The Research Council of Norway

INTERNATIONAL 2007 2008 POLAR YEAR

INTERNATIONAL 2007 2008 POLAR YEAR

THE NORWEGIAN CONTRIBUTION

The International Polar Year 2007-2008 (IPY) was one of the largest coordinated research programmes ever implemented. Through intensive observation and data collection over the course of a two-year period the programme has laid the foundation for studies that will improve our knowledge of the Arctic and the Antarctic in the decades to come. One key topic was the significance of the polar regions for global climate. IPY was also innovative in the way it linked research with education, outreach and communication. Norway was a major contributor to IPY. This book summarises the results and presents the preliminary scientific findings of the Norwegian IPY programme.

THE NORWEGIAN CONTRIBUTION




THE NORWEGIAN CONTRIBUTION

INTERNATIONAL 2007 2008
POLAR YEAR

Editors: Olav Orheim and Kristen Ulstein
Editorial committee: Øystein Hov, Ole Arve Misund and Kirsten Broch Mathisen
English translation team: Alison Coulthard, Carol B. Eckmann, Anna Godson, Darren McKellep
Cover photo: Bjørn Anders Nymoen, Jenny Bytingsvik, Svein Holo/Samfoto, Per Eide/Samfoto
Design: Fete typer as
Printed by: 07
Number of copies: 1000

Research Council of Norway
P.O. Box 2700 St. Hanshaugen
0131 OSLO
Telephone: +47 22 03 70 00
Telefax: +47 22 03 70 01
bibliotek@rcn.no
www.rcn.no

Oslo, June 2011
ISBN 978-82-12-02901-9 (printed version)
ISBN 978-82-12-02934-7 (PDF)

TABLE OF CONTENT

THE RESEARCH PROGRAMME

THE RESEARCH PROJECTS

OUTREACH AND EDUCATION PROJECTS

Foreword

The polar areas continue to play a vital role for Norway. This year we are celebrating the 150th anniversary of Nansen's birth and the 100th anniversary of Amundsen's arrival at the South Pole. Norway is responsible for the management of substantial resources in the Arctic and Antarctic. The treaty on maritime delimination with Russia in the Barents Sea and the Arctic Ocean has largely extended these responsibilities. Achieving sustainable management of these resources in a manner that benefits the world community requires extensive knowledge. In order to acquire this knowledge, we need strong polar research communities at Norwegian institutions as well as wide-ranging international research cooperation.

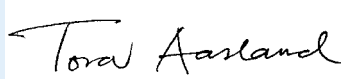
The International Polar Year (IPY) showed that there is great attraction in polar research, not only within the small group of countries that have interests in the polar areas, but throughout the world at large. Interest among young researchers is especially great.

Norway is one of the most important gateways to the Arctic, thanks to Svalbard, and we play a major role in the Antarctic as well. As a result, we have a special responsibility to ensure good working conditions for the many polar researchers from around the world. We have done this during IPY, and we will continue to do so in the future. Even though we are a small contributor to the worldwide science production, Norway is among the leading nations in polar research, in terms of quantity as well as quality.

Polar research is not a distinct discipline. It is a geographic delineation for a field of research and it encompasses a vast range of research activity conducted in the polar areas. Nonetheless, polar research has traditionally been dominated by various kinds of geophysical research. This time IPY expanded the scope of polar research to include researchers from the humanities and social sciences. The need for a broader knowledge base has emerged more clearly in light of the growing understanding that climate change may lead to dramatic changes in the living conditions of population groups in the polar areas.

There are claims in the public debate on research that a fundamental conflict exists between programme-based research and basic research fuelled by curiosity, and that it is the latter of these in particular that generates high-quality research. The experience with the IPY does not confirm such notions. Quite the contrary, this book is tangible proof that the Norwegian IPY programme has delivered research of the highest scientific standard.

I would especially like to congratulate the Research Council on the extraordinary efforts of the IPY programme to bring polar issues and polar research to the general public. Many of the projects have done an exemplary job of integrating research, outreach and communication. I would also like to acknowledge the contribution of His Royal Highness Crown Prince Haakon in giving a boost to IPY activities. The overall effort of everyone involved will be crucial to the understanding of and support for polar research in the years to come.



Tora Aasland
Minister of Research and Higher Education

Foreword

The International Polar Year (IPY) has achieved nearly all of its objectives. Over the course of a two-year period, internationally coordinated observation and data collection have produced unique data sets which would not have been possible to obtain in any other way. Analysis of the data has already given us a great deal of new knowledge, and it will continue to expand our understanding in the coming years about the global climate and the Arctic and Antarctic regions. Thanks to NOK 320 million from the Fund for Research and Innovation, Norway has distinguished itself as the third largest contributor of extraordinary funding to the International Polar Year.

The Research Council is pleased to have been given the task of administering the IPY activities in Norway. It is a task that has been both challenging and inspiring. At a time when internationalisation is high on the research policy agenda, it has been exhilarating to glean the experience from a research programme that has recognised the need to internationalise its research field since the 1880s. It has been motivating to capture and channel the interest of young people. The IPY programme has also managed to achieve what few research programmes can replicate – outreach to an entire nation through a comprehensive programme of education and outreach.

Especially promising is that so many young researchers are showing an interest in research on the polar regions. We know that this is where the most important keys to understanding the mechanism underlying climate change are found. This is why recruitment to polar research is crucial. We are proud to have given 50 research fellows this opportunity through the Norwegian IPY programme. One of the most important outcomes of IPY has been the establishment of the Association of Early Career Polar Scientists (APECS), which we have hosted in Tromsø.

Thanks to the Government's strong emphasis on polar research during the International Polar Year, Norway has successfully fulfilled its responsibility to provide logistics to the international research community. A key objective of the IPY has been to increase the use of the research infrastructure Norway has developed, most prominently on Svalbard. We have achieved this objective, and are building on the experience gained from IPY to develop integrated observation systems and establish a knowledge centre through the ESFRI project "Svalbard Integrated Arctic Earth Observation System" (SIOS). A total of 27 institutions from 14 countries are taking part in the planning, and the project will be a vital follow up to the international research cooperation established during IPY.

Norway has played a key role in creating a framework for the entire IPY programme – from start to finish. Norwegian research institutions were involved in the planning from an early stage, and Norway has helped to finance joint events and meeting places. The high point was when the Research Council was given the honour of assembling 2 300 polar researchers from around the world in Oslo in June 2010 for the largest polar research conference ever held.

The Research Council has recommended, and the Norwegian Government and Storting have agreed, that post-IPY funding for polar research should be continued at a high level. This will give us the opportunity to safeguard and expand on the knowledge and experience gained during IPY.

Arvid Hallén
Director General, Research Council of Norway

PAGE
10–53

THE RESEARCH PROGRAMME

The fourth International Polar Year (IPY 2007–2008) was the largest global research initiative to be carried out for 50 years. Some 50 000 researchers and technicians from 60 countries took part. The last time a collaborative international research effort of this scale had been implemented was during International Geophysical Year (IGY), the previous polar year, in 1957–1958.

The prelude to the International Polar Year

By Olav Orheim, Research Council of Norway, Head of the Norwegian IPY Secretariat

Many international organisations and numerous nations can claim a stake in polar research. The previous International Polar Years left behind no permanent organisation and no clear mandate to implement further coordinated initiatives. As a result the idea of organising a new International Polar Year arose in many different places, and the road to a establishing a unified international programme was far from smooth.

The first steps

The International Polar Year has a long history. International Polar Years were held in 1882, 1932 and 1957/8. The last of these was called International Geophysical Year (IGY), but it still had research on the polar regions as its primary focus. A period of 50 years separated the two first Polar Years. The second was on a much smaller scale than originally planned due to the economic depression in many countries at the time. For this reason the planners of IGY chose to embark on their new initiative after an interval of only 25 years. The International Council for Science (ICSU) (then the International Council of Scientific Unions) was responsible for IGY, and provided the funding for the collaborative international effort together with the United Nations Educational, Scientific and Cultural Organization (UNESCO). The World Meteorological Organisation (WMO), a specialised agency of the United Nations, played a key role in the management of data. IGY was originally intended to be, and came to be viewed as, the third Polar Year.

There were some attempts towards the end of the 1970s to implement a new Polar Year in 1982–83, which would have marked the 100th anniversary of the first Polar Year. Several of the IGY veterans were involved in the discussions, but these efforts never really gained momentum.

Meaningful discussions about launching a new Polar Year 50 years after IGY started around the turn of the millennium. Some people were still thinking in terms of events to commemorate the centennial anniversary. However, the leading polar organisations, which included the Scientific Committee on Antarctic Research (SCAR), the International Arctic Science Committee (IASC), the Arctic Ocean Sciences Board (AOSB), the European Polar Board (EPB) and the US Polar Research Board (PRB), gradually developed more elaborate plans. Between 2001 and 2002 the idea of implementing a fourth International Polar Year (IPY) gained ground. As under the three previous Polar Years, harvesting extra-ordinary observational data from the relatively little known polar regions was to be an important objective.

Concurrently with this, initiatives to organise an Electronic Geophysical Year (eGY) and an International Heliophysical Year (IHD) also arose, both as 50-year follow-ups to parts of IGY. As the plans developed, these initiatives went their separate ways. The eGY and IHY never acquired a scope anywhere near that of IPY.

The origins of the first three Polar Years can be traced back to certain individuals and landmark meetings. This was not the case with the fourth IPY, as there were many who had the 50-year anniversary in mind. During the period 2000–2002 a number of meetings were held at which the initial ideas were developed. Individual political initiatives, on the part of Russia for example, were also launched. ICSU and WMO were drawn into the process and on 21 May 2003 the WMO congress approved a decision to launch a new Polar Year under the leadership of

First meeting of the ICSU Planning Group (PG) in Paris in August 2003. Front: Vladimir Kotlyakov, Robin Bell (Vice Chair), Chris Rapley (Chair) and Hanne Kathrine Petersen. Behind from left: Tim Moffat, Michael Kuhn, Gino Casassa, Olav Orheim, Vladimir Ryabinin, Ian Allison, Robert Bindschadler, Zhanhai Zhan and Gerard Duhaime. Photo: ICSU

WMO. Shortly afterwards, on 9 June, the ICSU management approved a decision to establish a nine-person planning group for IPY, of which I, in my role as Director of the Norwegian Polar Institute, was a member.

In the summer of 2003 there were therefore two "polar" initiatives underway supported by world organisations, whilst other initiatives such as eGY and IHY were being planned as well. Signs indicated that the process towards realising a new IPY was not going to be easy.

International plans are coordinated and gain momentum

The first meeting of the ICSU Planning Group was held on 31 July to 2 August 2003. The group drew up a five-page document outlining the background to and visions for IPY, as well as a letter of invitation to the research community to submit ideas for IPY by mid-December. Parallel to this, ICSU and WMO agreed to exchange information about their respective plans, and a representative from WMO was invited to attend the second meeting of the ICSU Planning Group. The same autumn the initiative gained the support of several organisations, including UNESCO and the Arctic Council.

The second Planning Group meeting was held on 17–19 December 2003, by which time ICSU had expanded the group to 12 people. The group approved a decision (with some dissenting votes) to recommend that ICSU and WMO assume joint responsibility for IPY and at the same time emphasised that IPY must incorporate a broad scientific approach encompassing both natural and social science studies. Some feared that with WMO as co-sponsor the research focus could become too narrow, while others pointed out the value of having an international organisation such as WMO involved, for example in gaining the support of China and the South American countries. A total of 135 research proposals from 22 nations were received for consideration in response to the letter of invitation sent out three months earlier. The Planning Group organised the various proposals according to thematic area, and noted that little interest had been shown thus far by the social sciences. The Planning Group therefore circulated a second invitation for submission of ideas.

Over the next two months it was established that ICSU and WMO would work together, and assume joint responsibility for IPY. By February 2004 some 14 nations had established national IPY committees or designated national points of contact.

WMO and ICSU take the reins and the research community is mobilised

The third Planning Group meeting took place on 1–3 April 2004. WMO now took on a more prominent role in the work of the group, which was still formally under ICSU. On the table were a large number of additional proposals that had been received for consideration at the meeting, as well as the results from an open discussion meeting held at the same venue the day before. In addition to the Planning Group, this was attended by eight international organisations and IPY representatives

Headquarters of the World Meteorological Organization (WMO) in Geneva.
Photo: Kristen Ulstein

Logo for IGY (1957–1958)

The international logo for IPY (1957–1958)

Key IPY leaders gathered in Geneva on 25 February 2009 to celebrate the end of the last field season. David Carlson (left) headed the International Programme Office in Cambridge, Ian Allison and Michel Béland cochaired the ICSU/WMO Joint Committee for IPY.
Photo: Kristen Ulstein

from seven nations, and provided valuable input for the discussions that followed.

The Planning Group's meeting resulted in the preparation of a 40-page planning document entitled "International Polar Year 2007–2008: Initial Outline Science Plan", which was published online on 20 April. Attached to the document were 15 pages summarising the over 350 proposals that had been submitted by March 2004. It was clear that the IPY plans had generated great enthusiasm, particularly in the natural science research community.

However, a meeting of the Senior Arctic Officials (SAO) under the Arctic Council in early May showed that not everybody had the same view of the process. Although the meeting warmly supported the idea of IPY, representatives of the indigenous peoples pointed out that the human dimension had not been sufficiently addressed in the planning so far. Just a few days later a similar message was conveyed by the Fifth International Congress of Arctic Social Sciences.

During the course of the summer months ICSU and WMO formally assumed joint responsibility for IPY. Many suggestions for improving the "Initial Outline Science Plan" were received, in part in response to the criticisms received in May.

Like the previous meetings, the fourth and final meeting of the Planning Group was held in Paris. The meeting was preceded by a two-day open discussion forum held on 13–14 September at which over 60 people participated. Participants included representatives of 13 national committees, important research funding bodies, as well as 15 members of the Planning Group. Interest in IPY had clearly escalated. The discussions indicated widespread support for the idea that the social sciences should be a separate pillar of IPY. Most of the participants of the discussion forum were against the establishment of identified flagship projects and favoured a more democratic submission process in which all research groups could participate, regardless of the size of the project. Research councils pointed out that it would nonetheless be beneficial to identify the major challenges. The forum also discussed what IPY could do to secure the involvement of young researchers, IPY's relationship with commercial partners as well as numerous questions related to the actual implementation of IPY.

The Planning Group meeting took place over the subsequent two days. The original planning document was significantly revised to incorporate the input received over the previous few months and from the forum just held. New sections relating to data management and education, outreach and communication activities were included. The various scientific proposals were organised in terms of thematic area instead of along traditional disciplinary lines.

The final document entitled "A Framework for the International Polar Year 2007–2008" was published online on 1 November and shortly afterwards by ICSU as a 38-page printed pamphlet.

The Planning Group also discussed the next steps in the process, including the establishment of the IPY Secretariat in Cambridge, UK and an IPY steering committee, to be known as the Joint Committee (JC). Potential members of the JC were also discussed at the meeting. It was agreed that neither the Planning Group nor the JC should have responsibility for ranking the submitted proposals. This was to be done by the national research councils in line with their normal procedures. Instead the JC was to check the projects against the identified criteria, to ensure, for example, that the project was to be carried out during the IPY period, that it was international in scope and that it had a plan for data management. The JC was also given the charge of coordinating overlapping proposals.

This brought the planning stage of IPY to an end. The next step was to prepare for implementation.

From planning to implementation

In November ICSU and WMO announced the appointees to the Joint Committee, which were mostly new names. They sent out a further invitation to the research community (this time in six languages) asking for "Expressions of Interest". The JC held its first meeting in November 2004, by which time over one thousand project ideas had come in. During the course of the following year the JC coordinated and integrated these project ideas into 228 endorsed IPY projects. These formed the basis for the internationally coordinated research effort, which was launched on 1 March 2007.

The JC took on a major task in coordinating the project ideas and played a key role in increasing the attention given to communication activities and data management. However, the JC had no funds of any significance, and as a result the level of funding and activity in these two areas, and others, were to a large extent dependent on the contributions of the individual nations. Several letters were sent by the JC to the national IPY committees asking for contributions to help co-fund specific activities. In reality the JC had relatively little influence on the content of IPY, especially its research activities.

Because of the way it came about, IPY gained wide support within the research community. It incorporated research groups focusing on topics not traditionally thought of as "polar" in nature. IPY's relevance, especially for the Arctic nations, was strengthened by the inclusion of the human dimension and the participation of those living in the Arctic. The emphasis given to the human dimension also attracted many young researchers and helped to ensure that education and communication activities became a key component of many of the projects.

But this bottom-up process also had its disadvantages, as the JC itself pointed in 2011in its summing-up document. Most critical of these may have been that the selection processes of the research funding bodies were not coordinated. A vision for IPY was to carry out groundbreaking polar research that could only be achieved by many nations pulling together in a major concerted effort. Stronger management at a central level, for example the identification in advance of a few key programmes, would have made it easier to achieve this aim.

Some attempts were made to bring cohesion to the process through an informal organisation which went by the name of HAIS (Heads of Arctic/Antarctic IPY Secretariats) and through the management of the organisations carrying out field work in the Antarctic and the Arctic, the Council of Managers of National Antarctic Programs (COMNAP) and Forum of Arctic Research Operators (FARO). In practice these meetings proved most useful at the bilateral level.

The list of the 228 approved IPY projects (170 in research, 1 in data management and 57 in education and communication) provided the basis for activities in all of the participating countries. However, in the countries that allocated their own funding to IPY calls for proposals for IPY projects were issued in accordance with their own national practices, and there was no international coordination in terms of content or timing. Grant allocations were based (as usual) on the scientific merit of the project proposals submitted at national level. This meant that in some cases lack of national funding led to undesired gaps in the overall research effort. On the whole, contact between the research councils did not take place until after the national grant allocation process had been completed.

The International Polar Year 2007–2008 provided an international platform for research cooperation. It was up to each individual country to organise and fund national activities that would provide the content. Photo: Kristen Ulstein

What made the International Polar Year so big in Norway?

By Olav Orheim, Research Council of Norway, Head of the Norwegian IPY Secretariat

The International Polar Year (IPY) was a grandiose idea – hatched in international researcher forums. It was by no means a foregone conclusion that it would lead to major allocations in the national budget. The fact that IPY grew to such a large size in Norway was the result of a long period of preparing stakeholders and a well-conceived organisation.

The first phase

In Norway, planning for IPY began in September 2003 in the Research Council's National Committee on Polar Research (NCPR). It organised a 50-person national meeting on IPY-planning in Tromsø in November, which prepared a first Norwegian response to the international IPY-preparations. On 11 December 2003 the Norwegian Academy of Science and Letters, in consultation with the Research Council, appointed the first IPY committee. The secretariat of the NCRP also served as secretariat for the IPY committee. The committee and the secretariat served as the national link to the processes taking place at the international level.

By 2005 it was clear that International Polar Year (IPY) would take place. The "owners" of previous Polar Years, the International Council for Science (ICSU) and the World Meteorological Organisation (WMO), had approved the plans and appointed a steering committee (the Joint Committee). IPY had received strong support in the high-level international political forums for the polar regions, i.e. the Arctic Council and the Antarctic Treaty Consultative Meetings. The idea was, of course, also widely endorsed by the scientific organisations involved in international polar research and had the full backing of the research community, which had submitted over a thousand different project proposals.

In Norway, IPY had also been discussed by the standing interministerial committee which coordinates the various ministries' handling of polar issues. In the national budget for 2006 three ministries joined forces to allocate NOK 5 million to the Research Council for IPY preparations. The same amounts were allocated for 2007 and 2008.

The Research Council takes on leadership role and the Norwegian IPY Committee is established

Once the preparations for IPY entered a more practical phase, Norwegian efforts needed a more formal organisation. This was started up on 22 August 2005, when the Research Council set up a secretariat with expanded resources at its disposal to deal with scientific coordination, logistics, contact with the authorities, communication and education activities. It was agreed to appoint a new IPY committee, which would serve as a subcommittee to the National Committee on Polar Research, reporting to it (and to the Norwegian Academy of Science and Letters). The then Division for Strategic Priorities set aside NOK 3 million for IPY for 2005 and 2006.

In the next two months the Research Council, in consultation with the National Committee on Polar Research and the IPY Secretariat, began the task of defining the structure for the planning and implementation of IPY. A key part of this was to draw up a policy document on Norwegian participation in IPY – a document that could outline the basic profile of Norwegian participation in IPY and provide the substance for the wording of a funding announcement.

Other important issues at this stage were the membership of the new IPY committee and the mandate and role of the various links in the organisational chain, including

Chair of the Norwegian IPY Committee Øystein Hov (behind) listening to His Royal Highness Crown Prince Haakon talking to children outside Oslo City Hall during the official launch of the Norwegian IPY effort on 1 March 2007. Photo: Kristen Ulstein

The Research Council of Norway served as secretariat for and was responsible for administering the Norwegian IPY programme. Here Director General of the Research Council Arvid Hallén welcomes Crown Prince Haakon and Minister of Research and Higher Education Tora Aasland at the Norway Trade Fairs facility in Lillestrøm for the official opening of the IPY Oslo Science Conference on 8 June 2010. Photo: John Petter Reinertsen, Samfoto

the secretariat and the different committees. The scope of the Norwegian initiative was also discussed, but that, of course, required input not only from the Research Council but also from the ministries allocating funding. By the end of the year the policy document and the proposed organisation of the Norwegian IPY effort were approved by the committees and the Board of the Research Council's Division for Strategic Priorities. The upgraded Norwegian IPY Committee comprised the following members:

Øystein Hov, Norwegian Meteorological Institute, Oslo, Chair
Hanne Christiansen, University Centre in Svalbard (UNIS), Longyearbyen
Olav Eldholm, University of Bergen
Kirsti Kolle Grøndahl, County Governor of Buskerud, Drammen
Kim Holmén, Norwegian Polar Institute, Tromsø
Grethe Hovelsrud, Center for International Climate and Environmental Research – Oslo (CICERO)
Ole Arve Misund, Institute of Marine Research, Bergen
Guro Dahle Strøm, Norwegian Space Centre, Oslo
Chair of the National Committee on Polar Research, ex officio member.

Olav Eldholm was representative for the Norwegian Academy of Science and Letters. Grete Hovelsrud represented Norway on the Joint Committee.

The Norwegian IPY Committee held its first of a total of 20 meetings on 17 November 2005. The last was on 11 April 2011. (One meeting was conducted by e-mail). The membership of the committee remained unchanged for the entire period, except that from 2010 Bo Andersen of the Norwegian Space Centre took over from Harald Loeng, Institute of Marine Research, as Chair of the NCRP.

The Norwegian IPY Committee was given overall responsibility for national IPY activities, and in practice enjoyed a high level of autonomy. The committee's mandate was largely based on the description of national-level IPY tasks drawn up by the Joint Committee, according to which the committee was to:

- serve as a channel of information from the Joint Committee to the Norwegian research community and convey Norwegian input to the Joint Committee
- maintain a comprehensive overview of Norwegian IPY activities
- help with the planning and implementation of Norwegian IPY projects, including providing Norwegian endorsement of proposals where appropriate
- ensure that data collected as a result of Norwegian IPY activities was available to others in accordance with Joint Committee guidelines
- take on a leading national role as regards education, outreach and communication activities
- promote the allocation of national funds, as well as logistical and other support for the implementation of Norwegian participation under IPY
- approve the division of responsibility and prioritisation of tasks between the Norwegian IPY Committee and the IPY Secretariat

The Norwegian IPY Committee played a fundamental role in the development of IPY in Norway. Between them the committee members had extensive experience and knowledge of Norwegian and international polar research, which was particularly important when it came to ensuring that the right paths were chosen along the way.

Profile and scope of the Norwegian IPY effort

As outlined in the policy document, IPY in Norway was to be a balanced national programme, linked to the international programme. The research effort was to be in keeping with the priorities set out in the research plans for the Arctic and Antarctic that had recently been approved by the Research Council. The following research and social objectives were identified:

- The Norwegian IPY effort should promote the acquisition of new knowledge of high scientific merit related to fundamental processes and key natural phenomena in the polar regions. It should generate knowledge of societal relevance that promotes sound management practices, including the development of methods to forecast climate change, management of resources and the environment and the impact of change processes on the northern areas.
- IPY should result in a significant expansion of long-term international cooperation, particularly with Russia, and greater use of Norwegian infrastructure in Svalbard by international researchers in cooperation with Norwegian research groups.
- IPY should lead to a measurable increase in interest among schoolchildren and students in the subject areas in which Norway has participated, particularly mathematics and the natural sciences.
- IPY should enhance understanding of the importance of polar research and the polar regions amongst the general public in Norway.

The total amount of funding sought by Norwegian IPY projects in grant applications submitted to the Joint Committee

was over NOK 2 billion. On the basis of this and of the way the international effort was developing, the NCRP proposed in November 2005 that a total amount of NOK 800 million in new funding should be made available for the budget years 2007–2010.

The Research Council's budget proposal became NOK 100 million per year for a period of four years, starting in 2007. The rationale behind such a sizeable investment was based on the following:

- Norway is the only country with management responsibilities in both polar regions.
- IPY could create a legacy for improved cooperation in the Arctic – as International Geophysical Year (IGY) had done for the Antarctic.
- IPY is part of the follow-up to the Government's High North Strategy.
- The research initiative could lead to better exploitation of Norwegian polar infrastructure in the long term.
- New research activity helps build research expertise.
- The research initiative would generate research results relevant for resource, environmental and cultural heritage management.
- IPY would promote interest in as well as recruitment to science subjects.
- IPY would boost technological and industrial development.

Late in 2006 the Storting approved an allocation of NOK 80 million for 2007 in the budget of the Ministry of Education and Research. The indication was that the total amount available would be NOK 320 million, NOK 80 million for each of the budget years 2007–2010.

Complex organisational structure

The policy document also clarified the roles of the various links in the organisational chain, as shown in the organogram below. Perhaps most important was that grant proposals were to be assessed, and funding allocated, through the Research Council's normal referee procedures, and not by the Norwegian IPY Committee or the National Committee on Polar Research. There was a separate process for allocation of funds to education, outreach and communication activities. Some additional guidelines for the overall profile of the Norwegian IPY effort were drawn up, and included:

- The greater part of the Norwegian IPY research effort is to take place in the Arctic rather than the Antarctic.
- Priority is to be given to research projects in which Norwegian research groups play a leading or major role, and where results can be expected to attract international attention.
- Priority is to be given to the use of Norwegian infrastructure, but funding should also be made available for Norwegian participation in other countries' research platforms.
- The overall portfolio should include projects involving significant Norwegian and Russian participation.
- Funds should be earmarked for communication and education activities.

The application review process is described in a separate article by Per Backe-Hansen, who was in charge of these efforts.

Support to research groups to develop IPY projects

Although most relevant research groups were aware of the IPY preparations there was clearly a need to inform the research community of how the process was to proceed. Towards the end of 2005 the Research Council therefore held information meetings in Bergen, Oslo and Tromsø.

In addition funding was announced for the development of collaborative projects, either by applying for funding to hold meetings in Norway or to participate at international meetings. A total of NOK 2 million was set aside for this purpose and project establishment support was allocated through a simple administrative procedure. A prerequisite for receiving funding was that the project in question was one of the IPY projects approved by the Joint Committee. If there were several potential Norwegian partners in such a project, they were required to prepare and submit a joint application.

Administration

Olav Orheim led the Norwegian IPY Secretariat at the Research Council for the duration of the period. A large number of employees of the Research Council also served on the IPY Secretariat on a part-time basis:

- Fridtjof Mehlum, national coordination of IPY-preparations
- Kristen Ulstein, responsible for education, outreach and communication activities – for the whole period
- Per Backe-Hansen, grant application processing and project follow-up
- Karin Refsnes, budget and project follow-up
- Sissel Berger, Lise Frøseth, Randi Isaksen, Vibeke Rosenberg and Margrethe Valler, consultants

The programme was placed under the then Department for Climate and the Environment. Kirsten Broch Mathisen was Department Director.

Responsibility for some of the educational activities was subcontracted to:

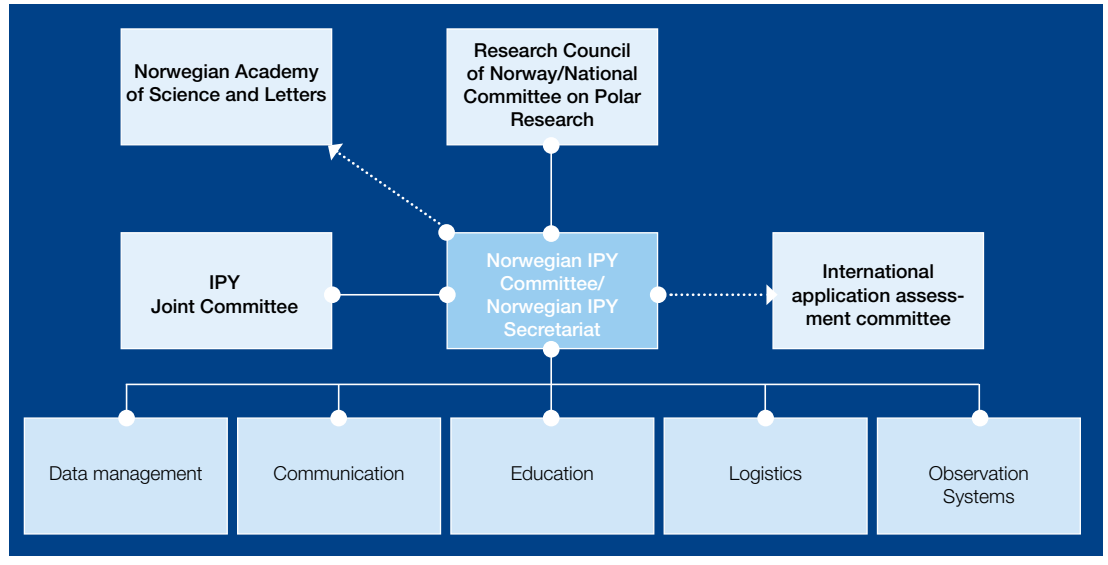
- Karl Torstein Hetland, Norwegian Centre for Science Education
- Eystein Markussen and Elise Strømseng, The University Centre in Svalbard (UNIS)

The following were involved on the communications side:

- Journalists Susanne Moen Stephansen and Anita Munch, web journalism
- Bouvet ASA, webpages
- Fete typer AS, graphic design
- Snöball Film AS, film/video editing and film archive.

All these played their part in making IPY large in Norway.

One of the objectives of the Norwegian IPY programme was that it should result in a significant increase in the use of Norwegian infrastructure in Svalbard by international researchers – for example in Ny-Ålesund.
Photo: Kristen Ulstein



The People's Polar Year

By Kristen Ulstein, Research Council of Norway, and Karl Torstein Hetland, Norwegian Centre for Science Education

Children were invited to bring along colourful "ice bricks" and build a decorative ice monument in front of the stage before the official opening on 1 March 2007. Photo: Scanpix

It was made clear in the early planning phases that the International Polar Year would be more than just another research initiative. Thanks to a wide variety of activities and communication measures, IPY was able to inform and involve the population at large throughout the world. Those of us who worked with education and dissemination had access to many enthusiastic, inventive professionals and adequate financial resources – all of which helped to make the "People's Polar Year" a reality.

This chapter sums up what was done in Norway and what came out of it, along with some of the reasons behind some of the choices made. Hopefully, these insights will benefit everyone who aims to bring science to the people. Some of the measures may even be duplicated by others in the future.

A solid strategic foundation

The initial framework document for the International Polar Year 2007–2008 was drawn up by the Planning Group under the International Council for Science (ICSU). Those involved in IPY planning activities in 2004 set out four main objectives. Naturally the programme focused on research and observation systems, but notably, two of the four objectives dealt with research communication:

- to attract and develop the next new generation of polar researchers and engineers;
- to engage the interest and involvement of polar residents, schoolchildren, the general public and decision-makers worldwide.

The opening of the Indigenous Peoples' IPY was held in Guovdageaidnu (Kautokeino), Norway. Photo: Kristen Ulstein

Outside Oslo City Hall, 1 March 2007. Photo: Kristen Ulstein

Crown Prince Haakon putting the finishing touches on the colourful ice sculpture in front of the stage. Photo: Scanpix

Thus from the very outset the documents laid a solid foundation for integrating IPY research activity with a major initiative on "Education, Outreach and Communication" (EOC), as the sub-committee was called. A total of 57 EOC projects, approved by the ICSU/WMO Joint Committee for IPY 2007–2008, are listed in IPY's scientific plan entitled "The Scope of Science for the International Polar Year" (World Meteorological Organization, 2007).

The framework document explains why research communication has been such a crucial aspect of IPY: "The polar regions provide a powerful context for teaching and learning, attracting a wide and diverse audience. The education, outreach and communication strategy for IPY must address the question: 'Why are the polar regions and polar research important to all people on Earth?' through a series of nationally and internationally coordinated programmes producing an improved understanding of the importance of the poles globally."

The Norwegian IPY Committee met for the first time in March 2004. The committee discussed the topic of communication from the very first meeting, and in November 2005 it was decided to appoint two sub-committees, one on communication and outreach and another on education. A communication plan had already been drawn up, but the measures to be implemented were developed during the course of 2006. The two sub-committees held their initial meetings in spring 2006 and received their mandates from the IPY Committee.

The University Centre in Svalbard (UNIS), located in Longyearbyen, was given responsibility for coordinating the measures targeted at higher education institutions, while the Norwegian Centre for Science Education at the University of Oslo signed an agreement with the Research Council of Norway to serve as the secretariat for the Sub-Committee on Education and the efforts to coordinate measures for and in the primary and secondary schools. The communications adviser in the Research Council's IPY secretariat was given responsibility for coordinating the communication and dissemination activities and directing the secretariat for the Sub-Committee on Communication and Outreach.

The Sub-Committee on Communication and Outreach assembled the communication directors of the most important research institutions, creating a highly beneficial strategic forum as well as an effective coordinating body. The sub-committee established the following strategic communication objectives for IPY in Norway:

- to bring Norwegian polar research to the attention of key target groups and the general public;
- to profile Norwegian polar research and Norway as a leading polar nation to the world at large;
- to generate more interest in polar research in particular and in mathematics and the natural sciences in general (a primary objective of the Sub-Committee on Education);
- to increase awareness of IPY in Norway.

Funding announcement for large-scale EOC projects

Funding was granted under the Norwegian IPY programme to a total of 22 dissemination and education projects following funding announcements in 2006. NOK 14 million was set aside for this purpose. Both the funding and grant allocation process and the projects that received support are presented in separate chapters.

IPY postage stamps were issued to celebrate the national event.

The journalist course gathered on the beach at Blomstrandhalvøya in Kongsfjorden in September 2006. Executive Director of Kings Bay AS Oddvar Midtkandal (back to the camera) briefing the group. Photo: Kristen Ulstein

Profiling a large-scale, nationwide endeavour

Positioning the International Polar Year as a large-scale, nationwide endeavour required a special course of action. The fact that the programme was organised differently from other programmes in the Research Council's portfolio made it possible to engage in branding. This was important to ensure that many ordinary TV viewers and newspaper readers became familiar with IPY. To secure a term that was easy to remember and refer to, we chose to brand "Polaråret" (The Polar Year).

In June 2006 an agreement was signed with the design firm Fete typer on the development of a graphic profile for the programme. A website was created during this same time period. In addition to a colour key, logo band and set of profile photos, attention was paid to development of the logo text. The logo for the international programme was old-fashioned and unclear. The solution was to use the logos together in some contexts. As the website was to have information pages in English, Russian and Sámi in addition to Norwegian, logos were designed in all four languages.

This resulted in a design concept that could be exported. With the consent of the international programme office in Cambridge, the Norwegian profile was offered to other countries. Several countries chose to use all or parts of the design, and a German version of the logo was created as well. Consistent use of the graphic profile in Norway helped to promote recognisability, which was crucial to ensuring that communication activities in various channels could enhance one another.

Early on, all the national IPY programmes in Scandinavia contacted their respective Royal Houses, which decided among themselves that the heirs to the throne would serve as the patrons for the Polar Year. This turned out to be invaluable as a symbol of the research programme's national significance and of the importance of the Arctic region for the Nordic countries. His Royal Highness Crown Prince Haakon of Norway showed great interest in, and good insight into, the scientific aspects of polar and climate issues. The involvement of the Crown Prince and the other heirs to the throne was crucial for generating interest among the general public.

Traditionally, commemorative stamps have only been issued to mark events of national importance. An application for a commemorative stamp for IPY in Norway was submitted; noting that one had also been issued in 1957 in connection with the third International Polar Year (renamed the International Geophysical Year). Norway Post, the national postal service, decided to issue two different stamp values (NOK 10.50 and 13), and Sverre Morken was awarded the design commission. The IPY secretariat worked closely with Mr Morken on the motifs and provided relevant copy that was used on a number of philatelic products. The commemorative stamps were issued on 21 February 2007.

Post Greenland published a compilation book that displayed the Polar Year stamps from all the Nordic countries, the US and Canada. The book also presented the national research programmes. The publication helped to draw attention to the international nature of IPY.

Polaråret on the web

The Norwegian IPY website played a key role in the profiling activities and served as a channel for basic information about and news from the IPY research programme. Importance was attached to ensuring that the website had an appealing design with room to publish a large number of photos. The interaction design employed a thematic mapping solution, making it possible to link all relevant content to thematic areas and/or to the research project in question.

The website had thousands of visitors through the duration of IPY. An average of 4 000 unique users visited the website each month, with a maximum of 6 000 visitors recorded in one month.

The overall web traffic increased dramatically once the webpages for the IPY Oslo Science Conference were created. On peak days the conference page registered 3 000 visits. In the period from January to August 2010, the conference page had registered almost 42 000 unique visitors, well over 100 000 visitors and almost half a million page views.

TV given high priority

The Norwegian IPY media strategy was based on the premise that IPY activities would be an excellent source of material for video-based media. The Arctic is still relatively inaccessible and exotic, polar research entails a certain amount of drama due to the demanding climate, complex logistics and heavy equipment is used, and a great deal of natural science research involves field work and sample collection. All of this makes for exciting video. So the secretariat contacted TV2, a private Norwegian television station, and the Norwegian Broadcasting Corporation (NRK) a year before IPY began and invited them to attend an information meeting to discuss potential cooperation.

The leadership of NRK was both interested in having access to the polar research and willing to set aside resources. TV2, on the other hand, did not respond to the inquiries or show any interest in collaboration. Although no agreements were signed, the management of NRK laid the groundwork for effective and mutually beneficial interaction between IPY in Norway and various editorial boards. NRK produced several programmes itself in addition to running many magazine and news reports on IPY-related issues. TV2 also covered news of some of IPY's activities, but in practice NRK served as the main channel for the Norwegian IPY activities.

The largest production by NRK was a six-part documentary (each programme consisting of 55 minutes) on Norwegian polar history. This was the first time that Norwegian polar history had been compiled into a documentary series. The programme's host, Ole André Sivertsen, and director, Håvard Jenssen, shot footage of most of the locations of significance for Norwegian polar history, including the Antarctic, South Georgia Island, Greenland, Franz Josef Land, Bjørneøya (Bear Island) and Svalbard. The series was aired for the first time in spring 2009. NRK also produced two long documentaries from the trips to Svalbard and Greenland made by the Scandinavian heirs to the throne in connection with IPY.

Four of the dissemination projects funded under the Norwegian IPY programme also supplied material to NRK. Thus, at the time of the IPY opening, NRK was able to show images from a sailing expedition to South Georgia Island and the Antarctic Peninsula by the nature photographers Arne Nævra and Stein P. Aasheim. Later, the journalist Unni Ødegård produced a series of reports for NRK's popular science show Schrødingers Katt from the first part of the US-Norwegian terrain vehicle expedition from the Troll research station to the South Pole. In July 2008 NRK aired the documentary "Hunt for the polar storm" (Jakta på polarstormen) – a film by the Polar Year

project THORPEX. Prior to the climate summit in Copenhagen, NRK broadcast a documentary about the research activity and monitoring being carried out in Ny-Ålesund.

Course for journalists on Svalbard

In the process of preparing the communication activities, it became apparent that very few news media journalists had experience from the polar areas or adequate knowledge of polar research. To ensure broader interest in and coverage of IPY research projects, the secretariat and the Ministry of Education and Research invited journalists to attend a course on Svalbard in autumn 2006. The course was implemented in close cooperation with infrastructure owners in Longyearbyen and Ny-Ålesund, the Norwegian Coast Guard and, not least, the key research communities.

The course lasted one week and gave a broad introduction to ongoing polar research activity, the research projects planned under the International Polar Year initiative, and the legal and geopolitical issues related to the administration of the archipelago. There were 40 journalists who applied for the course and 20 were granted a space. The course received very positive evaluations and laid the groundwork for the media's follow-up of IPY and the individual projects. Although no binding agreements were signed, it is natural that journalists will show an interest in and follow up on topics they already know something about.

Researchers with video cameras

As part of the follow-up of NRK, the editorial boards of Schrødingers Katt and the children's science show Newton were given an introduction to Norway's entire IPY portfolio in autumn 2006. The possibility of getting editors into the field was discussed, although it was clearly stated that space on the sea voyages and expeditions was limited. NRK showed tremendous interest in this material. As a result of this dialogue, it was agreed to equip the researchers with video cameras so they could document their own research activity themselves.

In spring 2007, three video cameras were purchased which would later be lent to IPY projects in the field. At the same time, an agreement was signed with the educational film company Snöball Film to establish a film archive and do the follow-up work based on the material. According to the standardised agreement with the photographers, the IPY programme had user rights to the material, while the research institutions were the owners. NRK, Snöball Film and the IPY programme invited the researchers who would be using the video cameras to a day-long workshop on their use. The course was held at NRK's offices at Tyholt, and included an introduction to the editorial activities of the two television science magazines produced in Trondheim. About 20 researchers, many of them young research fellows, took part in the course.

The video cameras were widely used, and the video taken by the researchers was incorporated into a number of news stories and longer reports. Snöball Film also produced short web films from several of the projects based on the footage. These were commissioned either by the IPY programme or the institution responsible for the project. Everyone involved in this pilot project gained valuable experience, which hopefully can also be incorporated into future research activities.

Extensive media coverage

It is not easy to measure the total media coverage of IPY and the research projects. Regardless of the search method employed, the number of hits on Google is large. However, the most important indication of the extensive media coverage is the information found in the research projects' own reports. At the end of 2010, a total of 850 stories in the mass media had been recorded.

