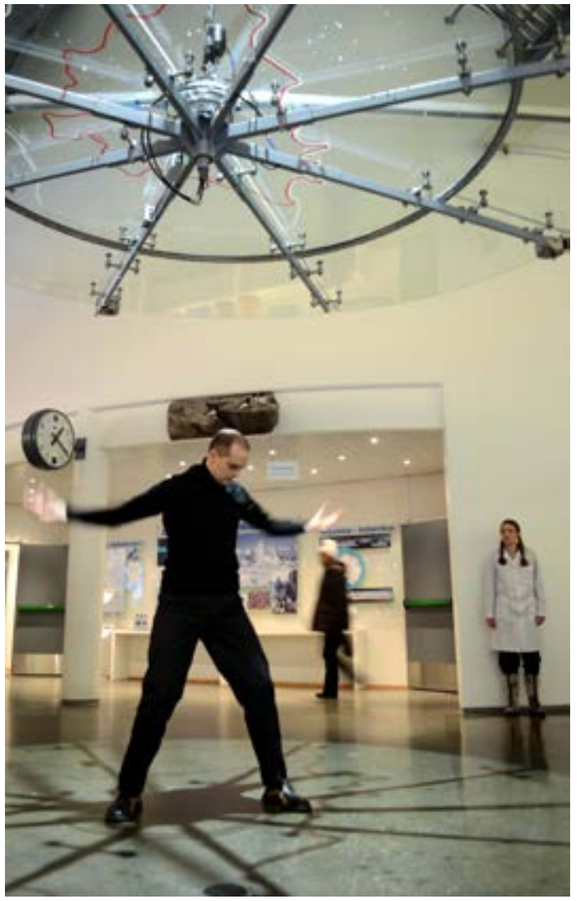
Helge M. Markusson // Fram Centre

The Research Plaza reaches far afield

THE ANNUAL RESEARCH DAYS constitute one of the more important outreach events for the Fram Centre, and the Research Plaza plays an important part. In 2012, about 4000 people visited the tent housing the Research Plaza in Tromsø. Here we see Senior Scientist Dorte Herzke explaining to several interested school students how environmental pollutants reach the Arctic. Herzke works at NILU - the Norwegian Institute of Air Research, one of the many institutions at the Fram Centre. Photo: Helge Markusson, Fram Centre

Helge M. Markusson // Fram Centre

Our Synthetic World



Actors Klaus Løkholm Bergli and Nina Rosenlund from Sadio Nor Theatre under the installation created by Lawrence Malstaf. Photo: Helge M. Markusson, Fram Centre

THE EXHIBITION "Our Synthetic World" is designed to spread knowledge about hazardous substances in the High North. Artists and scientists have come together to make a difficult theme easier to understand. The exhibition opened in Tromsø in January 2013.

Through an installation, storytelling, film and a theatre performance, they tell how humans and animals, climate and the environment are influenced by man-made substances, and how research contributes to improve our everyday life.

Scientists from the Fram Centre's Flagship "Hazardous substances - effects on ecosystems and human health" have collaborated with Sadio Nor Theatre, artists, and communication experts to tell people of all ages about this research. The scientists selected the themes for the exhibition: the food chain in the Arctic, health and human influence, climate change and multi-stress.

Our Synthetic World is shown in combination with a theatre performance, and the entire event was developed in cooperation between Polaria, Fram Centre and Sadio Nor Theatre.

The installation was created by Lawrence Malstaf, and the films were produced by Fersk Film. The project is financed by Troms County Council, VRI Troms, Fram Centre Intro-funding, and the Research Council of Norway.

Sigrun Høgetveit Berg // University of Tromsø

Politics between two poles

THE POLAR RESEARCH ENVIRONMENT in Tromsø is a large and productive one, also in the humanities and social sciences. Now they are writing the history of Norwegian polar policy from 1870 up until 2014.

"It will be a completely up-to-date book, containing the latest research, including the current initiatives in the High North," say two of the editors, Einar-Arne Drivenes and Stian Bones.

"We were given the challenge by Jonas Gahr Støre when he was here in Tromsø and received the book Into the Ice, *the English edition of* Norsk polarhistorie. *He said: 'Write about polar policy too,' so that's what we are going to do," say Drivenes and Bones with a smile.*

They are both historians, but political scientists are also participating, and the project is supported by researchers from the University of Tromsø, the Norwegian Polar Institute, the Fridtjof Nansen Institute, and the University of Stavanger.

The book will have several co-authors, and a subject reference group composed not only of researchers, but also of others who have taken an interest in the field, such as journalists and civil servants. The other co-editors, beside Drivenes and Bones, are Harald Dag Jølle (from the Norwegian Polar Institute) and Hallvard Tjelmeland (from the University of Tromsø).

FOUR MILLION FROM THE MINISTRY OF FOREIGN AFFAIRS

The polar policy project has been in the works for a long time, but it was a four million NOK grant from the Ministry of Foreign Affairs, given just before Christmas, that made the editors certain of full financing for the book - right through to printing.

"We would have been happy to write a book on polar policy based solely on the knowledge we currently possess, but we would have been unable to cover several areas. Now, we have the necessary funds for new basic research," says Drivenes.

"Since 1975, Odd Gunnar Skagestad's book Norsk polarpolitikk: hovedtrekk og utviklingslinjer 1905-1974, *published in 1975, has up until now been the only comprehensive work on the subject. It is high time new knowledge was introduced, and it is therefore very exciting to be able to include Skagestad in our reference group," Drivenes explains.*

THEMATICALLY, GEOGRAPHICALLY AND CHRONOLOGICALLY WIDE-RANGING

In addition to describing the 40 years after Skagestad's book was published, the new work on Norwegian polar policy will also look at the end of the 1800s. Naturally, Norwegian policy in both the Arctic and the Antarctic will be dealt with, and the themes will range widely, both North and South.

The plan is to publish parallel versions in English and Norwegian in 2015.

Jo Jorem Aarseth and Helge M. Markusson // Fram Centre

Bjerke and Rikardsen won the Fram Centre Awards

Audun Rikardsen and Jarle Bjerke were awarded the Fram Centre Communication Award and Research Award for 2012.

