

2002

POLAR RESEARCH IN TROMSØ

EDITORIAL

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POLARMILJØSENTERET



Back on the street!

The Roald Amundsen Centre for Arctic Research (University of Tromsø), the Polar Environmental Centre and the Norwegian Polar Institute published two issues of Polar Research in Tromsø in 2000. Due to a concatenation of circumstances no issues were published in 2001. However, it has now been decided that Polar Research in Tromsø will live on, with a single issue being presented annually. Polar Research in Tromsø is meant to give its readers glimpses of various polar science activities in the Norwegian Arctic and in Antarctica.

"The Gateway to the Arctic"

Tromsø, with its many nicknames, has a great deal of polar activity. Research at the University of Tromsø, the institutions of the Polar Environmental Centre, as well as several other institutions based in Tromsø focus on Arctic disciplines. The visitors centre Polaria, Tromsø University Museum and the Polar Museum offer insights into the northern regions,

and Tromsø's libraries (including the Norwegian Polar Institute library at the Polar Environmental Centre) boast some of the world's largest collections of polar literature. The NPI picture library stores images spanning more than a century of polar activity.

What is the Arctic?

We have chosen to define the Arctic as the geographical areas north of the Arctic circle. The Norwegian Arctic and the Barents Region are our main focus areas – the Barents Region comprising the northern part of the Scandinavian countries and Finland, and the north-western parts of Russia. With the exploitation of oil and gas in north-west Russia and the gas extraction development in the ocean off the coast of northern Norway, this area will receive much attention from scientific, political and trade and industry quarters in the time to come.

Norway in Antarctica

The majority of Norwegian Antarctic Research activities take place in the South Atlantic sector of Antarctica,

specifically Bouvetøya, the eastern Weddell Sea region and Dronning Maud Land. These areas have been designated as the main focus areas for Norwegian Antarctic research. Most Norwegian Antarctic research activities are conducted under Norwegian Antarctic Research Expeditions (NARE).

Presently, an air strip is constructed in the vicinity of the Norwegian Troll station in Dronning Maud Land, Antarctica. Troll is likely to become a key location for the logistical operations of western Dronning Maud Land as air operations become a primary mode of transport for the operators in the area.

Please give us a sign!

We are happy to present more research notes in this edition than we have had previously. We would be grateful to readers who alert us to topics that might be presented in Polar Research in Tromsø.

Enjoy your reading!

Polar Research in Tromsø

Polar Research in Tromsø is published once a year by the Roald Amundsen Centre for Arctic Research at the University of Tromsø, the Norwegian Polar Institute and the Polar Environmental Centre, Tromsø, Norway. Its aim is to describe all manner of education and research in polar (chiefly Arctic) studies at these centres and at those research institutes and companies in the Tromsø area with which these have close ties.

It is sent on request and free of charge to all persons who are interested in polar studies.

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Editor:

Gunn Sissel Jaklin
Norwegian Polar Institute,
Polar Environmental Centre,
N-9296 Tromsø.
e-mail: jaklin@npolar.no
telephone: +47 77 75 06 40
www.npolar.no

Sub-editors:

For the Roald Amundsen Centre for Arctic Research:

Geir Gotaas
e-mail: geir.gotaas@arctic.uit.no
telephone: +47 77 64 40 00
www.arctic.uit.no

For the Polar Environmental Centre:

Are Johnsen
e-mail: are.johnsen@npolar.no
telephone: +47 77 75 0 202
www.polarenvironment.no

For the Norwegian Polar Institute:

Helle Goldman
e-mail: goldman@npolar.no
telephone: +47 77 75 06 18
www.npolar.no

Glacier Monitoring in Svalbard Using Synthetic Aperture Radar (SAR) Satellite Imagery

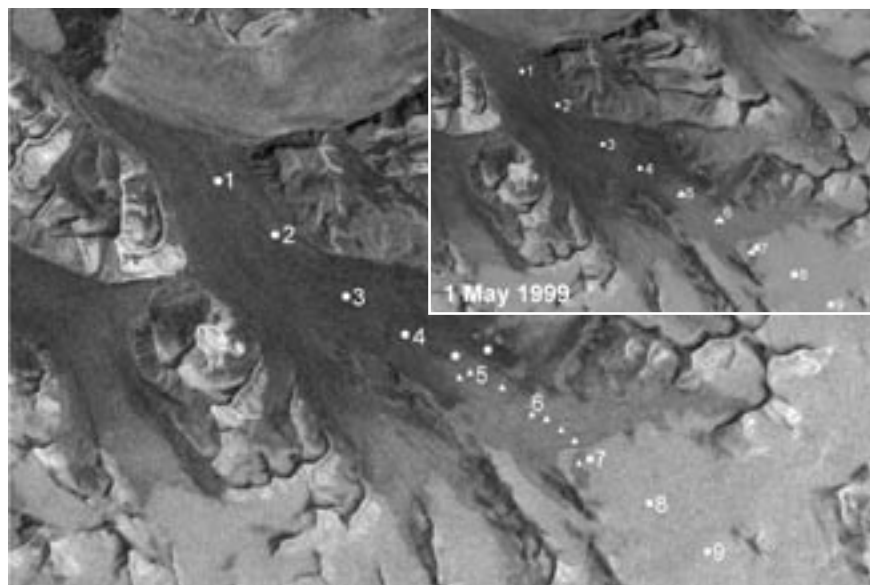


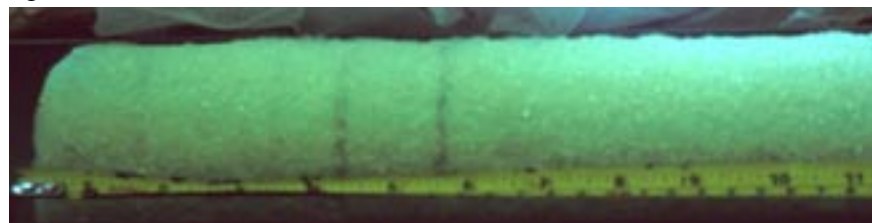
Figure 1
ERS-2 SAR images from Kongsvegen from 1 May 1999 and 24 February 2000. Sites where ice core analysis indicated presence of glacier ice (marked with dots) coincide with an area of medium backscatter, and fin core sites (marked by squares) coincide with an area of high backscatter. Note the highly crevassed tongue of the fast-flowing Kronebreen (upper left corner) giving high backscatter. The SAR image data was provided by the European Space Agency (copyright ESA 2000).

Max König (koenig@npolar.no) and
Jan-Gunnar Winther (winther@npolar.no).
Norwegian Polar Institute, Polar Environmental
Centre, Tromsø

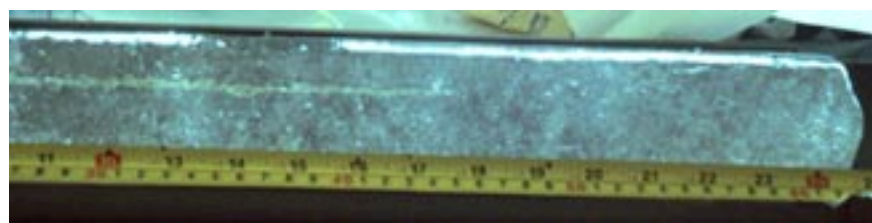
Glaciers serve as good indicators for changes in climate conditions, eventually reacting with retreat or advance. Many glaciers have therefore

been studied by yearly field surveys. While field measurements remain necessary, the use of satellite images allows extrapolating these over much larger areas. In addition, we are now able to observe from space large and remote areas which are hard or impossible to study in the field.

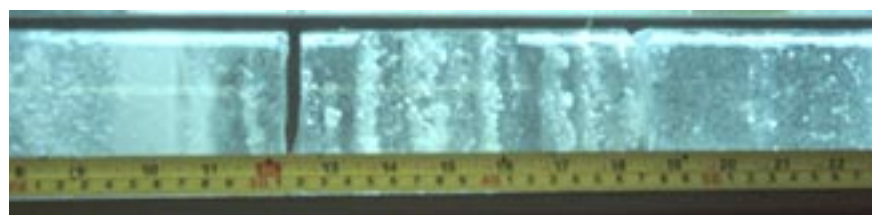
Figure 2. Ice cores



Firn: average $so = -0.6 \pm 0.6$ dB. 1999 Core Sites on Kongvegen: 7, 8, 9. 2000 Core Sites on Kongvegen: 7, 8, 9



Superimposed Ice: average $so = -6.2 \pm 1.6$ dB. 1999 Core Sites on Kongvegen: 5, 6, 7met. 2000 Core Sites on Kongvegen: 5, 5S, 5a, 6, 6a, 6b, 6c, 7met



Glacier Ice: average $so = -12.1 \pm 1.1$ dB. 1999 Core Sites on Kongvegen: 1, 2, 3, 4. 2000 Core Sites on Kongvegen: 1, 2, 3, 4, 4c, 5N

SAR

Synthetic aperture radar (SAR) images from European Space Agency (ESA) and ERS satellites are used for these studies. In contrast to optical images, the radar signal in the microwave region (5.3 GHz) allows observations during cloud cover and night-time conditions. It is also unaffected by the dry winter snow cover, detecting the end-of-summer surface during the entire winter.

One of the principle aims in using satellite imagery for glacier studies is the identification of various surface types on the glacier surface and to monitor their extent and variation across several years. Changes in the mass balance of a particular glacier will result in changes in extent of those surface types.