NRK reporter Eivind Molde interviewing Olav Orheim in the hold of the Russian icebreaker Ivan Papanin. Photo: Kristen Ulstein

Some 3 500 schoolchildren gathered outside Oslo City Hall for the official opening of the Norwegian IPY effort. Photo: Anita Thorolvsen Munch

Tour of the large polar tent on University Square during Norwegian Science Week in 2007. Photo: Kristen Ulstein

Students from Oslo University College teaching the art of igloo-building during Norwegian Science Week. Photo: Kristen Ulstein

Many school classes turned up for the opening of the Norwegian IPY effort with posters they had made themselves. Photo: Anita Thorolvsen Munch

Publications

On Denmark's initiative, a joint Nordic magazine in English was published in March 2007 to mark the launching of IPY. The magazine presented some of the intentions behind the Nordic countries' contributions to IPY.

The Norwegian programme published two editions of a magazine for mass circulation. The first of these was ready for distribution during Norwegian Science Week in 2007. The second edition came out at the same time the following year. The magazine was produced primarily for distribution in the schools, but it was also given out as the "main brochure" for IPY in Norway. Other printed publications were limited to smaller brochures of various types.

A total of 40 000 copies of the first edition of the Polar Year magazine were printed. These were distributed to the various classes in upper secondary schools and offered to middle schools on request. The response was overwhelming: 1 200 sets of the magazine were sent to the schools. This means that at least 35 000 pupils received the magazine, and many schools taught classes on climate using IPY-based material. The second edition of the Polar Year magazine was printed in 50 000 copies, which were also distributed during Norwegian Science Week and provided to the schools in equally large numbers. In total, 2 350 sets of the magazine were sent to schools.

Spectacular opening on 1 March 2007

The subcommittees for communication and outreach and education established the framework for the official opening of the Norwegian Polar Year. The IPY Committee approved the idea of holding a large-scale event outside Oslo City Hall to mark the beginning of the People's Polar Year. In Oslo a polar event was held for 3 500 schoolchildren from the area, who were encouraged to bring along "ice bricks" frozen in milk cartons. When the children arrived, they helped to build an ice monument in front of the stage, and they were encouraged to make snow sculptures from the snow trucked in for the event.

At the same time, on-stage entertainment was interspersed with video clips shown on a large screen – both from the square and from other places around the world. Opening events were also held in Longyearbyen on Svalbard, at the Troll research station in the Antarctic and in Tromsø. During the one-and-a-half hour long programme, the audience could watch clips from the Troll research stations and an interview with Liv Arnesen, who had just set out on an expedition to the North Pole. The musician Aggie "Frost" Peterson from Tromsø also performed on stage. Crown Prince Haakon officially opened the Norwegian Polar Year, and Prime Minister Jens Stoltenberg and Director General of the Research Council Arvid Hallén were two of the guest speakers. The entire opening event was taped in TV quality and broadcast directly on web TV at NRK.no and in several other platforms. A version with English interpreting was sent directly on the Arctic Portal. The opening received extensive coverage from NRK throughout the entire day and was also well covered by other media.

In the evening, a reception was held on board the polar vessel Fram at the Fram Museum for project managers, leaders of the research institutions, politicians, polar experts from the ministries and other friends of IPY. Attendance by State Secretary Lisbet Rugtvedt for the Minster of Education underscored the importance of the initiative to Norway.

Similar receptions were held several times during IPY. The Fram Museum was very cooperative and helped out with many small and large tasks, from lending items to decorate the University of Oslo's Aula (assembly hall) to hosting a barbecue for some 2 000 polar researchers from around the world during the IPY Oslo Science Conference. Parallel to the Norwegian event, an international opening

was held at Palais de la Decouvèrte in Paris. The opening in Paris was hosted by ICSU and Prince Albert II of Monaco carried out the official opening. National opening events were held in over 20 countries, but none was as spectacular as the celebration in Oslo.

A few weeks prior to this, the opening of the Indigenous Peoples' IPY was held in Guovdageaidnu (Kautokeino), Norway. The event was organised by the International Centre for Reindeer Husbandry, Sámi University College/the Nordic Sámi Institute, the Association of World Reindeer Herders, the Resource Centre for the Rights of Indigenous Peoples and Kautokeino Municipality. The opening included representatives of indigenous peoples from the entire Arctic region as well as climate researchers, public administrators, politicians, reindeer herders and pupils from Kautokeino. The Norwegian Government was represented by Minister of the Environment Helen Bjørnøy. Director General of the Research Council Arvid Hallén was among the speakers.

Norwegian Science Week 2007

In autumn 2007 IPY was the main theme of Norwegian Science Week. IPY received widespread coverage from the annual free insert about the programme included in Dagbladet, a Norwegian daily newspaper. In Oslo IPY sponsored the opening event in the University of Oslo's Aula assembly hall. Minister of Research Øystein Djupedal took part in the ceremony and was later given a tour of University Square where science booths featuring IPY activities were set up in a large tent in front of the assembly hall.

In preparation for Norwegian Science Week, a kick-off conference was also held on Svalbard in April for the local organisers. Nearly 50 enthusiastic participants involved in research dissemination took part in a programme designed to motivate and provide insight into the IPY projects and research on Svalbard.

The secretariat estimates that about 1 000 events were organised throughout the country during Norwegian Science Week. These events spanned the entire range of research, but it is estimated that well over 300 of them focused on polar issues.

World Environment Day – international opening in Tromsø in June 2008

The United Nations Environment Programme (UNEP) observes World Environment Day on 5 June each year. In 2008, the main international celebration was held in Tromsø, Norway. The Norwegian Polar Institute played an integral role in the planning. Many of the events in the period 3–5 June focused on the main theme of "Melting Ice – A Hot Topic", which was closely linked to IPY. At the same time, the Norwegian Government observed the 20th anniversary of the Brundtland Report "Our Common Future". Rajendra Pachauri, chair of the Intergovernmental Panel on Climate Change (IPCC), and Achim Steiner, head of UNEP, were among the participants. A gala performance held at the cultural centre in Tromsø was broadcast throughout the Nordic region. Crown Prince Haakon, who emphasised the importance of IPY, took part in the celebration.

Other events

When IPY was launched, the researchers who had received project funding were invited to attend a kick-off seminar in Lillestrøm on 30 November 2006. A similar meeting was held for those involved in the communication and education projects on 29 August 2007.

A national IPY conference was held in connection with the Arctic Frontiers conference in Tromsø in January 2008. Participation was rather low as it was still early in the research cycle for most of the projects. The Norwegian IPY programme was concluded with another national conference in Tromsø on 12–13 April 2011.

In several of the projects the school pupils were given the chance to try their hand as researchers. Seen here working on the Global POP project. Photo: Kristen Ulstein

Teachers receiving practical instruction in how to slaughter and skin reindeer during the teacher training course in Kautokeino. Photo: Karl Torstein Hetland

Snow classification was one of the topics studied on the teacher training course on Svalbard. Photo: Karl Torstein Hetland

The teacher training course visits Jørn Hurum and his team during the fossil excavations on Svalbard. Photo: Karl Torstein Hetland.

The numbers confirm success

The numbers reported to the Research Council show a success rate that far exceeds expectations in terms of linking extensive dissemination activity with the research conducted during IPY. In addition to the activities initiated and implemented by the secretariat and the committees, the projects also reported that a wide array of public and user-oriented information activities were conducted throughout the entire period and especially in 2009.

The Norwegian IPY programme reported 300 public-oriented and 500 user-oriented activities in 2009, making it the Research Council's highest scoring programme on these indicators. The IPY projects are among those that have received the most media attention. The number of presentations has also been impressive, both nationally and internationally.

TEACHING

The strategy of the Sub-Committee on Education was to reach out to pupils in the schools in two main ways: through measures targeted directly at the pupils and through enlisting the help of enthusiastic teachers. Competitions were the most important means of involving the young people.

Norway's participation in "Schools on Board" in April 2008

Vest-Telemark upper secondary school won a nationwide competition to send one pupil and one teacher to the Northwest Passage. They organised a polar camp in which most of the pupils and teachers at the school participated, and the project clinched the victory for the school. The lucky teenager who got to represent the school was Marit Haugen from Vinje. She was chosen for her interest in climate change and her outstanding marks in mathematics and natural sciences. Teachers and pupils from Sweden, Scotland, Germany, Canada and Norway participated in the "Schools on Board International Field Programme 2008", which was organised by the University of Manitoba in Canada.

Project competition held by the SciencePub project

The SciencePub research project announced the "On thin ice" competition, a climate project in which participants had to respond to predefined tasks. Two girls from Bergen, Liv Sofie H. Utvær and Ingrid A. Eidsvaag, won the competition with their report entitled "One degree more or less". The prize was a week of fieldwork with Norwegian researchers in northwestern Russia. The girls, who attend two different upper secondary schools in Bergen, worked together on the project in their leisure time during the autumn of 2007. Among other things, they administered a questionnaire to 113 teenagers about their attitudes towards climate change.

Project competition on climate issues

In cooperation with the GLOBE Program, pupils in lower and upper secondary schools were invited to participate in a project competition, and the winners got to take part in the Globe Learning Expedition in South Africa. The young people chosen in Norway were Mathias Thorshaug, Astrid Landstad, Kristine Iversen, Ingrid Anthonsen and Marianne Holsmo from Bodø upper secondary school and Ingrid A. Eidsvaag and Sofie H. Utvær from Katedralskolen and Fyllingsdalen upper secondary school in Bergen.

The group of pupils from Bodø submitted an essay entitled "The future of cod in the Salten region under the influence of hazardous substances and global warming", and the girls from Bergen won with another report on how climate change might affect the access to freshwater in Africa. The Norwegian participants did an outstanding job and presented their projects professionally in South Africa.

Course for teachers

A number of measures designed to spark teachers' enthusiasm for teaching about polar and climate issues were implemented. The most important of these was a special course for teachers which was offered on four different occasions.

A summer course (4–11 August 2007) and a winter course (19–24 April 2009) were held on Svalbard. In 2007, 22 Norwegian and five Danish teachers attended the course. In 2009, 210 teachers signed up for 23 spaces. The courses gave the participants a fantastic experience, and they generated many polar-related projects at the schools – both before and after. The teachers who participated were selected on the basis of their applications in which they described a plan for teaching about polar issues for their own class or the entire school in the coming year.

In cooperation with Sámi University College and the Tana Sámi Language Centre, the IPY programme arranged a course for teachers in Kautokeino (30 March–4 April 2008) and in the Tana and Varanger municipalities (7–12 June 2009). Twenty-five teachers from throughout Norway attended the courses, which explored Sámi culture and history and how the community can adapt to future climate change. The course in Kautokeino focused on reindeer husbandry culture and the one in Tana and Varanger looked at sea Sámi culture.

Teachers join an expedition

A few of the teachers were lucky enough to join a research expedition and help with data collection, side by side the researchers on board. The SciencePub project invited four teachers on board the KV Jan Mayen that sailed from Tromsø to Svalbard in the spring of 2007.

On 28 July the research vessel G.O. Sars set sail from the harbour in Bodø in search of gas hydrates on the floor of the continental shelf break off the coast of Nordland County. The expedition included researchers and students in the fields of geology, geochemistry, biology and microbiology – as well as two teachers.

Local project funding

Schools often have good ideas for projects, but they lack funding to cover small expenses. To meet this need, the Sub-Committee on Education created a separate budget to support teaching projects at individual schools.

The Norwegian IPY programme allocated almost NOK 700 000 to 77 local school projects in four funding rounds. In retrospect, it is evident that this gave a vital boost to polar education and that a great deal was accomplished with small sums of money. As a result of these small grants, 24 000 pupils have been directly involved in the Polar Year activities and learned more about polar conditions and polar research. All the schools submitted reports and their activities are documented in a single large report.

Journals and magazines

Several professional magazines and journals targeted at the schools dedicated a lot of space to the Polar Year. The journal Naturfag published a special edition prior to Norwegian Science Week in 2007. The edition ran articles on the schools' previous and planned activities, and provided background material on polar history, research and simple activities that could be carried out in the classroom. The Nysgjerrigper science magazine for children also published a special Polar Year edition in connection with Norwegian Science Week. The Nysgjerrigper Science Knowledge Project is the Research Council's initiative for pupils and teachers in primary schools.

HIGHER EDUCATION

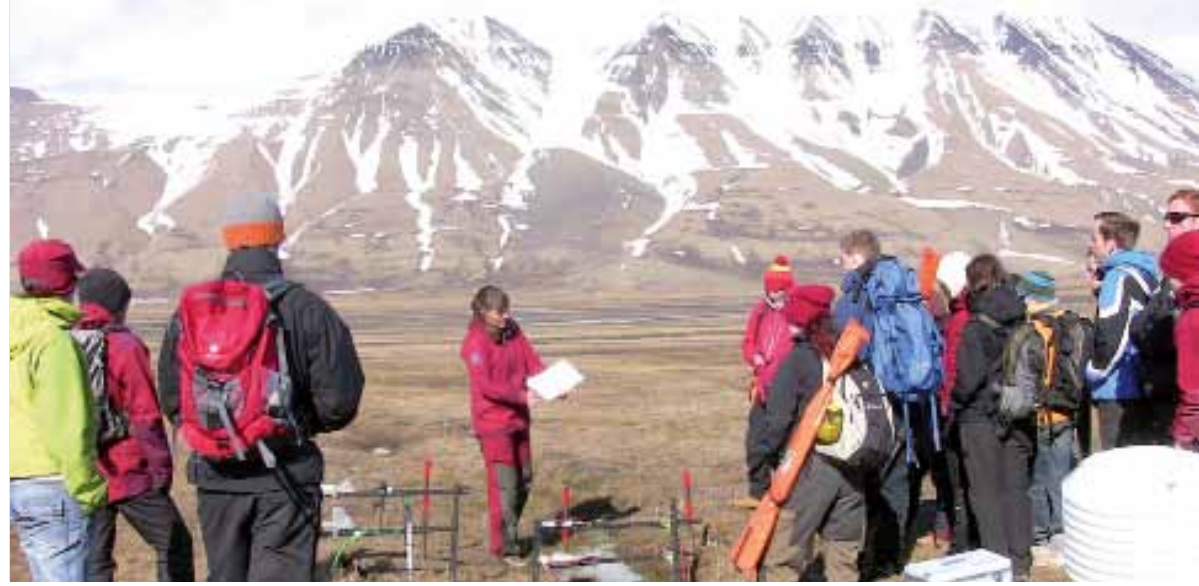
Network for young researchers

IPY's Youth Steering Committee (YSC) was established in 2005. Its purpose was to ensure that IPY achieved its goal of including the next generation of polar researchers and youth from around the world. The idea was for the committee to work through the national IPY committees. In autumn 2006, Kriss Rokkan Iversen and Lena Seuthe, both students at the Norwegian College of Fishery Science, contacted the Polar Year secretariat to get support for a youth committee in Norway. The Sub-Committee on Education allocated some funding for travel.

At the same time, discussions were underway to establish a more organised network for young polar researchers. The idea to establish the Association of Polar Early Career Scientists (APECS) was launched in spring 2007 and was actively supported by the programme office in Cambridge. In September 2007, 60 representatives for young researchers and the international and national YSC met in Sånga-Säby outside of Stockholm and created APECS. Kris Rokkan Iversen from Tromsø was elected as the first president of the organisation, which was quickly recognised by both the International Arctic Science Committee (IASC) and the Scientific Committee on Antarctic Research (SCAR).

At the end of 2008/beginning of 2009, the offices of APECS and its director Jenny Baeseman were in the process of moving. At that time the organisation had 2 000 members worldwide and was heavily involved in the planning of the IPY Oslo Science Conference 2010. Thanks to a cooperative effort between the Research Council and the University of Tromsø, APECS was offered office space in Tromsø, and the office was established in January 2009.

The establishment of APECS is an important legacy of IPY. The network has motivated and qualified many young researchers to work on polar issues. The organisation's activities promote internationalisation and network-building in a research field in which cooperation is crucial for utilising logistics and infrastructure efficiently.



Field school in 2009 in Adventdalen, Svalbard. Hanne Christiansen teaching. Photo: UNIS

Field school on Svalbard

In 2009, the University Centre in Svalbard (UNIS) took the initiative to establish an IPY Field School for students on Svalbard. This was to be a one-time activity, but the interest in the field school turned out to be enormous. Almost 300 students from 50 countries applied for 20 spaces. The first week-long course was funded by the IPY programme in Norway, the Norwegian Ministry of Foreign Affairs and UNIS.

The objective of the field school is to give an interdisciplinary introduction to environmental changes in the polar region, based on previous and ongoing research in the Arctic during and post IPY. The field school is intended to motivate undergraduate students and help them to gain research qualifications. Both APECS and the University of the Arctic (UArctic) have served as co-organisers. The course combines lectures with field work and excursions, and helps to build international, interdisciplinary networks. During the course, the students create posters and get advice on career opportunities.

Thanks to an extension of funding from the Ministry of Foreign Affairs, it has been possible to offer the field school in both 2010 and 2011. There continues to be great interest in this type of course on Svalbard.

Lecture tour in autumn 2008

Elise Strømseng of UNIS conducted a lecture tour in which all four of the large universities on the mainland participated. The purpose of the tour was to recruit students to polar research in general and to UNIS in particular, in addition to providing information about the IPY/APECS/UNIS field school to be held in the summer of 2009.

48 research fellows

The IPY research projects have had a positive impact on the recruitment of new polar researchers. The projects

Vest-Telemark Upper Secondary School at Polar Camp at Møsstrond near Hardangervidda.
Photo: Karl Torstein Hetland

Crown Prince Haakon meets with young polar researchers from all over the world. Here he greets the Director of the Association of Polar Early Career Scientists (APECS), Jenny Baeseman.
Photo: John Petter Reinertsen, Samfoto

250 young researchers and teachers from all over the world on a boat cruise on the Oslo fjord during the IPY Oslo Science Conference.
Photo: John Petter Reinertsen, Samfoto

One of IPY's aims was to draw attention to Norwegian polar research. Here national boulevard Karl Johans gate is adorned with banners during the IPY Oslo Science Conference. The conference was also clearly profiled in Lillestrøm. Photo: Steffen Aaland

have employed 22 doctoral research fellows, 11 of whom were women, and 26 post-doctoral research fellows, 9 of whom were women.

WORLD'S LARGEST POLAR SCIENCE CONFERENCE

It is not only the Norwegian Government's large financial contribution that has gained Norway the reputation as a leading polar nation during IPY. As early as 2006, the ICSU/WMO Joint Committee drew up a conference plan, and the national committees were invited to apply to act as host – including for a science conference in 2010. The Research Council submitted an application, with support from Minister of Research Øystein Djupedal, and Norway was selected in competition with Canada to host the event.

The main venue for the conference was the Norway Trade Fairs facility in Lillestrøm on 8–12 June 2010. A total of 2 300 participants from 53 countries attended the event, making the IPY Oslo Science Conference 2010 the largest polar research conference ever organised. As the host, Norway had the opportunity to make its mark on the event by drawing on its own experience from IPY activities.

Programme and special conditions for young researchers

No previous polar research conference has given such high priority to young researchers and to adapting the programme to their needs. Many young researchers were awarded research fellowships and given extraordinary opportunities to conduct field work through IPY. APECS, the young researchers' own organisation, made a major impact beginning with the IPY Open Science Conference in St. Petersburg in 2008.

Initiated by APECS and the EOC committee, the steering committee for the conference approved a grant scheme that encompassed 400 young researchers and 120 teachers. The grants covered half of the conference fee and free (low-cost) overnight accommodation in Oslo.

Not surprisingly, APECS and the young researchers had a clear impact on the conference. They organised two receptions and had a fjord cruise, and they awarded their own prizes for best presentation, best poster, etc. They also had a chance to meet Crown Prince Haakon and Prince Albert II and served as moderators for plenary sessions. In addition, over 100 participants attended an APECS workshop held at the University of Oslo over a two-day period prior to the conference.

Education, Outreach and Communication (EOC)

At the Oslo conference there was great interest in seeing what the various countries had accomplished with their communication and education activities during IPY. Early on, the international EOC committee discussed the opportunities for this at the conference. A meeting at the World Meteorological Organization in Geneva in February 2009 laid the groundwork for a major communication and education programme – in addition to the scientific programme. The components were:

➔ EOC (Education, Outreach and Communication) as a separate thematic area

The steering committee approved education, outreach and communication as a separate thematic area – in addition to and on equal footing with the five scientific areas. The decision was viewed as a milestone for polar EOC and it was well received by the groups involved. The turnout for "thematic area 6" during the conference disproved any dire predictions, and the participants' evaluation showed that EOC got the overall highest score of all six thematic areas.

➔ PolarTEACHERS

The international PolarTEACHERS conference was held in Oslo on 6–7 June 2010. The goal was to inspire teachers to continue to include polar research in their teaching activities in the primary and secondary schools – and to share experiences from IPY activities – under the topic "How to use polar science in your classroom". Since the participants were going to attend the research conference afterwards, steps were taken to prepare them for their encounter with a large-scale research conference. Another important goal was to establish good ties between teachers and young researchers, so the teachers' conference was held in conjunction with an APECS workshop at the University of Oslo. The response was overwhelmingly positive.

➔ PolarCINEMA

A large number of films, both documentaries and artistic works, as well as magazine and television news stories were produced throughout IPY. The EOC committee decided early that it would give priority to showing a selection of these productions. The production companies were invited to nominate films, and nominations were received for 90 pieces from 17 different countries. Four panels of judges were appointed (in Malaysia, the US (Alaska), the Netherlands and Norway), which assessed the submitted material and recommended films for the cinema programme. The judges and the committee chose a total of 69 productions, which were shown in a designated room throughout the entire conference. Thirty-eight films were shown on a big screen in the cinema; 24 of these in their entirety and 12 in edited form. The 40-hour programme also included debates and presentations by participating researchers and film producers.

So that people who did not attend the IPY Oslo Science Conference could watch some of the best films, cooperation was established with the Norwegian Film Institute to show eight selected films in full cinema format in a polar film programme that ran the entire week.

➔ PolarFESTIVAL

The EOC committee decided that the IPY Oslo Science Conference should not only be a closed science conference, but that it should reach out and communicate with people in Oslo. The ideas were consolidated in the PolarFESTIVAL concept – very similar to the model from the "research market" (Forskningstorget). Banners displayed along Oslo's main street, Karl Johans gate, drew attention to the conference, and a two-day PolarFESTIVAL was organised outside Oslo City Hall. Several research vessels (G.O. Sars, Oceania from Poland and KV Aalesund) were docked in the nearby harbour during this time, and eight Norwegian and international institutions set up tents and held activities along the pier.

➔ PolarEXCHANGE

The BBC science journalist Sue Nelson was hired to lead popular scientific plenary sessions. The programme was organised like a talk show in which she interviewed researchers on the main stage about various topics. Three such shows were produced, all of which were webcast. All the plenary sessions and several other posters in the conference programme were also sent via web-TV.

The webcast from the conference was made available in real-time on NRK.no/viten and ArticPortal.org. During the conference, the IPY conference website had 6 100 unique visitors. Over half of these were what can be referred to as the conference's "virtual community". The largest group of visitors to the conference site were from the US, followed by Canada, the UK and Germany. During the conference, and in the first few weeks following, the web-TV page had 13 000 visitors from 75 countries.

The documentary Silent Snow focuses on the spread of environmental pollutants. This was one of the films shown as part of the PolarCINEMA programme.

Patricia from Portugal and Andrés from Spain studying the density of water during the PolarTEACHERS conference.
Photo: Kerstin Mertens, Samfoto

Sámi institutions and Kautokeino Municipality made an impact at the PolarFESTIVAL at Oslo City Hall.
Photo: John Petter Reinertsen, Samfoto

Selection of the Norwegian projects under IPY

By Per Backe-Hansen, Research Council of Norway

The secretariat for the Norwegian IPY programme was established at the Research Council of Norway (RCN) in autumn 2005, on the condition that the Research Council would administer the Norwegian IPY effort like an ordinary research programme.

The official duration of the International Polar Year 2007–2008 was from 1 March 2007 to 1 March 2009. In preparation, the Norwegian IPY effort had to implement a process to select projects for funding. In order to ensure that the projects were up and running and could begin collecting data at the very start of the first summer season in the Arctic, a funding announcement had to be issued at least one year in advance of the opening of IPY. The allocation for the Norwegian IPY effort was finalised in autumn 2006, when the initiative received NOK 80 million per year for four years.

Funding announcement for research projects

A large-scale call for proposals of relevance to IPY was issued in January 2006, in the wake of a series of well-attended information meetings held in Norway's major university towns during autumn 2005. The call was first and foremost targeted towards research projects, but was open to applications for education, outreach and communication projects as well. As the duration of IPY was only two years, it was decided to issue only one call for proposals. Thus, the entire four-year allocation was to be awarded in a single funding round.

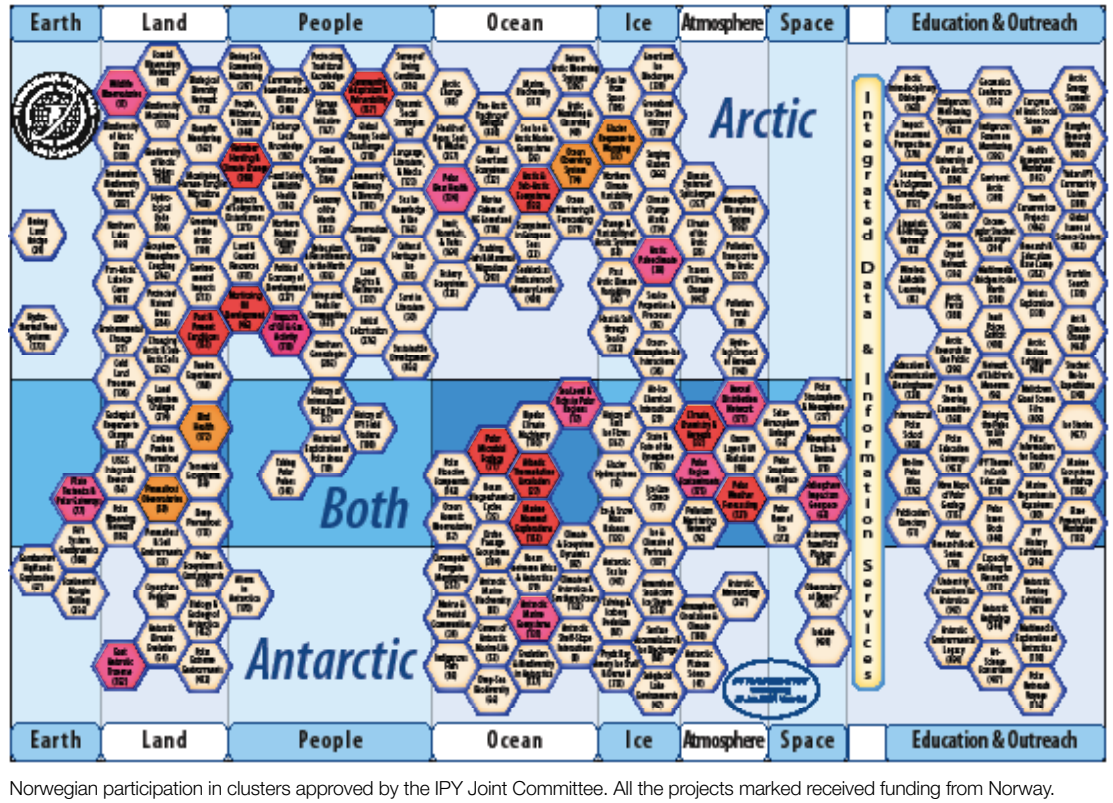
An international application Assessment Committee led by Sverre Lodgaard, then Director of the Norwegian Institute of International Affairs (NUPI), was established to ensure that the evaluation process was carried out responsibly and in compliance with to the RCN regulations on impartiality and confidence. The committee was appointed by the Research Board of the Division for Strategic Priorities in January 2006. It was decided that the grant proposals would be assessed by international referee panels before being submitted to the assessment committee for final review and allocation of grant awards.

The call for proposals set out important requirements and guidelines in keeping with the policy document on Norwegian participation in IPY 2007–2008 (Research Council of Norway, 2005). The project proposals were to be submitted by clusters endorsed by the IPY Joint Committee and to be of high international calibre. The overall Norwegian IPY research activities were to have a scope, scientific focus and breadth in accordance with national priorities, while at the same time balancing the need for basic research and research to support national interests relating to management of the polar areas. The scientific focus was to build on existing plans for Norwegian research in the Arctic and Antarctic as well as on other national strategies within thematic areas addressed by IPY. The projects were to also take an interdisciplinary approach to research questions that touched on several fields.

One objective of IPY was to establish and maintain permanent networks and observation and monitoring sites and systems in the polar areas, including for operational observation, to make Norway better equipped to monitor and forecast further developments in the polar areas with regard to the environment, natural resources and industrial activities.

Given Norwegian interests in the northern areas, the major share of Norwegian IPY research was to be carried out in the Arctic rather than the Antarctic. The overall Norwegian project portfolio was to include projects in which

The fourth polar year was the first to incorporate research on the human dimension – in practice this focused primarily on the living conditions of the peoples of the Arctic. Photo: Philip Burgess



Norwegian participation in clusters approved by the IPY Joint Committee. All the projects marked received funding from Norway. Projects coloured red indicate those for which the head of the international cluster was Norwegian; projects coloured orange indicate those in which a Norwegian was second-in-command.

Norwegian research groups played a leading or major role. The portfolio was also to include innovative and pioneering projects that would attract national and international attention and promote Norway as a leading polar nation. Finally, priority was to be given to projects that incorporated Russian participation, in order to cultivate cooperation between Norway and Russia in the northern areas.

By the deadline on 17 March 2006, the Research Council had received 71 grant proposals – 63 for research projects and eight for education, outreach and communication projects – for a total of NOK 1.2 billion. Two grant proposals submitted under the concurrent call for the Norwegian Antarctic Research Expedition (NARE) were seen as particularly relevant to IPY, and were assessed together with the IPY project proposals to achieve value added and secure co-funding.

Assessment and grant awards

Thirty international referees were appointed to six scientific panels in the marine sciences, terrestrial sciences, atmospheric physics, geosciences, toxicology and health sciences. There was also a panel in the humanities and social sciences, representing the human dimension. The panels convened in Oslo in May 2006 to assess the project proposals. When proposals lay outside the panels' spheres of expertise, assistance was sought from external experts.

Based on consensus, the panels prepared an assessment report for each proposal. The panels also assigned each proposal an overall mark and provided written feedback. Some of the panels ranked the proposals internally.

The international application assessment committee convened in Oslo on 8–9 June 2006. The committee had decided early on that only proposals awarded a mark of 6.0 or higher (7.0 being the highest possible score) would be processed further. The only exceptions were a few highly-ranked project proposals in the human dimension area that had achieved lower scores (due to the stringent assessment traditions in these disciplines), but were deemed "highly recommendable". Altogether, the proposals submitted for further processing added up to well over NOK 500 million in funding.

The committee ended up with a list of 29 project proposals that would be eligible for funding, given an adequate total budget. On the recommendation of the panels, applicants in several cases were asked to remove modules or elements from their proposals. In several other cases, two applicants were asked to coordinate or merge their project proposals. The idea of merging project proposals did not prove functional in practice.

The Research Council received three complaints regarding the rejection of proposals. All of these were dealt with according to the ordinary complaints procedure at the Research Council. In one case, the application assessment committee rescinded its decision and awarded a grant to the project. In another case, the Research Council Appeals Committee found that a processing error had taken place, and the project proposal was submitted for reassessment. The new assessment resulted in the same mark as the previous one, but the panel gave a more detailed justification in its report. The assessment committee did not find grounds to revoke the original decision, and the applicant accepted this.

The budget for the Norwegian IPY effort could not be finalised until the national budget for 2007 had been approved. Including funding set aside from the Fund for Research and Innovation, the initiative was ultimately allocated NOK 320 million for the four-year period from 2007 to 2010. Of this, NOK 289 million was to be awarded to research projects. In October 2006, the international application assessment committee finalised the project portfolio, which consisted of 26 research projects with a budgetary framework of NOK 290 million. An additional NOK 2 million was awarded to two education, outreach and communication projects. The requirements and guidelines set out in the call for proposals were fulfilled in a satisfactory manner. And with an allocation of this size, Norway was one of the major participants in IPY.

Representatives of the projects were invited to participate at a kick-off conference in Lillestrøm, near Oslo, on 30 November-1 December 2006.

Education, outreach and communication projects

Due to pending budget finalisation, the decision regarding how much of the IPY budget to allocate to research projects and Education, Outreach and Communication (EOC) projects, respectively, was not taken until autumn 2006. At that time, the Norwegian IPY Committee earmarked a total of NOK 14 million for EOC projects; however, only NOK 2 million had been awarded during the first funding round. Therefore a dedicated call for proposals for NOK 12 million for EOC projects was issued that autumn, with an application deadline of 30 November 2006.

Because proposals for EOC projects differ greatly from proposals for research projects, a second international application assessment committee was appointed, chaired by Professor Svein Sjøberg of the University of Oslo. Once again, the committee was responsible for all decisions regarding grant awards.

The call for proposals established a variety requirements and guidelines. Projects were to have national and/or international target groups. Project proposals did not have to be submitted by clusters approved by the IPY Joint Committee. Projects were to promote collaboration between research institutions and education and outreach institutions. Collaboration with at least one IPY science project was encouraged, but not required. Children and young people were to be key target groups for education projects, which were to strive to generate long-lasting interest in the polar areas and science subjects in general.

In addition, the Norwegian IPY Committee wished to create a broad-ranging portfolio, rather than one containing only a few spectacular projects. The committee recommended that priority be given to projects that had high visibility and that would reach a wide audience, and that more innovative projects also should be included. The projects should when possible seek to make the most of the chance to update the general public's understanding of polar research. A reasonable balance between education projects and other types of projects, preferably those that combined both education and outreach, should be sought, and the portfolio should include projects of particular relevance to or featuring the participation of indigenous peoples in the Arctic.

A number of school pupils and students got to try out life as scientists in the field. Students Malin Rue (left) and Vibeke Sundfjord accompanied scientists on an expedition on board the research vessel RV Lance in the Fram Strait in 2008. Photo: Private

Many journalists were given the opportunity during IPY to experience polar research first hand. Here a group from the course for journalists eagerly deploy their cameras at the front of the glacier in Kongsfjorden. Photo: Kristen Ulstein

By the deadline on 30 November 2006, the Research Council had received 67 grant applications: 24 for education projects, 33 for outreach and communication projects, and 10 for combined education and outreach projects. A total of NOK 93 million was requested, but only NOK 12 million was available for allocation.

In March 2007, the second international application assessment committee finalised the project portfolio, which consisted of 22 EOC projects with a budgetary framework of NOK 12 million. Once again, the requirements and guidelines set out in the call for proposals were fulfilled in a satisfactory manner. Since the EOC projects were not awarded grants until March, many of them started up a bit later than the research projects. However, several projects were implemented in spring 2007, and all of the projects were carried out in the course of IPY. A kick-off meeting was held in August 2007. Norway's portfolio of education, outreach and communication projects during IPY was larger than that of any other country.

Shared data management – vision and reality

By Øystein Godøy, Norwegian Meteorological Institute, head of DOCIPY and Norwegian IPY Data Committee

The primary purpose of the International Polar Year was the extraordinary, intensive, internationally coordinated collection of data. The many technological advances since the International Geophysical Year (IGY) have made it possible to collect larger datasets from the polar regions than ever before. These data will form the basis for research for decades to come – so it has been a vital concern to ensure that the vast volumes of data are both accessible and securely stored so as to leave a lasting legacy.

The challenge

One of IPY's great challenges involved getting scientists to look beyond their own work. The free exchange of background data and findings was an underlying principle meant to ensure a coordinated "burst" of research which utilised resources as efficiently as possible and avoided unnecessary duplication of effort.

The culture for sharing data varies greatly between scientific disciplines and between researchers within the same field. In general, however, researchers tend to keep "their own" data to themselves for a long time. One reason is the need to publish first, of course, while another could be due to technological challenges. The current culture does not reward scientists for developing and maintaining high-quality, widely-used datasets – thus public and private investment in observation and research may be underutilised.

Sharing data requires technical systems as well as a culture for making use of them. At the start-up of IPY, no systems for data management existed that were in line with the visions formulated for IPY– so they had to be established during IPY.

Technology and culture

Initially, IPY had very high ambitions for structured data management, with a vision of fully integrated data management systems in which users could upload, find, download, visualise and transform data.

Unfortunately, few activities in the area of data management were funded at the start of IPY, so in most cases data management systems were not established until after the research projects had begun collecting observations. Thus IPY lost the opportunity to influence the actual data collection methods from the outset, which could have simplified long-term data management. In order for users in any field to change their accustomed patterns, they must see the personal benefit of doing so.

Since roughly 50 years pass between such comprehensive studies of the polar regions, the data must be documented and managed over time in such a way that researchers without in-depth data skills can utilise them. Well-functioning data management requires a comprehensive approach and a focus on value added, from collection to long-term data management. These data are the capital in a knowledge bank.

It is difficult enough to establish structured data management within just one scientific field. There must be agreement on a common technological framework and common language, where each term is defined in such a way that everyone uses it uniformly. Content must be documented so that everyone comprehends it. So, given the complexity of devising a common concept system for a single field, the challenge facing IPY was greater still: creating an interdisciplinary concept system.

The foundation for establishing comprehensive IPY data management varied widely. In certain fields there were institutional, national or international systems in place, while in other fields no structured data management systems existed at any level. Disciplines within the natural sciences are relatively comparable, but IPY also encompassed the humanities and social sciences, with their very different scientific methods and systems of concepts.

International coordination

Internationally, data management was coordinated through the project "International Polar Year Data and Information Service" (IPYDIS), which was not a physical system but rather a loose organisation of data centres that wished to assist in IPY data management and in drawing up a common framework to this end. In light of the technological advances concerning distributed data management via Internet, IPY came a few years prematurely, yet it was still possible to establish workable systems.

IPY helped to raise awareness about data collections, their value, and their short and long-term management. In 2005 the US National Science Board published a report on data collections and associated risks. The term "data collection" encompasses factual data, technical infrastructure, procedures and human resources. The report defined three categories of data collections; at the lowest level are research collections, which are typically established for a specific project or purpose. At the highest level are reference collections with a global perspective and global user base. At the middle level are the resource collections, which are often associated with an institution, have a long-term perspective, and encompass multiple projects. Most of the collections that were connected under IPYDIS are of this type.

The research collections are most at risk for losing data, yet it is precisely these that manage large volumes of data and are always the first station in structured data management. IPYDIS primarily consisted of resource collections, but most of IPY's body of data is still stored in research collections.

The national perspective

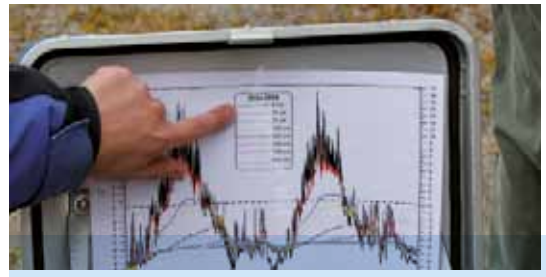
Within Norway, data management was coordinated through the project DOCIPY, whose two tasks were to develop a technical infrastructure and to compile an overview of the body of data.

Existing national infrastructure for and expertise in resource collections from the Institute of Marine Research, the Norwegian Polar Institute and the Norwegian Meteorological Institute were utilised in establishing a virtual data management system. The Norwegian Institute for Air Research (NILU) assisted in compiling the overview and contributed metadata from its own resource collections. The three systems that were connected synchronised metadata daily. The data itself was not synchronised. Once a week, information from the national system was submitted to the central IPY database at GCMD in the USA.

In this way, information about Norwegian datasets became visible internationally. One problem, however, is that only metadata is available for many datasets; the actual data are still stored in a research collection.

DOCIPY's second main task was to compile an overview of national datasets, including their management, to ensure that they complied with the IPY principles for data management. An important tool in these efforts was the data plans specified in the project contracts and annual updates. No other nation but Norway had this type of reporting, although many wanted it.

Further structuring of these documents, accompanied by a well-defined concept system, would have made them even more useful. Given that structured long-term data management was a new concept for many researchers, they interpreted it in different ways. It is not clear, for instance, what a dataset actually is.



Hanne Christiansen of UNIS measures permafrost temperature development. Here, recordings from a borehole in Adventdalen valley on Svalbard. Photo: Kristen Ulstein

Eli Haugerud (left) and Katrine Kongshavn were selected from 28 applicants hoping to join the research expedition on the RV Lance. Water samples were taken for the IPY project Contaminants in Polar Regions (COPOL). Photo: Karine Nigar Aarskog

Long-term data management requires standardised documentation and procedures that ensure the integrity of the data, in order to avoid losing the fruits of public and private investment when researchers change jobs, retire, or experience a disc crash. The majority of Norwegian research data is managed in research collections that are limited in both time perspective and capacity for coordination with other collections.

During IPY, researchers became acquainted with the concept of metadata, which is critical for long-term data management as well as for establishing coordination of existing collections in Norway and internationally. For the field of data management, perhaps the most important product of IPY is the raised awareness of data management itself and the technological and cultural challenges involved. IPY was the beginning of a transitional process, one that must continue. Structured, long-term data management generates value added for research data, safeguards public and private investments in observation systems and data collection, and paves the way for the replication and quality assurance of research.

During IPY, vast volumes of biological materials were collected. Here, Jon Aars of the BearHealth project takes a blood sample from a polar bear. Photo: Jenny Bytingsvik

The Norwegian IPY effort – activities and results

By Olav Orheim, Research Council of Norway, Head of the Norwegian IPY Secretariat

The Norwegian Government allocated NOK 320 million to the Norwegian IPY effort through the Research Council of Norway. A total of NOK 289 million went towards funding 27 research projects. These funds were allocated on the basis of a competitive call for proposals, the largest individual allocations amounting to NOK 33 million and the smallest to NOK 0.2 million. The Research Council also helped provide funding for a replacement vessel, thus enabling an expedition to be undertaken in the Southern Ocean on board the research vessel G.O. Sars, under the Antarctic Krill and Ecosystem Studies (AKES) project.

All the projects conducted under the Norwegian IPY effort are described in articles in this book. In addition to the projects described here, the Research Council provided funding for more than 10 projects closely related to IPY under the Large-scale Programme on Climate Change and Impacts in Norway (NORKLIMA), as well as numerous other smaller projects that were connected with IPY in some way or another.

The major portion of research funding under IPY was used to pay the salaries of 52 research fellows and numerous other researchers and technicians involved in the projects. About one third of the Norwegian IPY allocation was spent on purchasing instruments and other equipment, and some of it was also used to support field activities.