THE FRAM CENTRE RESEARCH AWARD 2012: JARLE BJERKE

Jarle W. Bjerke is a Senior Researcher at NINA - the Norwegian Institute for Nature Research.
Over a period of years, Bjerke's scientific productivity has been substantial and of high quality. He has mainly reported his findings in the form of articles in international journals, but also nationally through popular science articles. Additionally, Bjerke is able to communicate the results of his research to a broad audience, and displays the willingness and ability to be interdisciplinary in his research. His research is central to one of the Fram Centre's flagship initiatives, "Effects of climate change on terrestrial ecosystems, landscapes, societies and indigenous peoples."
Bjerke has a PhD in biology from the University of Tromsø (2003), and has been employed both at the University and at NINA. Bjerke works with the effect of climate change and extreme weather on vegetation in the North. His research also studies the effect of grazing by reindeer and geese, and how humans affect nature through changes in land use.

THE FRAM CENTRE COMMUNICATION AWARD FOR 2012: AUDUN RIKARDSEN

Audun Rikardsen (44) is a Professor at the University of Tromsø and has a 20% position as scientific adviser to NINA - the Norwegian Institute for Nature Research.

Over the past few years, Rikardsen has been studying the migration of Arctic charr, sea trout and salmon, and has used ground-breaking technology to accomplish this. His research interests are broad, and Rikardsen has also studied the effects of several factors on adaptation and survival of spawn and adult individuals of these fish species.

This is the first time the Fram Centre Awards have been handed out, an event which took place on the Fram Day, 16 November 2012. The awards each consist of NOK 25 000 and a work of art. In 2012 the artwork was by Gino Scarpa.

Top
Jarle W. Bjerke
Photo: Ellen Elverland

Bottom
Audun Rikardsen
Photo: Tor H. Evensen

Projects in the Fram Centre Flagships for 2012

Effects of climate change on sea and coastal ecology in the north (Fjord and Coast)

Physical-biological coupling: Oceanography and habitat use by predators and their prey

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
The role of sea ducks in benthic fjord ecosystems in relation to invasive red king crabs and varying ice conditions	Sveinn Are Hanssen	NINA, IMR	sveinn.a.hanssen@nina.no
Anadromous Arctic charr in Northern Norway – migration, habitat use and effects of climate change	Guttorm Christensen	ApN, NIVA, VI, UiT	kari.norheim@vetinst.no guttorm.christensen @akvaplan.niva.no
Atlantic salmon: an interdisciplinary approach, combining natural and social science, to improve the management of salmon sea-fisheries in northern coastal areas (ASCA)	Martin Svenning	NINA, NIKU, UiT, IMR	martin.svenning@nina.no
Drift of fish larvae, fish-stock interactions and their effect on seabird dynamics	Kjell Einar Erikstad	NINA, IMR	kjell.e.erikstad@nina.no
Seabird habitat use and migration strategies	Børge Moe	NINA, NPI	borge.moe@nina.no
Seabird habitat use	Tove M. Gabrielsen	UNIS, NINA, NPI, HI, UiT	tove.gabrielsen@unis.no

Structure, function and change in Arctic and boreal fjord ecosystems

Habitat structure and ecosystem function of eel grass (Zostera marina) meadows in the high north in relation to human traditional use and exploitation	Nina M. Jørgensen	ApN, NIVA, UiT, IMR, Norut	nina.jorgensen@akvaplan.niva.no
Marine base maps for the Porsanger fjord	Aivo Lepland	NGU	Aivo.Lepland@NGU.NO
Benthic biodiversity and ecosystem function in Svalbard and North Norway	Sabine Cochrane	ApN, NINA	sc@akvaplan.niva.no
Reduced sea urchin grazing—effect of climate change or predator change?	Hartvig Christie	NIVA, ApN, IMR, HiFi	hartvig.christie@niva.no
Ecosystem structure and use of marine resources from bivalve and fish bone proxies	Michael Carroll	ApN, NIKU	mlc@akvaplan.niva.no
Trophic interactions in pelagic ecosystems	Børge Moe	UNIS, NPI, ApN	tove.gabrielsen@unis.no

Human dimensions of ecosystem response to climate change

Mapping cultural seascape and changing environment in Porsanger fjord	Einar Eythórsson	NIKU, UiT	einar.eythorsson@niku.no
Climate change and institutional response: The cases of local/regional planning strategies and cultural heritage management	Arild Buanes	Norut, NIKU	Arild.Buanes@norut.no

Sea ice in the Arctic Ocean, Technology and Systems of Agreements

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Characterization of Arctic sea ice properties from remote sensing observations	Torbjørn Eltoft	UiT, NPI, Norut, Met. no, Kongsberg	torbjorn.eltoft@uit.no
Long-term variability and trends in the Atlantic water inflow region	Vladimir Pavlov Randi Ingvaldsen	NPI, IMR, UNIS, UiT	vladimir.pavlov@npolar.no randi.ingvaldsen@imr.no
Mesoscale modeling of ice, ocean and ecology of the Arctic ocean	Ole-Anders Nøst	ApN, IMR, NPI, SINTEF, Met.no	ole.anders.nost@npolar.no
Understanding Arctic shipping – Systematic and automatic collection and presentation of data on Arctic shipping and its driving forces	Eirik Mikkelsen	Norut, Capia, DnV, MarinTek, FNI	Eirik.Mikkelsen@norut.no
Fate, effect and risk modeling of accidental oil spill in the sea ice ecosystem	Lionel Camus	ApN, Norut, UNIS, UiT, NPI, NRPA, NIVA, NILU, SINTEF	lionel.camus@akvaplan.niva.no
Introduction of marine invasive species through ballast water and biofouling	Inger Greve Alsos	UiT, IMR, UNIS, NPI, ApN	inger.g.alsos@uit.no
Regulating Arctic shipping: Political, legal, technological and environmental challenges	Tore Henriksen	UiT, MarinTek, ApN	tore.henriksen@uit.no
Dynamic interactions between large zooplankton (amphipods and krill) and seals: Impacts of climate change (ZOOSEAL)	Tore Haug	IMR, NPI, ApN, UNIS, AWI, NVH	tore.haug@imr.no