Using SAR imagery, we have studied the glaciers in the Kongsfjorden area of Svalbard, focussing on Kongsvegen glacier. On the glacier, we drilled shallow ice cores (<50 cm) in April 1999 and 2000 at the locations marked in Figure 1. All of our SAR images from 1992 to 2002 show three distinct zones on the glacier surface. It has long been an open question as

to what exactly SAR is detecting on a glacier surface (König *et al.* 2001). From earlier studies we could expect that the area with high backscatter corresponds to firn, while the area with low backscatter corresponds to glacier ice (Engeset *et al.* 2002). The nature of the medium backscatter area, however, is not obvious at first. We compared our ice core results with the SAR images and found a very clear correlation: the area with high backscatter corresponds to firn, the area with low backscatter corresponds to glacier ice and the area with medium backscatter corresponds to superimposed ice.

While glacier ice is created by the metamorphism of firn to ice deep in the glacier, superimposed ice is water that has refrozen on the glacier surface. Until now, superimposed ice has not been observed on SAR images elsewhere. The question arises as to why SAR is detecting superimposed ice on Kongsvegen. Figure 2 shows photographs of ice cores from each surface type. The crystals in the firn core will reflect much of the incoming SAR signal back to the sensor, resulting in a high SAR backscatter. Glacier ice is very clear, having few reflectors,

thereby resulting in low backscatter. The superimposed ice core has layers with very large air bubbles or many small air bubbles. We believe that it is the differing air bubble content in superimposed ice that causes a higher backscatter compared to glacier ice. More details on this can be found in König *et al.* (2002).

To determine mass balance from space it would be necessary to distinguish the present year's snow from the older firn, as well as the present years' superimposed ice from older superimposed ice. Our analysis shows that this is not possible, since recent snow and old firn are indistinguishable on SAR, just as are new and old superimposed ice. This means that SAR images cannot give a yearly mass balance value or an equilibrium line altitude the way field measurements do. However, changes in mass balance will cause changes in the overall extent of the surface areas mentioned above. Our main goal is therefore to observe the variations of these surface zones on the SAR image and to correlate them to mass balance.

In conclusion, we were able to show that SAR is able to distinguish

glacier ice, superimposed ice and firn on Kongsvegen. The equilibrium line itself cannot be observed. Our objective is to extend our analysis over much larger areas in Svalbard, using SAR images from 1992 to today. We will then analyse any changes and trends and correlate these to glacier mass balance data. If successful, we will establish a satellite glacier monitoring system for Svalbard.

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Productive But Short: Non-Fish Food Chains in the Marginal Ice Zone of the Barents Sea

Haakon Hop (haakon@npolar.no),
Norwegian Polar Institute, Polar Environmental
Centre, Tromsø

Marginal Ice Zones (MIZ) are some of the most dynamic areas in the world's oceans. The latitudinal location of the ice edge during summer in the Barents Sea can vary by hundreds of kilometres from year to year, and there is a strong correlation between the North Atlantic Oscillation (NAO) winter index and the maximum sea ice extent during spring (Vinje 2001). The interaction between the atmosphere, ocean and sea ice is strong within the MIZ. The ice edge zone may undergo rapid changes in ice cover extent and concentration because of changing wind direction, and hydrodynamic instabilities produce eddies, jets and filaments that redistribute ice, heat,



Figure 1. Diving at the ice edge. Photo: Tor Ivan Karlsen

salt and momentum over scales of 5-10 km. The water masses of the northern Barents Sea are characterised by influxes of cold Arctic water from

the north. At the Polar Front, the cold Arctic water meets warmer Atlantic water from the North Atlantic Current, which subsides below the less

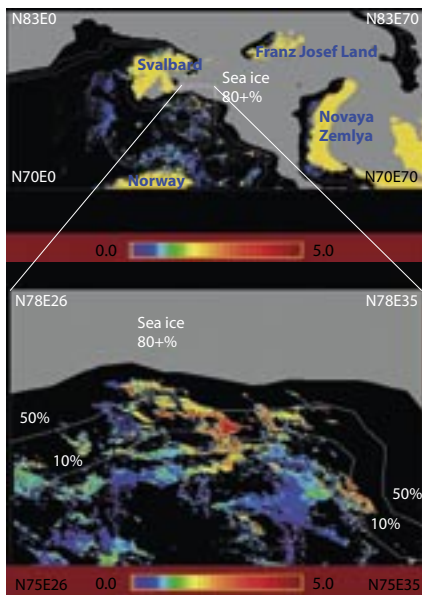


Figure 2

Ocean colour map of chlorophyll-a distribution (mg Chl-a/m³) in the Marginal Ice Zone of the northern Barents Sea based on SeaWiFS satellite data for the period of 6-21 May 1999 (Engelsen *et al.* 2002). Black areas contain no data due to quality flagging, whereas solid grey is areas with 80% or more sea ice concentrations on 16 May 1999. The two other grey isolines are 10% and 50% sea ice concentrations on this day. The area inside the white frame is shown enlarged, as a separate figure.

saline Arctic water masses. The Polar Front generally follows the bottom topography at 250 m depth, although the approximate location of the front can also be observed as the boundary between warm Atlantic and cold Arctic waters.

Marginal ice zones are highly productive areas. Arctic water masses north of the Polar Front are generally less productive than Atlantic water masses, but the production becomes concentrated in the vicinity of the ice edge. The ice edge effect has a major influence on the spring bloom pattern, although the spatial variability of the chlorophyll-a concentrations in this region is high, as shown by satellite images of ocean colour (Engelsen *et al.* 2002). If satellite information on phytoplankton biomass and/or primary production is to be used on a large scale, phytoplankton must be reliably quantified in terms of sea-surface chlorophyll-a, which can be extended to determine an integrated plankton biomass for the water column. Relationships between surface chlorophyll-a and mean water

Figure 3

- *Calanus glacialis*, an important copepod in Arctic waters.
Photo: Werner Hannappel
- Head of *Sagitta elegans*, an arrow worm.
Photo: Werner Hannappel
- The ctenophore *Mertensia ovum*, an important *Calanus* predator.
Photo: Haakon Hop



column concentrations within the euphotic zone (0-50 m) have recently been established for the Barents Sea MIZ (figure 2) (Engelsen *et al.* 2002).

The primary producers consist of both phytoplankton (Phaeocystis and diatoms) in the water column and ice algae (mainly diatoms) under drifting sea ice. In the spring, melt water causes salinity gradients in the water column, thus forming a Surface Mixed Layer, which confines the phytoplankton mainly within the euphotic zone where there is sufficient light for photosynthesis and growth (Engelsen *et al.* 2002). The stratification of the upper water masses combined with an ample supply of nutrients after the winter, increased radiation from rising solar elevations and decreased sea ice concentrations during the spring, sets the stage for vigorous phytoplankton blooms. The peak of the bloom may reach biomass (chlorophyll-a) values of 20 mg/m³ at the surface and integrated values up to 900 mg/m² for the upper 50 m of the water column (Hegseth 1992). The relatively high annual primary production in the northern Barents Sea (40-50 g C/m²; Hegseth 1998) is related to the fact that sustained algal blooms sweep across the sea during the seasonal retreat of the melting pack ice.

The large production along the ice-edge and far into the ice zone itself results in a high abundance and biomass of ice-fauna (Hop *et al.* 2000)

and zooplankton (Falk-Petersen *et al.* 1999). The strong seasonal pulse of energy, in the form of marine lipids, through the ice-associated and pelagic marine food webs directly influences the abundance of upper trophic levels. Marine mammals and seabirds represent the top levels of generally long food chains (4-5 trophic levels) in the MIZ, but many food chains are shorter. Because fish typically is the missing trophic level in the shorter chains, they can be referred to as non-fish food chains.

Examples of short pelagic food chains are ones that start with phytoplankton and continue with: *Calanus* spp. (copepods) and ctenophores (comb jellies), of which *Beroë cucumis* is the only main predator on *Mertensia ovum*; pteropods (winged snails or sea butterflies), of which *Clione limacina* rely on *Limacina helicina* as a prey; *Calanus* spp. and chaetognaths (arrow worms). These food chains may be referred to as dead-end food chains, since the energy of the species is not transferred to the top predators in the pelagic food web. Large abundance peaks of gelatinous zooplankton, possibly related to rapid climate changes, may have a significant impact on secondary production in the Barents Sea (e.g. grazing up to 10 % of the copepod biomass per day).

The Norwegian Polar Institute has carried out field research on the

marine food web of the Marginal Ice Zone as part of two multidisciplinary research programmes: "Ecological and physical processes in the Marginal Ice Zone of the Northern Barents Sea (ICE-BAR)" (1995-1996) and "Temporal and spatial variability of the ice-ocean system of the ice-edge in the Marginal Ice Zone of the Barents Sea" (1999-2000 cruises). The overall goal of the programmes, which were led by Drs. Stig Falk-Petersen and Haakon Hop, was to increase our understanding of the importance of the MIZ for the productivity and biodiversity in the northern Barents Sea. So far, the programmes have resulted in more than 40 publications in the primary literature, but there are still many gaps in our understanding. Particularly, the large spatial and temporal variability is inadequately described, and long-term changes in the Arctic marine ecosystem with respect to climate changes need to be further assessed. There are dramatic predictions for the Marginal Ice Zone. The ice extent in the Barents Sea may soon start to

increase because of an expected cold cycle, but the cold period may be of relatively short duration (5 years?) and the ice may then continue to retreat northward because of a general warming trend in the northern seas. The ice may disappear completely from the Barents Sea and the shelf north of Svalbard during the summer, with large consequences for the energy flow in the marine food web. The short pelagic food chains will likely become even more important in the ice-free Arctic seas.