However, only part of the funding for the overall Norwegian IPY research effort came from the Research Council. Total in-kind contributions from participating universities and institutions amounted to about as much as the main IPY allocation. These contributions covered the costs of permanent employees, as well as loaned equipment and logistics support, such as research vessels, stations and laboratories. Ship-time on the research vessels was not funded exclusively by the participating research groups. The Norwegian Coast Guard also made a significant contribution. In total some 500 person-years were expended under the IPY programme, and approximately 100 small and large-scale field expeditions and voyages were made to the Arctic and Antarctic.

Because of their expertise, individual Norwegian researchers participated in about as many projects under the international IPY effort as they did in projects funded by Norway.

The Norwegian IPY initiative was much more than a research effort. It was also a large-scale Education, Outreach and Communication (EOC) initiative. Dissemination activity is a normal component of research projects, but under the Norwegian IPY effort an unusual step was taken to earmark IPY funds specifically for communication and teaching activities. A total of NOK 14 million was allocated to EOC projects on the basis of open competition and a further NOK 10 million was spent on smaller-scale projects, websites, and other communication activities organised by the Research Council. These activities are all described in more detail in this book.

What did the nation get in return?

Research results

The most important thing to come out of IPY was new knowledge. In research new knowledge is built up gradually, step by step, so it is difficult to say that this leap in knowledge occurred as a result of the overall IPY research effort. It is even more difficult to sum up the results of the IPY effort so soon after its conclusion; many new research findings based on IPY activities will emerge over the next few years.

That being said, I am nevertheless going to take the chance and highlight some findings, which were reached not least as a result of the huge compilation of field data that took place under IPY. The research findings listed below are not the result of Norwegian research alone, but Norwegian researchers have had leading roles in all the projects listed. All the results are described in more detail in this book (the relevant project name is given in brackets):

- Data from new measuring stations together with the campaign featured in the documentary "Chasing the Polar Storm" have led to a measurable improvement in the forecasting of extreme weather in the Arctic (IPY-THORPEX).
- Time series for monitoring the flow of water into and out of the Arctic Ocean have been extended, our understanding of marine, sea ice and biological processes has increased, and sea state and ice forecasting has been improved using near real-time data (iAOOS-Norway).
- Austfonna (the largest ice cap in Svalbard) is thickening in the interior, thinning along the periphery and is significantly affected by meltwater (GLACIODYN).
- The greatest sources of black carbon found on the ice and snow in the Arctic, which increases ice melting as a result of solar radiation, are agricultural and forest fires, not coal and oil combustion (POLARCAT).
- Laboratory experiments with large water masses in Ny-Ålesund have uncovered unexpected differences between the microbial food webs in boreal and polar waters (PAME-Nor).
- Deployment of electronic tagging devices on 40 seals in the Arctic and Antarctic has generated unique oceanographic data from 110 000 point measurements taken from depths to over 1 000 metres (MEOP).
- Studies of marine ecosystems in the areas where the Arctic and Atlantic waters meet have not shown changes in primary production as a result of climate change (NESSAR).
- Arctic organisms are vulnerable both to parasites and pollutants (BIRD-HEALTH).
- Climate change will affect the presence and behaviour of contaminants in the Arctic, but significant uncertainty remains as to the extent of the contamination and whether it is likely to increase or decrease (COPOL).

The BearHealth project studied the health status of polar bears.
Photo: Jenny Bytingsvik

Ilker Fer and Helge Bryhni from the BIAC project assembling equipment on the deck of the research vessel RRS Ernest Shackleton in the Weddell Sea.
Photo: Kjersti Lundmark Daae

The tracked vehicle expedition from Troll research station to the South Pole was one of the most demanding IPY projects.
Photo: Stein Tronstad

- The water level in the subglacial lakes under the inland Antarctic ice sheet has varied. This may affect the movement of the large ice masses, and in turn lead to changes in sea level (TASTE-IDEA).
- Ocean circulation has played a role in precipitating very rapid natural climate change – the fjords in northern Norway went from having a full Ice Age climate to today's climate in the course of just 200 years (SciencePub).
- Sea ice formation increases CO_2 uptake and the acidification of the world's oceans (BIAC).
- Levels of persistent organic pollutants (POPs) in polar bears have fallen in recent years as a result of international agreements on the use and releases of POPs, but co-acting pollutants still have the potential to have negative effects on bear health (BearHealth).
- Arctic tundra ecosystems are changing rapidly. New species are entering the tundra and the lemming cycle is weakening or disappearing altogether – this is something the Arctic fox can help us to monitor (Arctic Predators).
- A complicated interplay of factors such as climate, vegetation and grazing animals means that a warmer climate will not necessarily lead to the tree-line moving northwards (PPS Arctic Norway).
- Sediment cores from lakes in the Ural Mountains indicate that the area was ice-free some 50 000 years ago with evidence of human settlement and mammoths, at a time when Scandinavia was covered by a huge ice sheet (ICEHUS II).
- In order to ensure the long-term sustainability of reindeer husbandry in the face of future climate change, traditional methods to increase the diversity of the reindeer herd should be reintroduced (EALÁT).
- Demography, the development of natural resources, infrastructure and management systems are as important for the further development of local Arctic communities as climate change (CAVIAR).
- The living conditions of the Nenets people in north-western Russia are being severely affected by large-scale oil and gas activity in the area, and they have little influence on developments (MODIL-NAO).
- Arctic inhabitants' understanding of security related to petroleum activity has been analysed (GAPS).
- As a result of research on the acoustic properties of krill and fish, estimates of the biomass of krill in the Southern Ocean, and also the catch levels, have been changed considerably (AKES).
- New sediment cores from the Southern Ocean and South Georgia show how the natural climate has changed over the past 20 000 years (PALEODRAKE).
- The thermal state of the permafrost in northern Norway and Svalbard has been mapped, and permafrost temperatures are now being monitored in 25 boreholes, in part to improve our understanding of the possible release of methane gas (TSP Norway).
- Ocean-bottom seismometers and seismic installations on Bjørnøya have improved our monitoring of earthquake activity in the area between Jan Mayen and Svalbard (Continental Margin).
- Analysis of historical sea level data, including a new 100-year long data series from Russia, has provided detailed information on sea level changes in the Barents Sea (LEVANS).
- Concurrent studies of the aurora in the north and in the south have unexpectedly shown that they are not mirror images of each other (IPY-ICESTAR).
- A prototype autonomous buoy has been developed that is to be deployed on the drifting sea ice in the Arctic Ocean and used for the acquisition of seismic reflection data (Seismic Buoy).
- Nearly half a million words in the Kven language have been documented as part of a research effort focusing on minority languages and cultures in the northern circumpolar region (LICHEN).

Many of these results will be of relevance to society, most obviously the more accurate weather forecasts. The following figures also provide a summary of efforts, but illustrate at the same time how impossible it is to do all the research results justice in such a short presentation.

Measurable results as of 1 January 2011 from the 27 research projects funded under the Norwegian IPY allocation include:

- **405 scientific publications, of which 299 in peer-reviewed journals and 54 monographs**
- **Over 1 200 presentations and reports, including over 400 presentations at international meetings**
- **23 doctorates completed or in the process of being completed**

Another obvious question to ask is what came out of the major international IPY effort as a whole? The management committee for IPY, the Joint Committee, provided a preliminary answer to this question in an 800-page report published in the spring of 2011.

As a teaser it can be mentioned that IPY has changed our understanding of the effect of melting ice masses on sea level. Before IPY, the estimate was that during the course of this century the sea level would rise by less than 1 metre. This included consideration of the effects of melting inland ice masses. Based on a number of studies of glaciers, in which Norwegian researchers have played leading roles, the conclusion is now that the rise in sea level will be 50 per cent higher, i.e. around 1.4 metres. This is a substantial increase that will have to be taken into account in community planning in many areas.

New polar researchers

IPY has brought forth a new generation of polar researchers both at the national and international level. The Association of Polar Early Career Scientists (APECS) was established under IPY and the organisation now has over 2 000 members.

The Norwegian IPY effort funded 23 doctoral fellowships and 29 fellowships for newly qualified postdoctoral researchers. Given the increased interest in Norway in the Arctic areas and the need to ensure the best possible management of these areas in accordance with social objectives, these young researchers will provide a necessary injection of new enthusiasm into the work of gathering knowledge. This formidable energy of the young researchers will undoubtedly leave its mark on Norwegian polar research in the future. One exciting feature of the group was that as many as 23 of the 52 were women. Another feature was that well over half of the research fellows came from non-Norwegian backgrounds.

Interest in science subjects and the polar regions

One of the objectives of the Norwegian IPY effort was to generate increased interest in natural science subjects amongst the general public in Norway and particularly among young people. In theory this aim could be assessed now. There has been a measurable increase in interest in science subjects among young people, as illustrated for example by the increase in the numbers choosing to study mathematics and the natural sciences at school. The difficulty lies in identifying the part IPY played in this increase, in relation to the many other initiatives that have also taken place during this period. But perhaps that is not all that important – it may be enough to know that IPY was part of this picture too?

There is a stronger basis for stating that IPY has led to an increased interest in the polar regions. Up until 11 January 2011 the following communication measures had been recorded:

- **850 stories related to IPY in the mass media**
- **Over 300 public-oriented dissemination measures under the projects, and**
- **Over 500 dissemination measures targeted towards selected target groups.**

At the same time it would be true to say that interest particularly in the northern areas has also increased as a result of activities that had nothing to do with IPY. These include research vessels sailing through the Arctic Ocean as a result of changes in drifting sea ice, the focus of the Norwegian Government on the High North as a key foreign policy area, and in 2010, the signing of the treaty on maritime delimitation and cooperation in the Barents Sea and the Arctic Ocean.

How has Norway's status as a polar research nation been affected?

Another expressed aim of our activities was to raise Norway's status in the field of polar research. We are confident that this has happened not least because the Norwegian IPY effort was the third or fourth largest of all the 60 participating nations. In terms of budget, the US was the largest, followed by Canada, with Norway in third place. Measured in terms of number of person-years Russia may also have been ahead of Norway.

Independent of third or fourth place, this situation is very unusual. Norwegian research makes up only a very small proportion of global research activity and even in polar research we are used to being outranked by Germany, Great Britain and France and sometimes also countries such as China, Japan, Korea and Italy.

The international polar research community has noted the scale of the Norwegian initiative and as a result Norwegian research groups have become more attractive as research partners. There are a number of concrete examples of Norwegian researchers being invited to participate in projects. Norwegian researchers have also been involved in preparing articles that have been published in influential journals and there is increased interest in cooperating with Norway both on Svalbard and at the Norwegian research station Troll in the Antarctic.

Cooperation with Russia was crucial for several of the projects. Here equipment is being loaded on to the Russian icebreaker Ivan Papanin for the Norwegian-US expedition to the South Pole at the quay in Oslo in October 2006. Photo: Kristen Ulstein

Terje Isungset playing ice instruments at the opening of the IPY Oslo Science Conference on 8 June 2010.
Photo: John Petter Reienertsen, Samfoto

The EU is now heavily involved in the Svalbard Integrated Arctic Earth Observing System (SIOS), which shows that the IPY effort has achieved the objective of enhancing international interest in Svalbard as a research platform. In Antarctica, Sweden and Finland are now considering establishing themselves at the Troll research station and Italy wants to use the station as a base for advanced astrophysical monitoring.

Cooperation with Russia

Another of Norway's aims was to enhance cooperation with Russia in the northern areas. A strong spirit of cooperation existed between Norwegian and Russian researchers throughout the entire IPY period. Norway supported the establishment of a regional IPY secretariat based at the Arctic and Antarctic Research Institute (AARI) in St. Petersburg.

IPY received high-level political support in Russia. During the IPY period the Russian authorities established separate, more flexible systems for allowing foreign research vessels into the Russian Arctic and for crossing the border with collected data and equipment. (But that does not mean that everything went smoothly in practice!) It is hoped that these improvements in the practical aspects of cooperation will continue even after IPY.

Data management

IPY had high ambitions for achieving a leap forward in terms of data storage and data exchange between projects. For this purpose, all Norwegian-funded projects were required by the Research Council to follow IPY's data policy. However, data management proved to be a complex field. At the national level, a foundation for achieving IPY's data management objectives was laid in the form of the development of a standardised data management system, but at the international level there is still a way to go before these goals are reached. More light is shed on this issue in one of the articles in this book.

IPY led to an advance in data exchange in that a number of projects established metadatabases, i.e., overviews of the data that exists and how they can be accessed. Another concrete result was the establishment of the Polar Information Commons (PIC), which was launched during the IPY Oslo Science Conference, IPY-OSC.

IPY Oslo Science Conference – the final IPY science conference

IPY-OSC was held at the Norway Trade Fairs facility in Lillestrøm, in June 2010. The conference was a great success involving over 2 000 presentations and participants and undoubtedly played a part in securing Norway's reputation as a polar research nation. The Research Council, which was responsible for organising the event, also enhanced its reputation as an administrator of polar research.

IPY's legacy

IPY led to the acquisition of new knowledge, new polar researchers and improved forms of cooperation. It is too early to draw final conclusions about the legacy of IPY and the way ahead, but new developments are already underway. On the basis of findings generated by IPY new ideas and models are now being presented under the auspices of the World Meteorological Organization (WMO) through an initiative entitled International Polar Decade (IPD). These indicate that in the long term it may be realistic to create robust climate forecasting systems for our part of the world. Research conducted under IPY has shown that there is a connection between several climate-related natural phenomena in the Arctic, and between the Arctic and lower latitudes. There are therefore good grounds for hoping that global support will be forthcoming for the need to study the Arctic more closely – which should be in Norway's national interests.

The way forward after IPY

Experiences and recommendations for the future

By Øystein Hov, Norwegian Meteorological Institute, Chair of the Norwegian IPY Committee

The IPY effort in Norway was larger and longer in duration than in most other countries. Measured in terms of the amount of extraordinary funding allocated, Norway was the third largest contributor in the world (after the US and Canada) and on top of this, while most countries implemented a two-year initiative, from March 2007 to March 2009, the Norwegian IPY effort extended over a period of four years.

The scale and length of the Norwegian IPY effort is consistent with Norway's fascination with the polar region. The exploration of the polar areas was important for nation-building during the period when Norway was under Swedish rule and in the establishment of Norway as an independent country in the decades around 1900. Even today polar exploration appears to bring the nation together and continues to play a role in cultivating a common Norwegian identity.

Framework for the Norwegian IPY effort

Planning for IPY 2007–2008 was already well underway in 2004–2005. The Norwegian Government allocated over NOK 320 million over a four-year period to the Research Council starting from 2007, and the first call for proposals for projects was issued in May 2006. The most intensive research efforts were carried out in 2007–2009, together with much of the field work, allowing two seasons for conducting observations and experimental work in the Arctic and Antarctic. Most projects were concluded at the end of 2010 and work was completed during the first few months of 2011.

Political interest in the High North has grown during the period in which IPY was planned and implemented. The northern areas are crucial to Norway both because of their geographic proximity and the natural resources available in the area, in the sea and under the seabed. The region is also important as a transport route, for emergency response planning and for fostering relationships with other countries that border the Arctic Basin, not least Russia. The issue of the maritime delimitation line with Russia in the Barents Sea was also resolved during the IPY period.

Some five years ago, the Research Council published a comprehensive call for proposals, which set out the aims of the Norwegian IPY effort:

- The Norwegian IPY effort is to promote the acquisition of new knowledge of high scientific merit related to fundamental processes and key natural phenomena in the polar regions. The initiative is to generate knowledge of relevance to society that promotes sound management practices, including the development of methods to forecast climate change, management of resources and the environment and the impact of change processes on the northern areas.
- IPY should result in a significant expansion of long-term international cooperation, particularly with Russia, and greater use of Norwegian infrastructure in Svalbard by international researchers in cooperation with Norwegian research groups.
- IPY should lead to researcher recruitment and a measurable increase in interest among schoolchildren and students in the subject areas in which Norway has participated, particularly mathematics and the natural sciences.
- IPY should enhance understanding of the importance of polar research and the polar regions amongst the general public in Norway.

It is not easy to say to what extent these aims would have been achieved without IPY, or to determine the extent to which IPY played a role. There has been a significant increase in Norway in the level of political and public attention focused particularly on the northern areas, but also on the Antarctic. It is quite likely that the Norwegian IPY initiative played a part in this.

The plan for the Norwegian IPY effort and the project funding announcement were consistent with the aims set out in the international IPY framework document, which had been produced by a group under the International Council for Science (ICSU), with support from the World Meteorological Organization (WMO). Key scientific and organisational considerations incorporated into the planning process included:

- closer ties with Russia;
- increased interest in and knowledge of the polar regions amongst children and young people in education, and in society at large;
- a common data management system for observations and other data from the polar regions;
- a scientific approach that would embrace natural science, as well as cultural and social science questions.

Lessons learned from the implementation of the Norwegian IPY initiative and its role in the international IPY effort

The four years (2007–2010) in which the Norwegian IPY effort was implemented were characterised by an extremely high level of activity, a high degree of professionalism and a result-oriented approach amongst all those involved. It will take time to digest everything that has come out of this major effort. The picture that is emerging of IPY in Norway is multi-faceted.

The modern research industry requires heavy and expensive equipment – here represented by the research vessel G.O. Sars. Photo: Kjartan Mæstad

Increased use of infrastructure on Svalbard was a key objective. Here the heirs to the Scandinavian thrones ready for a trip to the air monitoring station at Zeppelinfjellet together with Kim Holmén from the Norwegian Polar Institute. Photo: Karine Nigar Aarskog

Several spectacular events were organised in connection with IPY. Here from the opening of the Indigenous Peoples' IPY in Kautokeino in February 2007. Photo: Kristen Ulstein

- Research (classified by ICSU under six thematic areas: status, change, global linkages, new frontiers, vantage point and human dimension).
- Several subcommittees with particular responsibility for a number of overall thematic areas were established in Norway and linked to international coordination efforts that were headed by the International Programme Office based at the British Antarctic Survey in Cambridge, UK. These included subcommittees for:
  - Data management
  - Education, outreach and communication
  - Observations systems
- Guiding principles for the activities were:
  - field work and research under IPY;
  - a lasting legacy after IPY in the form of improved structures for monitoring and managing the polar areas, as well as for the utilisation of natural resources;
  - utilisation of the research infrastructure potential in Svalbard;

Several complex "spheres", that usually operate somewhat independently of one another, met in the course of IPY. These can be referred to as "the modern research industry", "the modern media industry", "schools, education and expert recruitment", "the situation of the indigenous peoples," and "the global data community". All these "spheres" were brought together partly as a result of the Norwegian Government's substantial IPY allocation, and partly because of the wording of the Research Council's funding announcement, and last but not least, because all the various "spheres" concerned managed to mobilise themselves and leave a lasting mark on IPY, both individually and together.

The modern research industry

Fridtjof Nansen conducted observation-based oceanographic research. On the basis of measurements that were like small pinpricks in a largely unstudied world, he used the knowledge available at the time and his own intuition, as well as many quiet hours spent on board the polar ship Fram or at Polhøgda, to form a picture of the ocean currents in the northern Atlantic Ocean and the Arctic Basin. This picture has remained largely intact right up to the present day.

Nansen was an outstanding researcher in a field where major fundamental problems remained unsolved. He developed research infrastructure, constructing instruments such as the Nansen bottle, and organised expeditions (e.g. the voyage across the Arctic Ocean onboard the polar vessel Fram). He built up a team to help him collect data and learn about the questions he had determined to solve. He had an international outlook, and a talent for publishing and communicating his findings as well as for attracting sponsors.

What motivated Nansen's investigative zeal is perhaps not so easy to say, but he undoubtedly possessed a well-developed competitive spirit, as well as a strong determination to develop his own abilities and realise his own visions. The need for a permanent position and a predictable life were perhaps not among the top motivating factors behind Nansen's enthusiasm for research.

The modern research industry bears many of the same characteristics as Nansen's research activity. But it has become an industry; research has become systematised and is to a large extent subject to market mechanisms. There are government targets for "productivity" and in this context publication figures, citation indices, media coverage, and the project budget's bottom line are paramount. As in industry, the language of the market has entered the world of research. The individual researcher as an intellectual and engineer has a less prominent place.

At the core of the research industry is the research team led by a research team leader. The legitimacy of these team leaders stems from the depth of their scientific expertise and ideas, their ability to treat people well, to network across national boundaries and relevant disciplines, to compete for funding with short timeframes (the four-year IPY effort is quite long in this context) and their enormous capacity for work. The normal working day of a research team leader cannot be described as "normal".

The modern research industry is thoroughly organised. The ability to compete requires an administrative support apparatus that is set up to ensure that the research community is successful in getting funding applications accepted and is able to administer projects effectively. Relevant factors in this context are:

- a predictable and research-oriented personnel policy;
- financial overview and management;
- organisation of the "production apparatus", which may include a combination of laboratory studies, research expeditions and observations in the field;
- the development and/or use of instruments;
- data collection, quality control of data, data flow, storage, retrieval, and the combination of various types of data;
- interpretation of data including theory formulation, and the development and use of models;
- platforms for research infrastructure (computers, data storage media, satellites, laboratories, ships, aeroplanes, research stations);
- overview of formal research-related networks at the national and international level (e.g. under ICSU, WMO or other international organisations and conventions);
- expertise in the fields of information and communication;
- and last but not least, insight into and knowledge of funding opportunities and underlying research policy and strategic research planning developments at the national and international level.

In the context of IPY, the Research Council was a key "commissioner" and "procurer" of "services" from the research industry.

The research industry is driven by individuals with some support from institutions, although this depends on the type of institution. As an institutional driving force for polar research, the universities are generally weaker than private research institutes, which rely on income from commissioned research and focus on applied research questions. As polar research is not classified as a discipline, the university and university colleges do not seek to conduct it. Many independent research institutes, on the other hand, have some institutional objectives relating to polar research.

In some countries independent research institutes receive larger basic allocations than in Norway. This is the case in Germany, France and North America, for example, while the situation in Great Britain is similar to that in the Scandinavian countries.

Research under the Norwegian IPY effort

Viewed in terms of the criteria set out in the Research Council's call for proposals, the research results generated by IPY in Norway can be considered extremely successful. Nearly all the projects involved extensive field campaigns and information gathering in the Arctic or Antarctic, interpretation and theory formulation and a somewhat intense level of publication activity. The short articles about each project in this book provide a taste of this.

Four of the 27 Norwegian IPY projects had people and society as their main focus. These were the linguistic project LICHEN, the EALÁT project, which studied the impact of climate change on reindeer husbandry and the living conditions of reindeer herders, and the MODIL-NAO project, which studied how oil activity in northwestern Russia is affecting the life of the Nenets reindeer herders. The CAVIAR project also looked at issues of vulnerability and adaptation to climate change in relation to people and local communities in the north.

and well-regulated international structures for monitoring and understanding the state and dynamics of marine resources, for improving the basis for climate and sea state forecasting or for understanding past and future climate trends. Projects in this group included the ecosystem project NESSAR and the AKES project, which involved a voyage to the Southern Ocean onboard the research vessel G.O.Sars, both coordinated by the Institute of Marine Research. The projects produced knowledge of relevance to the Arctic Climate Impact Assessment (ACIA), conducted under the auspices of the Arctic Council, which Norway sees as a key international body for promoting its High North policy, and the Convention on the Conservation of the Antarctic Marine Living Resources (CCAMLR).

Modern research requires team work. The ICEHUS II team of Norwegian and Russian researchers by Lake Bolshoye Shchuchye in October 2007.
Photo: Øystein Lohne

Hectic planning in the hangar at Andøya Airport Andenes on 3 March 2008. Jon Egil Kristjansson, project manager of the IPY-THORPEX project in the middle. Photo: Gudmund Dalsbø

The Norwegian IPY effort collected large volumes of data. The enormous EISCAT radar has been in use continuously for an entire year and has produced a unique dataset.
Photo: Kristen Ulstein

These projects provide an important context for the natural science projects. On the basis of interviews and other data collected, the CAVIAR project, for example, has shown that "climate change is not necessarily the greatest challenge that communities in northern Norway and northwestern Russia need to deal with. It is the interactions between social, political and economic factors, and the fact that their impacts are intensified by climate change, that together require adaptability and determine how vulnerable communities are." This finding may not be surprising, but here this statement is not politically or ideologically motivated, but is made on the basis of research.

Some of the projects were more spectacular than others, bearing obvious evidence of Norwegian determination to be at the front, and involving stories of hardship and sweat and unusual photographic opportunities. I am thinking, for example, of the TASTE-IDEA project and the US-Norwegian tracked vehicle expedition from the Troll research station to the South Pole.

Some of the projects had their roots in well-established

The basis for improved weather and sea state forecasting was addressed particularly under the IPY-THORPEX project, with a focus on the forecasting of extreme weather in the Arctic, and under the iAOOS-Norway project, which focused on integrated sea state, ice and weather monitoring in the Arctic.

The IPY-THORPEX project had its roots in R&D activities led by the World Meteorological Organization (WMO), which works to improve and maintain the quality of weather forecasts all over the world. These efforts have been developed over many decades. The iAOOS project will play an important role in establishing corresponding structures for ice and sea state forecasting. The POLAR-CAT project also examined how the northern polar areas have been affected by the transport of air pollutants from the south.

The largest group of IPY projects addressed the relationship between climate change and climate variability, and such issues as ocean circulation, the size of glaciers in the Arctic, the extent of forest vegetation in the Arctic,

the extent of the permafrost, and increased stress on ecosystems, on which animals such as the polar bear depend, as a result of climate change and pollution.

Some projects had as their primary objective to develop and use new instruments. This applies, for example, to the Seismic Buoy project – a project that offers considerable potential benefits for geophysical prospecting in ice-filled waters. Another spectacular example is the MEOP-Norway project, which used seals as "research assistants" to examine conditions in the polar oceans.

Another group of IPY projects focused on paleoclimate research and geological structures. Research on the Ice Age in the Ural Mountains, which the Department of Earth Science at the University of Bergen has conducted for many years, produced important findings relating to the extent of the ice cover during past Ice Ages and interglacial periods (ICEHUS II).

Paleoclimate research was also a component of the SciencePub project, led by the Geological Survey of Norway (NGU). By combining the human dimension with natural science, the SciencePub project managed to link together research activities and communication of climate change and adaptation strategies in an innovative way. Research on natural climate variability during the last Ice Age and on how the pioneer settlement in Finnmark adapted to the tremendous changes that followed was integrated into the communication activities. Research and communication were equal components of the project. Thus, the SciencePub project embraced several of the Norwegian IPY initiative's key aims, more so than many of the other projects.

The University of Bergen headed two other basic research-oriented projects. The PAME-Nor project studied the turnover of dissolved organic carbon in the microbial food webs of the polar waters. Experiments were carried out in Ny-Ålesund in Svalbard on sea water held in large containers and the connection between the ocean's chemistry and its biology was studied at the microlevel by treating the water in different ways and studying the various outcomes. The ICESTAR project was featured on the front page of the science journal Nature following the discovery that the auroras in the north and the south are not symmetrical.

Cooperation with Russia

Scientific cooperation with Russia was strengthened in many areas as a result of the Norwegian IPY initiative. Many research groups in Norway have good contacts in Russia, and these were given new momentum. The Russian research community has a proud tradition when it comes to field-based polar observations and theory formulation. Their research focuses on basic research questions, and is inspired by a strong academic tradition. Cross-border trade and contacts are growing in the north, and institutional ties are following suit. This may mean that the rules governing cross-border research cooperation become increasingly normalised so that efforts can focus more on the research itself and less on overcoming administrative obstacles.

Russian researchers played a significant role in many of the projects, and under many of the projects part of the research was undertaken in Russia. This was the case, for example, in the SciencePub, ArcticWOLVES, BIAC, CAVIAR, LEVANS, MODIL-NAO, IPY-THORPEX and ICEHUS II projects. Cooperation with Russian research groups also posed some specific problems, as described in the article on the BIAC project; while the technical aspects of cooperation with the Russians were successful, equipment and data from measurements taken in the strait between Franz Josef Land and Novaya Zemlya were confiscated.

Research in Svalbard

Taking full advantage of the research infrastructure in Svalbard was another explicit goal of the Norwegian IPY effort. This was achieved under the ArcticWOLVES project, which involved comparative field studies of Arctic predators in Svalbard and other places in polar Eurasia. Similarly, an area near Kongsfjorden was used to study the connection between pollution levels and the state of the common eider stock (COPOL).

Permafrost observations were carried out in Svalbard and on the mainland (TSP Norway). The POLAR-CAT project made use of the atmospheric chemistry research station on Zeppelinfjellet near Ny-Ålesund for conducting advanced observations to map the transport of air pollution into the Arctic. Austfonna (the largest ice cap in Svalbard) was the object of a glaciological study (GLACIODYN). Laboratory facilities in Ny-Ålesund were used under the PAME-Nor project and the IPY-ICESTAR project made use of the EISCAT radar in Adventdalen (Svalbard) for an entire year.

Several projects, such as the IPY-THORPEX and POLAR-CAT projects, used the airports in Svalbard during their field campaigns. For many of the other IPY projects the facilities on Svalbard were not relevant to use. Social infrastructure and research infrastructure in Svalbard were nevertheless important for the implementation of the Norwegian IPY effort, reducing the level of risk and enhancing the research results produced by many of the projects.

The international IPY activities

Projects carried out under the Norwegian IPY efforts were linked to the international IPY projects, which had been approved by the Joint Committee. The extent to which the international projects were realised was determined by the amount of funding allocated by the various countries to IPY, and of 200 approved projects some 160 received funding.

The international IPY project portfolio can best be illustrated by a beehive diagram (Figure 1). The diagram visualises various features of IPY: IPY was not hierarchical, but had a network structure. Each element in the beehive had substructures, which are not shown in the diagram. These consisted of individual projects, both national and multinational, that were mutually connected in terms of scientific focus and as a result of already established relationships between researchers and research groups in different countries. In many cases infrastructure made available by a group in one country was used by several projects within the same thematic area. This led to extensive joint publication activities across project and national boundaries and better utilisation of the research infrastructure.

The beehive diagram is static and gives few indications as to the legacy of IPY over and above the creation of publications, data and the emergence of new experts. More specifically, the diagram shows that there was no planning for how the shared benefits of several projects were to be realised or made permanent where this was relevant. The question of the legacy of IPY is discussed in more detail in a separate paragraph below.

Outreach, education and researcher recruitment

Another objective of the Norwegian IPY initiative was that it should promote researcher recruitment and lead to a measurable increase in interest among schoolchil-

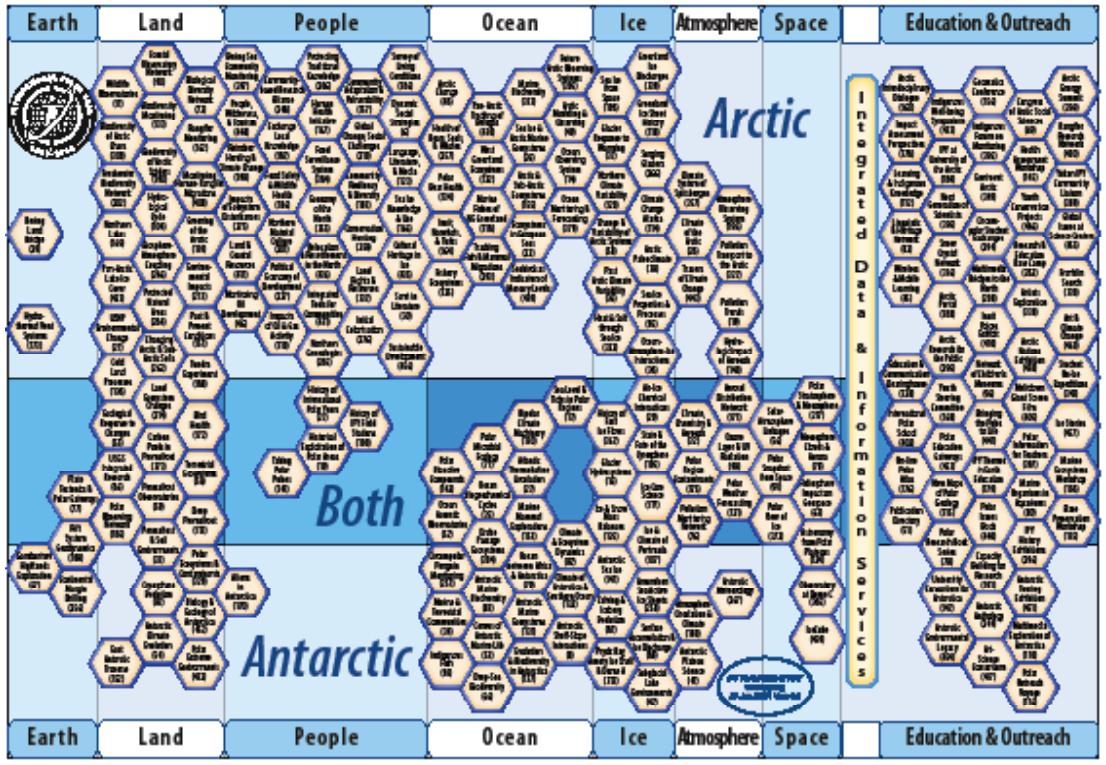


FIGURE 1: The international IPY project portfolio – the honeycomb diagram.

Students from Bergen, Liv Sofie H. Utvær and Ingrid A. Eidsvaag, won not just one, but two competitions. Here seen receiving congratulations and flowers from Eiliv Larsen and Astrid Lyså from the Geological Survey of Norway (NGU).
Photo: Gudmund Løvø

dren and students in the subject areas in which Norway participated, particularly mathematics and the natural sciences. Children and young people in education and their teachers, as well as young researchers played a key role in the implementation of IPY.

The kick-off event for the Norwegian IPY effort held outside Oslo City Hall in March 2007 was targeted particularly towards children and young people. The event also marked the beginning of the "People's Polar Year", which sought to focus the attention of the general public on polar research and to encourage greater understanding of research and in particular the natural sciences among children and young people. This is described in more detail in a separate article by Kristin Ulstein and Karl Torstein Hetland.

and ensure knowledge-based management of the polar areas in the future.

All those involved in the Norwegian IPY effort became acquainted with a new, dynamic organisation, the Association of Polar Early Career Scientists (APECS). It is an international and multidisciplinary organisation for undergraduate and graduate students, postdoctoral researchers, early faculty members, educators and others with interests in the polar regions. During the course of IPY, APECS moved its administrative office from the US to Tromsø, with funding from the University of Tromsø and the Research Council of Norway. This provided a lot of useful input to Norway's IPY efforts, particularly in connection with educational activities and preparations for the IPY Oslo Science Conference in June 2010.

Head of the Norwegian Centre for Science Education Anders Isnes carrying out experiments with dry ice. Oslo City Hall, 1 March 2007.
Photo: Kristen Ulstein

The Norwegian participants at the GLOBE Conference in South Africa.
Photo: Karl Torstein Hetland

SciencePub was one of the research projects that accepted the offer of the loan of cameras and they made several films – here field work from the river Dvina in Russia.
Photo: Gudmund Løvø

Education and outreach projects were a key component of the Norwegian IPY effort. Most of these projects were carried out at the local level and implemented with little or no financial support. A total of 22 projects were awarded funding following the announcement of NOK 14 million in funding for this purpose. The results of these projects are outlined in a separate article.

The Norwegian IPY effort also enabled many research groups to gain extensive experience of combining research and communication activities. All the research projects were required to have an education and/or communication component. The reports indicate that this requirement was fulfilled to a large extent in most of the projects. Few other research initiatives have resulted in this level of popular science dissemination and activity.

Some 50 doctoral students and postdoctoral fellows were involved in research projects under the Norwegian IPY effort. A new generation of polar researchers has emerged that will conduct curiosity-driven research

IPY media coverage

The third IPY "sphere" was the modern media industry. Professional journalists were involved in many of the research projects, primarily in connection with expeditions, voyages or field experiments where the level of activity was particularly intense, but also in connection with the communication of research results. Under the Norwegian IPY effort research communication was given high priority, much higher than is usual in research programmes. If the results are measured in terms of "quantity" (number of articles in the media, including radio and television, internet searches, contact between individual researchers and journalists and producers, focus on research in political circles), this meeting of the research industry and the media industry can be considered extremely successful.

There are, however, grounds for mentioning the more challenging aspects of this encounter. Media slant, exaggeration and the tendency to sum up a year's work in just a few sentences were new challenges for many researchers. In research, all the data material should be taken into consideration, including any reservations about the data where appropriate. The scientific lecture with its detailed explanations of hypotheses, terms, data collection, assessments and conclusions requires a longer focus than the modern attention span of 30 seconds.

The modern media industry is fascinated by individual people's stories and a need for drama that requires stories to be exaggerated even when there is no scope for embellishment. In research, conclusions and results must be supported by data, and the discussion of uncertainties and reservations about the data play a prominent role.

According to the media industry, research should be communicated in a way that makes it easy to understand and digest. The terminology used should come from everyday speech. Elements from advertising and marketing (branding, profiling) are employed. Research communication should entertain and retain the attention of the audience so that people are not tempted to change channel. Research communication should talk directly to the "tax payer". It is not set up to be a demanding learning process, which is, however, precisely what is at the heart of research and the true appreciation of research findings.

Researchers, too, are influenced by the pressures of the media industry. They may begin to believe that an article in the mass media is a stamp of high-quality research.

The Norwegian IPY effort leaves in its wake an exceptionally large amount of material and lessons learned from the meeting between the media industry and the research industry, two of society's major "spheres". Maybe someone should use this material to examine whether an intensive and protracted encounter of this type promotes or stifles the research process?

Common data management

Polar research is to a large extent observation-based. Understanding of natural processes, generalisations and theory formulation are dependent on insight that can be gained from observations, and the results of theoretical calculations can be used to inform new observations. As the knowledge base grows, the research field moves from an early, basic research-oriented phase to a more modern phase based on a more stable understanding.

The development of meteorology, which has gone from the breakthrough some one hundred years ago in the understanding of how weather systems develop to today's operational weather forecasting systems, is an example of this. In modern weather forecasting observations are reported in near real-time from satellites, aeroplanes and stations on the ground to numerical weather prediction centres, where they are used to finetune the start data in major weather forecasting models to produce the next day's or next week's weather forecasts. These, in turn, are then communicated via the Internet (cf. www.yr.no).

The collection of observational data is considered "research capital" and is an important result of investment in research. Observational data need to be accompanied by information about the parameters and variables that have been observed, the observational method, data calibration, quality control, ownership of the data, time frame or area covered, and information about where and how the data is stored. Such information is called metadata, i.e., data about the data.

A number of World Data Centres were established as a result of International Geophysical Year (IGY) in 1957. Thus, institutions assumed global responsibility for receiving, recording and making available observational data, such as that related to solar radiation or ozone layer measurements. The concept of "common data management" came into existence. This structure of global data centres has been growing ever since and has helped to organise and boost international R&D efforts. The development of the Internet, however, has created new opportunities for searching for, finding and gathering data of all kinds, but the Internet requires a different kind of centralised administration from that which was needed during the age of the letter or the fax. Then, being able to approach just a few central data stores, rather than trying to find each individual data source, saved time and was enough to provide researchers with an overview. But whilst they once provided a degree of order and enhanced research activities, the global data centres may today simply be "A legacy of confusion" (see David Carlson's comment in Nature, 20.1.2011, p. 293).

IPY sought to be a new turning point in terms of global data management, by making the metadata available on the Internet in a searchable format. Thus, anyone interested could find out what had been observed, where and how the observations had been conducted, who owned the data and the terms and conditions for gaining access to them. The original owner was to retain the physical data so that any improvements made to the quality of the data over time would automatically benefit the users.

Implementing such a revolution in data storage and data access requires both mental and physical adjustments. The physical adjustment lies in the fact that all interfaces between the users and the data have to be standardised. Drawing up standards and putting them into practice requires management and coordination at the central level. Under the Norwegian IPY initiative the Research Council took on this role and ensured that a systematic project was implemented to ensure that Norwegian IPY data is available in this way (see separate article on DOCIPY by Øystein Godøy).

At the international level a separate subcommittee was set up to deal with data policy and management, which did a lot to further global efforts in this area. These efforts got well underway, but were never fully realised. The "beehive structure" chosen by IPY provides part of the explanation for this in that the initiative lacked sufficient management at the global level in this area. But the trend is moving in the right direction, driven in part by the standardisation brought about by the Internet.

The mental change referred to above is connected with the researcher's identification and ownership of observations and other data. This issue of ownership has been given a new dimension by the growth of the research industry. Information and data are an important part of the capital in this industry. They are held back as long as their value remains high and can be used to secure new research assignments.

The development of a common data management system requires that all these factors are recognised as legitimate and that schemes are implemented that take them into account. One such measure would be a system of recognition of those who make their data available. This could be achieved through the establishment of a "data citation scheme", so that owners of data were credited when data was used in the same way that an author is credited when an article is cited.

The proposal to establish a Polar Information Commons (PIC) emerged as a result of IPY in 2009 (www.polarcommons.org). PIC data can be used freely provided certain rules are followed concerning recognition of the original owner of the data, citation, version control and notification of the data owner and as long as the data is used in accordance with the stipulated terms and conditions.

Some fields, such as meteorology, are leading developments in the area of common data management because the quality of operational weather forecasting is dependent on a global system for exchange of observations in near real-time and of proven quality. The development of the DOCIPY data management service has followed the same thinking as the WMO Information System (WIS), which is in the process of turning the global meteorological data stream "inside out". In the past meteorological data was reserved for the national weather services. WIS is making the data stream available to all in a way that is consistent with international standards for characterising and categorising data. Other disciplines are following their example.

The legacy of IPY

The combination of clear expectations and a substantial budget meant that the Norwegian IPY initiative was able to take advantage of the full force of the research and media industries and of the education system at all levels. It leaves behind it a significant legacy in the form of publications, collected data, new or improved research methods, media attention and a new generation of researchers. Interest in and knowledge of the polar regions has increased among children and young people in education and in society at large. The scientific approach that encompassed natural science as well as social science and cultural issues was invaluable. It was in connection with these aspects of IPY that the honeycomb structure (Figure 1) showed its worth.

Four points on the Norwegian IPY effort's wishlist remain:

1. a lasting legacy after IPY in the form of improved structures for monitoring and managing the polar areas, as well as for the utilisation of natural resources
2. the utilisation of the research infrastructure potential in Svalbard
3. closer ties with Russia
4. common data management system for observations and other data from the polar regions.

Research-based, operational services such as weather and sea state forecasting, or analysis of the development of marine resources, rely on a top-down management structure. These services require a "strong" infrastructure, i.e., observations and the development and use of long-term models cannot be managed according to short time horizons or shifting priorities and tastes. Institutions, centralised or decentralised, that uphold the vision of the services are essential.