Ocean acidification and ecosystem effects innorthern waters (Ocean acidification)

Understanding the physical and chemical mechanisms controlling ocean acidification in Arctic waters – past, present and future

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Establishing the current status of ocean acidification in the Norwegian Arctic (OA^{state})	Agneta Fransson Kai Sørensen	NPI, NIVA, IMR, UNIS	agneta.fransson@npolar.no kai.sorensen@niva.no
The role of sea ice processes on CO_2 exchange and calcium carbonate saturation levels (SICCA)	Agneta Fransson Melissa Chierici	NPI, IMR, NIVA, UNIS,	agneta.fransson@npolar.no Melissa.Chierici@imr.no

Ocean acidification effects on key components of the Arctic marine ecosystem

Effects of ocean acidification and temperature on Arctic vs. boreal zooplankton species and populations	Haakon Hop Howard Browman	NPI, IMR, ApN	haakon.hop@npolar.no howardb@imr.no
Effects of ocean acidification on the reproduction of the reef-building cold water coral Lophelia pertusa	Johanna Järnegren	NINA, SINTEF, UiT, NPI, IMR	johanna.jarnegren@nina.no

Socio-economics of ocean acidification

Economic value and ocean acidification	Claire Armstrong Eirik Mikkelsen	UiT, NIVA, Norut, NINA	claire.armstrong@uit.no Eirik.Mikkelsen@norut.no

Effects of climate change on terrestrial ecosystems, landscapes, society and indigenous peoples (Terrestrial)

Vegetation state change and herbivore management

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
NCoE-Tundra: Herbivore effects on tundra overgrowth, management and environmental gains	Jane Uhd Jepsen	NINA, UiT	jane.jepsen@nina.no
TUNDRAscape: Analyzing the effect of climate and human uses on tundra ecosystems by remote sensing	Dorothee Ehrich	NINA, NIKU, UiT	dorothee.ehrich@uit.no

Ecosystem effects of extreme climate events and changing seasons

Svalbard terrestrial ecosystem – climate impacts and trophic interactions	Åshild Pedersen	NPI, NINA, UNIS	ashild.pedersen@npolar.no
Climate-dependent infectious agents and diseases in reindeer (wildlife diseases)	Morten Tryland	NVH, VI, UiT	Morten.Tryland@veths.no
EWWA: Winter climate and effects of extreme warm weather on vegetation in northern ecosystems	Jarle W. Bjerke	NINA, Norut, Bioforsk, UiT	jarle.werner.bjerke@nina.no
Climate changes and archaelogical deposits	Elin R. Myrvoll	NIKU, Bioforsk, UiT	elin.myrvoll@niku.no

Capacity for adaptation in indigenous people and local societies

Traditional indigenous knowledge 21st Century – climate change and adaptation	Astrid Ogilvie	CICERO, NIKU, UiT	astrid.ogilvie@cicero.uio.no
Climate & reindeer 2	Bård J. Bårdsen	NINA, CICERO	bard.jorgen.bardsen@nina.no

Adaptive management of ecosystem services

GOOSEHUNT: (Reducing damage to agriculture by migratory geese by means of population control by hunting)	Ingunn Tombre	NINA, NIKU, Norut, Aarhus University	ingunn.tombre@nina.no
MIGRAPOP: (Adaptive management of migratory populations: North-Norway, Svalbard and the European continent)	Ingunn Tombre	NINA, NIKU, Bioforsk	ingunn.tombre@nina.no
Climatic adaptation: Reindeer herding and adaptation to climatic changes	Jan Åge Riseth	Norut, NINA, Uppsala University	janar@norut.no

Observation systems for climate effects

COAT: Climate-ecological-Observatory-for- Arctic-Tundra	Rolf Ims	UiT, NINA, NPI, UNIS, Met.no	rolf.ims@uit.no
LIPA: Limnological systems in Pasvik	Karl Øystein Gjelland	NINA, UiT, Bioforsk, ApN	karl.gjelland@nina.no

Hazardous substances – effects on ecosystems and human health (Hazardous substances)

Human health and society

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Mixtures and metabolic syndrome	Torkjel Sandanger	UiT, NILU	Torkjel.Sandanger@nilu.no
Mixtures and hormonal changes	Jon Ø. Odland	UiT, NILU	jon.oyvind.odland@uit.no
ARCRISK – Time trends and modeling	Torkjel Sandanger	NILU, UiT	Torkjel.Sandanger@nilu.no
Contaminants, food security in the border region (Kolarctic)	Marit Aure	ApN, Norut, NILU, UiT, NRPA	marit.aure@norut.no

Animal health and ecosystem

New contaminants (chlorinated paraffins and Me-Hg)	Nicholas Warner	ApN, NIVA, NPI, NILU	Nicholas.Warner@nilu.no
COPOL II – Importance of primary and secondary sources	Anita Evenset	ApN, NIVA, NPI, NILU	Anita.Evenset@akvaplan.niva.no
Influence of pollution and climate variation in rivers and coastal waters indicated by freshwater and marine bivalves – Sør-Varanger	Paul E. Aspholm	Bioforsk, ApN, NINA	paul.eric.aspholm@bioforsk.no
Environmental stress in seabirds	Jan O. Bustnes	ApN, NINA, NILU, NPI	Jan.Bustnes@nina.no
Effects of contaminant exposure on energetics	Heli Routti	NPI, NILU, UiT, UiB	heli.routti@npolar.no
Arctic charr population at risk? Lake Ellasjøen, Bjørnøya	Anita Evenset	ApN, NIVA, NILU, UiT	Anita.Evenset@akvaplan.niva.no
Exposure to pollutants and quantification by qPCR of IFN gene expression in arctic wildlife	Jacques Godfroid	NVH, NPI, NILU	Jacques.Godfroid@nvh.no
Reproductive health of pied flycatcher – Pasvik	Oddmund Kleven	NINA, Bioforsk, NRPA, UiT	oddmund.kleven@nina.no
Raptors-multistress	Jan O. Bustnes	NINA, NPI	Jan.Bustnes@nina.no