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Hooded Seals – Expert Divers in the Arctic Oceans



Figure 1
Adult female hooded seal (*Cystophora cristata*) with her pup (called "blueback").
Photo: Michele Di Paolo

Lars Folkow larsf@fagmed.uit.no
Arnoldus S. Blix asblix@fagmed.uit.no
Department of Arctic Biology and Institute
of Medical Biology, University of Tromsø

There has always been a fascination in how seals and whales, air-breathing animals as they are, dive to great depths and for extended periods of time. Laboratory and field studies have revealed many of the adaptations that make this lifestyle possible. One species which has recently been subject of quite detailed studies at the University of Tromsø's Department of Arctic Biology, is the hooded seal, *Cystophora cristata* ("klappmyss" in Norwegian). This seal is quite abundant, breeding in ice-covered waters off the east coasts of Canada and Greenland in March/April. Adult male hooded seals ("hettakall") may reach weights of 300 - 400 kg, while females are about half this size.

We used satellite-linked dive-recorders to study the distribution and diving behaviour of free-living hooded seals from the Greenland Sea ("Vestisen") population, and found that these seals sometimes dive to depths exceeding 1,000 m and stay submerged for more than 50 minutes. While at sea, they dive repeatedly around the clock for weeks at a time, spending more than 80% of their time under water. This performance is made possible by their very large blood volume – corresponding to about 25% of their body mass, compared to only 6-7% in man – and by very high concentrations of the oxygen-binding blood pigment hemoglobin, which may reach levels of about 270 g l⁻¹ (human are barred from competition if their levels exceed 185 g l⁻¹). These adaptations allow large quantities of oxygen to be stored for use during diving. We also found that hooded seals have the

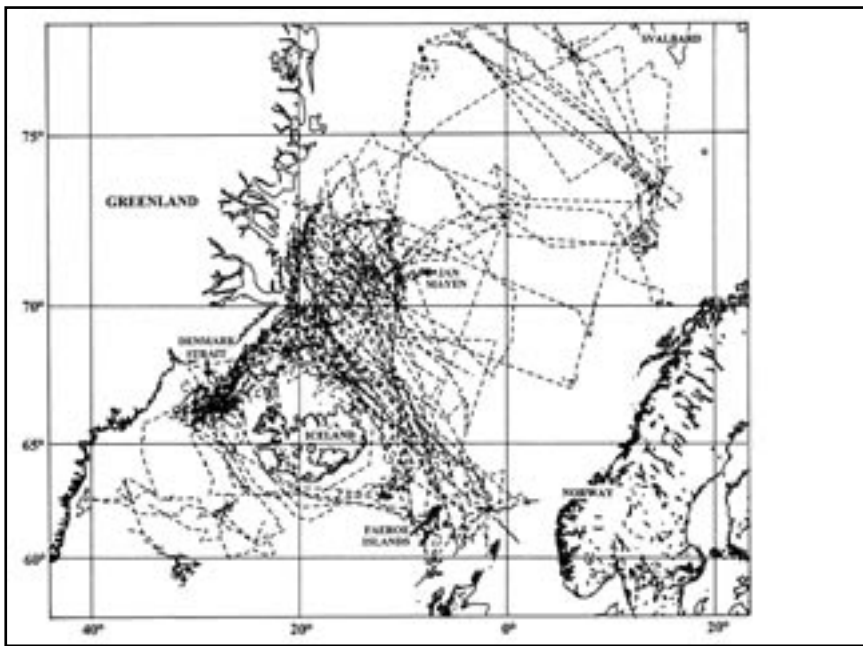


Figure 2

The movements of 15 subadult/adult hooded seals (5 males, 10 females) between moulting in July 1992 and breeding in March 1993. All seals were equipped with satellite-linked dive recorders which yielded data on both the daily locations and the diving behaviour (diving depths and durations) of the tagged seals.

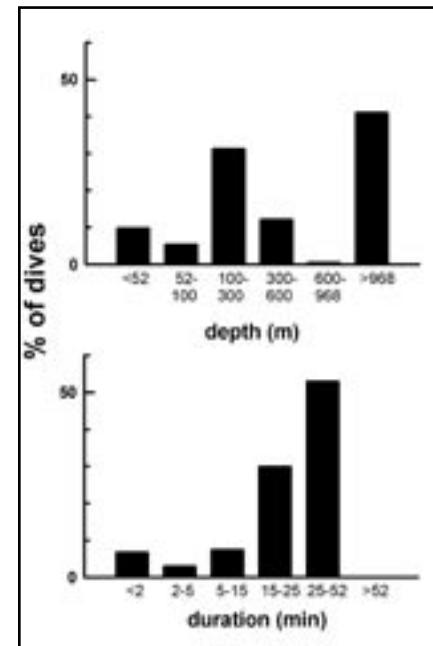


Figure 3

Frequency distribution of the maximum depths (upper panel) and the durations (lower panel) of 1,145 dives performed by an adult male hooded seal near Jan Mayen in winter (January). Note that more than 40% of the dives reached depths exceeding 968 m.

highest concentrations of the oxygen-binding muscle pigment myoglobin ever recorded in any mammal (>9 g%), which further contributes to the impressive oxygen-storing capacity of these animals.

However, even though their oxygen stores are large, they are not unlimited. The seals must therefore conserve them during long-duration diving. They do this by selectively distributing the blood to the brain and the heart (which depend on oxygen) while the rest of the body may have to sustain metabolism without oxygen, or utilize local oxygen stores (in the muscles). In addition, hooded seals display a pronounced fall in brain temperature of up to 3.5°C, when they dive. This cooling of the brain decreases its rate of oxygen consumption, and since it is the main consumer of blood-borne oxygen during long-duration diving, cooling limits the use of oxygen

stores and thereby extends dive duration even further.

We assume that these seals dive to such great depths to find food. Hooded seals are known to prey on several deep-water species such as redfish (*Sebastes* spp. – "uer"), Greenland halibut (*Reinhardtius hippoglossoides* – "blåkkeite") and squid (e.g. *Gonatus fabricii*). But how do these animals, which are abandoned by their mothers less than one week after birth and receive no training – know where to dive to find food, and how do they locate and catch prey in complete darkness at 1,000 m depth? Current studies at the Department of Arctic Biology and elsewhere suggest that use of acoustic and visual cues may be important in some situations (the latter at shallow depths or in locating bioluminescent prey). However, these senses are probably of secondary importance compared

to the tactile senses of their highly sensitive whiskers, which detect small currents created by swimming prey at closer range, and thereby allow their capture in complete darkness.

The Bjørnøya Study: Transport, Deposition and Uptake of Persistent Organic Pollutants in Two Arctic Lake Systems

Anita Evenset

anita.evenset@akvaplan.niva.no

Guttorm N. Christensen

guttorm.christensen@akvaplan.niva.no.

Akvaplan-niva, Polar Environmental Centre,
Tromsø

During recent years, multidisciplinary studies have been carried out on Bjørnøya, the southernmost island of the Svalbard archipelago, elucidating the presence of persistent organic pollutants (POPs) in this pristine Arctic environment. High concentrations of conventional persistent organic pollutants, mainly polychlorinated biphenyls (PCB) and the DDT-metabolite p,p'-DDE, have been measured in sediment and biota from lake Ellasjøen, a lake located in the southern, mountainous part of Bjørnøya. Concentrations of POPs in the muscle of Arctic charr (*Salvelinus alpinus*) from Ellasjøen are among the highest ever reported from remote Arctic regions (e.g. research note p. 9). In lake Øyangen, located only six km north of Ellasjøen on the central plains of the island, levels of POPs are several times lower.

One reason for the different POP contamination levels in Ellasjøen and Øyangen is probably differences in the precipitation regime between the southern mountainous part of the island and the central plains, leading to differences in the deposition of air transported contaminants. Another possible source for contaminants to Ellasjøen is large colonies of seabirds that occur close to the lake – mainly kittiwake (*Rissa tridactyla*), little auk (*Alle alle*) and glaucous gull (*Larus hyperboreus*). These seabirds feed in the marine environment and deposit large amounts of guano (excrement) directly into the lake or in the precipitation field of the lake. Guano may therefore act as a transport medium for contaminants from the marine to the limnic environment. Øyangen is much less influenced by seabirds than Ellasjøen.



Figure 1
Ellasjøen, Bjørnøya.

These two hypotheses are being investigated on Bjørnøya through two projects run by Akvaplan-niva, the Norwegian Institute for Air Research, the Norwegian Polar Institute (all partners in the Polar Environmental Centre in Tromsø) and the Norwegian Meteorological Institute. A range of POPs are being analysed in samples of air, rainwater, snow and fog, as well as guano samples from the seabirds living in the vicinity of Ellasjøen. Meteorological data (rain- and snow-fall, occurrence of fog, temperature etc.) from the Ellasjøen area and from the northern part of the island is continuously monitored. Uptake and transport of POPs through the freshwater food-chains are being investigated through a sampling programme on lake biota.