The Norwegian IPY effort relied to quite a large degree on "weak" infrastructure. Field work, expeditions and temporary observation platforms do not result in the creation of lasting "strong" structures, but they are more readily available in the research industry's changing market of commissioned research assignments, where the aim is something other than ensuring high quality operational services.

This type of organisation based on "weak" infrastructure can produce significant results in the short term. But it can easily overlook or underestimate the fact that dynamic systems, such as those that govern climate, natural resources, weather, ocean circulation, ecology and other natural processes, must be mapped over a long period of time and in many geographical places, if a systematic picture of their variability and behaviour is to be obtained. In many cases IPY produced a good picture of only a limited extract of the variability of one of these dynamic systems.

An organisation such as the EU's system for Global Monitoring for Environment and Security (GMES) (http://www.gmes.info/), which will become operational from 2015, is needed if there is to be a permanent improvement in the monitoring and management of the polar areas, as well as the utilisation of natural resources. GMES services cover sea state forecasting, forecasting of changes in and the development of land-based ecosystems, air quality forecasting and forecasting of environmental emergency situations such as floods, landslides, avalanches, droughts and forest fires.

The traditional gap between "research observations" and observations that are essential for operational services (e.g. weather, sea state and ice forecasting, or analysis and forecasting of natural resources) is smaller today than it was previously.

Research observations, not least in the polar areas, also need a "strong" infrastructure if they are to be reliable. Centralised management is crucial if a common data management system for observations and other data from the polar regions is to be achieved and if stronger ties are to be established with Russia. There are several examples of situations where the Norwegian IPY effort and the international IPY effort have been essential for or have played a role in strengthening already planned activities. During the course of IPY the Research Council played a leading role in a European Strategic Forum on Research Infrastructure (ESFRI) initiative to promote Svalbard as a European research platform (Svalbard Integrated Arctic Earth Observing System (SIOS). Several Russian institutions are partners in the SIOS project.

The Norwegian Meteorological Institute has signed a protocol with the Ministry of Natural Resources of the Russian Federation allowing for the exchange of observations and forecasts of weather, ice and ocean conditions in the Barents Sea, and the development of research that supports the operational services. A project entitled BarentsWatch, run by the Norwegian Coastal Administration on behalf of the Ministry of Fisheries and Coastal Affairs, seeks to develop a web-based surveillance and early warning system that will cover the information needs of all kinds of operational activities along the coast of Norway and in the northern areas.

An International Polar Decade?

Russia has proposed that IPY should be succeeded by an International Polar Decade (IPD). From a scientific point of view this is a very interesting proposal, because it would pave the way for a decade of intensive systematic observations of a number of dynamic systems in the polar regions (climate, weather, ice, ocean circulation, marine and land ecosystems). These systems are not easy to understand because they behave so differently from what we would expect. We humans are inclined to think in a linear fashion, and find it difficult to understand why Europe have had such cold winters when the amount of CO_2 is apparently increasing. Systematic observations over a ten-year period would provide an extended mapping of the variability of many dynamic systems. It would facilitate better understanding of the systems and therefore enhance our ability to predict future situations.

However, many nations may hesitate to take on such a commitment for financial reasons. Two more specialised proposals that have been taken a step further are: Global Cryosphere Watch (GCW) and the Global Integrated Polar Prediction System (GIPPS).

The Norwegian Polar Institute, under the Ministry of the Environment, has areas of responsibility relevant to GCW, while the Norwegian Meteorological Institute, under the Ministry of Education and Research, deals with areas that could gain a lot from the further development of both GIPPS and GCW. Norway's management of the polar regions would benefit if both these specialised projects and IPD were to be realised.

The Norwegian IPY programme leaves behind it a wealth of lessons learnt from the meeting between the media industry and the research industry. IPY received extensive media coverage in part due to the trips by the heirs to the Scandinavian thrones to Svalbard and Greenland. Photo: Karine Nigar Aarskog

PAGE
56–177

THE RESEARCH PROJECTS

The research projects formed the core of IPY. A total of 28 projects received funding from Norway. Most of the projects were part of one of the 160 active international IPY clusters. Several of these clusters were run from Norway. A total of NOK 290 million was allocated to research under the Norwegian IPY initiative.

Toward better forecasts of extreme weather in the Arctic

By Jon Egill Kristjansson

Photo: Christian Mallaun

IMPROVED FORECASTING OF ADVERSE WEATHER IN THE ARCTIC REGION – PRESENT AND FUTURE (IPY-THORPEX)

Project owner: University of Oslo
Project manager: Jon Egill Kristjansson
Total budget: NOK 30 million
Doctoral fellowships: 1
Post-doctoral fellowships: 2
Dissemination measures, public and user-oriented: 58
Mass media coverage: 148
Articles published in scientific and scholarly journals: 24
Books published: 1
Presentations published from international meetings/conferences: 31
Other reports and lectures from scholarly fora: 38
Home page: http://www.ipy-thorpex.no

The Arctic poses particular challenges for weather forecasting, due to sparse data coverage and the existence of poorly understood weather phenomena such as polar lows. Polar lows are fierce, small-scale (100–500 km in diameter) weather phenomena that develop frequently over the Barents Sea and Norwegian Sea in winter when very cold air from the Arctic Basin sweeps across open seas that are 30–40°C warmer than the air. This results in intense convection, a process which is not adequately treated in the weather prediction models. Extreme winds generated by mountainous terrain are also typical for the Arctic. As the dense Arctic air impinges on the mountains, it is forced to move around them, thereby generating intense wind jets such as in the fjords and at the southern tip of Spitsbergen. During IPY-THORPEX unique aircraft measurements were carried out within polar lows. Findings from the project have helped to measurably improve Norwegian Meteorological Institute forecasts for the Arctic.

Chasing the polar storm

The overall objective of the IPY-THORPEX project was to improve the forecasting of adverse weather in the Arctic. The most important activity implemented to meet this objective was a sophisticated field campaign to sample high-quality observational data of Arctic weather phenomena. It was carried out from 25 February to 17 March 2008. Campaign headquarters were at the Andøya Rocket Range, and a Falcon 20 research aircraft from the German Aerospace Center (DLR) carried out 15 flight missions of 56 hours altogether. The aircraft was equipped with three classes of instruments: a) High-frequency (100-Hz) sensors on the fuselage and in a 2-metre-long nose boom; b) Laser-based instruments (LIDAR) for remote sensing of wind and humidity; c) Dropsondes for continuous measurements of atmospheric parameters during the sonde's descent through the atmosphere.

The campaign succeeded in meeting its objectives; for instance, for the first time, three flights were carried out through a polar low at different stages of its development. These data have provided new insight into the driving mechanisms of polar lows. Also, remote sensing by LIDARs revealed detailed fine-scale structures generated by mountains and fjords on Svalbard.

In addition to the manned research aircraft, the project experimented with the use of unmanned microaircraft. Two different systems were tested, and one of these (SUMO, with a wingspan of 90 cm and a take-off weight of 580 g) flew 30 successful profile measurement missions, up to 1 500 m above the ground. Ten of these missions were launched from the Norwegian Coast Guard vessel KV Svalbard, while the remaining 20 were flown in Adventdalen valley on Svalbard.

At Ny-Ålesund, the project investigated the influence of clouds, sea ice and snow-covered surfaces on the radiative balance. With the aid of instruments attached to a tethered balloon, for the first time, simultaneous in situ measurements were performed inside clouds of solar radiation, size and shapes of cloud droplets and ice crystals. Measurements of incoming and reflected solar radiation at the ground were also carried out. These measurements are used to develop better descriptions of radiative processes in climate models.

Challenges underway

Not all went according to plan. On two occasions, a flight mission that ten scientists had spent an entire day planning had to be cancelled at the last moment. In one case, the cause of cancellation was a technical problem with the aircraft, while in the other case the cause was bad weather.

Another major challenge was the sometimes great uncertainty of the weather forecasts, which meant that the flight plans had to be modified at the last moment. This created complications vis-à-vis the aviation authorities, who need flight plans to be filed well in advance. On a few occasions the need arose to enter the air space of neighbouring countries. This posed no problems in the cases of the other Nordic countries, but once the chase of a polar low had to be aborted when it entered Russian air space.

Polar lows are unlike other low pressure systems

Following the campaign in 2008, careful analysis and interpretation were carried out. The main results of this work concerning polar lows are as follows:

- A denser observational network over the regions where polar lows form and develop would improve predictions.
- The growth mechanisms of polar lows have less in common with tropical cyclones than previously thought, for instance concerning the role of latent heat release.
- Polar lows in the Norwegian Sea can intensify through upwelling of warmer waters from below due to the strong surface winds.
- The ability of the numerical weather prediction models to simulate polar lows is improved if the horizontal grid spacing is reduced from 12 km to 4 km or less.
- The weather prediction models simulate some polar lows better than others, but the reasons for these differences are still not well understood.
- In a future warmer climate, polar lows will occur farther north than today due to sea-ice retreat.

The KV Svalbard in rough weather.
Photo: Erik W. Kolstad

Airplane and crew at Keflavik International Airport in Iceland.
Photo: Christian Mallaun

Better observations and more cooperation

The project has contributed greatly to the extension and improvement of the ensemble prediction system of the Norwegian Meteorological Institute: the integration domain is larger than before, the spatial resolution is higher, and the forecasting frequency has been doubled to twice daily. The forecasts are now systematically better than corresponding forecasts from the European Centre for Medium-Range Weather Forecasts.

New, advanced satellite data yielding vertical profiles of temperature and humidity were tested out in the project, and this system is now in operational use at the Norwegian Meteorological Institute.

As a contribution to improved observational coverage in the Arctic, nine new automated weather stations were deployed at Svalbard in 2010, for measurements of air pressure, temperature, wind and humidity. Furthermore, instruments for long-term measurements of solar and infrared radiation were deployed at Bjørnøya. Nine Norwegian commercial aircraft flying out of southern Norway toward northern Norway and Svalbard now transmit near-real time measurements from standardised meteorological instruments, and this effort has been partly financed by the project. The project has also provided financial support for the establishment of a 400-m-high measurement tower on the west coast of Iceland, in collaboration with Icelandic scientists.

During the campaign, additional balloon measurements were carried out from Russian stations at Novaya Zemlya and the Kola Peninsula. This collaboration helped form the basis of a broad collaboration agreement between the Norwegian Meteorological Institute and its counterpart Roshydromet concerning scientific and technological collaboration in the polar regions.

A number of results from the project have already been published in international scientific journals. In addition, an overview paper will appear in late 2011 in the Bulletin of the American Meteorological Society. More specific papers will be published in late 2011 in a special issue of the Quarterly Journal of the Royal Meteorological Society.

Some of the research activities will be continued in a new project, "High Impact Weather in the Arctic (HIMWARC) – Fundamental Understanding and Future Projections", headed from the University of Bergen.

Polar storm on TV

Early in the project planning a decision was taken to place strong emphasis on outreach activities. Funds for financial support of a TV documentary were allocated in the proposed budget. An agreement was signed with Univisjon in Bergen to make a documentary, and from day one of the campaign the scientists had TV cameras and microphones all around them during the planning discussions.

This produced some informative footage showing the scientists in intense discussions on where and how to fly into the storms. The 50-minute documentary "Chasing the polar storm", which also focuses on the social relevance of the research, was shown for the first time on Norwegian television in prime time between Christmas and the New Year in 2008, and has thereafter been re-broadcast three times. The documentary was seen by 718 000 viewers, with positive feedback. In the autumn of 2010, the documentary was shown on the Arte channel in France and Germany.

A professional multimedia show starring two of the project's scientists was produced on the Andøya campaign and its social relevance. The show was broadcast a dozen times during the PolarFESTIVAL in the summer of 2010, and was furthermore one of the main attractions at the Oslo Science Fair the same year.

Measuring albedo – how much a surface reflects solar radiation – in Adventdalen valley. Photo: Erik W. Kolstad

How is air pollution transported to the Arctic?

By Andreas Stohl

Photo: Harald Sodemann/NILU

POLAR STUDY USING AIRCRAFT, REMOTE SENSING, SURFACE MEASUREMENTS AND MODELS, OF CLIMATE, CHEMISTRY, AEROSOLS, AND TRANSPORT – NORWAY (POLAR-CAT)

Project owner: Norwegian Institute for Air Research (NILU)
Project manager: Andreas Stohl
Total budget: NOK 17 million
Doctoral fellowships: 1
Post-doctoral fellowships: 1
Dissemination measures, public and user-oriented: 1
Articles published in scientific and scholarly journals: 23
Presentations published from international meetings/conferences: 52
Other reports and lectures from scholarly fora: 3
Home page: http://www.polarcat.no/

The POLARCAT project set out to study the sources of Arctic air pollution, its long-range transport into the Arctic, its vertical structure, and its impact on atmospheric chemistry and climate. The multi-national collaboration involved more than 200 researchers, eight research aircraft and a research vessel.

Haze and visibility in the Arctic's atmosphere

The Arctic troposphere was long believed to be extremely clean. Shortly before the last International Geophysical Year in 1957/58, however, pilots flying over the Canadian and Alaskan Arctic encountered a strange haze that significantly decreased visibility. Since then this so-called Arctic Haze has been a recurring phenomenon observed every winter and spring. In the 1970s, it became evident that this haze was caused by long-range transport of aerosols into the Arctic from mid-latitude pollution sources. Along with the aerosols, gaseous pollutants were also being transported into the Arctic.

In the past few decades, interest in Arctic Haze focused mainly on the pollution it brought to the Arctic. More recently, however, concerns have grown about the climate impacts of the haze. For instance, black carbon aerosols from combustion sources absorb solar radiation – particularly over the bright Arctic snow and ice surfaces – and lead to a heating of the atmosphere. When deposited on the snow or ice, black carbon absorbs radiation at the snow or ice surfaces and can trigger melting. Other pollutants as well – such as ozone, a major short-lived greenhouse gas – can cause Arctic warming. While it is clear that increases of long-lived greenhouse gases are the main reason for Arctic warming, it is of interest to quantify the contribution of these shorter-lived factors.

POLARCAT objectives

The POLARCAT project set out to study the sources of Arctic air pollution, its long-range transport into the Arctic, its vertical structure, and its impact on atmospheric chemistry and climate. To achieve these ambitious goals, one of the largest atmospheric measurement campaigns ever to be conducted was designed. It consisted of coordinated programmes run by several countries, involving a total of more than 200 researchers. Multi-national collaboration enabled the project to deploy eight research aircraft (from France, Germany, Russia and the USA), a research vessel, and an instrumented train carriage to the field. In addition, intensive measurement campaigns were conducted at ground stations, for instance at Summit in Greenland and on Svalbard.

Except for one campaign in spring 2007, the activities were concentrated in spring and summer 2008. In addition to the campaign activities, the POLARCAT project made extensive use of satellite data, analysed long-term monitoring data from several Arctic measurement stations, and used computer models to help to interpret the campaign findings and put them into a broader perspective.

Norwegian institutions played a key role in the POLARCAT project. The project was initiated and coordinated by the author of this article, together with a French co-coordinator, Dr. Kathy Law. Together we organised several workshops, planning sessions and data analysis meetings. The Norwegian Institute for Air Research (NILU) participated in all POLARCAT campaigns by providing forecast products used for the detailed planning of the research flights and by carrying out a balloon campaign. NILU performed analyses of both the data obtained during the field missions and long-term data, investigating

in particular the sources of the measured pollution. The University of Oslo (UiO) analysed LIDAR (Light Detection And Ranging, an optical remote sensing technology) data obtained at ALOMAR and performed model simulations of an Icelandic dust storm and cross-polar pollution transport. Both UiO and Met.no studied the climate impacts of Arctic aerosol.

Black carbon from agricultural burning and forest fires transported to Arctic atmosphere

A very important finding of the POLARCAT project is that the largest source of black carbon in the Arctic is not the combustion of fossil fuel, but biomass burning. During the spring and summer 2008 campaigns, extensive layers of biomass burning plumes originating from both agricultural and boreal forest fires in Kazakhstan, Siberia and Canada were observed.

This important source of Arctic black carbon was overlooked in the past because biomass burning plumes are mainly found in the free troposphere – and are less evident near the ground, where most measurements were taken before the POLARCAT campaigns. Still, re-evaluation of long-term monitoring data confirmed the presence of biomass burning aerosol also at the surface. This finding has important implications for environmental and climate policy, as project results show that the biomass burning emissions must not be overlooked, and must be reduced in order to control Arctic black carbon concentrations.

The analysis of black carbon data from four Arctic surface stations (Alert, Canada; Barrow, Alaska; Summit, Greenland; Zeppelin, Svalbard) has also shown that high-latitude Eurasia is the most important source region for black carbon near the surface. While black carbon concentrations have decreased during the 1990s because of emission reductions in Eurasia, their concentrations have stabilised since roughly from year 2000. Modelling studies suggest that black carbon emissions in the Arctic must be closely watched because even relatively small Arctic emissions due to increasing ship traffic, for instance, could have a substantial impact on the Arctic.

For the sake of brevity, the above discussion focuses on one particular topic, black carbon. However, the POLARCAT project has generated new knowledge about many other substances and processes. These results are now being published in the peer-reviewed literature.

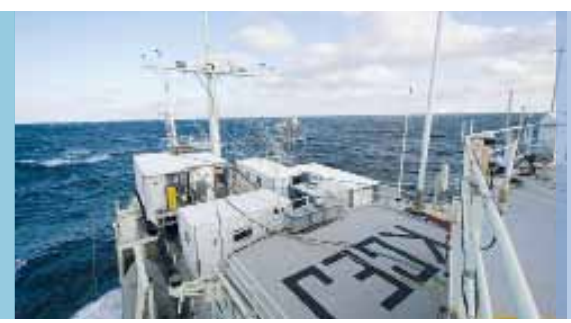
Although the project concluded in summer 2010, data is still being analysed. The POLARCAT project has provided a unique three-dimensional snapshot of the chemical composition and aerosol content of the Arctic atmosphere during spring and summer 2008, which will serve as a reference for future studies. Without doubt, the Arctic atmosphere is changing rapidly. Comparisons between measurements taken under POLARCAT and in the future will allow researchers to quantify these changes.

Cristina Prados does a pre-flight instrument check on board the DLR Falcon. Photo: John Buchardt

The project's two research aircrafts being prepared for a joint flight over Greenland in summer 2008. Foreground: The German Aerospace Center (DLR) Falcon. Background: the NASA DC-8. Photo: John Buchardt

Jim Kirchner and Paola Massoli prepare the air samplers north of Svalbard during the ICEALOT campaign, part of the POLAR-CAT project. Photo: John Buchardt

The foredeck of the research vessel Knorr, with five containers from the US National Oceanic and Atmospheric Administration (NOAA) for atmospheric measurements during the ICEALOT campaign. Photo: John Buchardt



Instruments aboard the NASA DC-8, one of the largest aircrafts available for atmospheric research.
Photo: Hans Schlager

Better ocean and ice monitoring and forecasting in the Arctic

By Cecilie Mauritzen

Photo: Rudi Caeyers

INTEGRATED ARCTIC OCEAN OBSERVING SYSTEM: CLOSING THE LOOP (IAOOS-NORWAY)

Project owner: Norwegian Meteorological Institute
Partner institutions: Norwegian Polar Institute, Institute of Marine Research, Universities of Bergen and Tromsø, University Centre in Svalbard
Project manager: Cecilie Mauritzen
Total budget: NOK 33 million
Post-doctoral fellowships: 6
Dissemination measures, public and user-oriented: 76
Mass media coverage: 95
Articles published in scientific and scholarly journals: 52
Books published: 4
Presentations published from international meetings/conferences: 73
Home page: http://www.iaoos.no

More and more of the Arctic Ocean is opening up as the sea ice melts. The iAOOS-Norway project has focused on improving safety in the Arctic through advances in monitoring and forecasting. This interdisciplinary project included researchers from six major Norwegian institutions. It helped to set standards for IPY as a whole, especially in data management.

The project had three main goals:
1) to close the loop: to monitor the upstream and downstream conditions of the Arctic Ocean;
2) to work towards an international operational monitoring and forecasting system for the Arctic;
3) to improve our understanding of processes in all parts of the system – ocean, sea ice, biology and meteorology.

More and longer time series, quicker access to data

Norway maintains some of the world's longest meteorological and oceanographic time series. Such series are extremely important in climate research. Many of the Norwegian time series were continued and new ones started through iAOOS-Norway. We have observed both the inflow of Atlantic water northwards into the Arctic Ocean and the current of cold water flowing out of the Arctic Ocean.

In addition to continuing existing measurements, the project has introduced new, cutting-edge instruments. Seagliders are autonomous underwater vehicles that can be programmed and remotely controlled and travel for months at a time, reporting temperature, salinity and current measurements back to researchers by satellite. In situ measurements were made from the sea ice in the Arctic Ocean and particularly in the Fram Strait, where most of the exchange of water and sea ice between the Arctic and the World Ocean takes place. The Norwegian Coast Guard provided invaluable assistance, allowing researchers from iAOOS-Norway to carry out field work from their icebreaker KV Svalbard. This provided a wealth of physical and biological data.

Rapid access to data is one of the most important recent developments in oceanographic monitoring. Previously, scientists have had to wait months or even years for their measurements, but with new methods and satellite communications, data from more and more places are being relayed to researchers and operations centres at hourly intervals.

iAOOS-Norway has used the new data in innovative ways, especially for real-time or near-real-time operations. The project has followed in the footsteps of weather forecasters, combining satellite measurements of the sea surface and underwater measurements of temperature, salinity and current speed, all in near-real-time, to improve ocean and ice forecasts.

The Norwegian Meteorological Institute's ice and ocean forecasting system combines observations with the fundamental laws of physics governing fluid flow to describe current and future status (ocean temperature, salinity, current velocity, waves and ice cover) as precisely as possible. The model is used to forecast changes in the ocean that are expected over the next few days, just like a weather forecast. The snapshots of current conditions are also important for monitoring and for better understanding of climate change in the Arctic. iAOOS-Norway has for instance produced a satellite-based ice drift data set that describes drift speed and ice deformation better than older products.

SELECTED SCIENTIFIC RESULTS

Monitoring the Norwegian Atlantic current using seagliders and moored current meter arrays

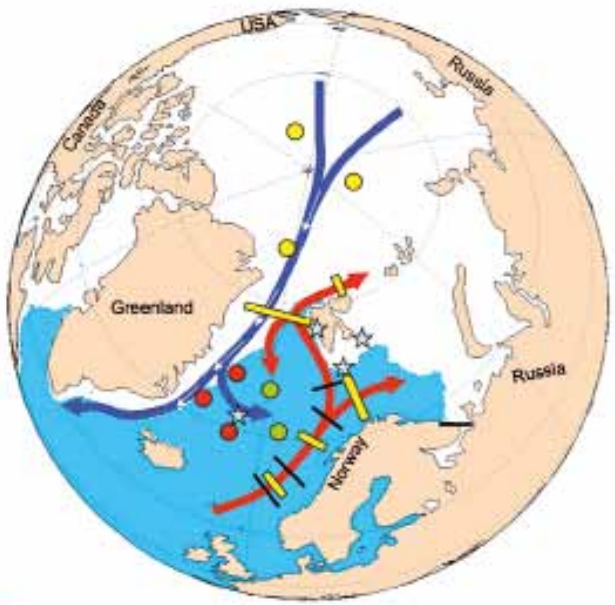
The Norwegian Atlantic Current has two distinct branches. The eastern branch has been monitored using current meters since 1995, and the temperature in the core has been stable at 8°C for the past five years. The maximum monthly mean (8.3°C) was measured in 2003. The volume of water transported has also been stable in the past few years.

Much less was known about the western branch, which the iAOOS project has been monitoring with remotely controlled seagliders. Analytical tools have been developed to quantify volume and heat fluxes based on the seaglider data. The western branch of the current has proved to be just as strong as the eastern one. This means that it plays a very important role in heat transport northwards and thus for the amount of heat exchanged with the atmosphere along the Norwegian coast. Analysis of the seaglider data also shows that there is a great deal of water exchange and mixture of the two branches of the current.

Monitoring of the western branch should continue in order to determine long-term variations in total heat transport in the Atlantic current. We find seagliders particularly useful for this purpose because the western branch of the current is relatively wide and therefore difficult to monitor using moored arrays. In addition, the western core of the current is weaker that the eastern core, allowing gliders to easily travel through it.

Mixing of water masses

The density of seawater varies with both temperature and salinity – cold water is denser than warm water, and salt water is denser than fresh water. The project has studied an area west of Svalbard where warm, saline Atlantic water



Instrumentation deployed for the IAOOS project.

Sediment samples being brought on board KV Svalbard in the Fram Strait.
Photo: Rudi Caeyers

Photo: Rudi Caeyers

flows northwards and meets cold, fresher Arctic water of about the same density. This means that there is more potential for mixing of salt and fresh water masses in this area than in most parts of the oceans.

Eddies with a diameter of 10–50 km play an important role in the mixing process. The eddies can be as important as the direct atmospheric cooling of the Atlantic water as it is transported northwards. The mixing mechanisms vary both between seasons and between years, depending on when eddies are formed. Both the topography of the seabed and small density differences between Atlantic and Arctic water influence the formation of eddies. Eddies of Atlantic water were found to have prevented the formation of sea ice along the coast of Svalbard throughout several winter seasons.

Reflection of solar radiation from ice and snow

The project has made optical measurements both on and underneath the sea ice at ice drifting stations in the Arctic Ocean (the schooner Tara) and in the Fram Strait (KV Svalbard). At the Tara station, solar radiation was measured continuously at high spectral resolution for six months in 2007. This provided measurements throughout the entire ice-melt season in this record-breaking year (sea ice extent reached the minimum for the period 1979–2010 in September 2007).

The measurements show that about 2/3 of the radiation that penetrates through the ice to the water in the course of a year does so in the two-month period mid-June to mid-August. The amount of sunlight available is of crucial importance for life in and under the ice, for example ice algae and plankton. Measurements suggest that the fauna itself affects the light budget under the ice – organisms close to and within the ice reduce light levels in the ice and the uppermost water layer.

Measurements at the Tara station were made at a fixed spot on an ice floe, whereas the two surveys from KV Svalbard in 2007 and 2008 involved measurements at many different sites in the Fram Strait. This allowed us to measure surface albedo (reflectivity) and light transmission through the ice in many different types of ice. These data are important in improving climate models, as many feedback mechanisms in the climate system are known to be related to surface albedo.

Changes in ice thickness during the IPY period

The Arctic pack ice is in constant motion. Its thickness changes with freezing and melting processes, and the motion causes mechanical stresses that also alter ice thickness. Where the ice is compressed, ridges and rafts form, resulting in thicker ice.

Measurements across large areas of the Arctic Ocean therefore show a wide range of ice thicknesses. Thin, recently formed ice is only 10–50 centimetres thick, whereas heavily ridged and rafted ice may be up to 40–50 metres thick. Some of the ice types have undergone a number of processes that change its thickness, including freezing, melting and mechanical stresses. Some of the ice is formed in the current season (first-year ice), whereas some ice has persisted for several seasons, and is called multi-year ice. In the distribution of sea ice thickness there is a clear difference between first-year and multi-year ice.

The wide variations in ice thickness, age and dynamics make it difficult to relate changes in ice thickness to specific causes. Long time series of measurements are required for this, and iAOOS-Norway therefore deployed instruments in the Fram Strait that have been providing continuous measurements of ice thickness since 2007, continuing a series that was started in 2004. Since most of the ice transported out of the Arctic Ocean passes through the Fram Strait at a fairly even rate, this is an ideal place to establish a time series of ice thickness observations.

Our preliminary analyses show that there was a substantial loss of multi-year ice in the period 2005–09. The average thickness of multi-year ice in winter declined from about 3.0 metres in 2005 to 2.1 metres in 2007 and 1.9 metres in 2009, an overall reduction of 37%. The multi-year ice was thinner in 2009 than in 2005 throughout the season. The most interesting finding was that

Scientists on the sea ice during the research cruise with KV Svalbard in the Fram Strait in April 2007. Photo: Rudi Caeyers

Copepods are one of the most important marine zooplankton groups both in the Arctic and elsewhere.
Photo: Christian Wexels Riser

Collecting zooplankton from below the ice on the East Greenland continental shelf using a MultiNet plankton sampler deployed from KV Svalbard. Sometimes there was barely enough open water to take samples. Photo: Camilla Svensen

At work in the laboratory onboard.
Photo: Rudi Caeyers

the greatest loss took place before September 2007. This means that ice thickness declined before the sea ice cover, and that the decline in thickness probably contributed to the reduction in ice cover in the subsequent melt seasons.

Carbon cycling and plankton in the western Fram Strait

Field studies in the western Fram Strait have led to a better understanding of nutrient supplies and the growth and species composition of small plant and animal plankton (1 µm–5 mm), which support the rest of the food web. The project has shown that nutrient supplies for algae are much better outside and along the margin of the East Greenland continental shelf than nearer the coast. Nearer the coast, the surface waters flowing from the Arctic Ocean are nutrient-poor, due to several seasons of algal growth. There is little replenishment from the nutrient-rich deep water because of strong stratification and thus very limited vertical mixing. This means that even if the ice cover shrinks, allowing more light penetration, primary production near the coast will not necessarily increase. Similar results have been obtained north of Canada.

Another important finding is the part played by microbial organisms and processes in carbon cycling. Their importance in Arctic waters has been underestimated. Reults from our project show that small photosynthesizing algae (2–5 µm) and mixotrophic ciliates (single-celled organisms that can both photosynthesise and graze on small particles and cells) play an important role in transition period from winter to spring. Despite very low concentrations of algae in the water below the ice, the system at most of the stations on the outer shelf investigated in April–May 2008 was autotrophic. This means that the algae production is large, and that they absorb more CO_2 than bacteria and zooplankton emit during respiration. The low algal concentrations are thus not a sign that the biological system is still in a resting winter state, but are a result of heavy grazing of algal cells, so that little algal biomass accumulates or sinks down through the water column.

These results show how necessary it is to use field observations and process studies to supplement satellite or other remote monitoring of biomass in developing a complete understanding of carbon cycling in Arctic marine ecosystems.

Monitoring freshwater transport out of the Arctic Ocean through the Fram Strait

There is outflow of relatively fresh water from the Arctic Ocean through the Fram Strait in the upper layers of the East Greenland Current. Direct measurements of this freshwater transport over time make it easier to understand the variability of the hydrological cycle in the Arctic.

The project's instrumentation and surveys in the Fram Strait have contributed to the first long-term estimates of the freshwater transport. On average, roughly two thousand cubic kilometres of freshwater per year is transported through the Strait. This transport has been fairly constant over time, which is remarkable given the major changes otherwise taking place in the Arctic.

Analysis of water samples taken during the surveys makes it possible to differentiate between the various sources of freshwater in the Strait, and thus to explain the results. It turns out that there has been a change in the distribution of the sources. There has been no increase in the transport of melted sea ice, even after sea ice extent in the Arctic reached a minimum in summer 2007. On the other hand, there was a rise in the volume of water that has been involved in freezing of sea ice (when sea ice forms, most of the salt is expelled as brine). This result has led to the hypothesis that a higher rate of freezing in autumn/winter – which is a result of the shrinking area of ice in summer – has increased net distillation of freshwater in the Arctic Ocean. More salt is transferred to deeper water layers, and more freshwater is exported in the sea ice on the surface.

Dissemination – a key part of the iAOOS project

During the two main surveys in 2007 and 2008, KV Svalbard carried a film team, photographers, artists, bloggers and journalists in addition to the scientists and crew. This has resulted in wide media coverage, including many news stories, a Japanese television documentary, two art exhibitions and four blogs. In 2007, an open day was held on KV Svalbard after the survey to give the public insight into the research.

Media coverage has been a priority throughout the project, and there have been more than a hundred press and other media reports. A seminar was organised for journalists who cover climate and the environment.

Popular science articles about the surveys, about new findings from the project, and so on have regularly been published on the website www.iaoos.no. The project scientists have given numerous talks, aimed towards the science community, schools, policy makers and stake holders. Many of them have also joined in the public debate by publishing opinion pieces and taking part in panel debates.

The Polar Oceans in the Atlantic sector: the sources of deep water circulation and uptake of CO_2

By Tor Gammelsrød

Photo: Kjersti Lundmark Daa

BIPOLAR ATLANTIC THERMOHALINE CIRCULATION (BIAC)

Project owner: University of Bergen (UiB)
Project manager: Tor Gammelsrød /Svein Østerhus
Total budget: NOK 32.8 million
Doctoral fellowships: 4
Dissemination measures, public and user-oriented: 14
Mass media coverage: 37
Articles published in scientific and scholarly journals: 50
Other reports and lectures from scholarly fora: 135
Home page: http://www.bccr.no/biac/

Only 3% of global warming is accumulated in the atmosphere, compared to 90% in the ocean. This ocean warming may be caused by less deep water production in the Polar Regions of the Atlantic Ocean, whose water masses spread to the depths of every ocean. The BIAC project has focused on dense water production processes and their significance in deep water circulation, and on ocean CO_2 uptake.

BIAC is one of the major international IPY projects coordinated from Norway. A total of 13 countries were involved, the most active being Germany, Russia and the UK.

Project design and method

The project placed greatest emphasis on observations in the Arctic, particularly the Barents Sea, and in the Antarctic, mainly in the Weddell Sea. Data have been collected using research vessels and drifting ice floes, using advanced electronic instrumentation, water samples and measurements in the ice. Several year-long time series have been obtained using instrument moorings and remote measurements by satellite. Laboratory experiments and analytical and numerical models have been applied to aid in data interpretation and design of field experiments.

BIAC project members have carried out several expeditions in the Barents Sea and the Weddell Sea in the Antarctic. Norwegian and Russian research vessels were used in the Arctic, while the three BIAC expeditions to the Antarctic were aboard German and British ice breakers.

Challenges underway

Using Russian research vessels, five scientific moorings were deployed in 2007 between Franz Josef Land and Novaya Zemlya carrying a total of 15 instruments for one year. From a technical standpoint the expeditions were a success, but unfortunately all the instruments and data were confiscated by the Russians immediately after recovery in September 2008. This is the most crucial data set for BIAC in the Arctic, and it was supposed to estimate the role of the Barents Sea in global circulation.

Uptake of CO_2 in polar regions and acidification of the oceans

Before the start of IPY it was considered good news that atmospheric CO_2 levels were lower than expected, since roughly 50% of the atmospheric anthropogenic CO_2 emission was absorbed by the ocean. In recent years, however, it has been confirmed that CO_2 uptake in the ocean leads to ocean acidification, which may threaten several ecosystems.

Ocean uptake of CO_2 is most efficient in polar regions, where the ocean water is cold. Under the BIAC project, scientists studied uptake and dissipation of CO_2 in the Nordic Seas, the Eurasian Basin in the Arctic, and in the Antarctic. Measurements in the Weddell Sea indicate a slower uptake of CO_2 in the ocean than predicted using the present increase in atmospheric CO_2 concentration. The measurements also indicate, in contrast to earlier understanding, that ice formation enhances ocean CO_2 uptake.

Does Arctic ice melt from above or below?

The ice extent in the Arctic has shown a negative trend during the last few decades, with an absolute minimum observed in September 2007. Both melting and drifting of ice out through the Fram Strait have been offered as possible explanations.

Measurements from numerous field expeditions to the Arctic in both summer and winter indicate that the heat transport from deeper layers towards the surface is an insignificant contributor to melting. Melting of the ice is mainly due to solar warming of the upper ocean layer between the ice floes, melting the ice from below, and increased absorption of solar radiation in melt ponds on the ice surface, melting the ice from above.

The densest water in the world is formed in Storfjorden, Svalbard

Moorings deployed over the winter in Storfjorden showed that as the temperature dropped to the freezing point, salinity increased. This is due to the fact that most of the salt in seawater is expelled from the ice when it is formed. Cold, saline water is dense, hence this is the densest water mass found in the world's oceans. This water mass therefore has the potential to cascade down to great depths and contribute to deep ocean circulation, thereby affecting climate. (Figure 1 and 2)

The Barents Sea is a heat sink for the Arctic rather than a heat source

Earlier estimates indicated that also the Atlantic Water entering the Barents Sea was carrying an important amount of heat when it entered the Arctic Ocean via the strait between Novaya Zemlya and Franz Josef Land. The BIAC project's measurements and models indicate that the Atlantic Water in the shallow Barents Sea is effectively cooled by the atmosphere, such that when it enters the Arctic the heat flux is small and may even be negative. (Figure 3)

Cold bottom currents: Dynamics and mixing

Understanding the Thermohaline Circulation requires knowledge about the role of the bottom jets carrying dense water down the continental slopes to great depths. These jets have been studied in Storfjorden (Svalbard),

The icebreaker Ernest Shackleton in the Weddell Sea.
Photo: Kjersti Lundmark Daae

Polar bears inspect an instrument hut secured to the sea ice
Photo: Kjersti Lundmark Daae

the Faroe Bank Channel and the Weddell Sea. The rate of mixing of overlaying waters into these jets determines their volume transports. Under the BIAC Project, direct measurements of mixing and turbulence in these currents were taken for the first time.

Some results were surprising: the turbulence in the Faroe Bank Channel, for instance, was 1 000 times more vigorous than is typical for ocean currents. These bottom jets are concentrated; they are typically 100 m thick and roughly 10 km wide. It is a challenge to include such small-scale features in ocean numerical models. One problem has been that terrain-following models have produced incorrect results for steep slopes. The BIAC project developed a new algorithm to avoid this problem. The algorithm can easily be implemented into other models, and will hopefully increase their precision.

Mysterious oscillations of the ocean currents on the continental shelf in the Weddell Sea

Five current meter moorings were deployed on the continental slope in the Weddell Sea to monitor outflow and bottom water formation. These observations revealed many interesting characteristics, e.g. nearly every instrument recorded episodes of oscillations with periods of 1.5, 3 and 6 days which could not be explained by tides. The causes of these oscillations are not understood, nor is their role in mixing and therefore the production of deep waters in the Antarctic.

Monitoring the world's coldest ocean current in Antarctica

For more than three decades Norwegian scientists have been observing an interesting cold bottom current in the Weddell Sea. This super-cooled water originates below the floating ice shelf and is the coldest water mass in the world. Cold water is more compressible, so this water has the potential to sink to great depths. This is the origin of the water that is observed near the floor of all the world's oceans. Monitoring this current provides clues to the variability of the ocean abyss circulation.

The BIAC project designed and developed a monitoring mooring system which was deployed in February 2009. The lifetime of this mooring is believed to be at least 10 years. Data is transferred by acoustic links when a ship is nearby. The first year-long time series was transferred in 2010 and showed the cold bottom jet to be stable.

Significance for research fields and follow-up

Results from the BIAC project will provide a basis for multiple future research projects on global ocean circulation, processes in polar regions, and the carbon cycle – particularly when it comes to field work, instrument development and modelling.

A long-term ocean monitoring mooring system was developed during the BIAC project; its prototype was deployed in the Weddell Sea, Antarctica, in February 2009. A modified version was anchored in the Barents Sea in 2010. This instrument cluster is now available on a commercial basis: one has already been deployed in the Faroe Bank Channel, and another one is on its way to the Mediterranean Sea.

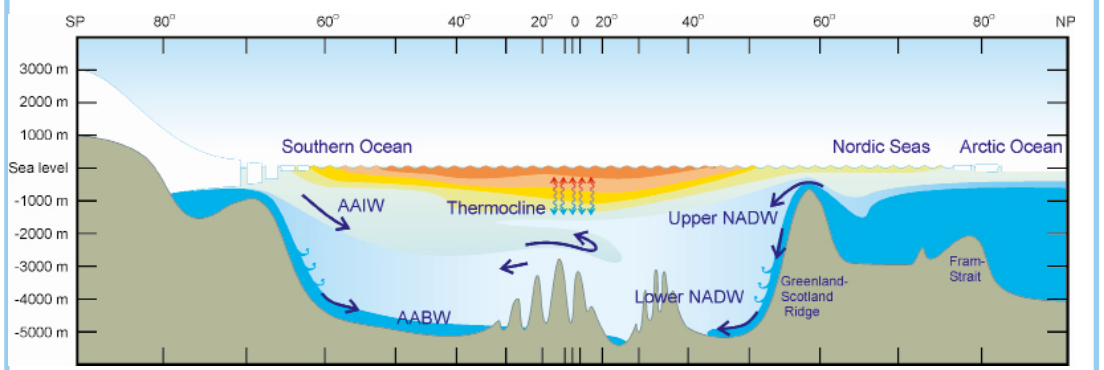


FIGURE1: Cold and heavy water is produced in the polar regions and fills the world's oceans.

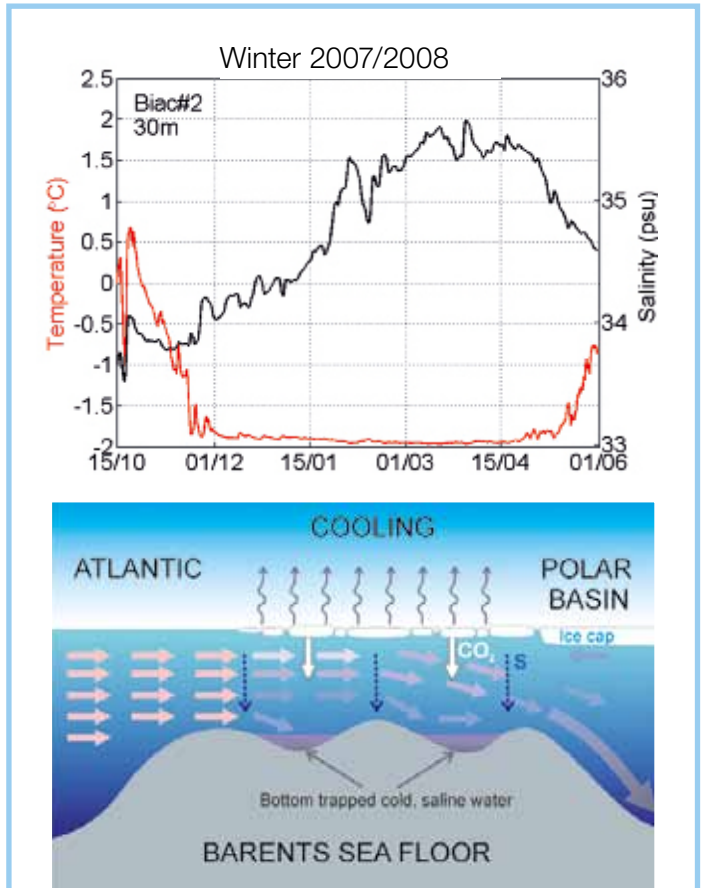


FIGURE 2: Variation in temperature and salinity through one winter in Storfjorden, Svalbard. The freezing point of seawater with salinity S = 35 is roughly -1.9°C. As freezing begins in December, seawater salinity increases because salt is expelled when ice forms.