Petroleum pollution

The combined effects of radionuclides, metals and organic contaminants in produced water on early life stages of Calanus finmarchicus	Louise K. Jensen	NRPA, UiT, NIVA	louise.kiel.jensen@nrpa.no
Physiological responses to petroleum-related compounds in polar cod	Jasmine Nahrgang	UiT, UNIS, ApN, IMR, MMBI	jasmine.m.nahrgang@uit.no
“Oil in ice” – Fate, Effect, and Risk Modeling	Lionel Camus	ApN, NIVA, NRPA, Norut, NPI, SINTEF, UiT, UNIS	lionel.camus@akvaplan.niva.no

Risk communication

Understanding strategies and communication	Alena Bartonova	NILU, Norut, UiT	alena.bartonova@nilu.no

ABBREVIATIONS

ApN: Akvaplan-NIVA Inc.; **AWI:** Alfred Wegener Institute; **Bioforsk:** Norwegian Institute for Agricultural and Environmental Research; **CICERO:** Center for International Climate and Environmental Research – Oslo; **DnV:** Norwegian Veritas; **FNI:** Fridtjof Nansen Institue **IMR:** Institute of Marine Research; **HiFi:** Finnmark University College; **Kongsberg:** Kongsberg Satellite Services; **Kystverket:** Norwegian Coastal Administration; **MarinTek:** The Norwegian Marine Technology Research Institute; **Met.no:** The Norwegian Meteorological Institute; **MMBI:** Murmansk Marine Biological Institute; **NGU:** Geological Survey of Norway; **NINA:** Norwegian Institute for Nature Research; **NIKU:** The Norwegian Institute for Cultural Heritage Research; **NILU:** Norwegian Institute for Air Research; **NIVA:** Norwegian Institute for Water Research; **Nofima:** The Norwegian Institute of Food, Fisheries and Aquaculture Research; **Norut:** Northern Research Institute; **NPI:** Norwegian Polar Institute; **NRPA:** Norwegian Radiation Protection Authority; **NTNU:** Norwegian University of Science and Technology; **NVH:** Norwegian School of Veterinary Science; **SINTEF:** The Company for Industrial and Technological Research; **TØI:** The Institute of Transport Economics; **UiB:** University of Bergen; **UiT:** University of Tromsø; **UNIS:** The University Centre in Svalbard; **VI:** Norwegian Veterinary Institute

Many of these projects also involve a significant amount of international cooperation

Recent doctorates

Anaïs Beatrice Aubert

Stoichiometry of lipid synthesizing calanoid copepods in Arctic and sub-Arctic marine regions. Insights into limitation and elemental cycling from characterization of C:N:P ratios

In this PhD thesis, ecological stoichiometry theory was applied to determine which of the chemical elements (C, N, P) is limiting for the growth of copepods in Arctic and sub-Arctic marine regions during the period of intensive growth in spring. The samples taken included copepods at different stages of development, from different areas and periods of time, in both Arctic and sub-Arctic regions. The results show that the amount and quality of the food are important for copepods, and that accurate measurement of copepod lipid content requires that the fat stores and the rest of the animal's body be analysed separately. Moreover, the stoichiometric analyses must take into account the food supply and the different stages of development. The results for phosphorus in the copepods' food and faecal material are among the first reported from the Arctic and the copepods' faecal material is shown to be rich in phosphorus. This makes it an important source of phosphorus, both with regard to export to deeper waters and recirculation of nutrients.

Link to the thesis: http://hdl.handle.net/10037/4768

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

12 December 2012

Lilja Run Bjarnadóttir

Processes and dynamics during deglaciation of a polar continental shelf. Examples from the marine-based Barents Sea Ice Sheet

This PhD thesis deals with the melting of a large ice sheet that covered the Barents Sea towards the end of the last Ice Age. Marine-geophysical and geological data were used to map land forms and sediment deposits, which tell us how the ice sheet behaved during the period of deglaciation. The thesis work is a detailed study of the retreat of an ice stream in Kveithola, a small trench northwest of Bjørnøya Island, and a new reconstruction of the main features of the melting of the ice sheet in the central part of the Barents Sea. In all parts of the work the volume of subglacial meltwater is shown to be an important factor for ice flow dynamics and the types of deposits.

University of Tromsø
Faculty of Science and Technology
Department of Geology

Joint supervision with the Department of Arctic Geology, University Centre in Svalbard

20 December 2012

Ellen Elverland

Late Weichselian to early Holocene vegetation and bird activity on Andøya, Nordland County – as evidenced primarily by macrofossils

Several sediment cores were obtained from deposits at the bottom of Lake Endletvatn on the island of Andøya, and plant and animal remains were washed out of the sediments. By comparing these finds with the present-day extent of plant and animal life, it is possible to reconstruct and create a picture of what the habitat and climate must have been like in this far-western outpost. The climate was essentially cold and conditions must have been similar to those found in Svalbard today. The vegetation was dominated by grass and the arctic poppy. During brief periods the climate improved, however, and permitted a more varied vegetation. Bones of the little auk bear witness to the existence of a large seabird colony in the area. The bird guano helped improve habitat conditions for the plants, and the vegetation beneath the nesting cliffs must have been much richer than elsewhere in the area. Traces of DNA from spruce and pine in the cores indicate that during climatically mild periods, trees may have grown on Andøya. The findings challenge the classic perception that these species did not migrate to Scandinavia until several thousand years later.