The results obtained so far support both hypotheses. The amount of precipitation as well as the occurrence of fog is significantly higher around Ellasjøen than on the central plains further north. Analyses of the different atmospheric transport media (air, fog, rain, snow) further indicate that fog may be very important for deposition of airborne contaminants. Moreover,

analyses of guano from little auk, kittiwake and glaucous gull indicate that seabirds contribute significantly to the elevated levels of pollutants in Ellasjøen. Separated by a distance of only six km, these lakes exhibit distinctly different mechanisms of contaminant transport.



Figure 2
Bjørnøya including Øyangen, Ellasjøen and the meteorological station.

Winter Emaciation Sensitizes Arctic Animals toward Persistent Organic Pollutants Like PCB



Figure 1
Akvaplan-niva, here represented by Anita Evenset, detected extremely high levels of PCB in Arctic charr from Ellasjøen. Photo: Guttorm Christensen.

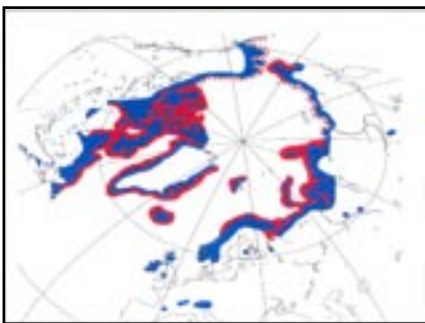


Figure 2
The distribution of Arctic charr. Blue colour represents the total distribution area and red colour represents the distribution of the sea-migrating (anadromous) form. The circumpolar distribution and abundance of this species throughout the whole Arctic has made the Arctic charr an excellent candidate for monitoring pollutants in the Arctic.

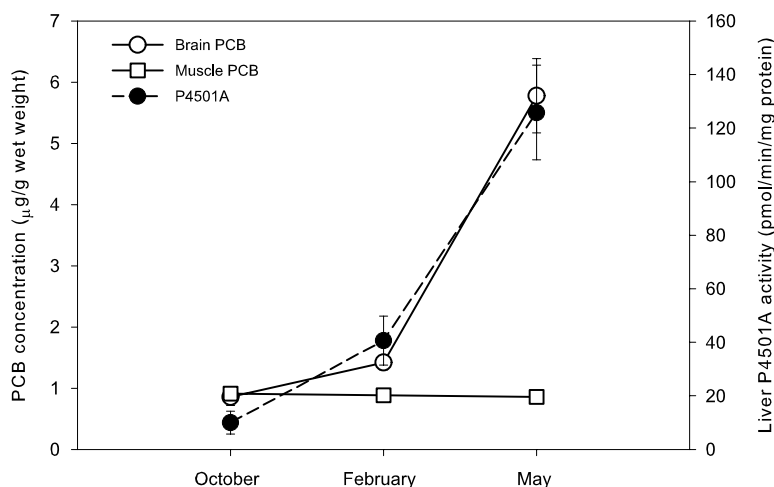


Figure 3
Change in brain and muscle PCB concentrations, and liver P4501A enzyme activities, in non-feeding, overwintering anadromous Arctic charr given 1 mg PCB/kg in August.

Even Jørgensen

Norwegian Institute for Nature Research,
Polar Environmental Centre, Tromsø

The Arctic charr (*Salvelinus alpinus*) is the northernmost distributed freshwater fish. In both resident freshwater and marine migratory (anadromous) forms the species is numerous throughout the whole Arctic (Figure 2). The Arctic charr is well suited for a polar life and manifests many biological adaptations typical for high-latitude animals. One such adaptation is the ability to tolerate very low food availability during winter. Akvaplan-niva, Tromsø, detected in 1998 extremely high levels of PCB (polychlorinated biphenyls) – up to 5 mg/kg muscle wet weight – in Arctic charr from Ellasjøen, Bjørnøya (Figure 3). The levels exceed thresholds associated with reproductive disorders and immunosuppression in laboratory animals. This has motivated research on the effects of PCB on winter-fasting Arctic charr.

In the Arctic, food availability varies substantially throughout the year and like many other high-latitude animals, the Arctic charr display pronounced seasonal cycles of “fattening” and emaciation. During the 7-9 weeks summer residence in the sea, the body weight of anadromous Arctic charr may double, and the storage of body lipids increase up to six-fold. During overwintering in freshwater, body weight decreases and the lipid stores are totally depleted by the time the fish embark upon a new seaward migration next summer. Lipid-soluble persistent pollutants, like PCB, deposit in the body lipid stores, where they do little harm. It is known among humans that extreme emaciation (e.g. associated with anorexia) results in mobilization of deposited pollutants like PCB and an increased risk of toxic effects. Little is known, however, about the behaviour of such pollutants, and their toxic potential, in association with natural fasting and emaciation. To investigate these mechanisms, well-fed Arctic charr returning from the sea

in July were given an environmental realistic dose of PCB. Thereafter they were held in captivity at natural water temperatures and without being fed until May. In October, February and May six fish were collected for measurement of body lipids, tissue PCB concentrations and liver 4501A enzyme activities. These liver enzymes respond to the presence of pollutants like PCB in a dose-dependent way, and they are therefore extensively used as biomarkers of pollutant exposure.

During winter the fish lost approximately 74% of their total body lipids, and this loss was similar to that found in wild charr overwintering in the lake. This indicated that the experimental set-up was realistic as a model to study toxicological processes associated with natural fasting. During winter the total PCB body burden decreased by only 20%, which shows that PCB is very persistent in "cold-blooded"

animals living in ice-cold Arctic waters. There was a net loss of PCB from the muscle, the main lipid storing organ in Arctic charr, and a net input of PCB to the liver and brain during winter. This indicates that the ability of the muscle to store PCB decreased along with the mobilization of muscle lipids depots. As a result of these processes, the average brain PCB concentration increased six-fold from October to May (Figure 3). In the liver, CYP1A enzyme activity increased 12-fold during the same period (Figure 3), showing that the biological activity of PCB (which reflects the toxic potential of PCB) was at least 12 times higher in May than in October, despite the fact that the total body burden of PCB had decreased by 20 %.

These changes points to an increased risk of pollutant-associated stress during periods when energy stores are depleted.

In general, the finding indicate a lowered dose-response threshold in Arctic inhabitants that exhibit annual episodes of lipid depletion. In support of this, recent experimental studies have shown endocrine and immunological dysfunction in lean Arctic charr at very low PCB concentrations, whereas fat Arctic charr seems to be able to handle very high burdens of PCB.

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New Act for Protection of the Svalbard Environment

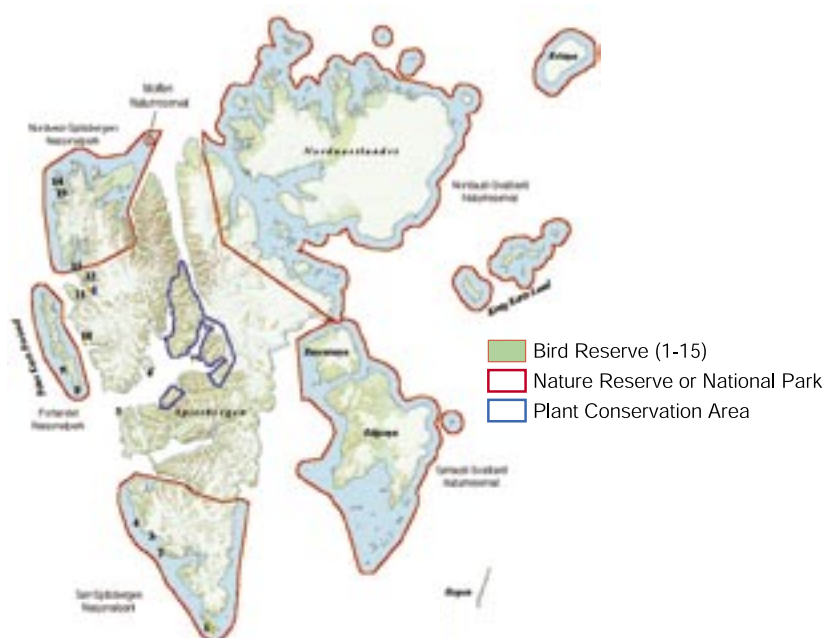
It is an overriding objective of the Norwegian government to preserve Svalbard's distinctive and natural wilderness. The archipelago is to

be known as one of the world's best managed wilderness areas, and when environmental considerations conflict with other interests, the environment is

to take precedence. The Norwegian authorities want Svalbard to be an international platform for polar research, in accordance with international agreements and current Norwegian legislation.

A new Svalbard Environmental Protection Act entered into force in July 2002. The purpose of the Act is to preserve a virtually untouched environment in Svalbard with respect to wilderness areas, landscape, flora, fauna and cultural heritage.

Anyone planning, in charge of, or participating in research projects in Svalbard carries a responsibility to keep up to date with laws and regulations which apply in the archipelago. Project leaders are legally obligated to inform their subordinates about the relevant laws and regulations. Check the Internet at <http://www.miljo.no/handbook> for information on field work in Svalbard. The site also has a link to the English version of the Svalbard Environmental Protection Act.



Playing an important role as reference areas for research, Svalbard's protected areas shall be as untouched by human activities as possible. Scientific projects will be allowed following an application as long as the activities do not interfere with the main objective of the protected area; the research cannot be done in areas other than those named in the application.