FIGURE 3: Warm Atlantic Water is effectively cooled in the Barents Sea. The formation of ice accelerates CO_2 uptake and seawater salinity increases. The water has become so cold by the time the current carries it into the Polar Basin that it further cools the water there.

Recording permafrost temperatures in Norway and Svalbard

By Hanne Hvidtfeldt Christiansen

Photo: Kristen Ustein

PERMAFROST OBSERVATORY PROJECT:
A CONTRIBUTION TO THE THERMAL STATE OF PERMAFROST IN NORWAY AND SVALBARD (TSP NORWAY)

Project owner: The University Centre in Svalbard (UNIS)
Partner institutions: University of Oslo, The Meteorological Institute MET.no, International Centre for Geohazards (ICG), Geological Survey of Norway (NGU), Norwegian University of Science and Technology (NTNU), Instanes Polar
Project manager: Hanne Hvidtfeldt Christiansen
Total budget: NOK 5.5 million
Post-doctoral fellowships: 1
Dissemination measures, public and user-oriented: 11
Mass media coverage: 15
Articles published in scientific and scholarly journals: 10
Other reports and lectures from scholarly fora: 2
Home page: http://www.tspnorway.com

With sensors placed in 25 boreholes throughout northern Norway and Svalbard, the TSP Norway project monitors permafrost temperatures. The state and development of permafrost is of vital importance for climate models. Deeper thawing of the permafrost in the summers could trigger an anaerobic bacterial breakdown of organic materials, a process that releases the potent greenhouse gas methane.

Research question

The main objective of the TSP NORWAY project was to measure and model the permafrost thermal state and its influence on periglacial geomorphological processes in northern Norway and on Svalbard. The project established permafrost observatories which, together with the empirical and numerical permafrost modelling developed, have equipped the researchers to address the impacts of past and future climate variability on permafrost distribution and associated geomorphic effects.

The TSP NORWAY project has contributed to the international knowledge base about the thermal state of permafrost in key parts of the North Atlantic region. Together with Nordic colleagues and colleagues from the Norwegian basic research project CRYOLINK, the TSP researchers instrumented existing and new boreholes along a west-east line from western Greenland over Iceland to Norway, Sweden and Finland, and along a north-south line from Svalbard to northern Norway and down to southern Norway.

Project design and research method

The project drilled 13 boreholes in northern Norway along altitudinal transects across a west-east transect from the moist, warm coastal mountains over the more continental inner parts of the mountains in Troms County and into the cold, dry landscape of the interior continental plateau in Finnmark County.

On Svalbard 12 boreholes were drilled into different permafrost landforms in the central, most continental Longyearbyen area, and in the westernmost maritime Kapp Linné area. The boreholes were located at different elevations and in bedrock, sediment and organic material to span the variations of permafrost conditions.

The boreholes range in depth from 2.5 m to 58.5 m. Each borehole is equipped with a string of thermistors recording the temperature at regular intervals, thus providing the first systematic investigation of the study areas' near-surface heat fluxes and thermal offsets between the atmosphere and the permafrost temperatures. Three of the boreholes provide data online in near real-time. All ground temperatures collected in the project are stored in the Norwegian Permafrost Database (NORPERM) designed and operated by the Geological Survey of Norway (NGU). NORPERM is the TSP NORWAY database, providing free access to the project data.

Particular challenges

Gaining access to permafrost requires drilling boreholes. In northern Norway the researchers used NGU's coring drill rig, which needs road access and can only drill in bedrock, so drill sites were limited to along roads. The highest borehole was located at 990 m elevation. Bedrock cores were obtained from all 13 boreholes drilled. No boreholes were drilled in sediments or organic material, since the higher-elevation landscape consists almost entirely of bedrock. Drilling was unsuccessfully planned at the highest mountaintop in Troms County (Njunis, elevation 1 717 m), which is road-accessible due to military activity.

In Svalbard a hammer drill rig was first available from the winter of 2008; however, it could drill through both

The team from the University Centre in Svalbard (UNIS) measured movements in the top layer of the permafrost due to thawing and deep freezing. Photo taken in Endalen on Svalbard. Photo: Kristen Ulstein

UNIS students and Professor Bo Elberling hand drilling into permafrost in Zackenberg, NE Greenland. Here they are starting to obtain the core sample.
Photo: Hanne H. Christiansen

sediments and bedrock. Reaching the Kapp Linné west coast drill sites with roughly four tonnes of drill rig equipment was challenging, but winter transport over land was accomplished using a rented heavy-duty sledge and bulldozer. This mode of transport took a full day each way but made an intensive drilling campaign possible in the Kapp Linné area in April 2008.

Key results

For the very first time, permafrost temperature information from different periglacial landforms in Svalbard (Figure 2) and at different elevations in northern Norway was obtained. Thanks to international cooperation with the TSP projects of Canada, Alaska and Russia, we now know that the Svalbard permafrost temperatures of -2°C to -5°C are the highest recorded during IPY this far north in the Northern Hemisphere (Figure 1).

In northern Norway permafrost temperatures were close to 0°C in all the mountain boreholes below 990 m elevation, and several of the drilled boreholes did not have permafrost, but rather were located just below the local permafrost limit. The results from Troms and Finnmark confirm the overall pre-IPY model with a lower permafrost limit at 900–1 000 m elevation in the outermost coastal areas, decreasing to 700 m in the more continental interior parts and descending to 500 m on the plateau of interior Finnmark. However, at 1 550 m elevation the permafrost is relatively cold (-2.5°C) at the nearby Tarfalaryggen borehole in Sweden, equalling the permafrost temperature at sea level in the warmest part of Svalbard. This indicates that northern Norway's highest mountaintops also have permafrost with temperatures comparable to those found at sea level in Svalbard.

Thanks to close collaboration with the local intermunicipality "Rockslide in Troms" project, we found permafrost consisting of almost pure ice below the regional permafrost limit in special landforms such as the 15–25 m deep open crevasses of a larger rockslide at Nordnes in central Troms. This demonstrates the need to enhance knowledge about the local mountain permafrost distribution to understand its potential influence on geohazards such as rockslides, especially in northern Norway, where such sites are located close to the regional permafrost limit.

Outreach and education

Through Nordic cooperation and funding, a special University master level permafrost field course was held during IPY. Students compared permafrost conditions in Svalbard to northeast Greenland, focusing on obtaining permafrost cores by hand drilling. The newly identified greenhouse gas nitrous oxide (N_2O) was identified as occurring in significant amounts in the upper part of the permafrost from these cores. Among the six high Arctic sites investigated, the Svalbard cores had the highest N_2O content.

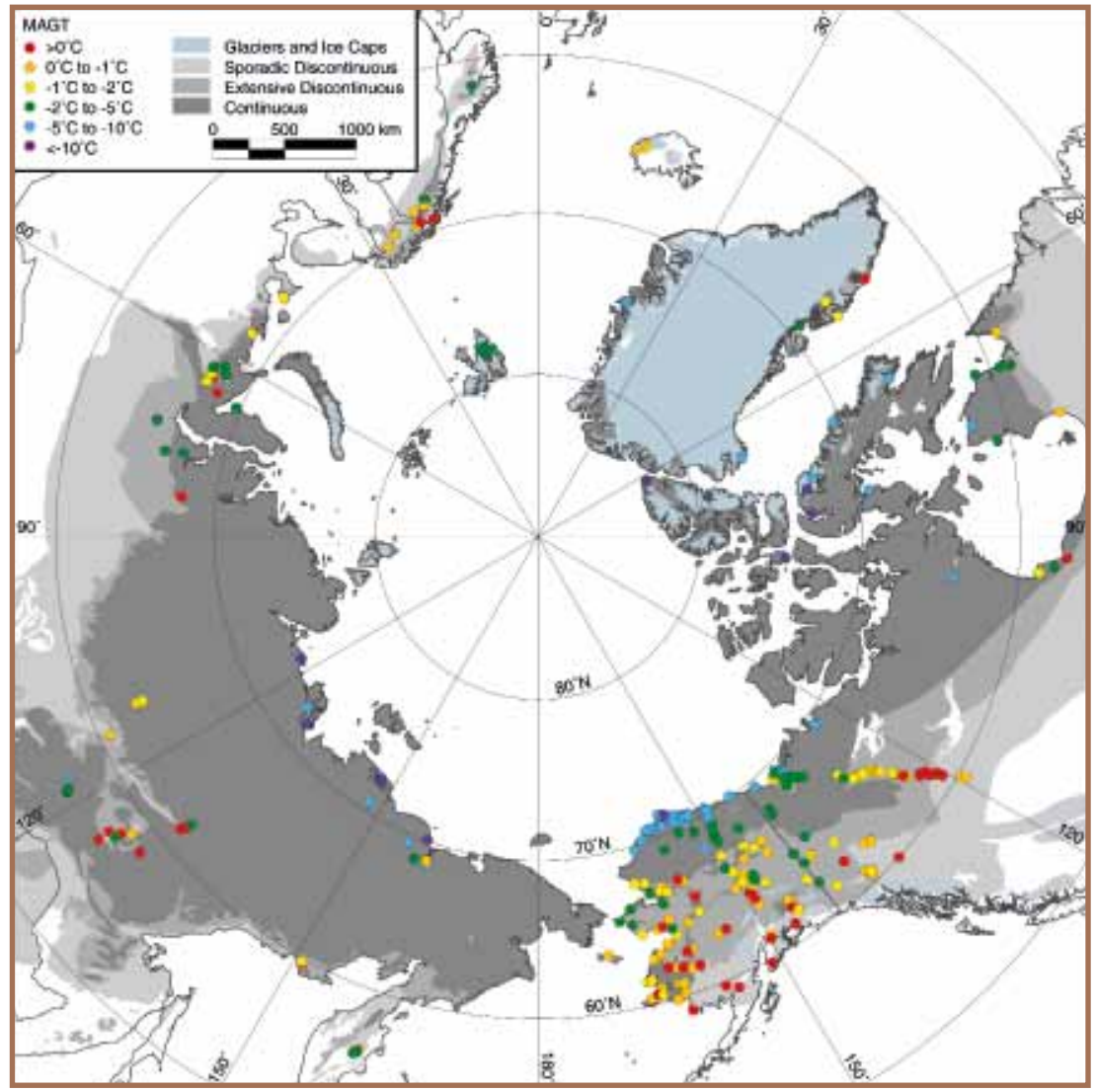


FIGURE 1: Mean annual ground temperature (MAGT) snapshot from all the Northern Hemisphere boreholes from which data is available during IPY 2007–2008 (from Romanovsky et el., 2010).

Hanne Christiansen at one of the measurement points deep in Adventdalen on Svalbard. Photo: Kristen Ulstein

Permafrost shapes the landscape. Photo taken at Kapp Linné. Photo: Kristen Ulstein

The Third European Conference on Permafrost was held on Svalbard in June 2010 to present the results of the IPY permafrost research carried out internationally and on Svalbard by both Norwegian and international researchers; 241 researchers from 27 nations participated.

The TSP legacy

The primary legacies of the TSP NORWAY project are:

- The establishment of long-term permafrost observatories with boreholes monitoring the thermal state and geomorphological effects of permafrost in northern Norway and on Svalbard in different periglacial landforms. Monitoring will continue after IPY and will comprise significant national parts of SAON and SIOS.
- The establishment of the permanent NORPERM open access database, allowing future use and ensuring the Norwegian permafrost data contribution to the international Global Terrestrial Network on Permafrost (GTN-P). As NORPERM is further developed it will become ever more valuable as the volume of data increases.

The hammer drill rig bores into an ice-rich pingo on Svalbard. Photo: Hanne H. Christiansen

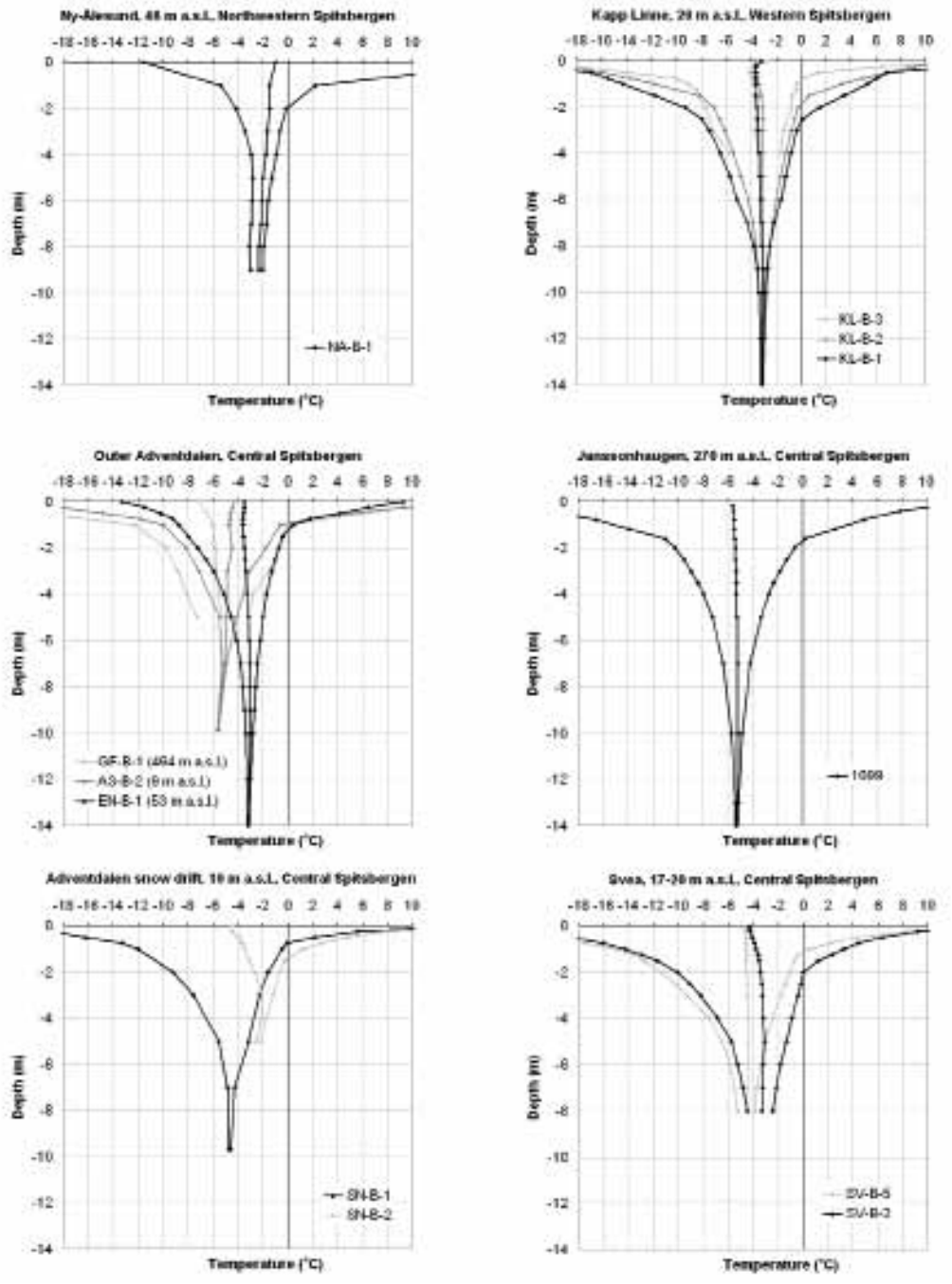


FIGURE 2: Ground thermal snapshots (minimum, mean and maximum temperatures) as measured on Svalbard. The left-hand graphs show the more maritime west coast sites, while those on the right-hand side illustrate continental sites on central Svalbard (from Christiansen et al., 2010).

How do Arctic glaciers react to global warming?

By Jon Ove Hagen

Photo: Jon Ove Hagen

THE DYNAMIC RESPONSE OF ARCTIC GLACIERS TO GLOBAL WARMING (GLACIODYN)

Project owner: University of Oslo
Project manager: Jon Ove Hagen
Total budget: NOK 14 million
Doctoral fellowships: 2
Post-doctoral fellowships: 1
Dissemination measures, public and user-oriented: 19
Mass media coverage: 10
Articles published in scientific and scholarly journals: 19
Other reports and lectures from scholarly fora: 77
Home page: http://www.geo.uio.no/glaciodyn/

The Arctic glaciers and ice caps are melting at different rates. In some parts of the Arctic, as in the Canadian Arctic, accelerating mass loss have been observed over the last ten years while in other parts, such as the Svalbard archipelago, a more steady decrease has been observed. Svalbard's Austfonna Ice Cap, which is one of the world's largest ice caps, has been studied in the Norwegian part of IPY-GLACIODYN. The ice cap has been growing in thickness roughly 50 cm per year at its summit while its lower areas have thinned, so its surface mass is nearly balanced. Austfonna's calving ice front has retreated and icebergs are produced so that it is currently losing mass at a rate of roughly two cubic kilometres per year.

Research question

Glaciers and ice caps store a volume of water equivalent to 0.5 m of global mean sea level. They currently contribute to global sea level change roughly the same as the large ice sheets of Greenland and Antarctica combined. The smaller ice masses are expected to continue to contribute substantially to sea level changes throughout the 21st century.

About 50% of the world's glaciers and ice caps are found in the Arctic. Up to 30–40% of their total mass loss is caused by calving. However, there are large uncertainties in both the surface mass balance and in the estimated calving fluxes. Over the last 10–15 years the glaciers have been observed not only melting more on the surface, but in many areas also gliding faster, producing more calving and thus transporting more ice mass from land to the oceans. This has been observed on many outlets from the Greenland Ice Sheet. The extent to which increased melt rate may change the dynamics of other glaciers in the Arctic as well is not known.

This was the background for the GLACIODYN project under IPY. The overall objective of the project was to provide better estimates of the total future fresh water transport from the glaciers to the oceans and thus better estimates of future global sea level changes. The project was part of the international IPY GLACIODYN project that studied selected glaciers in the Arctic.

Project design and methods

The strategy was to focus on selected glaciers and ice caps in order to:

1) map the current rate of change of Arctic glaciers and ice caps,
2) study the physical processes behind the changes, and
3) model future development.

The modelling involved the input of data from selected field investigations together with satellite remote sensing data.

Field activities

Previous studies of the major Arctic ice caps are few. These ice caps are found in Northern Canada, Svalbard and the Russian archipelagos Franz Josef Land, Novaya Zemlya and Severnaya Zemlya. A large part of the GLACIODYN project's field activity was on the Austfonna Ice Cap in Nordaustlandet, Svalbard. Austfonna is the largest ice cap in Svalbard at just over 8 000 km^2 and one of the world's larger ice caps outside of Greenland and Antarctica.

Surface mass balance measurements were taken on Austfonna to see whether the ice cap is growing or shrinking. Elevation changes across the ice cap were measured by kinematic GPS profiles, and snow thickness and snow distribution measured by snow radar. Laser elevation profiles were performed by airplane, and automatic weather stations, made it possible to conduct detailed and con-

tinuous measurements that would not have been possible only a few years ago. Data samples were taken on the ground, by airplane and by satellite.

Kronebreen is calving in the inner part of Kongsfjorden in northwestern Spitsbergen. Using continuous observation with automatic cameras and radar over a two-year period, studies were carried out on the calving processes, including velocity, calving flux and the relationships between water depth, velocity and meltwater.

At Engabreen, an outlet from the Svartisen Ice Cap in Northern Norway, basal sliding was observed from subglacial tunnels under 200 m thick ice. In connection with a hydropower station, access tunnels and a subglacial laboratory have been constructed under the glacier, providing a unique opportunity to study subglacial processes.

Particular challenges

The logistics of accessing ice caps of the Arctic are often difficult. They are several thousand square kilometres in area, so conducting field campaigns poses great challenges. To be able to work on Austfonna, a large depot had to be established on the coast for storing field equipment, snow scooters and fuel. Small wooden huts had to be built to protect the depot from snow, wind and inquisitive polar bears. The depot was set up in summer by the Norwegian Polar Institute vessel Lance and helicopter support. Each summer the depot has been restocked and the snow scooters have received maintenance.

Field expeditions have been carried out over 4–5 weeks in April–May each year, using tent camps established on the summit of the ice cap. Setting up camp at the summit and not on the coast was necessary not only to reduce the polar bear danger, but also to manage the long measurement profiles, since the ice cap is 100 km across.

Frequent storms created snow drift and difficult conditions, however, so it was impossible to carry out field work roughly half of the days during each period. The weather changes very fast, and safe navigation by snowmobile – using only GPS in zero visibility for hours at a time – can be extremely challenging.

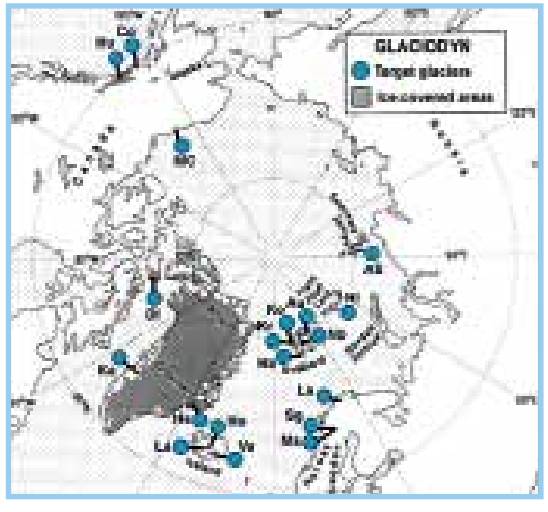
Key results

Newly developed measurement techniques using satellite data have been validated by field observations on Austfonna, demonstrating that high-quality data can be obtained for glacier elevation change and thereby also volume and mass changes over large parts of the Arctic. Arctic glaciers, both in Svalbard and elsewhere, are rapidly melting and thinning at their lowest-lying parts near the ocean, while the higher-elevation parts are reacting in complex ways: some are thickening, some are stable and some are thinning uniformly. The Austfonna Ice Cap has been growing by roughly 50 cm per year at highest elevations, while its lower areas have thinned, so its surface mass is nearly balanced. Austfonna's leading edge has retreated and icebergs are calving, so that it is losing mass at a current rate of roughly two cubic kilometres per year.

Analyses of satellite data for all of Svalbard show that the mean thinning rate has decreased from circa 36 cm/yr in the 1990s to circa 12 cm/yr in the period 2003–2009. At the same time an increasing thinning rate is observed in other parts of the Arctic, especially in Arctic Canada.

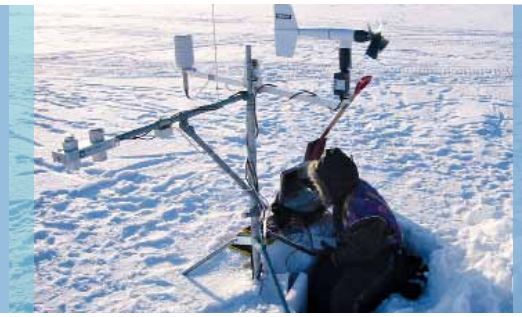
Campsite at Austfonna's summit in 2008. Photo: Thorben Dunse

Austfonna on Svalbard is one of the world's largest ice caps.



All the glaciers measured under the auspices of the international GLACIODYN project.

Snow radar and GPS elevation profiling at the summit of Austfonna Ice Cap. Photo: Jon Ove Hagen



Automated weather stations provide valuable data for monitoring and modelling of mass balance. This station is on Austfonna, Svalbard, April 2009. Photo: Jon Ove Hagen

Time-lapse cameras monitored the ice flow and calving of Kronebreen glacier, Svalbard. Photo: Monica Sund

Twenty automated GPS stations have been installed in two fast-flowing ice streams on Austfonna and on Kronebreen in Kongsfjorden. These monitor positions every hour year-round, yielding very interesting data about how dynamics vary throughout the year and showing a clear correlation to the hydrology with up to a doubling of the flow velocity at the beginning of the melt season and during high-melt events. These GPS stations will remain in service for years to come, monitoring flow velocities and validating satellite data.

Outreach and education

The most important outreach channel has been through scientific papers in international peer-reviewed journals. Several Ph.D. students have worked under the GLACIODYN project and more than 100 presentations as posters and talks have been given at different conferences. This will continue far beyond the IPY period.

Data have been collected that will be used in publications for years to come. In addition, several popular science presentations and school visits have been held. For instance, a group of 11-year-old school children from Reipå in Meløy municipality in Nordland visited Engabreen on Svartisen to learn how and why the glacier moves and is measured, and how end moraines are formed. Together with the GLACIODYN researchers working beneath the glacier, the IPY project PolarEduSpace also contributed, with satellite photos and maps.

Continuation in the international context

The international IPY GLACIODYN project had partners from 17 countries and a co-coordinator from Norway. The group has arranged a joint meeting once a year. The project has placed much more focus on glacier dynamics, and its activities are being followed up through new projects and modelling initiatives such as:

1) The EU project ice2sea (2009–2014), in which several of the European GLACIODYN partners participate.
2) Under the European Science Foundation's PolarCLIMATE programme, the project "Sensitivity of Svalbard glaciers to climate change (SvalGlac) (2009–2012)" comprises a consortium from ten European countries; all former GLACIODYN partners. Norwegians initiated SvalGlac and coordinated the application process.
3) The Norwegian partners and several of the Nordic partners in the GLACIODYN project recently established a Nordic network of glaciologists that was granted status as a Nordic Centre of Excellence within the Nordic Council's Top-level Research Initiative subprogramme Climate Change Interactions with the Cryosphere. The centre, Stability and Variations of Arctic Land Ice (SVALI), has 17 partners from all the Nordic countries. It is coordinated by the University of Oslo's Department of Geosciences and has been awarded funding for the period 2011–2015. This is a direct result of the GLACIODYN project.

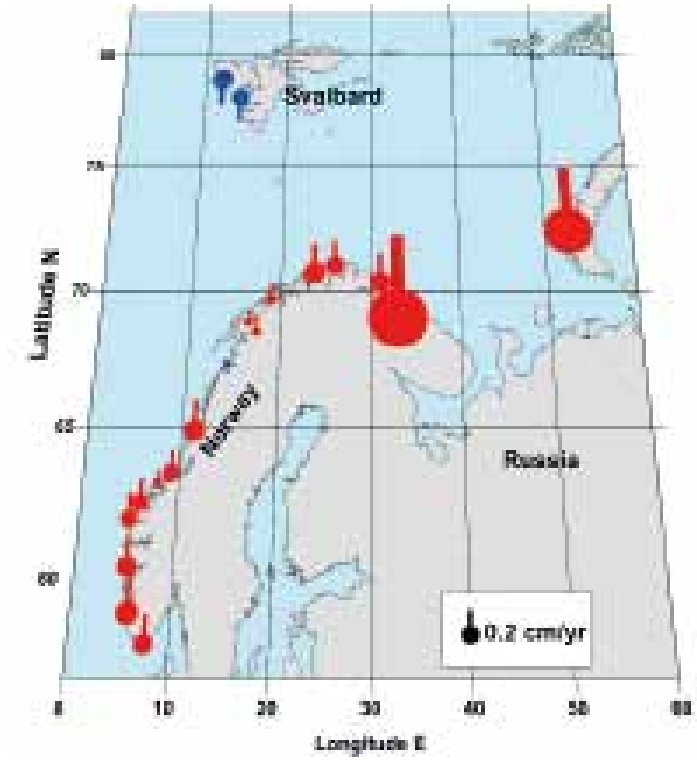
Sea-level changes in the Nordic Seas

By Vladimir Pavlov

Photo: Stavanger Aftenblad

LONG-TERM SEA LEVEL VARIABILITY IN THE NORDIC SEAS (LEVANS)

Project owner: Norwegian Polar Institute (NPI)
Partner institutions: Arctic and Antarctic Research Institute (AARI), Russia
Project manager: Vladimir Pavlov
Total budget: NOK 300 000
Dissemination measures, public and user-oriented: 1
Articles published in scientific and scholarly journals: 2
Presentations published from international meetings/conferences: 3
Other reports and lectures from scholarly fora: 2
Home page: http://npweb.npolar.no/prosjekter/IPYsealevelvar



Distribution of sea-level trends in coastal zones of the Norwegian Sea and Barents Sea. Trends were calculated based on tide gauge measurements since 1980, corrected for vertical land movement. Red indicates rising sea-level trends, while blue indicates sea-level reductions.

Sea level is one of the best indicators of a changing climate. The results of numerous analyses of records from tide gauges and satellite altimetry data show a mean global sea level rise. However, sea level change in different areas of the World Ocean varies from the global mean because of variations in the atmospheric, oceanic and cryospheric factors that influence sea level.

It is difficult to use sea level rise alone as an indicator of climate change because sea level integrates virtually all of the static and dynamic processes in the hydrosphere and atmosphere. It is the net result of many individual effects of environmental forcing.

Therefore the main goal of the project was to study the response of sea level in the Nordic Seas (NS) to changes in the atmospheric, oceanic and terrestrial processes in the European Arctic regions.

New analyses of historical sea level data

The project involved an analysis of the existing historical data sets. Most of the data are currently available from Norwegian and international archives (e.g. www.vannstand.no, www.psmsl.org). Numerous sources of historical information found through the project's main collaborator, Arctic and Antarctic Research Institute (AARI), were collected, reviewed and analysed.

After processing and quality control, these data were sent to the international Permanent Service for Mean Sea Level (PSMSL). Of particular interest are the earliest Arctic sea level records from the Polyarniy tide gauge station, dating from 1906, which are now available as a direct result of the LEVANS project (see www.psmsl.org).

A full statistical analysis of the sea level records was undertaken during the second stage of the project, calculating sea level variability for different time scales (from seasonal to decadal) at each tide gauge station.

The third stage of the project was the estimation of the contribution of different factors in forcing sea level variability on different time scales. Records from tide gauges encompass the vertical movement of the land, giving only relative sea level. The most important process contributing to post-glacial vertical land movement is glacial isostatic adjustment (GIA). This is a result of the glaciation and deglaciation on the planet, where large-scale reorganisations in surface mass cause changes in the Earth's shape. The GIA processes continue to exert a significant influence on modern tide gauge measurements of secular sea level trends. Maximum GIA trends (Peltier 2004, G5ice model) are found for stations located in the coastal zone of the Barents Sea, with over 0.2 cm/yr, and in the southern part of the Norwegian Sea, where GIA trends reach 0.3–0.4 cm/yr at stations such as Oscarsborg, Trondheim and Helgeroa.

The project also examined the adjustment for atmospheric forcing and found that the areas with maximum correlation (called maximum atmospheric impact zones) are not located at the position of the tide gauge stations, but quite far from them in the open sea. The project used this approach in further analysis. To estimate the contribution of oceanic processes, static steric expansion was calculated using hydrographic data for the Nordic Seas obtained from the NPI, AARI and international data sets. Using a 3D baroclinic model, the project simulated the changes in sea level resulting from the reorganisation of water circulation in the NS.

Changes in atmosphere and ocean influence sea level

In the coastal zone of these seas, sea level has a significant annual cycle with an average seasonal amplitude on the order of 16–34 cm. At all the stations in the Norwegian Sea, the minimum values were observed in May. Sea level sharply increases from May, reaching its maximum in winter (December–January). In the Barents Sea the annual absolute sea level maximum is observed in October or December and minimum in April.

Seasonal sea level variability has a strong negative correlation (R=-0.83) with seasonal changes of sea level pressure. The mean amplitude (from peak to peak) of the seasonal sea level oscillations in the Nordic Seas is 24.9 cm. It was concluded that changes in atmospheric pressure in the Nordic Seas are the main cause of the sea level annual cycle.

Analysis of sea level inter-annual variability showed that during the three decades prior to 1980, almost all stations in the coastal zone of the Nordic Seas showed pronounced negative trends of annual mean sea level (on average -0.739 cm/yr in the 1950s, -0.585 cm/yr in the 1960s and -0.624 cm/yr in the 1970s). From the early 1980s the trends became positive and exhibited an average sea level rise with GIA correction of 0.184 cm/yr for the Norwegian Sea and Barents Sea.

There are different contributions to trends of annual mean sea level variability in different months. Maximum trends were obtained in winter (January–February) at almost all stations and a minimum in spring and autumn, mostly in April and October. The project found a very high correlation between the inter-annual variability of sea level and sea level pressure for each station, especially in winter months, when the correlation reached -0.9 at many stations. Such high correlation coefficients allow us to conclude that atmospheric factors contribute most to sea level variability in the NS. For the period 1980–2009 the contribution of the atmospheric factors to sea level rise are estimated to be on average 0.113 cm/yr in the NS.

Oceanic factors contribute on average 0.061 cm/yr to sea level rise. A sea level rise of 0.052 cm/yr cannot be accounted for by GIA, atmospheric factors or oceanic processes. It may be attributed to an increase in global ocean mass caused by melting ice caps, and to the effect of the observed global warming on the Greenland and Antarctic ice sheets.

Thus the results of the project have provided answers to the two main questions: what is the rate of sea level change in the NS, and what are the contributions of the individual factors to observed sea level change?

More work ahead

We plan to continue this work on the basis of joint Norwegian-Russian FRAM Lab activities (AARI, St. Petersburg, www.fram.nw.ru). In particular we will analyse satellite altimeter data and carry out more numerical modelling of sea level variability in the NS.

Storm surge flooding in Bøfjorden, west coast of Norway.
Photo: Håkon Haukøy

Clues to historical climate variation and future changes in sea level buried in the Antarctic ice

By Jan-Gunnar Winther and Elisabeth Isaksson

Photo: Stein Tronstad

NORWEGIAN-US ANTARCTIC IPY TRAVERSE (TASTE-IDEA)

Project owner: Norwegian Polar Institute
Partner institutions: NORUT IT, University of Oslo, Cold Regions Research Laboratory, Colorado State University, Dartmouth College, National Snow and Ice Date Center, University of Colorado, University of Maine, University of Nevada and University of Vermont
Project manager: Jan-Gunnar Winther
Total budget: NOK 16 million
Post-doctoral fellowships: 2
Dissemination measures, public and user-oriented: 99
Mass media coverage: 135
Articles published in scientific and scholarly journals: 12
Books published: 1
Other reports and lectures from scholarly fora: 45
Home page: http://traverse.npolar.no

This project investigated changes in the mass of the ice sheet in Dronning Maud Land in order to improve our understanding of the role Antarctica plays in the global climate system and, in particular, what effect changes in the Antarctic ice masses have on global sea level. The team completed two challenging expeditions across the inland ice of Antarctica, which have generated important new knowledge on historical climate variation and future changes in sea level.

The main objectives of the project were 1) to investigate climate variability in Dronning Maud Land in East Antarctica on time scales of years to millennia, 2) to calculate the mass balance for the ice sheet in this part of Antarctica and its significance for global sea level, 3) to investigate the impact of atmospheric and oceanic variability on the chemical composition of snow, firn and ice, and 4) to make new measurements in areas that have not been visited since the 1960s to detect possible changes and establish benchmark data sets for future research efforts.

Journey of 2300 km in tracked vehicles to drill ice cores

The first leg of the expedition, a traverse from the Norwegian Troll Station in Dronning Maud Land to the South Pole, was organised by the Norwegian Polar Institute between October 2007 and January 2008. The research team included both Norwegian and US participants. They travelled into the least known part of Antarctica and obtained unique data and measurements. Norway has never before carried out such a logistically complex expedition in inland Antarctica.

Four tracked vehicles pulling two sledges each, a load weighing more than 70 tonnes, travelled the 2300 km long route. The sled trains included a sleeping module, a living module and a workshop, and carried large amounts of fuel and field and scientific equipment. The expedition met harsh conditions, with temperatures down to -50°C, as it climbed to almost 4000 metres above sea level.

In the austral summer of 2008–09, the expedition returned to Troll along a different route and with some new members. The main focus in the second season was the investigation of recently-discovered subglacial lakes, which may play an important role in ice flow and thus how quickly the ice reaches the sea, where it calves to form icebergs. If the rate of calving accelerates, the sea level will rise.

Reading more than 1000 years of climate history from ice cores

During the first expedition season, a series of ice cores were drilled to reconstruct climate conditions more than 1000 years back in time. More than 700 metres of ice cores were transported to the US and to Tromsø, Norway, at the end of the season. Thermometers were inserted into three 90-metre deep boreholes, and are sending real-time data via satellite. The data will be used to reconstruct temperature variations over the past 50 years. Snow samples were also taken for the analysis of various types of pollutants.

Two automatic weather stations, which also send real-time data, were stationed on the inland ice. Four different types of radar instruments were used to study ice properties along the whole route of the expedition. An unmanned micro-aircraft (drone) for the collection of geophysical data was tested for the first time on the Antarctic Plateau.

Three of the ice cores showed that the accumulation rate was more than 20% lower in the period 1815–2007 than in the period 1641–1815. Currently, annual precipitation varies between 16 and 32 mm water equivalent at the various drilling sites. This means that the whole area meets the definition as desert (annual precipitation < 200 mm). The precipitation declines with height above sea level.

A borehole in the ice. Photo: Stein Tronstad

Ice core and drilling assembly. Photo: Stein Tronstad

Precipitation levels can be deduced from the depths at which substances from known volcanic eruptions can be identified in ice cores. The year 1815 is important because of the eruption of the volcano Tambora in Indonesia; traces of this event are easily identified when the chemical and electrical properties of Antarctic ice cores are analysed. Nuclear tests carried out in the 1950s and 1960s are also used as time markers. If the results from the traverse are representative of a larger area, they indicate that snow accumulation has declined in parts of East Antarctica. However, radar data from an 860-km track connecting drilling sites, which provides spatially continuous information on accumulation, shows rather higher values for precipitation than the ice core results. The radar data also indicate that precipitation in recent years has been higher than the average for the period 1815–2007, which is in agreement with the results of other studies in East Antarctica.

Lakes below the inland ice

Similar measurements were made during the second season, but special priority was given to a survey of the Recovery Lakes under the inland ice sheet. Extensive radar measurements were carried out to map the size of these subglacial lakes. Measurements of ice flow using GPS and a gravimetric survey were also carried out above the lakes. Until the new measurements were made, it was thought to be four separate Recovery Lakes. However, the expedition showed that two of them are in fact connected by a channel. The three lakes lie in clearly-defined basins. The data suggest that the basins are partly filled with water-saturated sediments or slush ice, while the ice floats on the water in other areas. In other words, the lakes are shallower and their volume is smaller than suggested by the surface topography (large horizontal surfaces).

It also appears that the water level in the lakes has previously been higher. This may mean that they regularly fill and empty. Nothing is known about how often this happens or how quickly the lakes drain. A sudden outflow of water from a lake will exert a force on the overlying ice masses and cause the ice to flow more quickly towards the coast. This in turn will accelerate calving at the ice edge and affect global sea level. Information on the filling and emptying cycle would improve our understanding of the role these lakes play in motion of the ice.

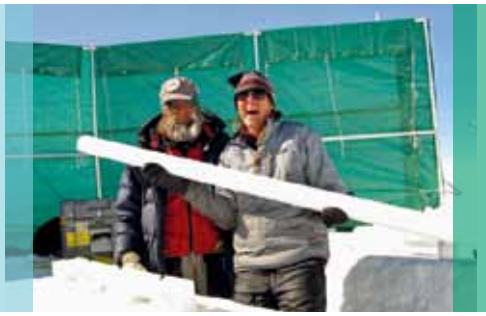
Enhanced cooperation between Norway and the US

During the 1960s, the US organised three traverses from the South Pole to inland parts of Dronning Maud Land

Typical set-up of a camp site during the traverse to the South Pole. Taken from the mast at Plateau Station, half-way through the first leg of the expedition. Photo: Stein Tronstad

The members of the expedition during the first season, photographed at the South Pole. Photo: Jan Gunnar Winther

Mary Albert of Dartmouth College, USA, measuring the thermal conductivity of ice cores in the laboratory tent.
Photo: Stein Tronstad



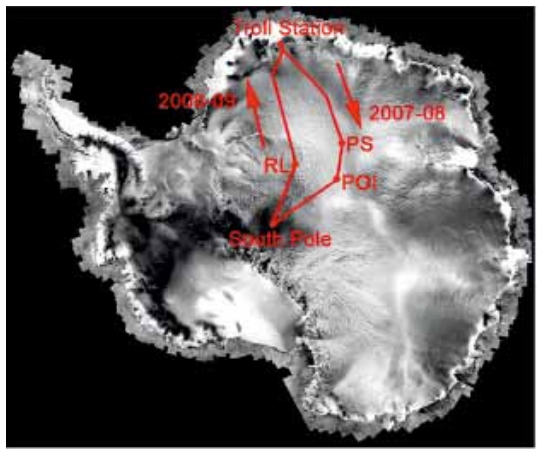
Glen Liston and Lou Albertshardt holding an ice core.
Photo: Stein Tronstad

in three different field seasons. One Norwegian researcher took part in each of these expeditions. Before IPY 2007–08, data from these three traverses provided virtually all the surface measurements available for the area, which is perhaps the least known region on Earth.

The Norwegian-US traverse during IPY proved to be a productive way of following up the earlier cooperation. Norwegian research institutions were responsible for logistics, radar measurements and unmanned flights. US institutions and the Norwegian Polar Institute shared the responsibility for sampling and analysis of ice cores. US researchers had the main responsibility for temperature measurements, benchmark measurements for comparison with satellite data, gravimetric surveying and sampling for analysis of long-range air pollutants.

New information from the least accessible parts of Antarctica is important for an understanding of trends in the mass balance in all parts of the inland ice sheet and for quality assurance of satellite measurements, and provides information for use in climate models and for developing better estimates of future sea level. In many ways, developing an understanding of the Antarctic climate can be compared with putting together a large jigsaw puzzle. The Norwegian-US traverse has made it possible to slot a new piece of the puzzle into place.

Data analysis continues, and many researchers and students will be involved in this for years to come. The data from 2007–08 will also provide a benchmark data set for use by future generations of climate researchers.



The route taken on the Antarctic traverse between Troll and the South Pole during the two seasons. The map also shows the research areas Plateau Station (PS), the Pole of Inaccessibility (POI) and Recovery Lakes (RL).

How could climate change affect Earth's largest ocean current?

By Ulysses Ninnemann, Jostein Bakke and Øyvind Paasche

Photo: Øyvind Paasche

PALEOCEANOGRAPHIC AND CLIMATIC VARIABILITY ON DECADAL TO MILLENNIAL TIMESCALES ACROSS THE DRAKE PASSAGE (PALEODRAKE)

Project owner: Bjerknes Centre for Climate Research
Project manager: Ulysses Ninnemann
Total budget: NOK 185 000
Dissemination measures, public and user-oriented: 1
Mass media coverage: 7
Presentations published from international meetings/conferences: 2
Home page: http://www.bjerknes.uib.no/

The circumpolar current surrounding Antarctica is the largest on Earth and plays a central role in maintaining the properties and circulation of the world's oceans. Now, the winds that drive this current are changing as the planet warms.