Link to the thesis: http://hdl.handle.net/10037/4565

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

26 October 2012

Jannike Falk-Petersen

Management of the alien invasive red king crab : Integrating natural and social science perspectives

The king crab (*Paralithodes camtschaticus*) represents a valuable resource, but also a potential threat since it is an invasive alien species in the Barents Sea. The thesis explores use of various cross-disciplinary tools to analyse how ecological, social and economic interests could be taken into account when determining how king crab should be managed in Norway. Ecological information is reviewed in order to establish what is currently known about the king crab and form the basis for further analysis. Bio-economic modelling and discourse analysis concerning the king crab are used to look at how the uncertainty and the entire range of services the ecosystem provides can be integrated in king crab management. The thesis shows that while ecological knowledge is important, the social sciences also have an important role to play in integrating the views and values of stakeholders into king crab management. The use of frameworks to identify ecosystem services can be useful in the discussion, integration and evaluation of ecological and social science research information.

Link to the thesis: http://hdl.handle.net/10037/4236

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Norwegian College of Fishery Sciences

12 June 2012

Tore Hattermann

Ice shelf–ocean interaction in the Eastern Weddell Sea, Antarctica

This oceanographic study explores the melting of ice shelves in Dronning Maud Land. Ice shelves consist of up to several hundred-metre thick slabs of glacier ice that float on the sea around the coast of Antarctica. Melting on the underside of the ice shelves is thought to play an important role for the mass balance of the ice cap and global sea levels. Using new oceanographic measurements underneath the Fimbul Ice Shelf and numerical ocean modelling, this study seeks to contribute to a better understanding of the processes that control the melting along the coast of the Norwegian sector of Antarctica. The results of the study suggest that the Fimbul Ice Shelf has not seen an increase in melt rate. In this it differs from other locations around the white continent, where climate change has brought about an increased loss of ice mass. The study also shows that heat transport towards the ice shelves in Dronning Maud Land is controlled by a complicated interaction of wind, the annual cycle of freezing and melting of the sea ice on the surface of the ocean, and circumpolar currents deep within the Southern Ocean.

University of Tromsø
Faculty of Science and Technology
Department of Physics and Technology

10 December 2012

Ann Merete Hjelset

Female life-history parameters in the introduced red king crab (*Paralithodes camtschaticus*, Tilesius 1815) in the Barents Sea: A study of temporal and spatial variation in three Norwegian fjords

The subject of Hjelset's PhD thesis is how the population of red king crab (*Paralithodes camtschaticus*) has developed in Varangerfjorden, Tanafjorden and Laksefjorden in recent years. One finding is that female crabs lay eggs considerably fewer times during their lifespan than they did previously. There can be several reasons why the females do not live as long as they used to, including extensive fishing of large males which normally play an important role in protecting egg-laying females. Hjelset's doctoral thesis is based on studies that have been ongoing since 1994. Two noticeable changes have taken place in recent years: it used to be possible to find large females that had laid eggs 12-15 times. They are now gone. The crab populations in Tanafjorden and Laksefjorden are also considerably smaller than they were a few years ago.

Link to the thesis: http://hdl.handle.net/10037/4561

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

28 August 2012

Siv Huseby

Metabolic fingerprinting applied in diatom taxonomy

Diatoms are important primary producers in the marine nutrient network. A correct description of these species and a greater knowledge of their function in the marine environment are therefore important for our understanding of life in the sea. The thesis examines whether the chemical fingerprint of diatoms, measured using mass spectrometry, makes it possible to distinguish between samples of different species. The results show great chemical diversity between species of diatoms. Even closely related species differ chemically from one another to a considerable degree. There was also a tendency to greater chemical diversity at low temperatures. The thesis also includes a thorough comparison of clones belonging to the same species collected from two different geographical areas: the coast of Northern Norway/the Barents Sea and the Mediterranean. The results support reclassifying this species as two or more species. The results also show that chemical fingerprinting can be used to provide additional information in taxonomic studies of diatoms.

Link to the thesis: http://hdl.handle.net/10037/4269

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

18 June 2012

Patrycja Ewa Jernas

Benthic foraminifera in an Arctic fjord: recent distribution and fauna of the last two millennia

The main purpose of the study was: 1) to increase the understanding of how and how quickly small unicellular organisms (foraminifera) that live on the seabed react to climatic and environmental changes in the Arctic, and 2) how this knowledge may be used to better understand the climatic and environmental changes that have taken place in Svalbard over the past 2000 years. The study is based on analyses of seabed samples and measurements of the properties of the water masses in Kongsfjorden and Hinlopenstredet in Svalbard. The results show that the presence and species diversity of the foraminifera have been controlled by different factors through the ages. The most important factors are food supply, sea ice coverage and the effect of glaciers, along with inflow of relatively warm and salty Atlantic Water that is transported with the Gulf Stream along the Norwegian coast and north towards Svalbard. Over the last two millennia, the inflow of Atlantic Water has varied and led to repeated changes, for example in the extent of the sea ice around Svalbard.

Link to the thesis: http://hdl.handle.net/10037/4647

University of Tromsø
Faculty of Sciences and Technology
Department of Geology

13 September 2012

Bernd Ketelsen

Characterization of a cytokinin response factor in *Arabidopsis thaliana*

The ability to adapt to changing environments is extremely important in the life of plants. Plants react to changing conditions by shedding their leaves in the autumn and putting out shoots in the spring. The better a plant species is able to adapt to change, the better it is at competing with other species. The phenotypic plasticity of a plant is stored in its genes, and plants react to changing conditions by turning certain genes on or off. The transcription factors play an important role in this process. This thesis presents a study of the function of the transcription factor CRF5 in mouse-ear cress (*Arabidopsis thaliana*). CRF5 is known to be involved in signalling of the plant hormone cytokinin and in cotyledon development. It was possible to confirm that CRF5 regulates not only the expression of genes encoding components of the cytokinin signalling, but also other components of the signalling pathways. In addition, the study showed that plants that overexpress CRF5 have shorter roots and fewer shoots, and that these effects may be caused by a change in sugar metabolism.