Arctic Ecosystem Response to Severe Air Pollution

Henning Jensen

henning.jensen@npolar.no
Geological Survey of Norway,
Polar Environmental Centre, Tromsø

Substantial areas in the Norwegian – Russian – Finnish border region are affected by pollution emanating from the Russian industrial complexes of Nikel and Zapoljarnyj. These areas represent some of the most polluted and severely damaged ecosystems in Europe. Air pollution by sulphur dioxide (SO₂), heavy metals and organic pollutants poses environmental problems to the ecosystem. How does the ecosystem respond to this heavy air transported pollution?

An international scientific group has prepared a joint project to study the effects of air-borne pollution on the Arctic ecosystem. Biologists and remote sensing scientists from the Norwegian Institute for Nature Research (NINA), biologists from Finland's Forest Research Institute (METLA), soil scientists from Russia's Institute of the Industrial Problems of the North (INEP) and geochemists from the Geological Survey of Norway (NGU) have formed an interdisciplinary project group with financial support from regional funds. The group has carried out field work and sampling at a total of 31 field and sampling stations north, south and west of Nikel – spanning in severely polluted areas close to Nikel and areas further away from Nikel. Selected species of plants and animals (birds, insects, small mammals) and soil have been described in the field and sampled for further analysis.

Plant vitality recorded for trees as well as ground vegetation shows that vegetation health increases with distance from Nikel. Measurements of plant vitality using a "Plant Stress Meter" on leaves from downy birch, mountain birch and blueberry bushes show that the plant species have different photosynthetic efficiency. Higher photosynthetic efficiency is



Figure 1
Damaged vegetation in the vicinity of Nikel.
Photo: Ragnar Våga Pedersen, Svanhovd miljøsenster



Figure 2
Picture taken with an infrared camera to demonstrate plants vitality for trees and ground vegetation around the Nikel smelter.
Photo: Henning Jensen

equivalent to less stress. Mountain birch is sensitive to pollution induced stress, whereas downy birch and blueberry are less reactive to pollution induced stress. Another method – infrared camera photography – shows reduced vitality of the trees close to the smelter in Nikel.

Levels of pollution are measured in plants and the top of the soil layer. Birch tree (*Betula pubescens*) and blueberry (*Vaccinium vitis-idaea*) plant chemistry reflect the level of air pollution stress within the ecosystem. The nickel (Ni) and copper (Cu) concentrations in birch and blueberry

leaves decrease with increasing distance from the smelters. These heavy metals are emitted from the smelters along with aerosols, which are deposited in the surrounding areas.

The vulnerability of the ecosystem depends on many factors. Future work will investigate the complexity of the ecosystem through application of statistical methods. Integration of biological data, soil data and geochemical data will help us to gain a better understanding of how the ecosystem responds to severe air-borne pollution.

Indigenous Political Influence in the Arctic

Oran R. Young

oran.r.young@dartmouth.edu
Faculty of Social Science, University of Tromsø

The Arctic's indigenous peoples are few in number and poorly endowed with resources, such as money or votes, ordinarily regarded as essential to the exercise of political influence. Yet during the last several decades, these peoples have achieved some notable successes in pursuing their objectives both within individual countries and in a variety of international forums. How can we explain these achievements, and what are the prospects for continued or even enhanced success during the near future? These questions lie at the heart of several research initiatives under way or under development at the University of Tromsø.

Through much of the modern era, the indigenous peoples of the Arctic have suffered from a variety of more or less severe problems, ranging from low life expectancies to a lack of recognition of rights to self-determination and access to land and living resources. But the last 3-4 decades have witnessed significant improvements in the lot of these peoples. Southern governments have moved to recognize and settle the claims of Arctic peoples to ownership and control of land and natural resources. New political units have emerged (e.g. the North Slope Borough in Alaska, the Greenland Home Rule, Nunavut in Canada) in which Natives are in the majority. Access to services – including health, education, and welfare – has improved in many northern predominantly indigenous communities. The Arctic Council recognizes six indigenous peoples organizations as Permanent Participants. The voice of the Arctic's indigenous peoples has gained strength at the global level as well. Arctic peoples have played important roles in such initiatives as the drafting of Chapter 26 of Agenda 21, the negotiation of the Stockholm Convention on Persistent Organic Pollutants, the effort to formulate



Figure 1

Nenets from the Enysei River in Western Part of Taimyr Autonomuos Okrug, Russia.
Photo: Konstantin Klovov

an international Declaration on Indigenous Peoples, and the creation of the UN's Permanent Forum on Indigenous Issues.

Although much remains to be done, these achievements are striking. A number of factors operating together appear to account for this success.

- The indigenous peoples of the Arctic have organized effectively through the creation of bodies like the Inuit Circumpolar Conference (ICC), the Sámi Council, and Russian Association of Indigenous Peoples of the North (RAIPON),
- These bodies have coordinated their efforts and cooperated with other actors (e.g. environmental groups) on specific issues,
- Indigenous peoples have benefited from broader developments including the rise of non-state actors and the growth of global civil society,
- The Arctic states have provided substantial support for northern predominantly indigenous communities as a means of maintaining sovereign authority in the North,
- Northern peoples have benefited from a broader shift toward devolution of authority from central to regional and local governments,

- These peoples have gained as well from the spread of new perspectives on minority and indigenous rights,
- The growth of the idea that dominant societies have certain ethical obligations to indigenous groups residing in their midst has increased respect for the rights of the Arctic's indigenous peoples,
- By and large, the indigenous peoples movement in the Arctic has been blessed with strong leadership.

How have these factors interacted to produce specific results, and what additional consequences can be expected to flow from these interactions in the future? How will the interests of indigenous peoples fare in the face of mounting pressures to develop the natural, and especially nonrenewable, resources of the Arctic? These questions form the core of the research agenda on indigenous political influence in the Arctic.

Further information

ICC Inuit Circumpolar Conference:
www.inuit.org
Sámi Council:
www.saamicouncil.net
RAIPON Russian Association of Indigenous Peoples of the North:
www.raipon.org

Norwegian Radiation Protection Authority



Soil sampling under a bird cliff in the Kongsfjord area, Svalbard.
Photo: Sebastian Gerland

In the summer of 1999, the Norwegian Radiation Protection Authority (NRPA) established an Environmental Unit in the Polar Environmental Centre in Tromsø. The NRPA, with its head office at Østerås, is organized under Norway's Ministry for Health and is the country's authority on the topic of radiation protection and nuclear safety. NRPA is also the expert authority for the Ministry of the Environment on the issue of radioactive pollution of the environment. The Tromsø Environmental Unit was formed to promote collaboration between the NRPA and the other Polar Environmental Centre institutions in developing the Centre according to its visions and maximizing utilization of Centre resources.

The Tromsø Environmental Unit currently consists of Dr Mark Dowdall and Dr Justin Gwynn, who have expertise in radioecology, radiochemistry, environmental biology and oceanography. Important tasks for the unit are research, monitoring, impact assessments, and enhancing knowledge on sources, transport processes and uptake mechanisms of radioactive pollution in Arctic areas.

There are many sources that contribute to radioactive contamination in the northern and Arctic regions. The most important of these are long-range transport of



Sampling sea ice in Kongsfjorden, Svalbard. Photo: Sebastian Gerland

radioactive pollution via air and ocean currents following the atmospheric weapons testing programmes, the Chernobyl accident and releases from European nuclear reprocessing activities. Russian nuclear operations also release radioactive materials to the Ob and Yenisey rivers that flow into the Kara Sea. In addition, there are many potential sources, such as nuclear powered vessels, nuclear installations and dumped nuclear waste, that might in the future result in increased radioactive pollution in the northern marine environment.

The Environmental Unit's activities include research, fieldwork, sample processing and measurements, combined with analysis, publication and presentation of data and findings. Fieldwork in the Arctic and Sub-Arctic with coordination and participation of staff from the Environmental Unit has included:

- Marine and terrestrial radioecological research and mapping in the Kongsfjord area, Svalbard.
- Marine radioecology in Fram Strait with RV Polarstern.
- Monitoring of possible pollution from the Russian submarine Kursk that sank in the Barents Sea in 2000.
- Monitoring of levels of technetium-99 (99Tc) in the marine environments near Bjørnøya, Hopen, Jan Mayen and Kongsfjorden.

The Unit's scientific work is linked to both national and international research projects (financed by the Research Council of Norway, the European Union and the Norwegian Department of Foreign Affairs). The laboratory of the Environmental Unit has been designed with flexibility in mind and is equipped to handle a range of radiometric analyses. Instrumentation consists of advanced gamma-detectors, of both high and low resolution, and beta-detectors that enable the detection of a range of radioactive materials in diverse environmental samples (e.g. soils, water, vegetation, and sediment). Some simpler instrumentation and hand monitors can also be used in the field in emergency situations or in the event of an accident. The presence of the Unit's laboratory, equipment and expertise constitutes an important local presence in the event of an accident involving radioactive materials.

Contact details

NRPA, Environmental Unit,
Polar Environmental Centre,
N-9296 Tromsø
Tel.: +47 77 75 01 70,
Fax: +47 77 75 01 71
www.nrpa.no

The European Incoherent Scatter Radar Association for Studies of the Auroral Ionosphere (EISCAT)

Finland, France, Germany, Norway, Sweden and the UK established the EISCAT in 1975. By 1980, two radar systems - a VHF system at 224 MHz and a UHF system at 993 MHz - were established near Tromsø (Norway) and receiving stations for the UHF system were set up in Kiruna (Sweden) and Sodankylä (Finland).