Are these changes unusually large relative to those that have occurred in the past? What will their impact be on this current and, in turn, on the global ocean and distant climates? Both theory and computer simulations suggest that these changes could potentially influence ocean circulation, the ocean's ability to absorb CO_2, the delivery of nutrients to global fisheries, and even faraway weather patterns.

Project design

Work under the PALEODRAKE project focused on the Drake Passage and Scotia Sea region; as the narrowest constriction point of circumpolar ocean circulation, this region is a key area for understanding the role of the Antarctic in the global ocean and climate systems. In recent decades ocean surface temperatures have increased more rapidly in this region than in most other ocean regions. Further evidence on the ground reveals that glaciers all along the Antarctic Peninsula are already responding to this change – highlighting the need to understand the close links between the atmosphere and the ocean on decadal to multi-decadal time scales. Despite its pivotal role in the global climate system, the region is seriously under-sampled and the full range of natural variability, both in the ocean and in the atmosphere, is not adequately understood. Closing this knowledge gap was one of the overall objectives of the PALEODRAKE project.

The history of the linkage between climate and ocean in the Drake Passage region has a direct bearing on fundamental questions at the heart of current polar climate-change research, including:

- What is the natural variability of the ocean and atmosphere on multidecadal and longer time scales?
- How have the Southern Westerly Winds varied with past climate and affected ocean circulation?

The PALEODRAKE project set out to address these questions by recovering geological archives recording oceanographic and climatic conditions during times in the past when atmospheric and oceanic circulation were different from today. Understanding how climate and the ocean varied in the past, such as during anomalously large, long, or rapid warming periods, provides insight into the impact of future climate change on the ocean.

Marine seabed coring

During the expedition in January 2008, we successfully recovered cores from the seabed at three locations in the Drake Passage and Scotia Sea. The coring sites are specifically situated to record changes in both the polar ocean surface properties (temperature, salinity, sea ice extent, etc.) and changes in the circumpolar current.

Preliminary results are promising and show that the sites will provide insights into changes in both climate as well as ocean property and circulation, extending back to the last glacial period over 20 000 years ago. Similarities between the project's reconstructed polar ocean changes and those found at intermediate ocean depths, and as far away as the tropical Pacific, suggest that the recovered archives could hold the key for understanding the sway of the polar ocean on these distant regions .

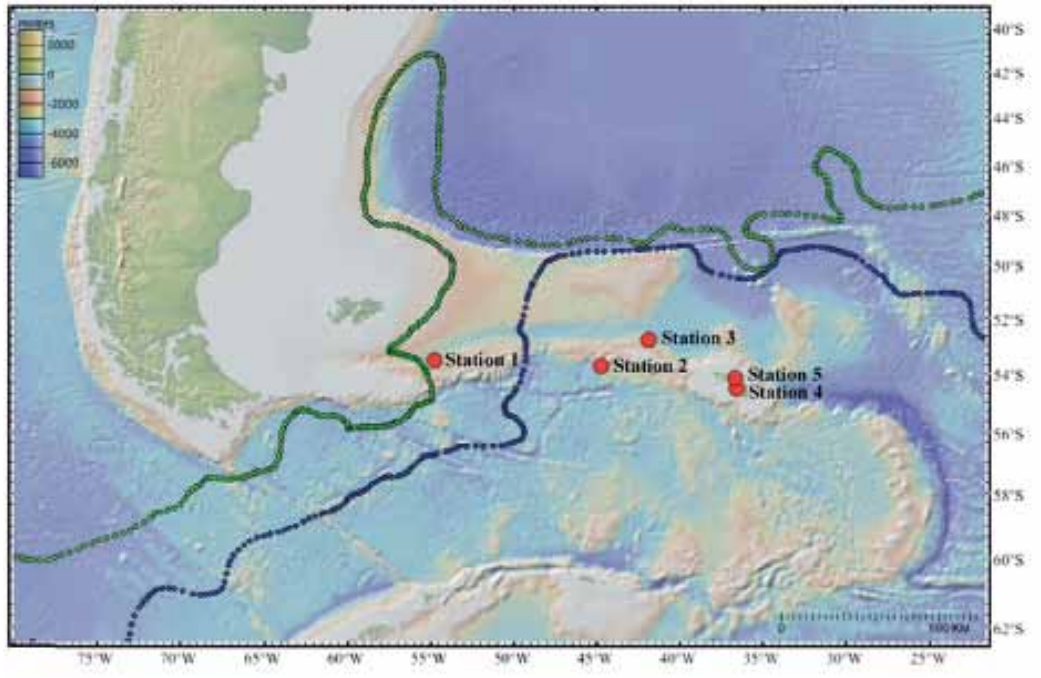
Glacial data from South Georgia

Following the open ocean marine campaign, coring continued both in the fjords and lakes of South Georgia. Magnetic measurements on the ocean and fjord cores have provided sorely needed paleomagnetic records from a region where few such records exist, and will finally allow a magnetic reference stratigraphy for this region to be realized.

Additionally, the terrestrial expedition on South Georgia recovered archives for piecing together the regional history of the alpine glaciers of South Georgia. These leave spectacular records of climate change. Lakes, moraines, and other landforms shaped by past glacier advances and retreats dominate the forelands of this mountainous island. The South Georgia cores and samples will help to further unravel the history of temperature and precipitation in the region.

Preliminary results reveal that the project captured continuous glacier records spanning the last 10 000 years (the Holocene) from both lake and fjord environments. The continuous record of glacier fluctuations from the Southern Ocean retrieved by this expedition opens a new avenue for understanding how bi-polar climates varied during the Holocene and for comparing these to recent changes. For example, one of the cirque glaciers scheduled for study had completely melted away by the time the crew arrived at South Georgia in 2008, and preliminary analyses of the sediments from a distal glacier-fed lake indicate that the glacier is currently smaller than it has been for the last 10 000 years. But it is not just the smaller glaciers are retreating; the Neumayer Glacier has retreated over 2 km since the early 1970s.

In conclusion, marine and land coring operations were a complete success – resulting in a unique set of marine and terrestrial archives for elucidating the history of ocean and climate change in this sensitive, and globally influential, polar region. Work on these archives is continuing and has spawned a number of new proposals and initiatives. The legacy from the PALEODRAKE IPY project will thus endure and, when combined with similar studies in the north, will finally allow us to place current aspects of bi-polar climate changes into an historical context.



PALEODRAKE project coring locations (red) plotted relative to the Subantarctic (green) and Polar (blue) fronts associated with the Antarctic Circumpolar Current.

Photo: Per Eide / Samfoto

Ecosystem study and krill survey aboard G.O. Sars in Southern Ocean

By Svein A. Iversen

Photo: Tonie Leonora Torgrimsby

ANTARCTIC KRILL AND ECOSYSTEM STUDIES (AKES)

Project owner: Institute of Marine Research (IMR)
Partner institutions: University of Oslo and Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR)
Project manager: Svein A. Iversen
Total budget: NOK 3 million for a replacement vessel
Articles published in scientific and scholarly journals: 13
Books published: 1
Presentations published from international meetings/conferences:
Other reports and lectures from scholarly fora: 14
Homepage: http://www.imr.no/tokt/en

In early January 2008 the research vessel G.O. Sars embarked on a three-month voyage (two trips of six weeks each) in the Southern Ocean. A primary objective was to obtain more reliable estimates of Southern Ocean krill abundance.

The AKES project was funded by the Institute of Marine Research (IMR), the Research Council of Norway – NARE (Norwegian Antarctic Research), the Norwegian Petroleum Directorate, Norsk Hydro and ABB. The study, however, fit naturally into the International Polar Year portfolio – and IPY had made the voyage possible by contributing funding for a replacement vessel to assume some of G.O. Sars' regular duties in the North Atlantic.

Background

The biomass of krill in the Southwest Atlantic sector of the Southern Ocean was estimated by the acoustic method in 2000 to be 44 million tonnes. One basis for that calculation was target strength (TS), i.e. the capability of an organism to reflect acoustic signals back to an echo sounder, which is a vital factor in converting echo values to biomass. Subsequent theoretical studies showed that the applied TS factor may have been too high, resulting in an underestimation of the biomass. The G.O. Sars is specially equipped to investigate acoustic properties of organisms, swarms and schools.

The main objectives of the survey were to investigate:

- acoustic properties of Antarctic krill (Euphausia superba), salps and mackerel icefish (Champsocephalus gunnari);
- distribution of krill, fish, marine mammals, birds, and phyto- and zooplankton relative to the hydrography;
- dynamics of krill swarms;
- krill biology and ecology;
- krill genetics and fish parasites.

Campaign route

The campaign started in Montevideo, Uruguay, on 4 January and sailed via the Falkland Islands to South Georgia for instrument calibration and TS investigations, then to Bouvetøya (Bouvet Island) before a mid-survey break in Cape Town after six weeks at sea. The second part of the survey went south from Cape Town down the 15°E meridian to the Astrid Ridge and then north along 7°E to finish in Walvis Bay, Namibia, on 27 March (Figure 1).

The total distance sailed was 12 500 nautical miles. The main worry before the survey started was that bad weather would severely hamper the study, which was taking place in areas with the stormiest weather on earth. Fortunately the crew experienced just one hurricane and a few storms, but ultimately bad weather and time constraints forced an early departure from the Bouvetøya area before all investigations could be completed.

Methods

Multi-frequency echograms make it possible to identify krill acoustically, and will simplify future krill abundance surveys by improving the method for identifying the krill portion of the total echo. TS can vary depending on species, size, swim bladder, and the organisms' orientation relative to the acoustic signal which is maximal when stretched horisontally. Due to these factors, TS analysis involves a great deal of data.

Hydrographic data were collected with a CTD (conductivity, temperature, density) instrument equipped with a fluorometer and oxygen sensor. Phytoplankton samples were collected by vertical net hauls and filtered from water samples. Zooplankton and fish were collected by MOCNESS, krill trawl, and Juday and WP-2 nets. Acoustic properties were investigated using a Simrad EK60 equipped with six frequencies (18–333 kHz).

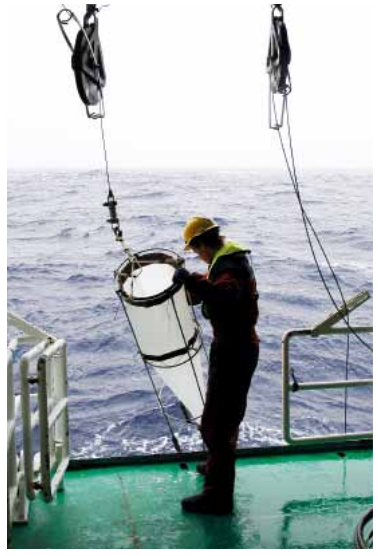


Photo: Kjartan Mæstad, IMR

Findings and results

We have so far cpmpleted the TS analysis of salps – gelatinous, free-floating tunicates that concentrate in large colonies. Partly on the basis of the project's preliminary findings on krill TS, CCAMLR adjusted the estimated biomass to 60 million tonnes in 2010.

Antarctic krill was observed in cold waters (< 2°C) south of 52°S. High concentrations were observed in the South Georgia area, which is an important krill harvesting area, as well as in a somewhat smaller area around Bouvetøya and in the southern part of the surveyed area.

To generate knowledge for sustainable management of krill in the Southern Ocean, genetic samples were collected throughout the survey period to obtain more information about stock structure.

Except for some samples in the South Georgia area, only small fish species were caught. A total of 82 species from 29 families were caught during the survey. Compared with krill volumes, the fish catches were small and dominated by lanternfish.

A large number of fish were screened for external macroparasites. In the 227 fully examined fish, 620 metazoan parasite individuals were collected. The intestines of all examined krill were infested with a single-celled (protozoa) parasite.

Very few bird surveys have been conducted in the area that was surveyed under AKES; in particular, the area south of 54°S is rarely surveyed. Most of the bird species observed on the second part of the voyage had recently entered a post-breeding phase. For some species, such as the wandering albatross group, the breeding birds still had eggs or chicks in the nests during the voyage period. It is thus likely that many of the breeding birds in the Southern Ocean were still fairly close to breeding colonies, which may have influenced both the numbers and distribution of the species encountered. Marine mammal sightings were performed during the second part of the survey.

The AKES survey also assisted and supported other national and international projects in biodiversity, paleoclimatology, fish physiology and air pollution (aerosol), and helped with the maintenance of hydrographic buoys and rigs.

Follow-up

The most important task that remains is to finish the TS work and to implement those findings in the CCAMLR management models. Other important tasks will be to investigate recruitment mechanisms for krill and to further investigate the relationship between the distribution of krill and their land-based predators such as birds, seals and penguins, and the dynamics of krill swarms.

Photo: IMR

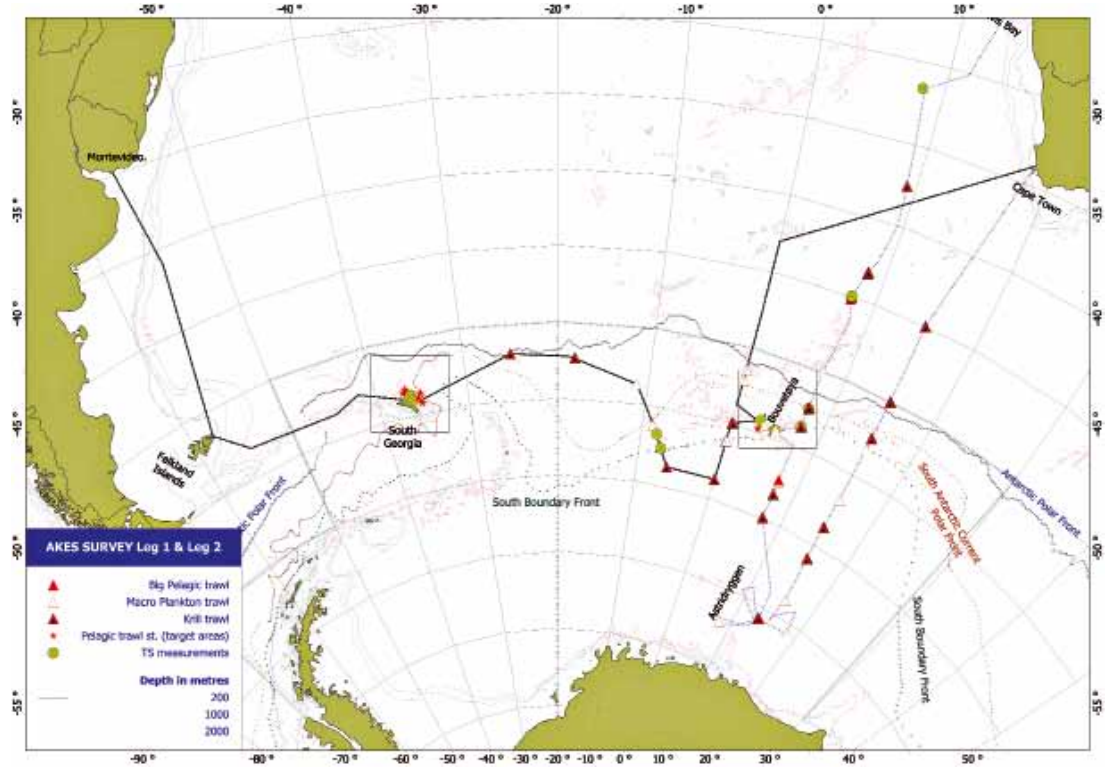


FIGURE 1: The survey grid worked by G.O. Sars in the Southern Ocean, 4 January to 27 March, 2008.
Figure by Jamie Alvarez, Marine Research Institute.

Seals used as “research assistants” in the polar oceans

By Kit M. Kovacs, et al*

Photo: Christian Lydersen

MARINE MAMMALS EXPLORING THE OCEANS POLE TO POLE (MEOP-NORWAY)

Project owner: Norwegian Polar Institute
Project manager: Kit M. Kovacs
Total budget: NOK 6 million
Doctoral fellowships: 1 (partial funding – 1.5 yr)
Post-doctoral fellowships: 1 (3 yr)
Dissemination measures, public and user-oriented: 9
Mass media coverage: 15
Articles published in scientific and scholarly journals: 3
Books published: 1
Reports and lectures from scholarly fora: 5
Home page: http://www.meop.info/en/updates/norway1.html

Many species of marine mammals spend large parts of their lives far out to sea and much of their time below the ocean surface. Species in polar regions, and particularly those found in areas with sea ice, are relatively little studied – largely because of logistical problems related to operating in such areas. With the help of new satellite technology and telemetric devices (“tags”) attached to the animals, it is now possible to study both the animals’ behaviour and the surrounding oceanographic conditions.

Under the IPY MEOP project state-of-the-art Conductivity-Temperature-Depth Satellite Relay Data Loggers (CTD-SRDLs) were deployed on strategically chosen, deep-diving marine mammals in both Polar Regions. These devices provide detailed information about the geographical location of the seals and report their behaviour in this spatial context, including how deeply they dive. In addition, these newly designed CTD-SRDL tags record physical, environmental data including temperature and conductivity (which allows for the calculation of salinity) at levels precise enough to use for oceanographic and climate modelling.

This is a completely new method for collecting huge amounts of data for studies of the world’s oceans and the habitats occupied by top trophic predators at sea. The primary objectives of the MEOP project were 1) to document the movements and foraging patterns of selected marine mammals in order to learn more about their general habitat use and 2) to collect high-quality oceanographic data from regions that are logistically difficult to reach other than by using tagged marine mammals.

Tagging devices attached to 150 seals

A total of ten countries participated in the MEOP consortium, which was headed by Norway. Research partners from Australia, Brazil, Canada, France, Germany, Greenland, South Africa, United Kingdom, and the US were involved. Over 150 CTD-SRDLs were deployed during the project period. (Figure 1)

Within the MEOP-Norway project 20 tags were deployed on hooded seals (Cystophora cristata) in the Arctic and 20 tags were deployed on southern elephant seals (Mirounga leonina) in the Antarctic. Field work in the Arctic began in the summer of 2007. The plan was to deploy 20 tags on hooded seals immediately following the moulting period. The timing was important because the tags are glued to the seals’ fur. It was therefore advantageous to attach the tags to the seals’ “new” coats, which would not be shed for a year, to have the tags remain on the animals as long as possible. However, due to insufficient sea ice the seals were spread thinly over a vast area, and were watchful and wary without the security of the group; thus only three tags were successfully deployed in the summer of 2007.

The next MEOP-Norway expedition was to Bouvetøya for deployments on southern elephant seals. Shortly before the intended time of departure it was discovered that the research station on Bouvetøya had disappeared in a landslide so the field team were forced to spend the 3-month long field season on the island in a tent camp. Despite the sometimes daunting challenges of bad weather, avalanches and somewhat uncooperative neighbours of the elephant seals – the Antarctic fur seals – the mission was successfully completed in February 2008.

In 2008 a new attempt was made to deploy the remaining tags on hooded seals in the Greenland Sea, but this time the field work was timed to coincide with the breeding season in March in hope that the herd would be tighter and that the animals would be easier to catch. Although there were again quite poor ice conditions (the pack-ice was very broken), and difficult weather conditions with gales and temperatures of -25°C, the remaining 17 CTD-SRDLs were deployed without any problems.

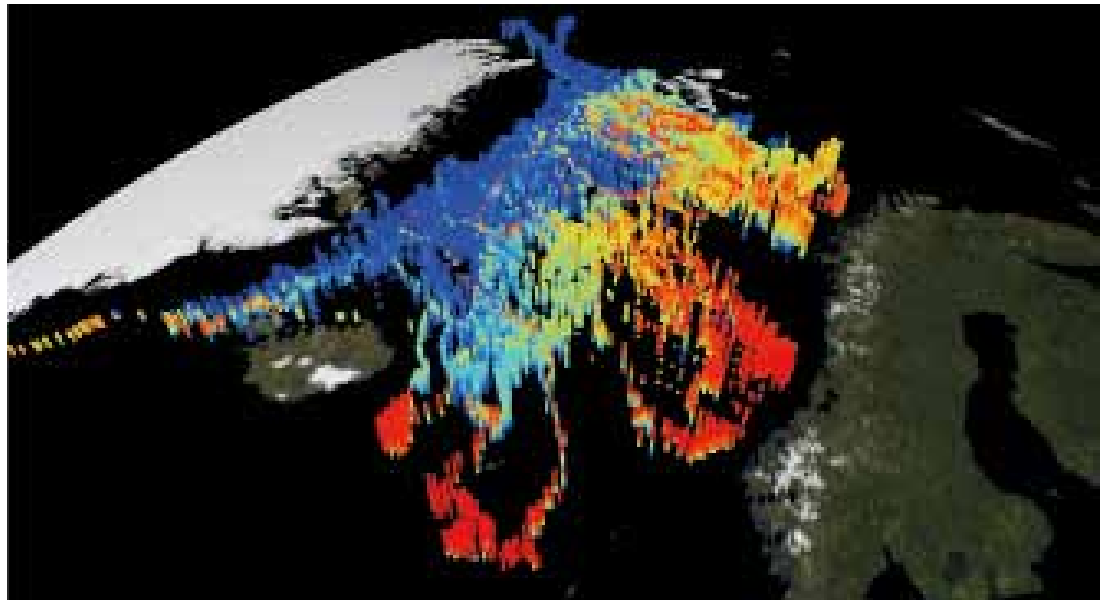
Large and unique data sets

A vast amount of exciting data was collected under the MEOP-Norway project. The tagged hooded seals provided data from an area of over 3 million km² in the Greenland and Norwegian Seas, from south of the Faroe Islands northward deep into the Arctic Ocean almost to the North Pole (88.5° N). These seals dived to depths of over 1 000 metres and during the 3 548 seal-days of data collection generated an unprecedented oceanographic data set comprising over 7 000 CTD profiles, with 110 000 point measurements.

The elephant seals also covered a vast oceanographic area within the Southern Ocean including regions from north of Bouvetøya all the way south to the coast of Dronning Maud Land in Antarctica. Surprisingly, some of the elephant seals spent the entire winter in areas with almost 100% ice cover. Over 13 000 CTD profiles were collected in the course of the 5 039 seal-days during which the tags reported data. (Figure 1)

The hydrographic data collected under the MEOP project was released in near real-time to the scientific community via the World Meteorological Organisation’s Global Telecommunications System, and was used for weather forecasting and such immediate needs as search and rescue operations.

The scientific analyses of the MEOP-Norway project did not begin in earnest until the data sets were complete, in the autumn of 2009. Since that time, ongoing efforts have been made to 1) define the complex hydrographic regimes of the eastern Weddell Sea and southeastern Atlantic Ocean that appear to play a part in determining the various feeding strategies of elephant seals, 2) study the movements of Warm Deep Water that flows onto the Antarctic shelf under



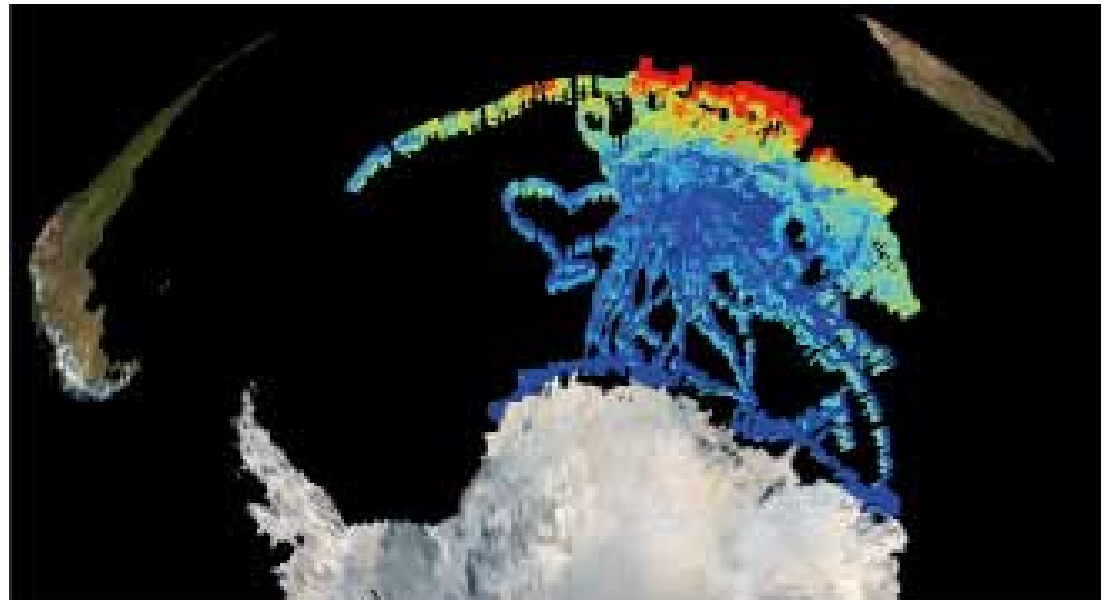


FIGURE 1: Temperature profiles throughout the water column, created using datasets collected by hooded seals in the Arctic (image above – temperature range from -2 to + 9°C) and southern elephant seals in the Antarctic (image to the right – temperature range from -2 to + 6°C).

the overhanging ice-shelf as a result of eddies interacting with winds and the topography of the sea bottom, 3) identify where the hooded seals find their food in the vast ocean regions that they cover and 4) study the seasonal variations in freshwater content of the East Greenland Current using data from the hooded seals and other sources.

Communication activities

The MEOP project has been, and continues to be, a wonderful "tool" for reaching the public and disseminating information about climate change and the consequences of climate change for our planet and in particular for the polar regions. The project has received a great deal of media attention both nationally and internationally. In addition, the MEOP project worked closely with the IPY Census of Marine Life project to ensure that it was part of the larger international IPY effort and reached a wider audience. Scientific publications generated by the MEOP project are starting to appear, and will continue to be produced for some time as the ever-extending MEOP "family" makes use of the MEOP project's unique data sets.

*) Co-authors: Martin Biuw, Ole Anders Nøst, Paul Dodd, Edmond Hansen, Quin Zhou, Mike Fedak and Christian Lydersen.

The MEOP team with hooded seals on broken, fast-moving pack ice north of Jan Mayen, in March, 2008. Photo: Christian Lydersen

The first CTD-SRDL tag to be used in the MEOP project was deployed on a hooded seal in the Greenland Sea in July 2007.
Photo: Christian Lydersen

Turnover of dissolved organic material in the polar microbial food web

By Tron Frede Thingstad

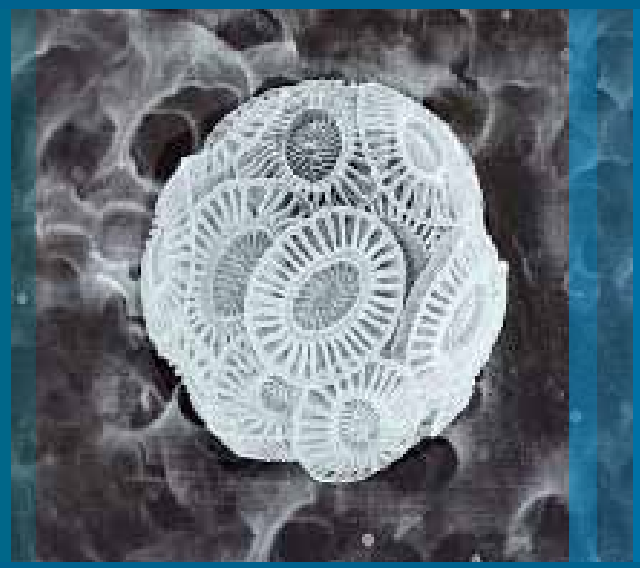


Photo: Ellen Karin Mæhlun

DOC TURNOVER IN POLAR MICROBIAL FOOD WEBS (PAME-NOR)

Project owner: University of Bergen, Department of Biology
Project manager: Tron Frede Thingstad
Total budget: NOK 8 million
Dissemination measures, public and user-oriented: 11
Mass media coverage: 6
Articles published in scientific and scholarly journals: 4
Other reports and lectures from scholarly fora: 6
Home page: http://www.uib.no/form/aktuelt/polararet/prosjekt/pame-nor2.htm

The ocean's chemistry and biology are linked together at the micro-level. To study these micro-scale processes and the organisms driving them, the PAME-Nor project carried out mesocosm experiments in which seawater was enclosed in large containers in order to compare the effects of different treatments.

Background

The microbes form a food web through which nitrogen (N) can be channelled through different pathways up to copepods. In this project, researchers used an idealised model for this food web (Figure 1) where at one level (Level 1) there are three entry points for inorganic N, labelled I1 (bacteria), I2 (autotrophic flagellates) and I3 (diatoms).

The system also has an underlying level of complexity (Level 2), resulting from the biodiversity within each of the communities represented at Level 1. At Level 2, N and organic material flow through the bacterial community via uptake through different species. The PAME-Nor project studied the relationships between these two levels of organisation and their influences on the degradation of organic carbon (C).

The work primarily consisted of two mesocosm experiments carried out in 2007 and 2008, based on previous experiments in boreal waters, in which a simultaneous supply of silicate (Si) and organic C (as glucose) led to the dominance of large diatoms (I3 in Figure 1). With most of the available N immobilised in diatoms, degradation of added glucose was inhibited due to bacterial N limitation. The researchers hoped that similarly designed experiments conducted in Ny-Ålesund would allow them to draw conclusions on similarities and/or differences between boreal and Arctic systems.

Experiments

As the station in Ny-Ålesund was not equipped for such experiments, we faced a series of practical challenges:

- the need for at least 10 tonnes of seawater
- this water had to be collected from one place at one time
- the water had to be unpolluted and without silt
- the experimental system would have to withstand waves and icebergs
- the available boat had limited deck capacity

The solution selected was to use several $1m^3$ plastic containers. These were attached to a chain, towed into the fjord, filled using a pump, and towed back to the harbour, where they were anchored in relative shelter from icebergs and waves for the duration of the experiment.

Results

Level 1: The result in 2007 was the opposite of what had been found in earlier experiments: Combined supply of Si and glucose led to the dominance of bacteria (I1) and disappearance of the diatoms (I3).

Most surprising, however, was the C metabolism: the more organic C that was added, the less total organic C accumulated in the system. This continued up to a certain level of glucose addition beyond which additional glucose did accumulate in the system.

We propose an explanation based on differences within the diatom community: the dominance in the 2007 experiment of a small Thalassiosira sp. (Figure 2), as opposed to large diatoms in previous experiments, reduced the difference in dynamics between I2- and I3-dominated systems, since small diatoms can be grazed by ciliates as well. The small diatom also had an extremely high ratio of C fixation to N consumption (C:N ratio of >35 as opposed to the norm of ca. 7 (molar)).When this diatom disappeared due to N competition from C-stimulated bacteria, the net effect of glucose-C addition was thus a reduced C accumulation, which continued until bacterial limitation shifted from C to N. Further glucose added had no biological effect and accumulated.

This brought up a new question: What determines cell size of the dominant diatoms? We chose to pursue a hypothesis based on differences in N source: vacuole:cytoplasm ratio increases with cell size. Diatoms can store NO_3 but not NH_4 in these vacuoles. While small cell size is usually considered advantageous for nutrient competitors, large diatoms would then get a competitive advantage in NO_3-pulsed environments. Since in the 2007 experiment we had exchanged NO_3 with NH_4 as the N source, the results so far were in agreement with this theory.

In 2008 we therefore combined the additions of glucose and Si with either NH_4 or NO_3, respectively. The hypothesis was:

- NH_4 as the N source would lead to small diatoms grazed by ciliates, which with sufficiently high addition rates of glucose would be outcompeted by bacteria, i.e. addition of glucose should shift the system from I3 to I1 (repetition of the 2007 experiment).
- NO_3 as the N source would lead to large diatoms immobilising the N so that addition of Si would shift the dominance from I1 to I3 (as in earlier experiments in temperate water masses).

Unexpectedly, no diatom growth and very little net growth of bacteria occurred. Irrespective of treatment, I2 (autotrophic flagellates) dominated. We believe this was caused by a particular structure in the grazing food

The mesocosm containers anchored in Ny-Ålesund harbour (2008). In the background is the marine laboratory. Photo: Tsuneo Tan

Mesocosm containers in tow in Kongsfjorden, Svalbard (2007). Photo: Henry Bittig

chain where a strong predation pressure kept bacteria (I1) and diatoms (I3) at low levels.

Level 2: If bacterial diversity is controlled from "below" by each bacterial species specialising in a given substrate, one would expect high richness in bacterial species in mesocosms where the C source is a (presumably) complex mixture of organic substances produced internally in the system. Adding glucose produces systems dominated by a single C source and thus reduced bacterial species richness would be expected. If, however, diversity is controlled from "above" by e.g. host-specific viruses preventing dominance of fast-growing species, one would expect minor glucose effects on richness. Community composition (which species dominates) would, however, be expected to shift as limitation shifts from C to N. The results indicated a comparable richness in all treatments, while community composition changed, particularly in response to glucose addition. The result is in line with the latter model of a top-down control of richness and a bottom-up control of composition.

At both Level 1 and Level 2 it is important to know whether bacterial growth is limited by organic C or inorganic nutrients. Bioassays performed during springtime expeditions in the Norwegian Sea indicated C limitation. In cooperation with the project, Olav Vadstein from the Norwegian University of Science and Technology (NTNU) performed assays from Vest Spitsbergen coastal waters (autumn). He concluded that there are large geographical variations as N, P, C and non-limited growth were observed at five different locations with more than one limiting element found in two of these.

Conclusions

From the three experiments – two in Kongsfjorden, Ny-Ålesund and one in boreal waters, each of them dominated by a different entry of N into the food web – it is difficult to draw conclusions on differences between Arctic and boreal water masses. The experiments do, however, clearly demonstrate how responses generally depend on both the type of perturbations and the initial internal state of this food web.

Variable structure of the microbial food web is also a main conclusion of a seasonal study done as part of a PhD study at the University of Tromsø. Together with the project experiments this gives a picture of a variable ecosystem with different response dynamics at different times.

Outreach and continuation

The project's main outreach activities involved cooperation with artist Ellen Karin Mæhlum, with whom we came in contact during our experimental work in Ny-Ålesund. Based on pictures from the electron microscope, she has produced a series of graphic works called "Plankton portraits", exhibited in several places in Norway (including the IPY Oslo Science Conference) and in Germany, and purchased by the University of Bergen's Department of Biology among others (http://www.ellenkarin.no/).

The mesocosm system developed by the PAME-Nor project proved robust and will be part of the Arctic equipment for Kings Bay Marine Laboratory participation in the FP7 EU project MESOAQUA, a network of mesocosm facilities providing research infrastructure throughout Europe (http://mesoaqua.eu/).

Knowledge about control mechanisms in the microbial part of the ocean's food web will be further enhanced in the project MIcrobial Network OrganiSation (MINOS), which is a so-called "Advanced Investigator Grant" from the European Research Council.

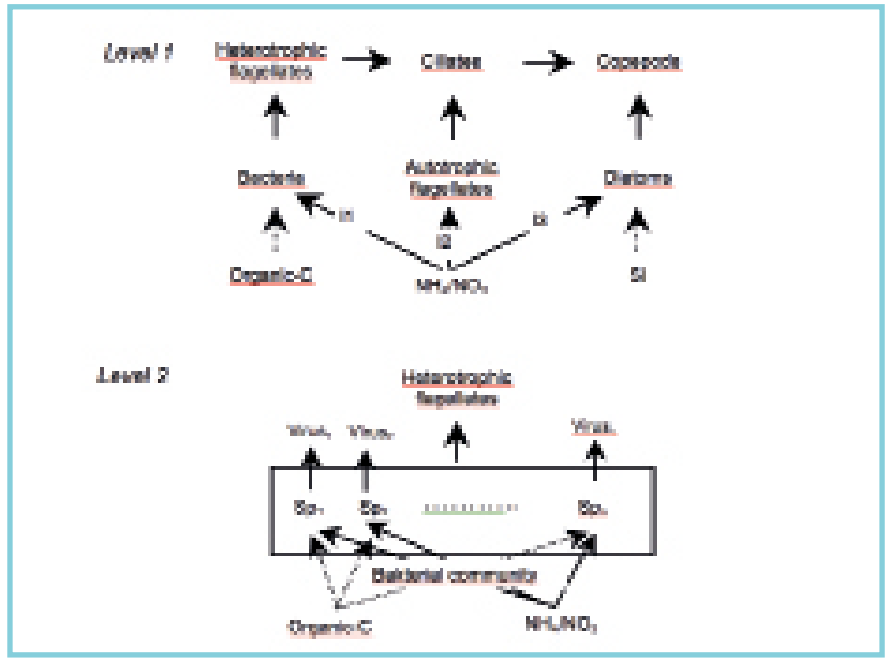


FIGURE 1: Idealised representation of the two levels of resolution studied for the microbial part of the pelagic food web: "between" communities (Level 1) and "within communities" (Level 2). The project studied: the effect of adding organic-C, inorganic-N and silicate, on the balance between the three entrances (I1, I2, and I3) for inorganic-N at Level 1; the effects on bacterial diversity at Level 2. These models were used to plan and analyse the experiments done in Ny-Ålesund in 2007 and 2008 as well as work done on expeditions in the Norwegian Sea and in the Fram Strait.

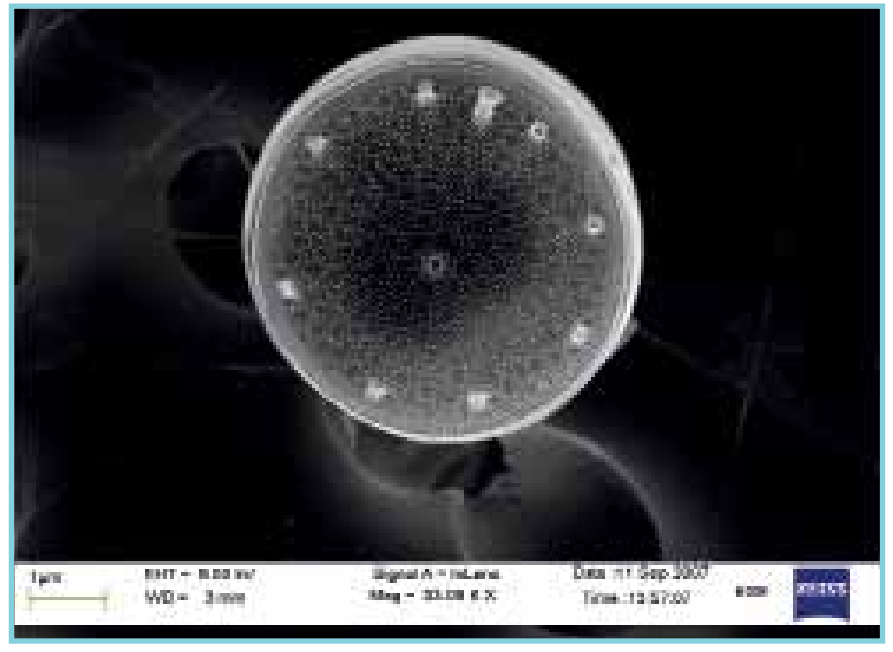


FIGURE 2: Electron micrograph of the small diatom (Thalassiosira sp.) predominant in the 2007 experiment. Photo Mikal Heldal/Erik Erichsen.

The common eider's vulnerability to pollution, climate change and disease

By Sveinn Are Hanssen and Børge Moe

Photo: Trond Johnsen

MAPPING THREATS TO ARCTIC BIRD POPULATIONS. THE EFFECT OF INFECTIOUS ORGANISMS AND POLLUTION ON BIRD HEALTH (BIRD-HEALTH)

Project owner: Norwegian Institute for Nature Research (NINA)
Project manager: Sveinn Are Hanssen
Total budget: NOK 6 million
Post-doctoral fellowships: 1
Dissemination measures, public and user-oriented: 6
Mass media coverage: 4
Articles published in scientific and scholarly journals: 2
Presentations published from international meetings/conferences: 2
Other reports and lectures from scholarly fora: 2
Home page: http://www.birdhealth.nl/

Marked seasonal variations in the environment influence the conditions for survival of Arctic organisms. In addition, the Arctic is not as clean and untouched as one would hope. Pollutants are being transported northwards both by sea and air currents. Once they enter the food chain, these pollutants can cause hormonal imbalances and damage the immune system, affecting wildlife in the Arctic. The BIRD-HEALTH project has studied the impact of increased stress from persistent organic pollutants (POPs) and parasites on the common eider duck. The project also looked at the effects of these stressors on the birds during periods of fasting.

The BIRD-HEALTH project has studied the health, reproduction and immune function of, as well as the level of environmental contaminants present in, common eiders from two different areas: Grindøya near Tromsø and Kongsfjorden in Svalbard. These two areas differ in terms of both climate and pollution levels. The use of two field locations made it possible to study various natural stressors (parasites, climate) as well as unnatural stressors (POPs) both in isolation and together. By studying the same individuals over a period of several years it was possible to determine how these stressors affect the number of offspring produced and the birds' survival rate.

Data collection and methodology

In both of the studied populations each incubating female eider was captured twice during the incubation period, with a 15-day interval in between. At each capture body weight was recorded and blood samples taken to test for the level of pollutants, stress and immune function. At first capture the females were treated either with an anti-parasitic medication or a sterile saline solution. This made it possible to measure the effects of the parasite treatment and any changes in pollutant levels on the fasting birds.

Three field seasons (2007, 2008 and 2009) were completed with the full experimental setup. A fourth season was also completed in 2010, during which long-term effects such as survival and egg production were recorded among the females studied under the project in previous years. The project had two active field teams, one on Grindøya near Tromsø and one in Kongsfjorden in Svalbard, which worked continuously for a period of about 6 weeks each season.

Parasites increase mortality rates

The results show that both on Svalbard and in northern Norway, the probability of the birds surviving to breed the following year increased in the group treated with anti-parasitic agent compared with the control groups. The increase was greatest in those birds that were in the worst condition. This shows that natural stress from parasites negatively affects the survival of the weaker females and illustrates the vulnerability of Arctic bird populations; if the environment deteriorates, the health of a larger proportion of the population is likely to be diminished, which could lead to increased mortality due to parasitic infections.

Fasting during incubation increases vulnerability to pollutants

The strategy of building up fat reserves for use in what could be described as ecological bottleneck periods is common in many Arctic organisms. However, fat-soluble pollutants in the form of organochlorines (OC) are found in high concentrations in many Arctic animals. When fat reserves are mobilised, levels of OC in the blood increase. High levels of pollutants are associated with negative effects on the immune system, parasite levels and hormone balance.