Link to the thesis: http://hdl.handle.net/10037/4620

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

15 May 2012

Hildur Pétursdóttir

Trophic relationships and the role of *Calanus* in the oceanic ecosystems south and north of Iceland

The areas southwest and north of Iceland have different physical conditions that give rise to different biological communities. This study focused on the importance of zooplankton such as the *Calanus* species as food for other key organisms in the two different ecosystems. Nutritional ecology and energy transfer up the food chain were calculated by tracing stable isotopes of nitrogen and carbon, and by identifying different fatty acids as markers for what was eaten by whom. Interannual variability in the amounts and composition of the zooplankton in the areas southwest and north of Iceland was also studied, and related to the varying physical conditions in the areas. The energy-rich *Calanus* species were found to be key organisms in transporting energy from phytoplankton to fish in both the ecosystems. They dominated in the biomass, and fatty acid markers were found in large amounts further up the food chain. The study presents novel insight into nutritional ecology and energy transfer in the various sea areas south and north of Iceland.

Link to the thesis: http://hdl.handle.net/10037/4661

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

3 December 2012

Kirsti Elisabeth Præsteng

Genetic identification and ruminal dosing of cellulolytic bacteria to reindeer in search of a future probiotic

Rough grazing forms the nutritional basis for Sami reindeer husbandry, although the reindeer are also given feed. Supplementary feeding can be challenging because digestive problems often arise. To determine whether cellulose-degrading bacteria isolated from the reindeer rumen can be used as a probiotic when the animals are given feed after starvation, bacteria isolated from the rumen were identified and their ability to degrade cellulose was examined. The effect of giving cellulose-degrading bacteria was examined in an animal study in which three reindeer were administered a live bacteria culture directly in the rumen. The results showed that bacteria of the types *Bacteroidetes* and *Firmicutes* dominated in the rumen. The majority of the bacteria represented hitherto unknown species. Studies where *Ruminococcus flavefaciens* was given to reindeer after a starvation period indicated that the introduced bacteria probably do not become established in the rumen. The addition of the cellulolytic rumen bacteria affected the bacterial ecosystem and led to reduced degradation of cellulose and feed in the rumen. The results support the supposition that there are important interactions between

the different bacteria in the rumen, and that development of a probiotic to promote fibre degradation in reindeer after starvation is likely to be difficult.

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

21 September 2012

Denise Christina Rüther

Palaeoenvironment of the Barents Sea during the last deglaciation and Holocene: processes and timing

This thesis studies the depositional environment in the Barents Sea from the last deglaciation and up to today. The primary emphasis is on reconstruction of processes and timing during melting of the great ice sheet that covered the entire Barents Sea. The Holocene development of the depositional environment on the Barents Shelf over the last 12 000 years was also studied. The focus is on two principal study areas: Bjørnøyrenna (Bear Island Trough), which is a long, cross-shelf trough, and Kveithola, a much smaller trough west of Spitsbergenbanken. As part of this thesis, the geomorphology and the internal structure of several grounding line systems in Kveithola and two systems in Bjørnøyrenna were examined in great detail. The main purpose of the study was to identify depositional processes during glaciation and deglaciation, and to determine the age of different stages in ice-marginal processes. The thesis also suggests that the impact and erosion caused by large tsunamis resulting from submarine landslides may provide an alternative explanation for observed sporadic deposition and erosion surfaces in the Holocene.

Link to the thesis: http://munin.uit.no/handle/10037/3876

University of Tromsø
Faculty of Sciences and Technology
Department of Geology

1 March 2012

Anna Siwertsson

Diversity along a speciation continuum – Ecology and morphology of Northern European whitefish (*Coregonus lavaretus*)

Formation of new species is a fundamental process that still puzzles researchers the world over. By studying the variations between populations within the same species, knowledge can be acquired of the significant mechanisms involved early in the process of species formation. This thesis includes studies of ecological and morphological diversity in populations of northern European whitefish. Whitefish colonised freshwater lakes in northern Fennoscandia as soon as the inland ice retreated after the last ice age, about 10 000 years ago. In northern Fennoscandia whitefish appear in one, two or three different morphs in the same lake. The largest number of whitefish morphs are found in large, deep lakes with a high nutrient content, where “vacancies” in the ecosystem and unused resources have probably been important causes of the split. The diversity is also higher in lakes further to the east, which can be explained events that occurred during the colonisation of the region by whitefish after the last ice age. This diversity of whitefish morphs has developed over the last 10 000 years, and is most probably a result of competition for resources, “vacancies” in the ecosystem, and natural selection.

Link to the thesis: http://hdl.handle.net/10037/4566

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

24 August 2012

Lucie Strub-Klein

Field measurements and analysis of the morphological, physical and mechanical properties of level ice and sea ice ridges

The main challenge to the development of oil and gas industries and the exploitation of these resources in the Arctic is sea ice. Designing safe structures and ships requires taking into account sea ice concentration, thickness and strength. Ice load modelling has progressed in recent years, but uncertainties remain concerning the magnitude of ice loads in structures and ships. In the absence of icebergs, ice ridges are the governing factor in Arctic marine design, but how these ridges form and age is yet not well understood (e.g. in the Fram Strait). This PhD project studied two types of sea ice: level ice and ridges. The level ice studies revealed that the compression strength of sea ice is strongly influenced by the localisation of brine pockets and channels in the ice. The ice ridge studies generated an extensive catalogue of the morphological properties of first-year floating ice ridges. Important correlations between ridge dimensions were established. The analysis also showed that ridges grow evenly in width.

University Centre in Svalbard
Department of Arctic Technology

22 May 2012

Kathrine Tveiterås

At the limits of a fairy tale – the economisation of Snøhvit LNG

This thesis is a study of the development of the Snøhvit LNG plant. Despite extensive preparations, the project joined the list of megaprojects that are not performing as planned, with delays and major cost overruns. Proposed solutions to change this classic trend of development have been about improving the use of management tools, with stricter requirements in terms of accuracy in economic calculations. This thesis argues that the focus on greater accuracy simultaneously overlooks what effect this demand has per se on how these megaprojects perform. In this way the study shifts the focus to the management tools themselves. What is their role in the dynamics of megaprojects? The more accurately the surroundings of the project are quantified, the more probable it is that things will develop differently. The management tools themselves are therefore central to the way in which megaprojects develop. An acceptance of this conclusion means that future research and societal questions should be framed in a way that is more relevant for the dynamics of megaprojects.