After more than 20 years of experience and development, EISCAT is now the most advanced system of its kind in the world. The incoherent scatter radar technique is by far the most powerful groundbased tool available today to observe and calculate a variety of physical parameters in the upper atmosphere - parameters that are of crucial importance for testing theories and models of the effects of solar wind disturbances, magnetic storms and auroral displays in the atmosphere. EISCAT, with its three sites, is unique in the world in that it enables the measurement of truly three-dimensional vector velocities of the ionospheric plasma.

In the early 1990s the EISCAT community decided to establish an incoherent scatter radar in Svalbard, and in 1996 the EISCAT Svalbard Radar (ESR) was operational. Following substantial contributions from Japan, who joined the EISCAT association in 1996, a second antenna was installed in Svalbard in 2000. The ESR increased the coverage of the EISCAT radars from the Auroral Zone to include the Polar Cap which is both the most dynamic and the least understood region of the near-Earth space environment. In Svalbard, EISCAT is developing the facility via inclusion of an MST radar for studies of the middle atmosphere and the polar mesosphere, a field of research strongly connected to the study of global climate change.

In addition to the incoherent scatter radar system EISCAT is operating a strong, high frequency



EISCAT Svalbard Radar. Photo: EISCAT Association

radio transmitter (HEATING) in Tromsø - a system used to create "artificial" northern lights, enabling closer investigation of this phenomenon.

A Council governs the activities of the EISCAT association, with members from each of the associate countries. One important scientific objective for the EISCAT association is to establish long-term data series describing fundamental physical parameters of the auroral zone and the polar upper atmosphere. Such time series have the potential of enabling researchers to study the possible effects of processes in the upper strata of the atmosphere on global climate change. To facilitate investigations of this type, the EISCAT association has established a common database containing information from both the EISCAT system and from other incoherent scatter radars.

The present EISCAT agreement terminates in December 2006. In the process of preparing for prolongation of EISCAT, the association is inviting new member countries to join the project. According to Professor Asgeir Brekke of the University of

Tromsø, an extension of the long-term database is a strong incentive for the continuation of the EISCAT project, but it is equally important to involve the EISCAT community in new and innovative science.

"Radio astronomy is one field where the EISCAT facility has a great, but so far only moderately explored, potential. In the future we should also seek ways of improving the radar system in order to open up new areas of research, e.g. interferometry - a technique used to study fine scale structures of filamentary currents in the polar atmosphere related to auroral events", says Brekke.

Contact details

EISCAT Scientific Association,
Ramfjordmoen,
N-9027 Ramfjordbotn
Tel.: +47 77 69 21 66
Fax: +47 77 69 23 80

Further information

Science director Tony van Eyken,
e-mail: Tony.van.Eyken@eiscat.uit.no
www.eiscat.no



Landmarks: The Polar Environmental Centre building resembles a ship's hull, providing excellent facilities for scientific work and conferences. The visitors centre Polaria is situated in the neighbouring, ice floe-inspired building. Photo: Polarmiljøseneteret AS

The Polar Environmental Centre in Tromsø

As Norway's focal point for research, environmental monitoring and advisory services in the Polar areas and the Barents region, the Polar Environmental Centre houses a number of large national research and administrative institutions. With a staff of over 200 people, the Centre comprises a significant and unique collection of knowledge, in terms of a broad academic perspective as well as depth of research.

Most fields of study within the natural environment of the polar areas and the Barents region are represented in the Centre, the proper name of which is Centre for the Environment and Co-operation in the Polar Areas and the Barents Region. Studies of air, water, land and living organisms are carried out in research and development projects and through management-related work. In conjunction with a vast contact network and co-operation with institutions home and abroad, the Centre is capable of undertaking both national and international assignments.

The Polar Environmental Centre was established as a result of the ruling by the Norwegian Parliament in 1993 to move the Norwegian Polar Institute from Oslo to Tromsø. There



The Norwegian Polar Institute anchors the Polar Environmental Centre and maintains research facilities in Svalbard and Dronning Maud Land, Antarctica. Among the other institutions found in the centre are Akvaplan-niva (aquaculture/environmental monitoring/marine and freshwater biology), the Norwegian Institute for Nature Research, the Norwegian Institute for Air Research, the Norwegian Mapping Authority, the Geological Survey of Norway, the Norwegian Radiation Protection Authority and Unilab Analyse AS. Photo: Jan Roald

has been concrete co-operation between the institutions since 1994, and in 1998 the institutions were co-located in a new building comprising 15,000 square metres in Tromsø's city centre.

To ensure ecologically sound management of the polar territories, a solid knowledge foundation based on research is required. Norway is situated to the far north, in the Arctic and sub-Arctic regions. The

geographical location forms a natural background for the nation's long traditions in research and enterprise in the polar areas.

Contact details

Polarmiljøseneteret AS
Polar Environmental Centre,
N-9296 Tromsø
Tel.: +47 77 75 02 00
www.polarenvironment.no

AMAP Conference

The Arctic Monitoring and Assessment Programme (AMAP) was established in 1991 to co-ordinate circumpolar Arctic pollution monitoring and assessment activities. A number of international conferences have been arranged, addressing issues ranging from levels and trends of radioactivity, heavy metals, acidification, oil and persistent organic pollutants (POPs), through to effects of pollution on wildlife and human populations. The conference and workshop on impacts of POPs and mercury on Arctic environments and humans, held at the Polar Environmental Centre in Tromsø in January 2002, was the first to summarize current knowledge of possible effects from these pollutants.

AMAP Symposium

held in Rovaniemi, Finland in October 2002, addressed pollution of the Arctic in an integrated circumpolar context, focusing on a variety of pollution issues and presenting work conducted under the auspices of AMAP during the period 1998-2003. The 2002 AMAP State of the Arctic Environment Report, Arctic Pollution 2002, was presented at the conference, and its findings prompted considerable media attention. Further information can be obtained from the programme's web site: <http://www.amap.no>.

China in the Arctic

Directors Qu Tanzhou of the Chinese Arctic and Antarctic Administration (CAA) and Olav Orheim of the NPI signed a memorandum of understanding in August 2002, which will lead to further development of polar studies and enhance bilateral co-operation on polar activities between China and Norway. The CAA operates under the State Oceanic Administration (SOA), and was in charge of a government delegation that visited Norway in September 2002. During their stay, the Chinese announced their intention to set up a scientific station in Svalbard within five years.

As part of a three-year research programme that will be completed in 2003, 16 Chinese scientists

participated in a scientific expedition to the archipelago last autumn. The expedition's objective was to compare the ecological system in Svalbard with the Qinghai Tibet Plateau in south-west China.

Fifth Conference of Parliamentarians of the Arctic Region

Tromsø hosted a conference in August 2002, arranged by the Standing Committee of Parliamentarians of the Arctic Region. The Committee started its activities in 1994, and one of its original priorities was to support the establishment of the Arctic Council. This new organisation, representing the eight Arctic states Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden and the USA, was founded in 1996.

The Tromsø conference focused the work of the Arctic Council and the World Summit on Sustainable Development and human development in the Arctic. The conference was attended by representatives from the national parliaments of the Arctic states and the European Parliament. Observers also participated from governments and interparliamentary organisations as well as from observer states and a number of international organisations. The conference adopted a statement, available at <http://www.arctic-council.org/tromso.html>, and made recommendations to the Arctic Council and to the governments of the eight Arctic states and the European Commission.

NySMAC Seminar

The Ny-Ålesund Seminar Series was initiated by the Ny-Ålesund Science Managers' Committee (NySMAC), to increase the collaboration between national programmes, the research stations and the scientific disciplines situated at the international research facility in Svalbard. The seminars invite the whole physical environment research community of Ny-Ålesund to present research results and exchange information about their research and monitoring activities.

All seminars have been organized by the countries that have established permanent research stations in Ny-Ålesund. The sixth seminar was

arranged by the Norwegian Polar Institute at the Polar Environmental Centre in Tromsø in October 2002. More than 60 delegates from 15 countries discussed the topic: "The changing physical environment". The proceedings from the conference (extended abstracts) were printed in the Norwegian Polar Institute's report series. About 15 peer-reviewed papers will be published in a special edition of Elsevier's Physics and Chemistry of the Earth in the spring of 2003.

ACIA

The Arctic Climate Impact Assessment process was initiated by the Arctic Council to assess and analyse the effects of climate change on the Arctic environment and people. Three ACIA workshops were arranged in 2002 by the Norwegian Polar Institute, which is the national secretariat for the process. The January workshop in Tromsø, which gathered around 35 people, focused on the effects of climate change on transportation, energy production and supply and settlement in northern Norway. The February workshop in Kautokeino, that was attended by 100 people, discussed the consequences for reindeer herding, agriculture and natural resource management. In April, approximately 60 people gathered for a workshop in Longyearbyen, which concentrated on the possible consequences climate change on Svalbard. A summary of all workshop proceedings can be downloaded from <http://www.acia.npolar.no>.