Photo: Trond Johnsen

We studied the effects of fasting on the blood concentrations of three fat-soluble OCs (PCB-153, P, p'-DDE and HCB). The blood concentrations of these substances increased by up to 8 times in 15 days. Although pollutant levels in eiders are relatively low compared with Arctic top predators such as polar bears and glaucous gulls, the rapid increase during the incubation time is worrying as it coincides with a period of high natural stress, when body reserves are low and vulnerability to parasitic infection is high.

The eiders' strategy of fasting and fat reserve mobilisation during the incubation period, as well as the fact that eiders are a relatively numerous colony-nesting species that are easy to catch for sampling, makes them an excellent model for research on fat mobilisation during ecological bottleneck periods and the effects of this on physiology, POPs and immune function/parasites.

Communication activities

Two popular science articles relating to the project have been published (in Ottar issued by Tromsø University Museum and in Labyrint issued by the University of Tromsø). Results from the project have also been presented at scientific conferences (including the IPY Oslo Science Conference in Oslo in June 2010). Additionally, the project contributed to the IPY project "The Arctic System", providing materials for an educational booklet and for the project website www.arcticsystem.no, as well as lectures at the Alta Museum and the Svanhovd research station (under the Norwegian Institute for Agricultural and Environmental Research – Bioforsk) as part of an open lecture series.

In 2009 and 2010 we provided lectures and assessed students' research projects as part of the International

Collecting samples. Photo: Tor Harry Bjørn

One of the recorded nests. Photo: Sveinn Are Hanssen

Polar Field School course at the University Centre in Svalbard. The project has received both national and international media attention. The project was presented on a nationally broadcast radio show in autumn 2009, and was replayed several times during spring/summer 2010. It was also featured in an article in the American popular science magazine Wildlife Conservation in April 2009.

Further research

The BIRD-HEALTH project has developed a time series on POPs, immune parameters and ecological variables from eiders in Kongsfjorden and Tromsø based on data collected during the course of three field seasons. Many of the samples were taken from the same individuals over two or three seasons. The results show that the condition of the birds, their immune status and the levels of pollutants present, in addition to ecological variables such as breeding success, breeding investment and survival, vary from season to season, from one bird to another and in individual birds from year to year. Identifying these variations over time enables us to predict the response of the entire bird population to natural and anthropogenic environmental variability.

The project will be followed up by further studies of the eider populations in Kongsfjorden and Grindøya. A pilot project that seeks to identify the wintering areas of eiders from Kongsfjorden using geo-loggers attached to the foot rings is already underway. These data will then be linked to data about levels and composition of POPs in eiders as well as body condition and reproductive investment.

Effects of climate change on the ecosystems of the Barents Sea and Norwegian Sea

By Ken Drinkwater and Kjell Arne Mork

Photo: Ken Drinkwater

NORWEGIAN COMPONENT OF THE ECOSYSTEM STUDIES OF SUBARCTIC AND ARCTIC REGIONS (NESSAR)

Project owner: Institute of Marine Research (IMR)
Project manager: Ken Drinkwater
Total budget: NOK 20 million
Doctoral fellowships: 1
Post-doctoral fellowships: 2
Dissemination measures, public and user-oriented: 13
Articles published in scientific and scholarly journals: 5
Other reports and lectures from scholarly fora: 53
Home page: http://npweb.npolar.no/prosjekter/nessar

The Arctic front is an important feeding ground for many commercial fish species, yet there are large knowledge gaps about the marine ecosystem at such fronts. The NESSAR project has been studying biological production and oceanographic processes at the frontal regions.

The NESSAR project in the Barents Sea and Norwegian Sea focused on the regions where colder, fresher waters of Arctic origin meet warmer, saltier Atlantic waters. In the Barents Sea the region is known as the Polar Front, while in the Norwegian Sea it is the Arctic Front. The impetus for the project came from the Arctic Climate Impact Assessment, which identified ocean fronts as a critical gap in our knowledge of marine ecosystems, and from the fact that fronts are important feeding areas for several commercial fish species such as herring and capelin.

Research questions and field work

NESSAR addressed three main research questions:

- Are the frontal regions more biologically productive than adjacent regions?
- What role do the physical oceanographic processes play at the front?
- Why and how do fish and other marine organism use the fronts?

To answer these questions, NESSAR conducted several field studies from 2007 to 2009. Measurements included temperature and salinity, currents, turbulence and mixing, nutrients, light penetration, phytoplankton species distributions and production, zooplankton distributions and egg production, benthos (in the Barents Sea only), and fish distributions and their diets. In addition to standard oceanographic instruments, newer instrumentation was deployed, e.g. autonomous gliders and towed instruments to obtain high-resolution data on the physical properties and plankton, a spectroradiometer to measure light penetration, and a fast repetition rate fluorometer to measure phytoplankton production.

In the Norwegian Sea, sampling from the research vessels G.O. Sars (June 2007) and Johan Hjort (May–June 2008) focused on the Arctic Front south of Jan Mayen and east of the Jan Mayen Ridge. The 2007 data provided repeat cross-frontal transects along a single line, while in 2008 differences in the along-front direction were investigated. Current meter moorings measured exchanges between the Norwegian Sea and Icelandic Sea. In the Barents Sea, a full suite of measurements was taken from Jan Mayen in the vicinity of Spitsbergen Bank and Storbanken in August 2007 and April–May 2008. In addition, surveys of the hydrography and benthos were conducted in May–June 2007, February–March 2008 and September–October 2009 from Lance.

The field studies faced few major hurdles with relatively successful completion of the planned programme. A major disappointment came in 2008 when ice prevented the ship from reaching the Polar Front on Storbanken, forcing re-routing to Spitsbergen Bank. Little sampling time was lost to bad weather, however, and there was only one major equipment failure, when one of the towing winches malfunctioned in the Norwegian Sea in 2008.

No increase in primary production at fronts

The NESSAR research to date has yielded new and interesting results. In both the Norwegian Sea and Barents Sea, the fronts exhibit strong changes in temperature and salinity across horizontal distances of 10–20 km in the depth range of approximately 50–300 m. Density changes across the fronts are small, owing to density compensation (temperature and salinity affect density).

There are intrusions up to 10 km long and 10–50 m thick of Atlantic Water into the Arctic Water and vice versa along lines of constant density. Mixing increases at the front relative to farther away, although it is still relatively weak. There is no evidence of upwelling at the front. In the top 50 m, there is a solar-heated surface layer with weak horizontal temperature but stronger salinity gradients.

The depth of light penetration into the ocean differs depending upon wavelength, affecting the amounts of phytoplankton and other material in the water. More accurate estimates of phytoplankton production need to take into account the light spectra (wavelengths); a model to do this has been developed.

Silicate appears to be the limiting nutrient for phytoplankton growth, and reduced silicates during the expeditions indicate the likelihood that blooms of phytoplankton called diatoms had occurred earlier in the season, except during April–May in the Barents Sea.

At the front there was no evidence of higher values of phytoplankton abundance or production. The plankton communities tend to differ in species from one side of the front to the other, but the front is penetrable, as some Arctic species were observed on the Atlantic side and vice versa.

In the Norwegian Sea, current measurements have shown upper-layer flow of water from the Iceland Sea into the Norwegian Sea in summer, and then reversed in winter in one of the channels through the Jan Mayen Ridge. This summertime flow is believed to be the source of the Arctic Water observed in the NESSAR transects of the front.

Zooplankton tended to be associated with regions of high concentrations of phytoplankton. Herring were located almost exclusively on the Atlantic side of the front but their diets consisted of a mixture of larger, higher-energy Arctic and smaller Atlantic species. This may be due to short excursions into the Arctic Water to feed and then return to the Atlantic Water, or feeding upon the Arctic species when they penetrate the front into Atlantic Water.

In the Barents Sea, the front structures the zooplankton by size, with the largest concentrations of small zooplankton in the front and increasing in size as one moves farther away from the front on its cold water side. Smaller, younger capelin are found close to the front while the bigger, older capelin feed upon the larger zooplankton in the waters of Arctic origin. Elevated levels of benthos biomass were not observed below the fronts, lending further support for no increased primary production at the fronts.

Further research

Analysis of the data is continuing and is expected to reveal more insights into the physical and biological processes at the fronts. Follow-up field work, pending funding, will further explore the physical-biological linkages at the fronts, the role of zooplankton in fish distributions, and the movement of the fronts both short and long-term as well as their causes. Additional modelling of the field data to test various hypotheses will also be undertaken.

Sea ice prevented northern progress. Photo: Ken Drinkwater

Bjørnar Eilertsen identifying species in a sample of bottom-dwelling organisms. Photo: Ken Drinkwater

Samples of capelin. Photo: Ken Drinkwater

A seabed sample is taken aboard. Photo: Ken Drinkwater

Autonomous “gliders” on deck. Photo: Ken Drinkwater

Conductivity, temperature and density (CTD) instruments. Photo: Ken Drinkwater

Arctic predators as indicators of climatic impacts

By Dorothée Ehrich, Nicolas Lecomte, Eva Fuglei, Rolf A. Ims and Nigel G. Yoccoz

Photo: Laurent Demongin

ARCTIC PREDATORS AS INDICATORS OF TUNDRA ECOSYSTEM STATE (ARCTICPREDATORS)

Project owner: The University of Tromsø (UiT)
Partner institutions: Norwegian Polar Institute, Nenetski Nature Reserve, Ecological Research Station of the Institute of Plant & Animal Ecology (Ural Division, Russian Academy of Sciences), International Biological Station Lena-Nordenskjöld, Ministry for Nature Protection of Sakha Republic, Wrangel Island Nature Reserve.
Project manager: Nigel Yoccoz
Total budget: NOK 9 million
Doctoral fellowships: 2
Post-doctoral fellowships: 1
Dissemination measures, public and user-oriented: 6
Mass media coverage: 1
Articles published in scientific and scholarly journals: 14
Other reports and lectures from scholarly fora: 25
Home page: http://www.arctic-predators.uit.no/

Due to the current global climate warming, Arctic tundra ecosystems are changing rapidly. The lemming cycle – once characterised by regular years of high densities, which have had an impact on plants and served as a food source for predators – is weakening or vanishing altogether in parts of the Arctic. This will likely affect the entire structure of the ecosystem.

At the same time, new species are entering the tundra from the south and establishing themselves as competitors to the typical Arctic species. Since the tundra and marine ecosystems are linked, phenomena such as retreating sea ice will affect processes on land. These are just a few examples in a long list of changes that put pressure on the tundra ecosystem across the entire Arctic. To document what is happening, several methods to monitor the state of tundra ecosystems need to be established.

Scientific basis

Ecosystems are complex systems; it is not logistically possible to follow the dynamics of all their species and flows of energy and nutrients simultaneously. In light of this, the choice of approach will be a trade-off between the resolution and its sensitivity to change. Moreover, Arctic tundra is vast and geographically variable, so methods that allow broad-scale comparisons must be developed.

One approach is through the study of food webs, which amounts to mapping who eats whom. Like all maps, simplification is required to highlight the features of greatest importance. The IPY Arctic Predators project focused on species at the top of the web – those that eat other species but are not themselves prey. A key species among such top predators is the Arctic fox, found all over the Arctic but in no other region. The Arctic fox is opportunistic in terms of its diet, which means that it is linked to many other species in the tundra food web. One very important link is to lemmings, though the Arctic fox nearly always exploits also alternative terrestrial resources, such as voles, reindeer, geese, ptarmigans and hares, especially when lemmings become scarce. The Arctic fox can moreover exploit marine resources such as seabirds and marine mammal carcasses, thus providing a link between marine and Arctic terrestrial food webs.

Through its diet, which integrates almost all types of energy sources available in the tundra, the Arctic fox provides a blueprint of how the food web changes across space and time. Arctic fox diet could therefore be a useful parameter for monitoring. Thus, one aim of the project was to evaluate the dependence of Arctic fox diet on the availability of potential food resources in different food webs, years and seasons as well.

Methods

Methods combined traditional collection and dissection of faeces with more modern analysis of the chemical compositions (stable isotopes) of fox fur. Fur and faeces were collected on short visits to fox dens, a sampling scheme that can be used on a circumpolar scale, at low cost and with little disturbance.

IPY Arctic Predators primarily involved scientists from Norway and Russia, with many months of fieldwork in both summer and winter at various sites in the Eurasian Arctic (Figure 1). Students from both countries have based Master's and PhD theses on the project, and scientists and students were rotated among the different sites to provide dynamic environments for social and scientific interaction.

The sites were selected to include major gradients of climate and different links to adjacent ecosystems (e.g. marine and sub-Arctic). The community of terrestrial predators was mapped, including Arctic fox dens. A great deal of effort went into quantifying the abundance of

Arctic fox on Svalbard. Photo: Nicolas Lacomte

Arctic Predator's PhD student Ivan Pokrovsky takes measurement of a peregrine falcon chick on Yamal. Photo: Nicolas Lacomte

potential prey species and their stable isotope signatures for the purpose of analysing predator diets. Such a concerted effort on such a large scale had never been carried out before in the Arctic, and indeed would not have been possible without IPY.

Results

The diet of the Arctic fox reflected much of the spatial and temporal variation within and between ecosystems, and in particular the importance of lemming abundance and dynamics (Figure 1). A larger variation than expected was found in the strength of the links between the Arctic fox and other components of these ecosystems, as well as in the relative importance of ecosystem components such as other herbivores (hare, ptarmigan, reindeer; Figure 2). While Arctic fox diet alone can quite reliably track major changes in the tundra food webs, the monitoring of other components in the community is needed to capture the quantitative variations in key parts of the ecosystem.

The world is on the cusp of an era of large modifications in the tundra biome. Some components will change quickly; invaders can colonise the Arctic in only a few years and lemming cycles can be lost abruptly, whereas others, such as vegetation, will change more slowly. Understanding the effects of climate change requires both models predicting how climate can affect ecosystems and empirical methods to map and monitor food webs and their main processes.

IPY Arctic Predators focused on this last approach. The project has provided new knowledge about what Arctic predators – especially the Arctic fox – can reveal about the food web to which they belong. The project has also yielded information about the current large variability in the structure and function of tundra food webs, especially across the Norwegian and Russian sectors of the Arctic. Together this could provide a useful baseline and legacy for future collaboration between Norwegian and Russian tundra ecologists.

Further follow-up

Finally, as related approaches were used by the Canadian participants in the IPY ArcticWOLVES project and by the Danish participants working in Greenland, the project is in the unique situation of having collected broadly consistent information from the entire Arctic. It is only through collaboration on continued monitoring that scientists will be able to better detect and predict how the terrestrial Arctic will change and, if needed, intervene to compensate for potential losses of biodiversity and ecosystem functions.

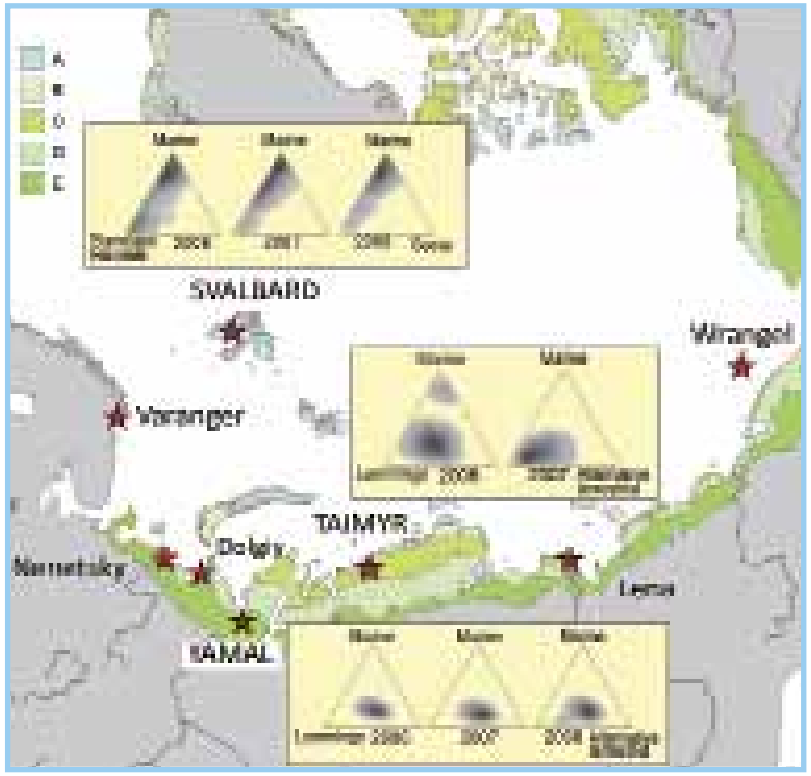


FIGURE 1: (left) ArcticWOLVES' study sites were spread more than 5 000 km in the Eurasian Arctic, and over a gradient from the Arctic island ecosystem of Svalbard, the high latitude Arctic tundra of Taimyr and Wrangel, to a middle Arctic ecosystem in the Lena delta and low Arctic ecosystems on Yamal, Nenetsky and Varanger. The triangles in the figure are based on the results of stable isotope analysis of Arctic fox fur and show the proportion of three different types of resources in the diet of Arctic foxes in different sites and years.

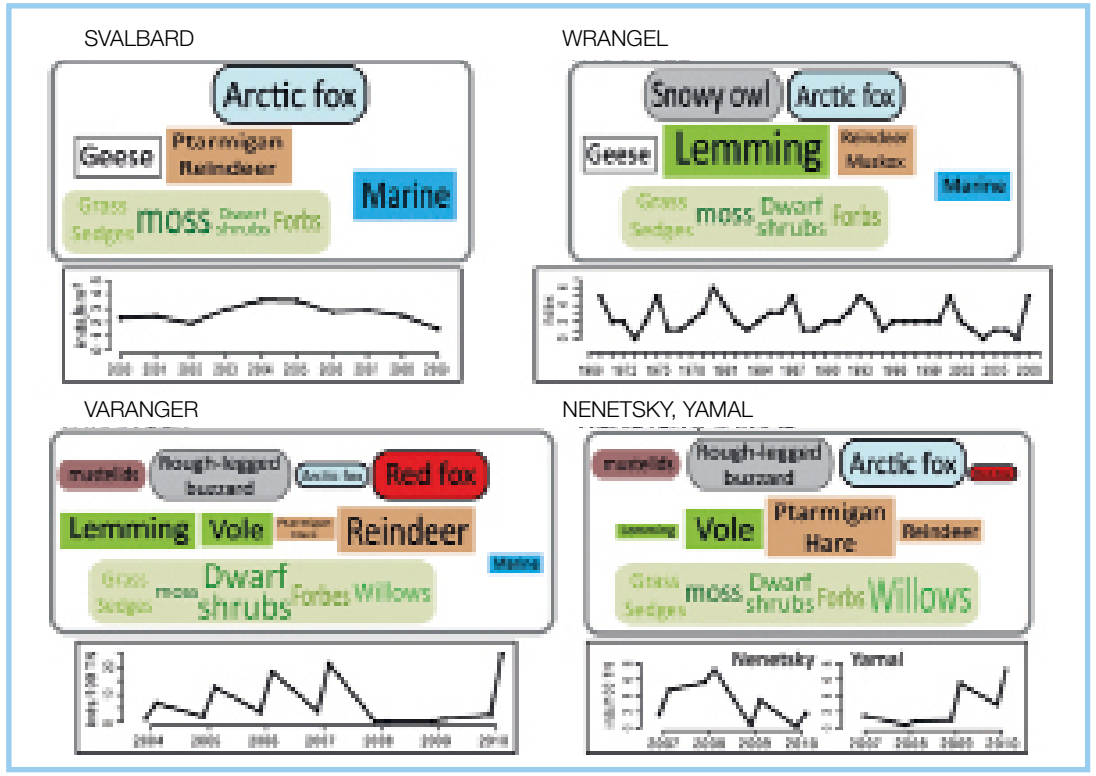


FIGURE 2: (right): Both the structure and the dynamics of key components of the ecosystems vary greatly between ArcticWOLVES study sites. Box sizes indicate the relative importance of species at each trophic level (top: predators; middle: herbivores; bottom: plants; "Marine" represents resources such as marine birds and marine mammals).

Are trees invading the Arctic?

By Annika Hofgaard

Photo: S. Aune

PRESENT DAY PROCESSES, PAST CHANGES, AND SPATIOTEMPORAL VARIABILITY OF BIOTIC, ABIOTIC AND SOCIO-ENVIRONMENTAL CONDITIONS AND RESOURCE COMPONENTS ALONG AND ACROSS THE ARCTIC DELIMITATION ZONE (PPS ARCTIC NORWAY)

Project owner: Norwegian Institute for Nature Research (NINA)
Partner institutions: Norwegian University of Science and Technology (NTNU), Norwegian University of Life Sciences (UMB), Moscow State University, Russian Academy of Science (Centre for Forest Ecology and Productivity, Apatity; Inst. of Industrial Ecology of the North, Apatity; Institute of Geography, Moscow).
Project manager: Annika Hofgaard
Total budget: NOK 9 million
Doctoral fellowships: 1
Post-doctoral fellowships: 1
Dissemination measures, public and user-oriented: 9
Mass media coverage: 3
Articles published in scientific and scholarly journals: 15
Presentations published from international meetings/conferences: 61
Other reports and lectures from scholarly fora: 23
Home page: http://ppsarctic.nina.no/

The circumpolar forest-tundra boundary is expected to move northward. As a result, a larger proportion of earth's surface area may become darker and thus absorb more heat. Through feedback mechanisms, change of this nature could have a major impact on global climate.

The PPS Arctic project examined the dynamics of the forest-tundra boundary. The predominant assumption is that a warmer climate will cause the forest line to advance steadily northward. Preliminary results from the project, however, do not confirm such an assumption outright. The mechanisms are more complex. Changes in permafrost, grazing pressure, fires and insect infestation, for example, must be considered together with climatic impacts in order to avoid potentially misleading interpretations of climate-driven forest expansion.

Background

The circumpolar forest-tundra transition is a complex region-wide boundary where latitudinal gradients in environment, land use, vegetation, and biodiversity undergo a major step change. The boundary is dynamic in its character at all spatial and temporal scales and is predicted to change in response to ongoing and future global environmental changes. A change in forest distribution would have consequences for the entire Arctic region and, through feedback mechanisms, for the overall global climate.

An exchange of present tundra with forest would decrease regional albedo (i.e. surface reflectivity), amplifying global warming, since dark areas such as forests reflect less solar radiation than the lighter tundra so that more latent heat is transformed to sensible heat. In addition, non-deciduous tree species such as most conifers would provide effective masking of the reflective snow. The resulting surface darkening would create a feedback loop where warming-caused forest expansion would cause yet more warming, and so on. This forest-caused atmospheric heating is similar in magnitude to the effect of a doubling of atmospheric CO_2, or a 2% change in solar radiation input (i.e. solar radiation difference between glacial and inter-glacial periods).

Despite considerable research activity over the last decades, little has been known about the causes of current characteristics and dynamics of the forest-tundra boundary. Even less is known about its likely responses to future global environmental changes and the implications of these for the global climate, the environment and the peoples of the north. Scientifically addressing these uncertainties and the complexity of the boundary requires a circum-Arctic approach using standardised definitions, concepts and methods.

Although causes and consequences of relocation and structural changes of the ecotone have been of scientific and political interest for many decades, the increasing awareness of human-caused global climate alterations is now leading to greater attention on the issue.

Is the forest line moving north as the climate warms?

Generally, a swift response with northward movement of the forest-tundra ecotone is expected to be the dominating scenario – based on some rather simple models that relate the position of the ecotone to local climate. The basic idea is that it is too cold for trees to exist north of the present-day tree line, so a warming climate ought to produce a northward advance of the trees (Figure 1).

Nature, however, responds in a complex manner to changing climate or other environmental changes. Temperature, precipitation, snow distribution, wind, soil conditions, tundra and forest fires, insect outbreaks, grazing, trampling, thawing permafrost and land use all interact, and the existing models need to be developed

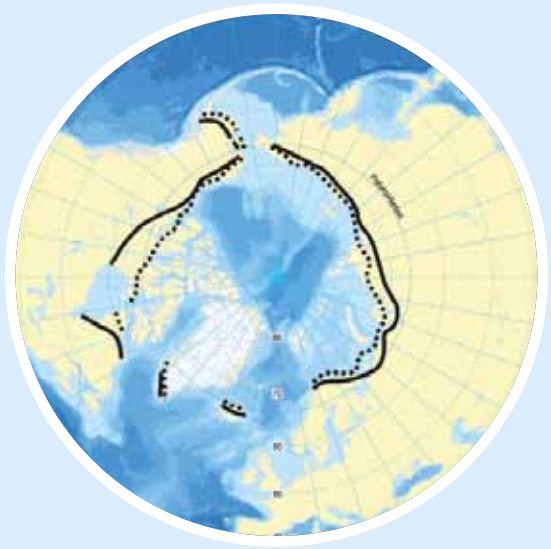


FIGURE 1: (left) The present tree line (solid line) in the circumpolar north is calculated to advance considerably in this century (dotted line) by 2090–2100. This represents an enormous rate of change averaging roughly two km per year. The fastest rates (on both sides of Hudson Bay) are roughly six km per year. (Source: ACIA 2005.)

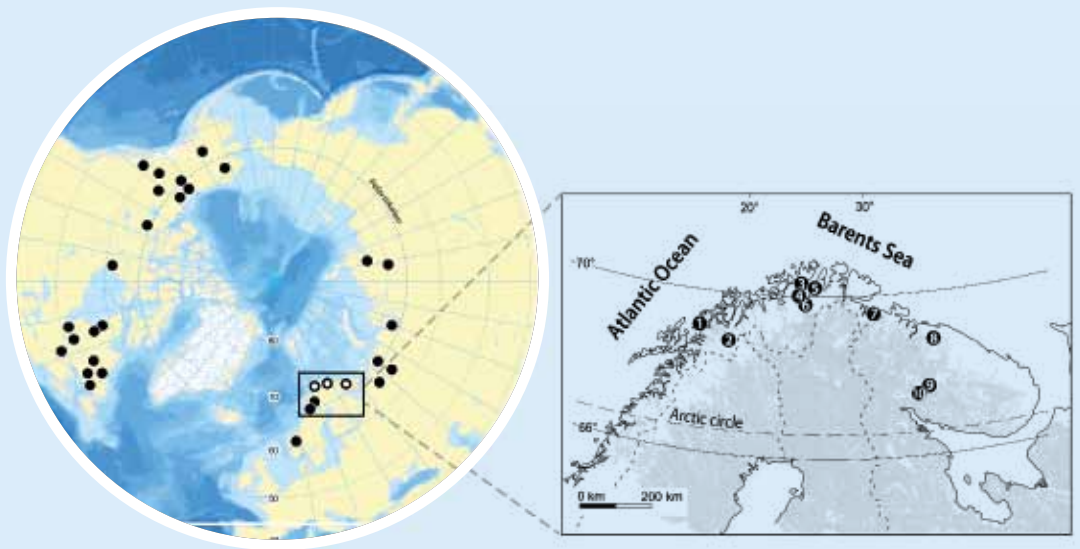


FIGURE 2: (right) PPS Arctic study sites in the circumpolar north (some dots represent multiple sites). The open circles in the Northern Norway / Kola Peninsula region represent 10 sites (see expanded map): 1) Ånderdalen, 2) Dividalen, 3) Olderfjord, 4) Stabbursdalen, 5) Børselv, 6) Porsangmoen, 7) Jarfjord, 8) Kanentiavr, 9) Tuliok and 10) Yumechorr.

and expanded to include more complex parameterised empirical data representing a diversity of climate and land-use sections of the circumpolar transition zone between the boreal forest and the tundra.

Project design

During the International Polar Year 2007–2008 the core project PPS Arctic was established to answer the over-arching question: Are trees invading the Arctic? The complexity of causes, responses and feedbacks surrounding any change of the ecotone must be considered. Activities under the PPS Arctic project revolved around three main sub-questions:

- Is the Arctic forest-tundra zone moving, and if so, in what direction and where?
- What controls the position and structure of the Arctic forest-tundra zone?
- What are the ecological and social consequences of changes in the position of the zone?

These questions have been approached methodologically through field data collection and analyses of tree structure, dynamics, and regeneration capacity in the transition zone, and through spatiotemporal characterisation of the zone by remote sensing at a large number of sites (Figure 2). The Norwegian segment of the PPS Arctic project focuses on the first two questions and uses coastal/inland locations in North Norway, the Kola Peninsula and Taimyr as study regions. The work was carried out in close cooperation with Russian colleagues.

PPS Arctic is a circumpolar core project focusing on the southern border of the Arctic. The international project is composed of individual national and bilateral projects jointly focusing on causes and consequences of changes towards shrub and tree domination in the transition zone. Annika Hofgaard of the Norwegian Institute for Nature Research (NINA) was project leader and coordinator of the international PPS Arctic project and its Norwegian segment. Co-coordinator of the core project was Gareth Rees of the Scott Polar Research Institute, Cambridge University, UK. The project included many partner institutions in Canada and Russia, as well as in Sweden, the UK and the USA.

Preliminary results

Comprehensive results representing the circumpolar perspective are not yet available, as these will be based on studies by the more than 60 graduate students (most of whom will defend their theses in the next few years). However, some preliminary patterns are evident:

- The influence of climate is seen at most sites, although this is complicated by differences in regional land-use patterns.
- Responses differ between different climate regions, between coastal and continental regions of the circumpolar north, and according to the dominant tree species.
- Examples of advancing, retreating and stationary forest-tundra zones are seen across study sites. Advancing zones seem to be dominating, but the rate of change does not confirm to modelled predictions.

The Ary-Mas study area on the Taimyr Peninsula. Photo: N. Kolupanov

Field work in northern Russia: Surveying fire-perturbed areas of the forest-tundra boundary zone for verification by satellite photography. Photo: G. Rees

Field work in Northern Norway: recording and surveying tree density, recruitment and age structure in a pine wood near the tree line. Photo: A. Hofgaard

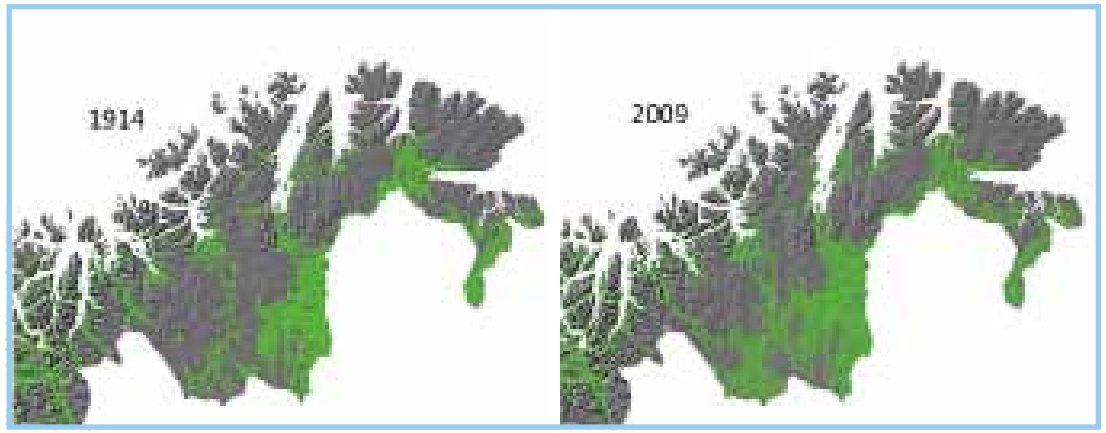


FIGURE 3: Forest expansion in Finnmark, Norway (1914 to 2009). In the documented period, pine (Pinus sylvestris) has shown a mean northward advance of 65 metres per year, while birch (Betula pubescens) has advanced roughly 150 metres per year. Source: Tømmervik et al. In prep.

Large Arctic herbivores such as reindeer and caribou (North American and Greenland subspecies of reindeer) can dominate forest-tundra zone dynamics at regional and species-specific levels by modifying e.g. tree recruitment, survival and growth. This is clearly shown for the birch forest-tundra zone in the North Norway-Kola Peninsula region, where forest-tundra areas in reindeer herding districts show stationary or retreating tree populations characterised by non-overlapping age distributions between trees and recruiting saplings, and low sapling survival (Figure 4).

In areas with low grazing pressure, tree sapling recruitment has generally been abundant over recent decades across the North Norway-Kola Peninsula region except in areas characterised by dry Arctic conditions, where both tree and sapling cohorts are old. Areas with high annual precipitation and low grazing pressure show advancing birch populations characterised by young individuals and partly overlapping tree and sapling age distributions.

Herbivores will limit an area's expected climate-driven tree expansion. To avoid misleading interpretations regarding rates of climate-driven encroachment, changes in grazing regimes and other perturbations (fire, insects, etc.) must be considered along with climate change. In addition, analyses of historical forest cover data and forest advance during the 20th century in North Norway indicate widely deviating northward forest movement rates compared to modelled rates (Figure 4), which emphasises the need for upgraded models.

The legacy of the PPS Arctic project

The PPS Arctic project will leave a lasting legacy, even after the present generation of graduate students has completed its work. This legacy will include newly generated scientific knowledge and understanding that provides a snapshot of the forest-tundra zone in the early 21st century as well as an extensive network of study sites across the Arctic, at which data based on standardised methods are available for use in future re-analyses or for long-term monitoring programmes.

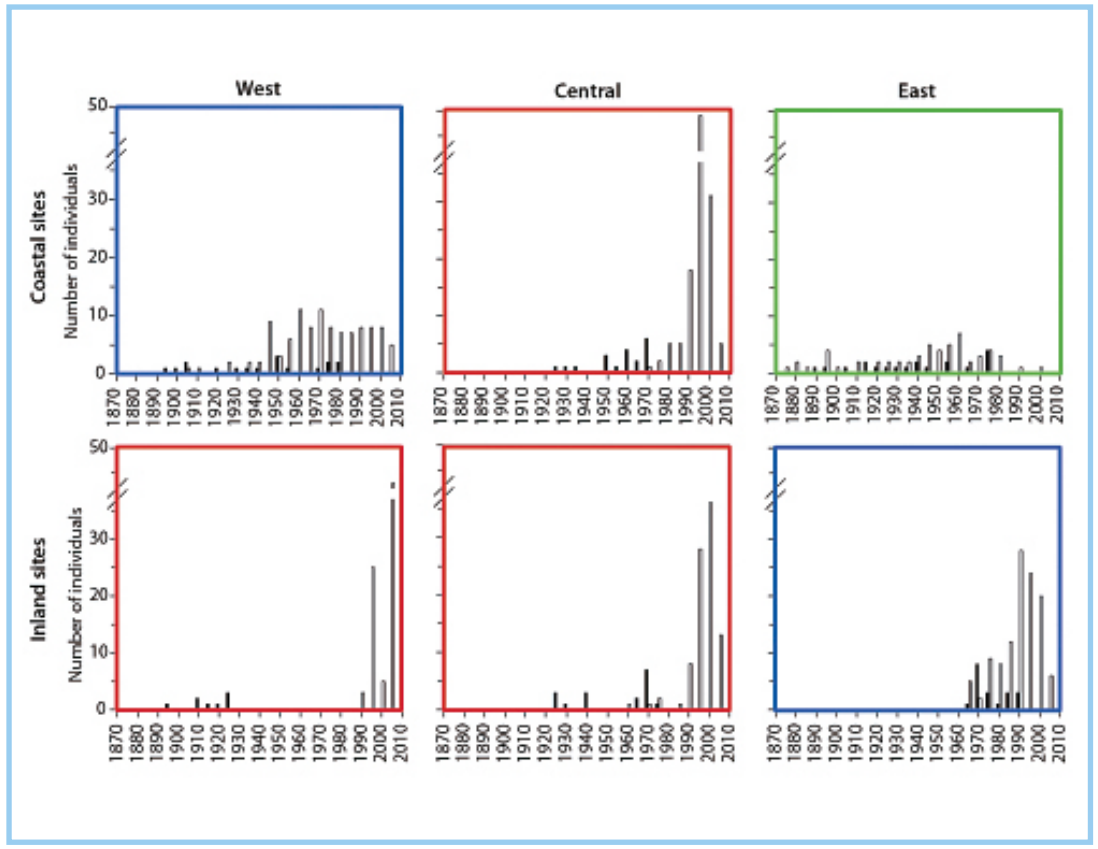


FIGURE 4: Age distribution of birch (Betula pubescens): saplings (grey columns) and tree-line trees (black columns) from three coastal and three inland sites in Northern Norway and Kola Peninsula. Site numbers, which correspond to Figure 2, are 1 and 2 in the west, 3 and 6 in central areas, and 8 and 9 in the east. Blue-bordered graphs indicate expanding forest-tundra boundary zones; red-bordered are stationary; green-bordered indicates retreating zones. Source: Aune et al. 2011

Polar bear health, pollution and climate change

By Bjørn Munro Jenssen

Photo: Jenny Bytingsvik

POLAR BEAR CIRCUMPOLAR HEALTH ASSESSMENT IN RELATION TO TOXICANTS AND CLIMATE CHANGING (BEARHEALTH)

Project owner: Norwegian University of Science and Technology (NTNU)
Project manager: Bjørn Munro Jenssen
Total budget: NOK 5 million
Doctoral fellowships: 1
Dissemination measures, public and user-oriented: 37
Mass media coverage: 14
Articles published in scientific and scholarly journals: 2
Books published: 2
Presentations published from international meetings/conferences: 3
Other reports and lectures from scholarly fora: 14
Home page: http://www.biologi.no/bearhealth.htm

Pollution and climate change are currently the two greatest threats to Arctic biodiversity and ecosystems. Pollutants are carried around the world in the atmosphere and by ocean currents, reaching the Arctic from the areas further south where they are produced, used and released. However, their concentrations in the Arctic are generally lower than further south.

Although levels of halogenated persistent organic pollutants (POPs) are often relatively low in Arctic fish and seals, very high concentrations have been found in species at the apex of food chains (top predators) in Arctic ecosystems. These include the polar bear, one of the species that has been found to carry particularly high loads of these pollutants.

Background

POPs are fat-soluble and accumulate in fatty tissue, and their concentrations increase from one stage of the food chain to the next, a process known as biomagnification. This explains why POP levels are so high in polar bears. Polar bears feed on seals, and a large part of their diet consists of seal blubber. Even though levels of POPs in Arctic seals are relatively low, polar bears eat such large amounts of blubber that they accumulate very high loads of these pollutants.

Polar bears are also under threat from climate change. Global warming is melting the Arctic sea ice, and the main habitat used by bears when hunting is therefore shrinking. However, polar bears as a species survived several relatively warm periods between 150 000 and 100 000 years ago. This suggests that they are physiologically and behaviourally capable of adapting to and surviving a great deal of variability and change in climate and environmental conditions.

On the other hand, many organic pollutants can disrupt the physiology, health and behaviour of living organisms. It is therefore possible that exposure to high concentrations of POPs is disrupting the biological mechanisms that have previously enabled polar bears to adapt to and survive major climate change.

Objective of the project

The objective of the BearHealth project was to assess polar bear health, and particularly how POPs may affect their physiological ability to adapt to climate change in the Arctic. Researchers collected blood samples from 145 polar bears in Svalbard. Through collaboration with the National Environmental Research Institute in Denmark, the project was also given access to blood and organ samples from about 100 bears taken by local Inuit hunters in eastern Greenland.

Researchers also investigated a museum collection of polar bear skulls from Svalbard to find out whether POPs have had any effect on bone structure. In addition, they looked at changes in concentrations of POPs in polar bears from Svalbard in the period 1997–2008, and at the extent to which POPs transferred to cubs from nursing females affect the physiology and health of the cubs.

The results so far

Levels of several persistent organic pollutants have dropped considerably in polar bears from Svalbard in the past 10 years. This shows that international agreements banning or restricting the use and releases of POPs are having the intended effect. The Stockholm Convention (www.pops.int), where Norway played an active part, is particularly important. Despite the lower levels of contamination in polar bears, the results of the project show that the pollution load is still high enough to have negative effects on bear health.

The project focused particularly on the effects of POPs on the thyroid hormones, which regulate metabolism and are important in a number of physiological processes in all mammals, including people. They play

a vital role in temperature regulation and adaptation to temperature change in the environment, the growth and development of young animals, reproduction and the immune system. In Arctic mammals, they are also very important in regulating metabolism in periods when animals fast because little food is available or because they are hibernating.

The project has identified certain POPs that have serious negative effects on the metabolic hormone balance in polar bears. One surprising result is that the substances that most seriously disrupt the hormone balance in polar bears are often present in relatively low concentrations. The project has also shown that females and juveniles are most severely affected.

The project has also revealed interactions between the impacts of POPs and of climate change. Several physiological processes that are essential in adaptation to climate change are affected by POPs. There is therefore every reason to be concerned about the high levels of POPs found in polar bears from Svalbard and eastern Greenland, and whether this will affect their capacity to adapt to other environmental stresses such as climate change.

In further studies, it will be important to look into how the effects of POPs on biomolecular, biochemical and physiological processes in polar bears translate into effects at population level.

One of the most important contributions by the BearHealth project was a survey of polar bear exposure to POPs in Svalbard. The analyses of pollutant levels included both "classic" organic pollutants such as PCBs and DDT and emerging pollutants such as brominated flame retardants and perfluorinated compounds.

In addition, the project has analysed more than 100 biomolecular, biochemical, physiological and biological parameters related to the health status of polar bears. The data will be very valuable in developing an understanding of how POPs affect polar bears and other mammals, including people.

Further research

The data collected during the BearHealth project will provide a valuable basis for future monitoring of the pollution load in polar bears and their health status.

The pollution load carried by polar bears is a mixture of several hundred different substances. This project has shown that substances that are present in low concentrations may interact and cause more damage than pollutants that are present at higher concentrations. An important goal of future work should therefore be to investigate how different pollutants interact. This would also provide a better basis for making risk assessments of animal and human exposure to POPs.

What a size! Photo: Jenny Bytingsvik

Blood samples can provide important information about levels of organic pollutants in bears. Photo: Jenny Bytingsvik

Research fellow Jenny Bytningsvik taking samples from a polar bear during field work in Svalbard in spring 2006. Photo: Jon Aars

A helicopter was used to find polar bears. Photo: Jenny Bytingsvik

Jon Aars of the Norwegian Polar Institute with a sedated polar bear. Photo: Jenny Bytingsvik

Will climate change increase uptake and effects of contaminants in polar marine ecosystems?