Link to the thesis: http://hdl.handle.net/10037/4299

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Norwegian College of Fishery Science

29 June 2012

Birgitte Ulvevadet

The governance of Sami reindeer husbandry in Norway: Institutional challenges of co-management

This PhD thesis is based on a qualitative study of the governance of reindeer husbandry in Norway. The goal of reindeer husbandry governance in Norway is to attain an ecologically, economically and culturally sustainable husbandry. To increase the participation of resource-users, the Norwegian authorities have initiated a large and complex system of governance. It has proved difficult to get it to function as planned and there have been challenges on several fronts. Many groups are entitled to be involved in the governance, both Sami pastoralists and representatives of other industries who have interests in the same areas as those used by the reindeer owners. In this process some groups have been granted more power than others, and this has left its mark on the system of governance. The goal of higher economic earnings (economic sustainability) is sought to be achieved through the subsidy system. The goal of an ecologically sustainable reindeer husbandry is sought to be achieved through the subsidy system and laws and regulations. The subsidy system does not function according to its original intention, which was to reduce the numbers of reindeer while also compensating the reindeer owners for the loss.

Link to the thesis: http://hdl.handle.net/10037/4331

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Norwegian College of Fishery Science

15 June 2012

Anette Wold

Calanus glacialis – the role of lipids in the life cycle and for the Arctic pelagic food web

The objective of this study was to increase knowledge about important life cycle strategies of *C. glacialis* with focus on accumulation of important fatty acids, reproduction and seasonal vertical migration. Another focus was to study the role *C. glacialis* plays as food for animals higher up the food chain, such as seabirds and seals. *C. glacialis* overwinters in deep waters and ascends to the surface to eat and reproduce in spring. The timing of the migration to the surface must therefore match the time for primary production. In far northern regions and areas covered with ice, the period of primary production will be shorter and *C. glacialis* will be even more dependent on migrating up from the depths at the right time. The study of fatty acid composition in seabirds from Kongsfjorden shows that *Calanus* is an important component in the diet of little auk, black-legged kittiwake and northern fulmar. A comparison of fatty acid composition in hooded seal and harp seal shows an overlap in diet, although harp seals have a larger proportion of typical *Calanus* fatty acids than do hooded seals.

Link to the thesis: http://hdl.handle.net/10037/4152

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

Joint supervision with the Norwegian Polar Institute

23 May 2012

Katarzyna Agnieszka Zamelczyk

Arctic Ocean warmings from the last glaciation to the present: implementing and assessing the reliability of planktic foraminiferal paleoreconstructions

The aim of the PhD study was to use planktic foraminifera to elucidate paleoceanographic variability and the preservation state of calcium carbonate in the eastern Fram Strait throughout the last 30 000 years. The results show that the Atlantic water inflow governed the oceanographic development and had an important influence on the preservation state of calcium carbonate in the Fram Strait. The best preserved planktic foraminifera assemblages during the last 30 000 years were from the Last Glaciation Maximum. During the deglaciation and the Holocene, the preservation state of carbonates generally deteriorated. Changes in preservation are related to the extent and influence of the Arctic water and the marginal ice zone (MIZ) and its associated high organic productivity in the surface waters. This study of planktic foraminifera preservation has shown that carbonate dissolution is a common phenomenon in the Fram Strait and should be considered in paleoreconstructions based on planktic foraminifera fauna.

Link to the thesis: http://hdl.handle.net/10037/4148

University of Tromsø
Faculty of Science and Technology
Department of Geology

11 May 2012

Ann Kristin Balto // Norwegian Polar Institute
Photo: Paul Roer // Norwegian Polar Institute photo archive

Brit Hofseth and Ebbe Arneberg in action during the East Greenland Expedition of 1939

Brit Hofseth was one of the first female Norwegian geologists who worked in the field on Greenland. She was tough and fearless, and chose an unusual career. At 21, she started working for the Svalbard geologist Gunnar Holmsen, and her interest in geology was sparked. Holmsen attempted to dissuade Hofseth from becoming a geologist, arguing that it was a daring choice of livelihood and required a long education, in addition to being strenuous work. She told him:

"I know this is demanding work, but I want to become a geologist!"

Her desire to become a geologist was decidedly strong, and she proved to be eminently capable, so a geologist she became. She spent the summer of 1937 in Svalbard, and in 1939 she travelled to Greenland to carry out geological surveys on Clavering Island. This turned out to be an unforgettable summer with many exciting experiences. She had excellent company in Professor Ahlmann, the Swedish glaciologist, Captain Marø and a number of hunters, including the famous Henry Rudi - the Polar Bear King - and the journalist Nils Johan Rud, who later went on to write an intense love story based on the journey, entitled *Drifting boundaries* (Drivende grenser). Many of the travelling companions aboard the ship *Polarbjørn* can be recognised in the book, including Brit Hofseth, who was very popular on the trip. She went on to charm many others who crossed her path.

The Norwegian Polar Institute's photo archive contains around 90 000 polar images, half of which are available online: http://fotoweb.npolar.no

Two years after the expedition to Greenland, Brit Hofseth died of acute illness during a research trip in Troms, where she had gone to collect material for the Geological Survey of Norway, NGU. She was only 24 years old.

New books published in 2012

Six tidbits from the library

The hockey stick and the climate wars: dispatches from the front lines

Michael E. Mann. Columbia Univ. Press. xvi, 395 p. ISBN 978-0-231-15254-9

Professor Mann is the Director of Penn State Earth System Science Center, and has been central to the work of the IPCC. He is engaged in “the climate war” in the US, and in this book he describes how scientific information is met with aggressive campaigns from climate sceptics. The book also tells the story of “Climategate”, the 2009 email scandal.

LASHIPA: history of large scale resource exploitation in polar areas

Edited by Louwrens Hacquebord. Groningen: Barkhuis. xiii, 172 p. (Circumpolar studies; vol. 8) ISBN 978-9-49-143108-1

This is an interesting anthology recounting the results of a historic IPY project, which involved plenty of fieldwork in Svalbard. Among other topics, you can read about the historic background behind the Norwegian Polar Institute’s decision in 2011 to adopt Rijpsburg as an official place name in Svalbard. You can also find good answers to questions such as why and how the mining industry ended up in Spitsbergen. The book also confirms that the Pentagon was concerned about climate change and melting ice as early as 60 years ago.