Multidisciplinary Master's degree study

In the autumn of 2002, ten students were admitted to a new course of study at the University of Tromsø with a curriculum focusing on agriculture and the use and management of natural resources in Arctic regions. Reindeer husbandry, forestry, agriculture and watershed management will be cornerstones in the five year Master's programme. For further information, please contact the Faculty of Science at the University of Tromsø at postmottak@matnat.uit.no

Tromsø: Gateway to the Arctic

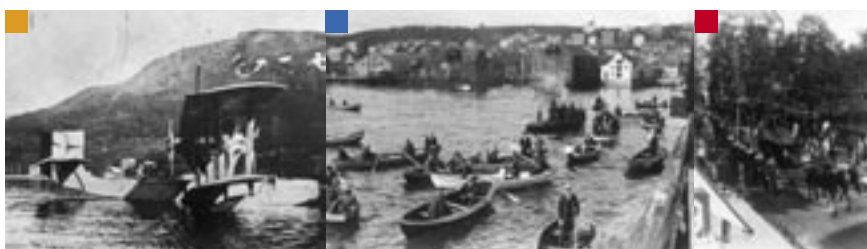
At 69°40'N, Tromsø is situated well above the Arctic Circle. Nicknamed "the Gateway to the Arctic," Tromsø has been a traditional starting point for expeditions to the far north. Historically, fishing and hunting that took place in the high Arctic was the basis for prosperity in this part of the world. The town's sailors, fishermen and hunters developed a unique knowledge of the Arctic, which made them valuable participants in most of the scientific expeditions that used Tromsø as a starting point.

In 1871, it was Elling Carlsen, a skipper from Tromsø, who found the remains of the Willem Barentsz' Expedition, which discovered the archipelago of Svalbard in 1596. When the Prince of Monaco set out on an expedition to the Arctic in 1906-07, he left from Tromsø on board his yacht *Princesse Alice*. This expedition is regarded the basis for the activities that led to the establishment of Norges Svalbard- og Ishavsundersøkelser (Norway's Svalbard and Arctic Ocean Survey) in 1928, which changed its name to Norwegian Polar Institute in 1948, as the geographical scope was broadened to comprise Norwegian interests in Antarctica.

On 4 April 1925 the American Lincoln Ellsworth and the Norwegian polar explorer Roald Amundsen arrived in Tromsø on board the coastal steamer, and the following days they were busy preparing for their voyage to Svalbard on board the *Hobby*, which would carry the two aircraft *N 24* and *N 25* to Ny-Ålesund (now a research base). Their attempt to reach the North Pole by air failed, but the following year they were back in Tromsø – this time on their way to Ny-Ålesund to attempt a flight with the dirigible (air ship) *Norge*. The international press was gathered in town, and much attention was brought to this small Arctic community. The expedition was a success. In 1928 the constructor and captain of the *Norge*, the Italian general Nobile, returned to Tromsø with the aim at undertaking a similar journey with an all-Italian dirigible, the *Italia*. Again Tromsø was the centre



Tromsø. Photo: Eiliv Leren, courtesy Destinasjon Tromsø, www.destinasjontromso.no



- Amundsen's *Latham* in Tromsø before its last departure.
 - Townsfolk showing their interest in the *Nautilus*.
 - The body of Andrée transported through Tromsø's Main Street.
- Photos: Norwegian Polar Institute Library

of international attention, which increased as Nobile went missing, and Amundsen left Tromsø on board the French seaplane *Latham* in search of the *Italia* and its crew. Amundsen was never to return from this mission, and it is still a mystery how and where the *Latham* disappeared. Nobile, however, was rescued and brought back to Tromsø. He later erected a memorial in town for those who perished during the dramatic days of June 1928.

In the summer of 1930 Tromsø was again in the news due to dramatic polar events. The Bratvaag expedition had left town to hunt and undertake scientific investigations in Franz Josef Land, but en route they found the remains of the Swedish engineer Andrée's camp on Kvitøya and returned to Tromsø with the bodies of Andrée and one of his crew members on board. Andrée had set out in 1897 to fly over the North Pole in a balloon, an attempt which failed. The following

year the Australian Wilkins made headlines as his submarine *Nautilus* left Tromsø for Svalbard. The idea was to sail underneath the Arctic ice cover. Also on board was the oceanographer who was later to become the first director of the Norwegian Polar Institute, Harald U. Sverdrup. The expedition was regarded a failure as mechanical difficulties prevented it from diving under the ice. It is thought a fearful crew member may have sabotaged the vessel.

Events such as the ones mentioned above have forever linked Tromsø with Arctic waters and polar exploration and research, and the city continues to have strong links with Svalbard and adjacent waters. Today, Tromsø has developed into a world centre for polar knowledge, and its polar research community covers a broad range of disciplines, including natural and physical sciences as well as the humanities.

Recent Doctorates in Polar Studies at the University of Tromsø

2000

Dr. med.

Tone Smith-Sivertsen

Air pollution and health in the Norwegian-Russian border area. A cross-sectional population-based study of nickel and sulphur dioxide.
Tone.Smith-Sivertsen@isf.uib.no

Dr. scient.

Erik Mårten Blixt

Local magnetosphere-ionosphere coupling and consequences of magnetohydrostatic equilibrium: pressure driven convection.
marten.blixt@phys.uit.no

Geir Gotaas

Energy expenditure in reindeer (*Rangifer tarandus tarandus*). Application of the Doubly Labelled Water (DLW) technique in a northern ruminant.
Geir.Gotaas@arctic.uit.no

Andreas Joachim Kirchhefer

Dendroclimatology on Scots pine (*Pinus Sylvestris* L.) in northern Norway.
andreas.kirchhefer@matnat.uit.no

Olav Lanes

Characterisation and determination of the molecular basis for cold adaption in uracil-CNA glycosylase from Atlantic cod (*Gadus morhua*).
olav.lanes@biotec.as

Steinar Paulsen

Expression of lysozyme in Atlantic salmon (*Salmo salar* L.) – in vivo and in vitro studies.
Steinar.Paulsen@fagmed.uit.no

Ole-Petter Pedersen

Life cycle strategies of *Calanus finmarchicus* on the Norwegian midshelf and adjacent areas – A study of generation patterns and impact of physical processes.
olepp@nfh.uit.no

Marit Reigstad

Plankton community and vertical flux of biogenic matter in north-Norwegian fjords: Regulation factors, temporal and spatial variations.
maritr@nfh.uit.no

Audun Håvard Rikardsen

The relationships between individual growth and anadromy of Arctic charr, *Salvelinus alpinus* (L).
audun.rikardsen@ninatos.ninani.no

Trond Svenøe

Re-evaluation, statistical analysis and prediction based on the Tromsø total ozone record.
trond.svenoe@npolar.no

2001

Dr. art.

Anders Hesjedal

Samisk forhistorie i norsk arkeologi 1900-2000.
andersh@imv.uit.no

Tora Ingeborg Eline Hultgren

Den russiske fangsten på Svalbard. En reanalyse av arkeologiske og historiske kilder.
tora@imv.uit.no

Dr. jur.

Tore Henriksen

Utviklingen av internasjonal forvaltning av vandrende fiskebestander: Mot et lukket hav? En analyse av funksjonen til sub-/regionale fiskeriforvaltningsorganisasjoner etter "Avtalen om fiske på vandrende langtmigrerende fiskebestander".
tore.henriksen@jus.uit.no

Dr. med.

Trond Bratlid

Light- and psychoneuroendocrine investigations of seasonal disorders in a sub-Arctic population.
trond.bratlid@unn.no

Dr. scient.

Are Edvardsen

Biophysical rates of zooplankton - A study of methods for measurement of zooplankton dynamics.
edvard@nfh.uit.no

Vera Helene Hausner

Scenarios for managing biodiversity in coastal birch forests fragmented by spruce plantations. (Joint supervision with Norwegian Institute for Nature Research, Polar Environmental Centre).
vera.hausner@ninatos.ninani.no

Heidi-Marie Gabler

Feeding ecology and resource partitioning in Atlantic salmon parr (*Salmo salar* L.) and freshwater sculpins (*Cottus gobio* L. and *C. Poecilopus Heckel*) in sub-Arctic rivers.
hmg@fm-tr.stat.no

Lis Lindal Jørgensen

Benthic faunal associations in northern areas related to environmental variables.
lisj@nfh.uit.no

Yoshie Kasajima

Tidally Induced Topographic waves in the Northern Seas.
yoshie.kasajima@bjerkes.uib.no

Erland Hilmar Tonning Lebesbye

Late Cenozoic glacial history of the southwestern Barents Sea.

Helge Liltved

Disinfection of water in aquaculture: Factors influencing the physical and chemical inactivation of microorganisms.
helge.liltved@niva.no

Ulf Ove Lindstrøm

Foraging ecology of minke whales (*Balaenoptera acutorostrata*): Composition and selection of prey in the northeast Atlantic.
ulfl@nfh.uit.no

Eirik Reiherth

Adaption to arctic light conditions. Shedding light on the chronobiology of an Arctic resident, the Svalbard ptarmigan.
eirik.reiherth@adm.uit.no

Hans Kristian Strand

Intensiv produksjon av kveiteyngel.
hanss@nfh.uit.no

Dr. med.**Vegard Skogen**

Diphtheria – the recent epidemic in the former Soviet Union. Sero-epidemiological and Molecular Studies.

vegards@fagmed.uit.no

2002**Dr. scient.****Ingrid Bakke**

Characterization of mitochondrial DNA sequences and molecular phylogenetics of the family Gadidae and related taxa.

ingridb@fagmed.uit.no

Pål Arne Bjørn

The physiological and ecological effects of salmon lice, *Lepeophtheirus salmonis* Krøyer, infection on anadromus salmonids.

paalab@nfh.uit.no

Svein Morten Eilertsen

Utilization of abandoned coastal meadows in northern Norway by reindeer.

svein.eilertsen@planteforsk.no

Elin Moe

The molecular basis for cold adaptation of uracil-DNA N-glycosylase from Atlantic cod (*Gadus morhua*).

elinm@fagmed.uit.no

Liv Plassen

Stratigraphy and sedimentary environment in north-Norwegian and Spitsbergen fjords

liv@ibg.uit.no

Ingvild Warttinen

Methane-oxidising bacteria in arctic wetland soil from Spitsbergen, Svalbard (78°N)

ingvild@ibg.uit.no

Katrine Borgå

Organochlorine contaminants in Arctic marine food webs: distribution in pelagic and sympagic fauna. (Joint supervision with the Norwegian Polar Institute).

katrine.borga@npolar.no

Recent Doctorates in Polar Studies at Other Universities, with Tromsø Affiliation

2000**Dr. scient.****Terje Brinck Løyning**

Thermobaric Effects in Cold Seawater. University of Oslo. (Joint supervision with the Norwegian Polar Institute)

loyning@npolar.no

Sabine J. Cochrane

Taxonomy and systematic selected marine soft-bottom fan-worms. University of St. Andrews (Scotland). (Joint supervision with Akvaplan-niva, Polar Environmental Centre)

sabine.cochrane@akvaplan.niva.no

2001**Dr. scient.****Francois Criscuolo**

Université Claude Bernard, Lyon, France. (Joint supervision with CEPE-CNRS, Strasbourg, France and the Norwegian Polar Institute)

Joerg Haarpaintner

Brine formation through ice production in Storfjorden, Svalbard, estimated by ERS-2 SAR imagery and simple ice drift and ice formation models. University of Versailles - St. Quentin-En-Yvelines, France. (Joint supervision with the Norwegian Polar Institute)

jhaarpaintner@natice.noaa.gov

Marzena Kaczmarzka

Intensity of Calving of Arctic Tidewater Glaciers with Reference to Climatic Regions of the Arctic. University of Silesia, Sosnowiec, Poland. (Joint supervision with the Norwegian Polar Institute)

marzena.kaczmarzka@npolar.no

Mette Mauritzen

Patterns and processes in female polar bear space-use. University of Oslo. (Joint supervision with the Norwegian Polar Institute)

Mette.Mauritzen@imr.no

2002**Dr. scient.****Nina Eide**

Spatial ecology of Arctic foxes – relations to resource distribution, and spatiotemporal dynamics in prey abundance. Agricultural University of Norway. (Joint supervision with the Norwegian Polar Institute)

nina.eide@nina.no

Ronny Aanes

Spatio-temporal dynamics in Svalbard reindeer. Norwegian University of Science and Technology (NTNU), Trondheim, Norway. (Joint supervision with the Norwegian Polar Institute)

ronny.aanes@npolar.no

INSTITUTIONS AT THE POLAR ENVIRONMENTAL CENTRE

N-9296 TROMSØ Ph: +47 7775 0000
www.polarenvironment.no

Akvaplan-niva AS

Ph: +47 7775 0300 Fax: +47 7775 0301
www.akvaplan.niva.no

Geological Survey of Norway

Ph: +47 7775 0128 Fax: +47 7775 0126
www.ngu.no

Norwegian Institute for Air Research

Ph: +47 7775 0375 Fax: +47 7775 0376
www.nilu.no

Norwegian Institute for Nature Research

Ph: +47 7775 0400 Fax: +47 7775 0401
www.nina.no

Norwegian Institute for Cultural Heritage Research

Ph: +47 7775 0400 Fax: +47 7775 0401
www.niku.no

Norwegian Mapping Authority Troms

Ph: +47 7775 0450 Fax: +47 7775 0451
www.statkart.no

Norwegian Polar Institute

Ph: +47 7775 0500 Fax: +47 7775 0501
www.npolar.no/

National Coastal Administration

Ph: +47 7775 0480 Fax: +47 7775 0481
www.kystverket.no

Norwegian Radiation Protection Authority

Ph: +47 7775 0170 Fax: +47 7775 0171
www.nrpa.no

North Atlantic Marine Mammal Commission

Ph: +47 7775 0180 Fax: +47 7775 0181
www.nammco.no

Polarmiljøsenderet AS

Ph: + 47 7775 0200 Fax: +47 7775 0201
www.polarenvironment.no

UNILAB Analyse Ltd.

Ph: +47 7775 0350 Fax: +47 7775 0301
www.unilab.no

RESEARCH INSTITUTES IN THE

NORUT GROUP

N-9291 TROMSØ
www.norut.no

NORUT Information Technology Ltd.

Ph: +47 7762 9400 Fax: +47 7762 9401
www.norut.no/itek/

NORUT Social Science Research Ltd.

Ph: +47 7762 9400 Fax: +47 7762 9461
www.samf.norut.no

NORUT Technology Ltd.

P.o.b. 250, N-8501 Narvik
Ph: +47 7696 5350 Fax: +47 7696 5351
www.tek.norut.no

Norwegian Institute of Fisheries and Aquaculture Research

Ph: +47 7762 9000 Fax: +47 7762 9100
www.fiskforsk.norut.no

NORUT Medisin og Helse Ltd, Tromsø

Ph: +47 7762 9407 Fax: +47 7762 9402
www.norut.no/medisin/

OTHER INSTITUTIONS

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P.o.b. 54, N-8483 Andenes
Ph: +47 7614 4400 Fax: +47 7614 4401
www.rocketrange.no

EISCAT Research Station

Ramfjordmoen, N-9027 Ramfjordbotn
Ph: +47 7769 2166 Fax: +47 7769 2380
www.eiscat.no

Kongsberg Satellite Services

N-9291 Tromsø
Ph: +47 7760 0250 Fax: +47 7760 0299
www.kosat.no

National Archives of Norway

Regional State Archives of Tromsø

N-9293 Tromsø
Ph: +47 7767 6611 Fax: +47 7767 6520
www.riksarkivet.no/tromso/om.html

Norwegian Centre for Telemedicine

University Hospital of North Norway

P.o.b. 35, N-9038 Tromsø
Ph: +47 7775 4000 Fax: +47 7775 4098
www.telemed.no

Norwegian Meteorological Institute - Div.

for Northern Norway

N-9293 Tromsø
Ph: +47 7768 4044 Fax: +47 7768 9003
www.dnmi.no

Norwegian School of Veterinary Science

Dept. of Arctic Veterinary Medicine
N-9292 Tromsø
Ph: +47 7766 5400 Fax: +47 7768 4411
www.veths.no

Polar Museum

P.o.b. 900, N-9259 Tromsø
Ph: +47 7768 4373 Fax: +47 7761 1720
www.polarmuseum.no

Polaria Visitors' Centre

N-9296 Tromsø
Ph: +47 7775 0100 Fax: +47 7775 0101
www.polaria.no

Svanhovd Environmental Centre

N-9925 Svanvik
Ph: +47 7897 3600 Fax: +47 7897 3601
www.svanhovd.no

Tromsø College, Dept. of Engineering and Economics

N-9293 Tromsø
Ph: +47 7766 0300 Fax: +47 7768 9956
www.afi.hitos.no/

University Centre on Svalbard (UNIS)

P.o.b. 156, N-9170 Longyearbyen
Ph: +47 7902 3300 Fax: +47 7902 3301
www.unis.no

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FACULTIES, DEPARTMENTS AND CENTRES AT THE UNIVERSITY OF TROMSØ

N-9037 TROMSØ

Ph: +47 7764 4000
www.uit.no

Centre for Sámi Studies

Ph: +47 7764 5535 Fax: +47 7767 6672
www.uit.no/ssweb/

Faculty of Humanities

Ph: +4777 64 4240 Fax: +47 7764 4139
www.hum.uit.no

Faculty of Law

Ph: +4776 4197 Fax: +47 7764 4775
www.jus.uit.no

Faculty of Medicine

Ph: +47 7764 4601 Fax: +47 7764 5770
www.fm.uit.no

- Department of Arctic Biology
www.fm.uit.no/info/imb/aab/
- Department of Medical Biology
www.fm.uit.no/info/imb/

Faculty of Sciences

Ph: +47 7764 4001 Fax: +47 7764 4765
www.matnat.uit.no

- Department of Biology
www.ib.uit.no
- Department of Geology
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- Department of Physics
www.phys.uit.no/
- Tromsø Geophysical Observatory
www.tgo.uit.no/

Faculty of Social Science

Ph: +47 7764 4296 Fax: +47 7764 4905

- Department of History
www.sv.uit.no/seksjon/historie/
- Department of Archaeology
www.sv.uit.no/seksjon/ark/

Norwegian College of Fishery Sciences

Ph: +47 7764 6000 Fax: +47 7764 6020
www.nfh.uit.no

Roald Amundsen Centre for Arctic Research

Ph: +47 7764 5241 Fax: +47 7767 6672
www.arctic.uit.no

Tromsø Museum - University Museum

Ph: +47 7764 5000 Fax: +47 7764 5520
www.imv.uit.no

The University Library of Tromsø

Ph: +47 7764 4000 Fax: +47 7764 4590
www.ub.uit.no