Circumpolar health atlas

Senior editor: T. Kue Young. Univ. of Toronto Press. ix, 190 p. ISBN 978-1-4426-4456-4

A richly illustrated book of facts describing the current situation for Arctic people on three continents. Work has begun to translate the book into Russian. The book deals with factors affecting people's health. Can education and research bring good health?
The entire Northern part of Norway is included in this book's circumpolar world.

Caution & compliance: Norwegian-Russian diplomatic relations 1814-2014

Editors: Kari Aga Myklebost & Stian Bones. Stamsund: Orkana akademisk. 201 p. ISBN 978-82-8104-158-5

Another historical anthology. Should you become bored by all the polar stuff, this book looks at exciting diplomats, such as Aleksandra M. Kollontai, who laid the groundwork for good, neighbourly relations between two “young states”, the Soviet Union and Norway, way back in the 1920s. And what was the true story behind Norway acknowledging the USSR in 1924, at the same time as the USSR fully acknowledged the Svalbard Treaty? Did key politicians from the Norwegian Labour Party deliver secret documents to the Soviet Union during the inter-war period?

Permafrost hydrology

Ming-ko Woo. Springer. xii, 563 p. ISBN 9783642234613

A thorough description of the connection between frost in the ground, groundwater and water carriage. The author postulates that this field is by nature both interdisciplinary and applied. Knowledge of these processes is an important basic prerequisite for polar environment management.

Det norske geografiske selskab 1889-2000: “nasjonsbygger, helter, vitenskap, folkeopplysning”

Jens Fr. Nystad. Fram Museum. 231 p. ISBN 978-82-8235-058-7

Since many of Fram Forum’s readers understand Norwegian, we would like to include a small appetizer from a book in that language. Why did J.F. Nystad dissolve an honourable society in 2000, and then write a book about it a few years later? Many Norwegian polar expeditions are closely connected to the history of the Norwegian Geographical Society. Indeed, without polar research there would scarcely have been a society to write about.

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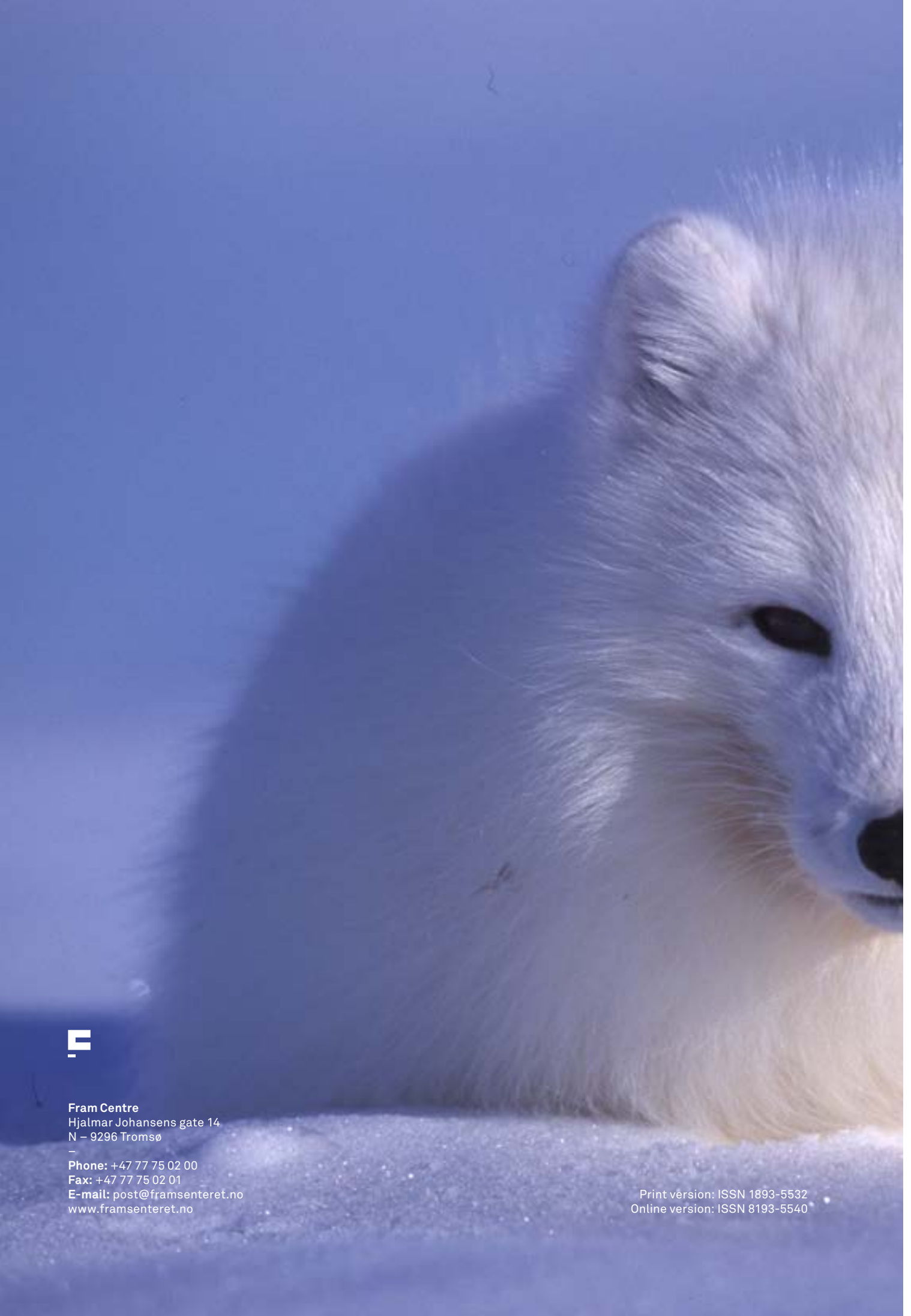

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