By Geir Wing Gabrielsen, et. al.*

Photo: Geir Wing Gabrielsen

CONTAMINANTS IN POLAR REGIONS – DYNAMIC RANGE OF CONTAMINANTS IN POLAR MARINE ECOSYSTEMS (COPOL)

Project owner: Norwegian Polar Institute (NP)
Partner institutions: Norwegian Institute for Water Research (NIVA), Akvaplan-niva, Norwegian Institute for Air Research (NILU), Norwegian University of Science and Technology (NTNU) and Norwegian Institute for Nature Research (NINA)
Project manager: Geir Wing Gabrielsen
Total budget: NOK 12 million
Post-doctoral fellowships: 1
Dissemination measures, public and user-oriented: 45
Mass media coverage: 18
Articles published in scientific and scholarly journals: 10
Presentations published from international meetings/conferences: 8
Other reports and lectures from scholarly fora: 26
Home page: http://www.copol.net/

The objective of the International Polar Year (IPY) project Contaminants in Polar Regions (COPOL) was to understand the dynamic range of man-made contaminants in marine ecosystems of the polar region and assess the extent of climate-induced alterations of the marine food webs (contaminant exposure and food quality). In order to fulfil these aims the research was directed toward three areas: 1) food web contaminant exposure and fluxes, 2) transfer of contaminants to higher trophic levels and potential effects, and 3) synthesis and integration.

The COPOL project was an initiative from the Fram Centre in Tromsø and the Oslo Centre for Interdisciplinary Environmental and Social Research (CIENS). Research activities were carried out from 2007 to 2009, and encompassed expeditions and extensive field campaigns during the spring and summer months in two Arctic fjords (Kongsfjorden and Liefdefjorden) of the Svalbard archipelago. Seasonal and annual changes in contaminant loads were investigated in marine species from several trophic levels of both benthic and pelagic food webs. Chemical analyses of mercury and persistent organic pollutants (POPs) were performed by national and international laboratories.

Background

The Arctic is one of the regions that the Intergovernmental Panel on Climate Change (IPCC) anticipates will be most affected by climate change. Some of the expected and already documented alterations are: thinning of the pack ice, less multi-year ice, increased river discharge into the Arctic Basin, accelerating melting of glaciers, warmer surface temperatures and greater inflow of Atlantic water masses. These changes may potentially alter species distributions, food web structures and carbon cycling, and subsequently tropho-dynamics and transport and uptake of POPs into and within the Arctic.

The Arctic environment is also characterised by high seasonality in light intensity, primary production, food availability, lipid concentration in organisms, migration of organisms, and ice cover. These "naturally occurring" factors also influence the availability of POPs and their uptake in the organisms and in food webs. This is in addition to the potential alterations caused by climate change.

It is not yet clear how climate change will affect accumulation of POPs in marine food webs. Modelling and sensitivity analyses have identified sea ice cover, temperature, precipitation rates, and altered primary production as having the largest impact on POP transport and accumulation in the Arctic environment. However, much uncertainty remains regarding prospective changes in relevant input parameters for the models. Increased empirical knowledge is needed on how alterations to variables that act both regionally and globally (i.e. climate) may influence the disposition of contaminants in ecosystems.

A total of 3 000 samples have been collected during the COPOL project. A total of 1 500 samples have been analysed in the project so far. Two doctoral students and four master students have completed their degrees under the COPOL project.

Zooplankton as indicators

The COPOL project has shown that accumulation of POPs in marine organisms varies with year and season – in marine organisms at both lower trophic levels (zooplankton) and higher levels (fish and marine birds). However, the seasonal pattern in accumulation and magnification differs depending on the chemical and group of organisms involved.

Zooplankton are well-suited as a group of organisms for assessing seasonal and climatic alterations to POP uptake/accumulation, since they reflect environmental changes in POPs at the base of Arctic food chains more rapidly than longer-lived organisms at higher trophic levels. Zooplankton also provide the link between primary production and fish, marine birds and marine mammals.

Caused by seasonal variation or by climate change?

In all species of zooplankton studied, POP concentrations decrease from May to October. This coincides with decreasing POP concentrations in seawater and increasing lipid stores in the plankton during the same period. Investigation of the accumulation and magnification from zooplankton to fish and birds generally identified July as the month when magnification was greatest, since POP concentrations in the fish species and (for some POP compounds) kittiwakes were highest in July. The fact that POP concentration in zooplankton was observed to decrease from May to October further underscored the magnitude of increased accumulation through the food web. These results indicate that estimates of the uptake and accumulation of POPs are dependent on the time of sampling (i.e. season).

The level of POPs in marine birds varies between years. In kittiwakes (pelagic feeder) the levels of PCBs and DDE were 50% higher in 2008 compared to 2007. In common eider ducks (benthic feeder) concentration levels were reduced by 50–60% from 2007 to 2008. This shows that diet can exert a great influence on contaminant load. Concentrations of POPs continue to be found at high levels in top-level predators such as glaucous gulls and skua from Kongsfjorden. Studies investigating hormonal effects in marine birds from Kongsfjorden show that stress levels are influenced by the current contaminant loads.

Master's student Anja Johansen Haugerud conducts measurements and blood sampling of a glaucous gull in Kings Bay to study the effects of persistent organic pollutants (POPs).
Photo: Kjetil Sagerup

Doctoral student Ingeborg Hallanger sorts copepods to collect a total of 5 g for measuring POPs and mercury.
Photo: Geir Wing Gabrielsen

Knowledge about the significance of seasonality is essential to be able to differentiate between seasonal variation in accumulation and magnification of POPs versus alterations caused by climate change. Identifying possible alterations caused by climate change in a seasonal environment is a complex and difficult task. Clearly, climate change has the potential to alter POP concentrations in the Arctic. However, the degree to which these concentrations will change, and whether a warmer climate will bring a net increase or decrease of POPs in the Arctic, is still uncertain.

Follow-up

The Norwegian COPOL project is one of the first projects to study how climate change will influence the contaminant load of Arctic marine food webs. The COPOL project has generated knowledge about new contaminants in the Arctic (i.e. siloxanes) and has received a great deal of media attention both nationally and internationally. The project has shown how much more can be achieved by taking an interdisciplinary approach.

The COPOL team will continue its efforts under the new flagship programme established at the Fram Centre in Tromsø. Many scientific articles have already been published, and there are many more to come, especially with regard to synthesis and integration, once all the chemical analyses have been completed.

* Co-authors: Anders Ruus, Anita Evenset, Guttorm Christensen, Jan Ove Bustnes, Ingeborg Hallanger, Ida Øverjordet, Eldbjørg Heimstad, Nicholas Warner and Katrine Borgå.

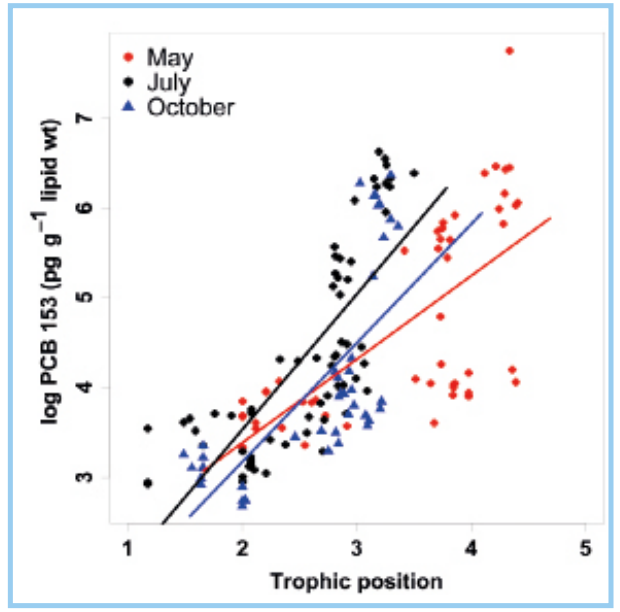


FIGURE 1: Relationship between trophic position and lipid-normalized PCB-153 concentration. Individual values of samples over the sampling periods: May (red), July (black) and October (blue). Figure: Ingeborg Hallanger

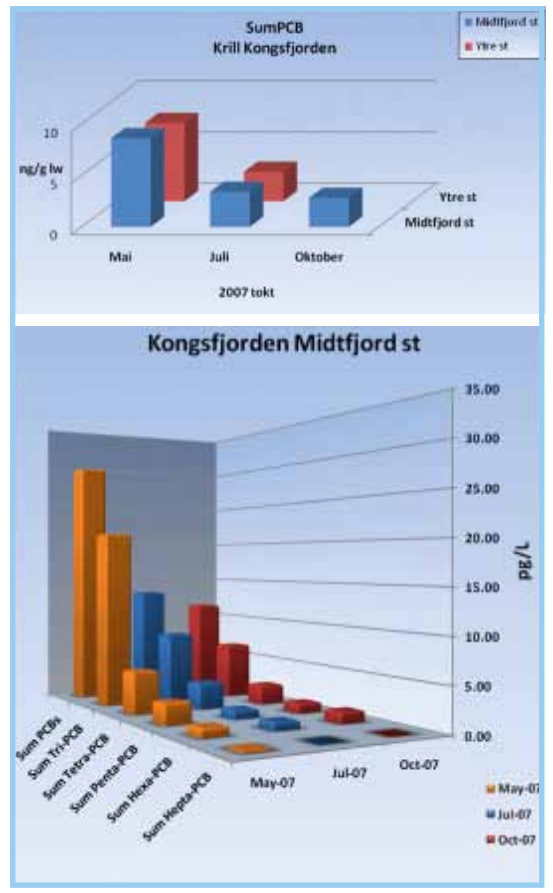


FIGURE 2: Seasonal variation in PCB levels in seawater and krill samples collected from Kings Bay in 2007.
Photo: Geir Wing Gabrielsen

Adaptation in the Arctic: to what and by whom?

By Grete K. Hovelsrud

Photo: Denis Laptander

COMMUNITY ADAPTION AND VULNERABILITY IN THE ARCTIC REGIONS: FOCUS ON NORTHERN NORWAY AND NORTHERN RUSSIA (CAVIAR)

Project owner: CICERO Center for International Climate and Environmental Research
Project manager: Grete K. Hovelsrud
Total budget: NOK 6 million
Doctoral fellowships: 1
Dissemination measures, public and user-oriented: 30
Mass media coverage: 37
Articles published in scientific and scholarly journals: 7
Books published: 1
Presentations published from international meetings/conferences: 4
Other reports and lectures from scholarly fora: 38
Home page: http://www.cicero.uio.no/projects/

The CAVIAR project was partly inspired by the 2005 Arctic Climate Impact Assessment (ACIA). The latter concluded that climate change will have major impacts on people and communities throughout the Arctic, but that too little is known about what local effects to expect and how community adaptability and resilience will be affected.

The full CAVIAR project comprised 26 case studies in eight Arctic countries, including Norwegian-funded studies in northwestern Russia (Revda and Lovozero, Tyumen and Arkhangelsk Oblasts) and northern Norway (Nesseby, Hammerfest, Lebesby and Vestvågøy municipalities), and involved indigenous peoples in both countries.

The case studies have shown that the impacts of climate change on people and communities are complex, and that climate change is not necessarily the greatest challenge these communities have to deal with. Climate change may intensify other problems facing communities, or in some cases offer new opportunities. In-depth studies of local conditions have revealed new and unexpected links between climate change, communities and adaptation needs.

Objective of the project

The underlying purpose of the CAVIAR project was to learn more about how Arctic communities are affected by changing environmental and climatic conditions, and how these changes interact with social factors. The aim was to gather knowledge that would be useful in developing policy.

A distinctive feature of the CAVIAR project was that in contrast to other climate-change projects, it involved local communities in identifying research topics for each case study. The aim was to ensure that the research was relevant to each community. The project was also designed so that the results of individual studies could be compared and used in developing a more general understanding of the impacts of climate change on community adaptation and vulnerability.

Research questions

Collaboration between the partners in the international CAVIAR consortium resulted in the development of a set of research questions to be used as a framework for the 26 case studies. They were as follows:

- How are local communities affected by environmental, climatic and social changes, and what are the consequences for people's lives and livelihoods?
- How do local communities adapt to changing conditions, and which strategies are available to deal with change?
- What external and local factors influence vulnerability and in what ways?
- How do cultural, economic and political processes at various scales affect sensitivity to climate change?
- How do conditions affecting communities and their adaptive capacities vary, and why?
- What can be learnt by generalising the results across the various cases?

In addition, the project considered projected changes in relevant climatic and social conditions, and considered how these are likely to affect vulnerability, using new knowledge on community adaptability as a basis. All the case studies used a common framework for organising data and information (see Figure 1).

Methods

The project teams used a range of tools and methods to build up an overall picture of community adaptability and vulnerability in the past, present and future. They compiled information from sources including statistics, reports, newspaper and other media, research papers and other relevant material.

The first visit to each study area was used to ensure community participation and to define the most relevant research questions locally. As a result, the research focus varied from case to case. In each community, a series of consultations and informal interviews was held with key people in the administration, business sector and other interest groups. Experience gained during the earliest field work was used to develop an interview guide, which was used in later interviews and discussions.

In all, the Norwegian and Russian research teams made 17 field trips and held a series of consultations, group meetings, informal interviews and talks, including about 140 interviews and six public meetings. The Norwegian case studies included close collaboration with the Norwegian Meteorological Institute to develop downscaled climate projections for the relevant areas.

The data were analysed to identify the current exposure-sensitivities of the communities at present, and the adaptation strategies they are using. The next stage was to assess how future change will affect exposure-sensitivities if adaptive capacity remains unchanged. This work is being continued.

Climate change is not the greatest challenge

The research findings indicate that climate change is not necessarily the greatest challenge that communities in northern Norway and northwestern Russia need to deal with. It is the interactions between social, political and economic factors, and the fact that their impacts are intensified by climate change, that together require adaptability and determine how vulnerable communities are. For instance, warmer seas and more frequent extreme weather events combined with legislation that permits fishing using small vessels further out

Interviewing Mayor Inger Katrine Juuso of Nesseby municipality. Photo: Grete K. Hovelsrud

The quayside at Kjøllefjord, Lebesby municipality. Photo: K. Hovelsrud

to sea will make adaptability even more important. To build an understanding of adaptive capacity and exposure-sensitivities, a variety of factors need to be considered together with climate change. Examples are social factors including demography (depopulation, imbalance between the sexes) globalisation, the development and management of natural resources, development of infrastructure and industry, a lack of economic flexibility (what has happened to people who used to combine fishing and farming?), and a lack of flexibility in natural resource management.

Vulnerability and barriers to adaptation

When changing conditions mean that local knowledge of weather and wind conditions and natural resources is no longer adequate, and the impacts of climate change on the natural resource base (for example on fish stocks) are becoming apparent at the same time, communities become more vulnerable.

The project found that communities are already adapting, but that this process is being driven by local enthusiasts rather than by national guidelines and policies. The findings also indicate that northern communities are so used to highly variable weather conditions and to coping with bad weather that many people do not see any immediate need to think about adaptation to climate change. Over time, as climate change becomes more marked, this will increase community vulnerability.

Extreme weather events increase people's awareness

Even though they are accustomed to changeable weather and wind, people in northern Norway and northwestern Russia are now observing real change: more extreme weather, more icing on ships and other structures, changes in prevailing winds, warmer winters, changes in fish stocks and a longer growing season. As a result, local authorities and different sectors are giving adaptation to climate change a place on the agenda.

Extreme weather events make people more aware of the changes that are taking place, whether or not they are directly related to human-induced climate change. Extreme weather events are expected to occur more frequently and be more severe in many parts of the world as the climate changes. This will have major impacts on society, and will require targeted adaptation policies at national level.

Detailed climate projections

For the Norwegian case studies, the Norwegian Meteorological Institute developed 30 detailed downscaled climate projections using the most relevant climate and weather parameters. Locally, the period 2021–50 was more relevant than a longer time horizon with the best possible spatial resolution. The Russian team did not have the opportunity to work at such a detailed level with the meteorological data..

Empirical downscaling and statistical adjustment of results from regional climate models made it possible to construct maps showing projected values for temperature and precipitation with a spatial resolution of 1 x 1 km. These can for example be used to show how precipitation is expected to change in different parts of the same municipality.

The local climate scenarios were developed in an iterative process involving two main processes: translating local priorities into elements for which projections can be developed, and developing local scenarios that give projections that are of practical use to local communities. This is a resource-intensive method, which cannot be applied to all local communities at this stage. However, the results are providing new knowledge of how communities are assessing local adaptation to climate change and which projections are relevant for users.

Dissemination

The preliminary results from Norway have been presented at public meetings in the municipalities involved, to provide an opportunity for feedback from the local partners. The project was presented in a radio documentary by the Norwegian Broadcasting Corporation, and has also been featured in various newspapers, magazines and radio and TV channels in Norway and abroad. Scientists involved in the project have given scientific or popular talks and presented posters at a number of seminars and conferences. The University of the Arctic will be offering a web-based lecture on the CAVIAR project in spring 2011, and the results have also been used in teaching at the University of Oslo. A peer-reviewed book on the project has been published.

Follow-up

One of the sessions at the Seventh International Congress of Arctic Social Sciences (ICASS VII), to be held in Iceland in June 2011, will focus on the CAVIAR project and the way forward. The aim is to bring together researchers who have been involved so far and new participants, and to draw up a research plan for the time ahead. The project has attracted a great deal of attention in a number of countries, and further research is expected to focus on the questions that have arisen during the project so far.

From Vestvågøy in the Lofoten Islands. Photo: Grete K. Hovelsrud

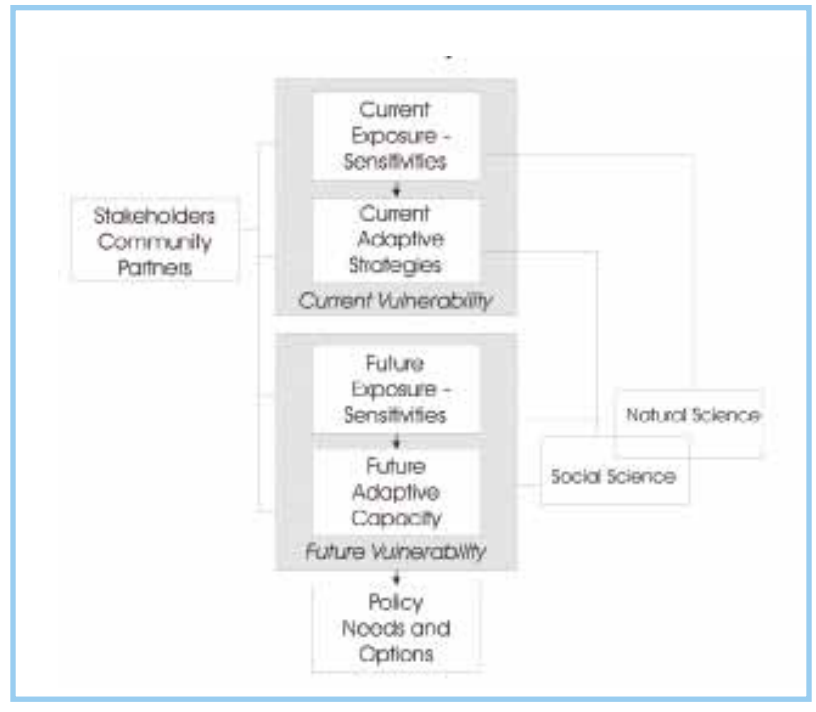


FIGURE 1: CAVIAR interpretative framework for community vulnerability and resilience assessment.

EALÁT – Something to live on

By Ole Henrik Magga, Svein D. Mathiesen, Anders Oskal and Philip Burgess et al. *

Photo: Anders Oskal

REINDEER HERDERS VULNERABILITY NETWORK STUDY: REINDEER PASTORALISM IN A CHANGING CLIMATE (EALÀT)

Project owner: Sámi University College and International Centre for Reindeer Husbandry
Project manager: Ole-Henrik Magga, Anders Oskal and Svein D. Mathiesen
Total budget: NOK 9 million
Doctoral fellowships: 3
Post-doctoral fellowships: 2
Dissemination measures, public and user-oriented: 249
Mass media coverage: 148
Articles published in scientific and scholarly journals: 19
Books published: 7
Presentations published from international meetings/conferences: 27
Other reports and lectures from scholarly fora: 70
Home page: http://www.ealat.org/

"Ealát" is a Sámi word meaning "something to live on" (especially with regard to reindeer), or "(sufficient) pasture". It is related to the word "eallu", which means herd, and both words are derived from the word "eallin" meaning "life". Pastures are the foundation of reindeer herding, and reindeer herds are the foundation of the lives of indigenous reindeer herding peoples throughout the circumpolar north. EALÁT is also the name given to the IPY project initiated by the Association of World Reindeer Herders (WRH).

Reindeer husbandry – a model for sustainable management

Reindeer husbandry is the traditional livelihood of more than 20 different ethnic indigenous peoples in Eurasia and involves close to 100 000 herders and about 2.5 million reindeer. This traditional livelihood represents a model for the sustainable exploitation and management of northern terrestrial ecosystems, a model based on experience that has been accumulated over generations and that has been conserved, developed and adapted to the climatic, political and economic systems of the north.

Reindeer herding can be described as a human-coupled ecosystem that has developed a high resilience to climate variability and change. The core survival strategy of the reindeer communities has always been based on knowledge about how to live in a changing biological, social and political environment.

The objective of the project

Nowadays climate change and the impacts of globalisation are helping to increase the pace of change in reindeer herding societies. The EALÁT project sought to examine the impact of these new challenges on reindeer herders and their communities, and to look at how they can best adapt, develop and prosper to ensure the survival of reindeer husbandry for future generations. The EALÁT project is a multicultural and multidisciplinary vulnerability study with three components: EALÁT Research, EALÁT Information and EALÁT Outreach.

EALÁT Research

The EALÁT Research project focused on reindeer husbandry in Northern Norway and in the Yamal-Nenets Autonomous Okrug (YNAO) in Western Siberia, Russia. Finnmark is the largest Sámi reindeer husbandry region (with approximately 160 000 reindeer and 1 500 reindeer herders), while YNAO is one of the largest reindeer husbandry regions in the world (with about 600 000 reindeer and 14 000 people (primarily Nenets) practising nomadic reindeer husbandry).

Reindeer herders on the Yamal Peninsula follow the reindeer herd every day all year round, migrating up to 1 200 km each year between winter and summer pastures. In contrast Sámi reindeer herders in Finnmark migrate up to 350 km between seasonal pastures. Reindeer husbandry in Norway is highly dependent on motorised support, unlike reindeer husbandry in the YNAO, which is entirely nomadic.

In order to study the climate, historical data from selected weather stations covering large areas of Eurasia were used and future climate developments estimated by scaling down the results of global climate models.

New temperature scenarios indicate that winter temperatures (Dec-Jan-Feb) in Finnmark and the YNAO may increase by 6 to 7°C over the next 100 years. These scenarios also indicate that in 2070–2100 the winter temperatures in YNAO may be comparable to present-day winter temperatures in Karasjok in Norway. Similarly towards the end of this century winter temperatures in inland Karasjok may be more like the present-day temperatures in Alta at the coast of Northern Norway

More detailed scenarios for Finnmark show that annual precipitation (rain and snow) may increase by 5 to 30 % over the next 100 years. The snow season may be 1 to 3 months shorter, while the annual maximum snow depth may decrease by 5 to 60 %.

The experience of reindeer herders is that temperature and precipitation conditions alone are not critical for the reindeer's grazing conditions, but that various combinations of these climate variables lead to different snow structures that affect the availability of pastures for the reindeer. In order to investigate this closer, a Swiss model was used to calculate the structure and density of different snow layers. The preliminary results are promising, as the model reflects the experience of the reindeer herders from the past few winters.

Oil and gas activities affect grazing opportunities

The YNAO is home to approximately 90 % of Russia's and 20% of the world's gas production. The future welfare of the Russian state is closely linked with the development of new gas fields on the Yamal Peninsula and industrial development has begun to come into conflict with major reindeer herding areas in the region. Landsat scenes between 1972 and 2010, as well as indigenous observations of changes over the past 30 years, indicate the sheer scale of oil and gas-related infrastructure development across grazing areas and the reindeer's migration routes.

As they are still able to migrate through the industrially developed areas, the reindeer herders have been willing to accept industrial development so far. However, the survival of reindeer pastoralism in the YNAO may be seriously threatened if industrial development becomes so dense that migration routes are blocked and/or disrupted. In Finnmark the oil and gas resources are

Sámi reindeer herder and participant in the EALÁT project Karen Anne Logje Gaup at work. Photo: Svein D. Mathiesen

EALÁT Information workshop with reindeer herders from the Sámi, Nenets and Khanty peoples. The workshop was held in Khralova on the Yamal Peninsula in Russia Photo: Svein D. Mathiesen

offshore, but they generate direct and indirect infrastructure development onshore that affects reindeer grazing areas, in particular coastal summer pastures and calving grounds.

New calculations confirm that continued piecemeal development (roads, housing etc.) will substantially reduce grazing grounds in coastal areas, even without further petroleum development. Coupled with extensive petroleum development, however, grazing grounds in Finnmark may be reduced by an additional 21 000 km^2. By 2050, up to 80% of the coastal ranges in northern Norway may be severely disrupted by industrial development, which will have a major impact on reindeer husbandry. The continued loss of grazing land will constrain reindeer husbandry practices and make it more difficult for reindeer husbandry as a livelihood to cope with other future challenges such as climate change.

The survival and long-term sustainability of reindeer husbandry will only be ensured if alternative ranges are identified, current ranges restored, or mitigation schemes to reduce the impacts of current and new activities developed. Impact assessment methods must also be improved and must incorporate reindeer herders' knowledge of traditional land use.

Linking traditional and scientific knowledge

The adaptive capacity of reindeer husbandry is an integral part of the practice and is based on cooperation between the herders. The EALÁT project has tried to learn more about these adaptation strategies by comparing traditional knowledge with modern scientific knowledge, with a focus on winter conditions. Over 60 elderly reindeer herders in Western Finnmark were interviewed in Northern Sámi (the professional reindeer herding language in the survey area) about snow and its role in reindeer herding. A new method was developed for Siida based (siida: Sámi reindeer herding group) monitoring of snow and grazing conditions, whereby weather, snow conditions and herd behaviour were recorded on a daily basis over a period of three years. These data were then compared with meteorological data.

This is a first step to gain insight into the effects of temperature and wind on local snow conditions and thereby the grazing conditions. Over 300 noun stems have been documented in Northern Sámi that describe various types of snow and snow conditions. This clearly illustrates a scope and depth of knowledge about snow, which until now has not been recorded.

Re-introduction of castrates?

Reindeer herders have traditionally maintained high levels of phenotypic diversity in their herds. The Sámi concept of a "beautiful" herd of reindeer (áppa eallu) incorporates an understanding of diversity, which is the antithesis of the monocultures of modern agriculture.

The diversity of the reindeer herd structure reflects a strategy that is aimed at reducing the vulnerability of the herds to the consequences of unfavourable – and unpredictable – conditions. In this way seemingly "non-productive" animals have particular roles, which contribute to the productivity of the herd as a whole. For example, in the 1960s reindeer herds in Finnmark (which today are found in the YNAO) typically comprised up to 50% adult males, many of which were castrated. Today few herds in Finnmark comprise more than about 10% large bulls due to the emphasis on meat production and the system of subsidies.

Castrates have many functions: they do not go into rut, are calmer, heavier and it is believed, better snow-diggers in the winter. Climate change and rising winter temperatures may lead to poorer conditions in the form of ice and hard snow layers, which may make access to food for females and calves more difficult. The EALÁT project proposed the re-introduction of castrates as a possible strategy for better winter survival and improved welfare for individual animals and for the herd, but this research is still in its preliminary stages.

The Sámi castration method "gaskit", was traditionally performed with the teeth, without anaesthesia. Animals castrated using the "gaskit" method appear to behave differently from those that are castrated using the modern Burdizzo method. In a pilot study under the EALÁT project, which combined traditional knowledge and new technology, reindeer bulls were also castrated after immunisation with an vaccine.

Significance of climate change

According to reindeer herders the behavioural patterns of reindeer can also be understood in terms of cyclical changes – based on seasonal variations throughout the year, the revolution of the moon and the cycle of day and night. The basic needs of the animals are access to food and water and space for rest, shelter and for physical activity. These are essential for the reindeer's growth and physical well-being and for rutting and calving. Although it can be assumed that climate change will affect the growth of reindeer calves, research under the project has shown that mean ambient temperature in the winter of gestation was only one of six abiotic environmental variables tested that could be associated with a putative climate-driven trend in the growth of calves. It seems likely that warmer winters projected for the region will enhance the growth of calves in the summer months.

Another effect of climate change is that reindeer lichen is likely to be exposed to increased UV-B radiation, so reducing the lichen's taste and digestibility. Under the project the interactions between usnic acid and the reindeer rumen microflora were studied in order to gain a better understanding of the reindeer's adaptive capacity and welfare. The result was the discovery of a new bacterium (Eubacterium rangiferina) in the reindeer rumen that has adapted mechanisms to deal with the antibiotic usnic acid. Usnic acid has the potential to depress rumen

Reindeer herding in the Yamal-Nenets Autonomous Okrug is a lifelong learning process. Rita Serotetto from Brigade 8 at Yarsalinsky reindeer herders association on the Yamal Peninsula in Russia. Photo: Ellen Inga Turi

The Sámi reindeer herders Nils Petter Utsi and Ole Isak Eira. Photo: Philip Burgess

methane production, and hence reduce loss of energy by the animal and mitigate the effects of greenhouse gas emissions.

Governance of reindeer husbandry and the value chain

Governance frameworks for reindeer herding at the regional, national and international levels have a fundamental impact on reindeer herding. Institutional settings, where reindeer herders' traditional knowledge and organisation are restricted, pose a significant challenge to the reindeer herders' inherent adaptive capacity. Crucial strategies in this respect involve modifying policy incentives or forces that counteract traditional herd diversity and organisation, removing obstacles that prevent access to pastures and improving the economic basis for reindeer herding by re-establishing access to and ownership of important activities in the value chain.

It is argued that the present loss of the most profitable parts of the reindeer meat value chain (slaughtering and marketing) seriously hampers the herders' ability to cope with change. The costs arising as a result of climate change can best be met by giving herders access to the profitable end of the market.

EALÁT Information

The EALÁT Information project held local community-based workshops in tundra and taiga reindeer herding regions, which focused on climate change, traditional knowledge and the loss of traditional grazing land. To date the project has organised 21 such workshops in Norway, Sweden, Finland, Canada and Russia.

The community-based workshops provided an arena for the exchange of scientific and traditional knowledge, facilitating dialogue between reindeer herding communities and researchers. Participants of the workshops were able to gain increased insight into the other group's knowledge base, understanding and perspectives. Local authorities were also invited to participate, thereby incorporating governance as a third dimension. Priority was given to securing the participation of young reindeer herders.

The reindeer herding regions studied vary considerably in terms of pastures, local climate and topographic conditions, indicating that the original adaptive capacity of reindeer herding as a system is high. The EALÁT project sees adaptation to climate change as something happening at the local level, where local reindeer herding societies themselves work together with researchers to define risks and possible adaptation strategies and to produce new knowledge.

Local capacity building is a key aspect of the EALÁT concept. To this end, three local information centres for reindeer herding have been established in the Sakha (Yakutia) Republic in eastern Siberia. Following the EALÁT workshops a housing programme for reindeer herders was implemented in Sakha, and in the village of Khatystyr in eastern Siberia a street with new houses was named after the EALÁT project. All the workshops voiced the importance of private ownership of individual reindeer (which is not the norm in Russia) as essential to strengthening the resilience, adaptive capacity and motivation of the reindeer communities.

EALÁT Outreach

The Reindeer Portal (www.reindeerportal.org), the EALÁT website (www.ealat.org) and the Reindeer Blog (www.reindeerblog.org) were created as a means of disseminating and providing information about reindeer husbandry in general and about the EALÁT project in particular. The EALÁT site carries information produced by the project itself, as well as photographs, maps, videos and social networking tools in English, Sámi and Russian. The combined traffic to the websites is now over 100 000 visitors from 161 countries who have visited over 250 000 pages. Web production partnerships were established with several communities in the Yamal Peninsula, the Republic of Sakha (Yakutia) in the Russian Federation and in Finland, and training sessions in multimedia production and web production were held.

In cooperation with the Sámi University College in Kautokeino, Norway, the EALÁT project developed a course in reindeer husbandry entitled "Learning by Herding". More than 55 students from reindeer herders' communities have participated in the course over the past 4 years. Leading scientists from both the natural and social sciences have taken part as teachers, supervisors and examiners, side by side with experienced Sámi reindeer herders.

Tailor-made online courses have also been developed (SAJO) and lessons learned from the process are being widely used at the Sámi University College. Experience so far indicates that it is possible to implement a vocational education model adapted to the needs of reindeer herders in a way that enables traditional knowledge and science to go hand in hand. Some 41 reindeer herders are currently participating in the online course and programme. The course was developed by a doctoral student in the EALÁT project, who was awarded a prize for best online teacher in Norway in 2010.

An online course entitled "Adaptation to Globalisation in the Arctic: The Case of Reindeer Husbandry" was also developed and launched in January 2011, with over 35 students from Russia, Norway, Finland, Sweden, the US, Canada and Mongolia. It is a Master's level course under the Thematic Networks programme of the University of the Arctic and is a follow up to ACIA Chapter 17 (Arctic Climate Impact Assessment). The EALÁT project has also organised two courses for more than 25 upper secondary school teachers from all over Norway.

Further activities

The EALÁT Research project is nearing its conclusion, but the network that was launched will continue thanks to the relatively recent establishment of the University of the Arctic Institute for Circumpolar Reindeer Husbandry (Arctic EALÁT Institute), as a legacy of IPY 2007–2008. The institute will be a tool for recruiting indigenous youth to scientific work, by continuing the work of the IPY EALÁT project.

*Co-authors: R. Benestad, M.P. Bongo,, R.G. Corell, A. Degteva, V. Etylen, I.M.G. Eira, R.B.M. Eira, O.I. Eira, I N.I. Eira, E. Førland, C. Jaedicke, I. Hanssen-Bauer, D.V. Schuler, D. Hendrichsen, D. Griffiths, J. Gebenlein, E. C. H. Keskitalo, V. Kryashkov, A.M. Magga, N. Maynard , L. Moe, C. Nellemann, E. R.Nergård, H. Omma, N. Oskal, Ø. Ravna, M. Pogodaev, K. E. Præsteng, E. Reinert, M. A. Sundset, E.I. Turi, J.M. Turi, E.Sara, M.N. Sara, N. Tyler, and I. I. Vistnes.

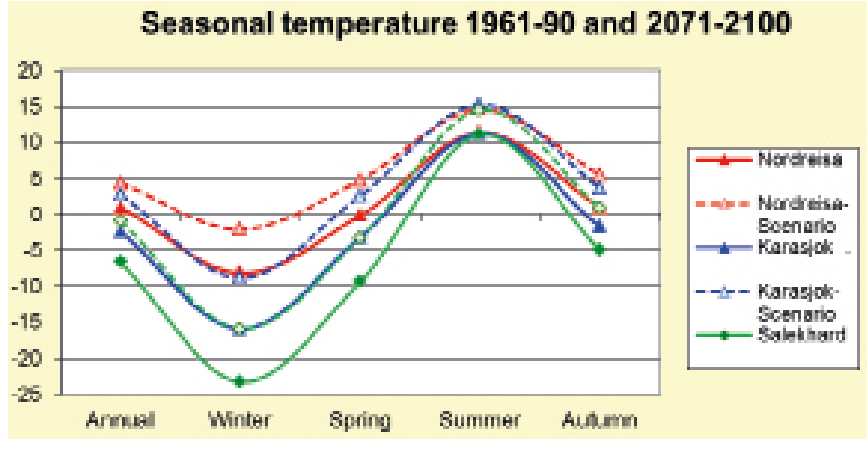


FIGURE 1: Average annual temperatures by season. The coastal areas in Finnmark, Norway (Nordreisa municipality) in red, inland in Finnmark (Karasjok) in blue, and the Yamal-Nenets Autonomous Okrug (Russia, Salekhard) in green. Solid lines show observed results from 1961 to 1990. Dotted lines show potential scenario from 2071 to 2100.

Sámi reindeer herder, linguist and doctoral fellow on the EALÁT project Inger Marie Gaup Eira assess the snow quality. Photo: Philip Burgess

Oil Activity in northwestern Russia and the living conditions of indigenous peoples

By Winfried K. Dallmann

Photo: Øyvind Ravna

MONITORING OF DEVELOPMENT IN TRADITIONAL INDIGENOUS LANDS OF THE NENETS AUTONOMOUS OKRUG, NORTHWESTERN RUSSIA (MODIL-NAO)

Project owner: Norwegian Polar Institute (NP)
Partner institutions: Association of Nenets People Yasavey
Project manager: Winfried Dallmann
Total budget: NOK 1.2 million
Dissemination measures, public and user-oriented: 1
Mass media coverage: 5
Presentations published from international meetings/conferences: 3
Other reports and lectures from scholarly fora: 4
Home page: http://npolar.no/ipy-nenets/

The Nenets Autonomous Okrug (NAO) in northwestern Russia is experiencing major environmental impacts as a result of oil and gas activity in the area. The tundra and reindeer pastures are being destroyed or polluted on a large scale. The MODIL-NAO project has mapped data and generated findings that are significant for future dialogue between the parties.

The NAO is home to an indigenous population of approximately 8 000 Nenets and 3 000 Izhma-Komi out of a total of approximately 42 000 people. Many of them depend directly or indirectly on reindeer husbandry, fishing and hunting for their livelihood. In the past, reindeer pastures covered almost all of the territory (Figure 1).

Impact of oil and gas activity

Now, however, large tracts of land have been degraded by oil prospecting and production or have become difficult to access across oil pipelines (Figure 2). Lakes and rivers are increasingly polluted. The Timan-Pechora oil province situated in the NAO and the Komi Republic is one of the largest oil development areas of the Russian north. Close to 100 oil and gas fields have been discovered in the NAO alone. Some 25 different oil companies have licences to develop the resources. The annual volume of crude oil extracted is more than 18.7 million tons (NAO, 2009) – out of a total Russian oil production of 580 million tons (2007).

Exposure to industrial development of this magnitude has resulted in significant environmental impacts that influence traditional livelihoods. Furthermore, there is an intricate legal system of land use rights in place, which – along with a variety of specific social factors – creates a complex socio-economic landscape for the indigenous population. Analyses are often hampered by the fact that even data such as that relating to the spatial distribution of affected areas remain unknown. In addition, public access to environmental map data is very limited in Russia.

Project design

The MODIL-NAO project was planned against this backdrop and carried out under the framework of International Polar Year during the period 2007–2009. The project was a collaborative effort between the Norwegian Polar Institute and the Association of Nenets People (Yasavey), with the participation of scholars from the fields of anthropology and law.

Unlike most of the IPY projects, the MODIL-NAO project was not part of a cluster. The reason for this was that it had been developed over a long time, on the basis of a relationship of trust between the main stakeholders. A high level of trust is considered essential in projects where representatives of indigenous peoples play a major role alongside scientists. It could undermine this trust if responsibility for the project had been transferred to a higher level and if the project had become too big. However, open data exchange was agreed with the GAPS and EALÁT projects, which had overlapping interests.

GIS database

The MODIL-NAO project sought to collect modern data on land use in the NAO and to convert the data into a form that could be used for the purposes of public debate. The primary objective was to give the indigenous population of the NAO a tool – a GIS map database – to use in promoting their interests. The database, which can be accessed openly on the Internet (from the MODIL-NAO project website: http://npolar.no/ipy-nenets), is interactive, and shows traditional and industrial activities in the NAO in a Google Earth compatible format.

Rights to maintain and extend the database are held by the Association of Nenets People Yasavey and the Norwegian Polar Institute, which provides help with technical maintenance and assists with the posting of new data at Yasavey's request. Figure 2 shows an example of map data from the database around the Varandey oil terminal.

Interviews, mapping, analysis

In order to assess the impacts of modern development on the traditional livelihood of indigenous people, a survey was carried out among traditional land users, mainly reindeer herders. Reindeer herders and other villagers from six areas in the NAO were interviewed about various aspects of their lives, their traditional occupations, their socio-economic situation, and the condition of their natural environment.

Information about land use was drawn into maps. The respondents were mostly interviewed by co-villagers who were trained for this purpose at seminars in the Okrug capital of Naryan-Mar. The six study areas encompass areas where the physical impact of oil-related activities is described as absent, moderate or strong. Satellite images from Google Earth (http://earth.google.com) were used to monitor visible, physical damage to the tundra.

A juridical analysis summarises federal and regional legislation on land use issues and investigates current licence agreements with respect to legal obligations.

Together with publicly available information, these data were used to assess several aspects of the situation of the indigenous population of the NAO. The data and the assessment have been published in a comprehensive project report.

Reindeer herding is the primary traditional occupation of the Nenets area Photo: Yasavey, september 2002

Seminar for interviewers from various villages, Naryan-Mar, September 2007. Photo: Winfried Dallmann

Challenges to project implementation

The particular challenges encountered during implementation had their origins in the very nature of the project itself: (1) the collaboration between scientists and indigenous people, and (2) working on politically sensitive issues in Russia.

A loose network between the main stakeholders of the project existed prior to the project. The existence of an already-established relationship of trust between the scientists and the indigenous people's representatives was undoubtedly an advantage and saved time. The local population could count on the fact that the scientists were not simply pursuing their scientific agenda but that their highest priority was to assist the indigenous society in meeting its knowledge needs. The indigenous representatives were also better placed to accept that proper scientific methods have to be applied and that researchers need to publish their results. The MODIL-NAO project was successful in creating an alliance between scientists and indigenous representatives and lessons learned from the project may be useful for future projects.

Cooperation with the regional authorities in the NAO posed another key challenge, and was hampered due to the rapidly changing political leadership in the NAO, and the resulting varying degrees of interest in the project. Although understanding and cooperation with some regional departments – especially those concerned with indigenous issues and reindeer husbandry – was good, it was not possible to obtain data on oil development from official sources. Apart from this, there were no political obstacles that prevented the project from being implemented as intended.

Indigenous people have little influence

Besides the establishment of the GIS database, the project resulted in a number of general findings, of which the following are considered the most important:

- As well as the deterioration and reduction of the pasture areas, reindeer herding units are experiencing a number of other difficulties. These include social factors such as poor management, reindeer husbandry's loss of prestige as a livelihood, the loss of traditional knowledge, a significant change of values in the Nenets community, social apathy, unemployment, and, in connection with the latter, alcohol abuse.
- There are frequent complaints by local populations regarding oil companies and their responsibilities in respect of pollution of pastures, illegal waste disposal, pollution of water resources, decrease of fish stocks, poaching by oil workers and others, and attacks by stray dogs on domestic reindeer.

Criss-crossing vehicle tracks caused by driving on unfrozen ground in the Varandey area. Such activity causes considerable harm to the tundra soil and vegetation and is illegal in Russia. Photo: Yasavey, september 2002

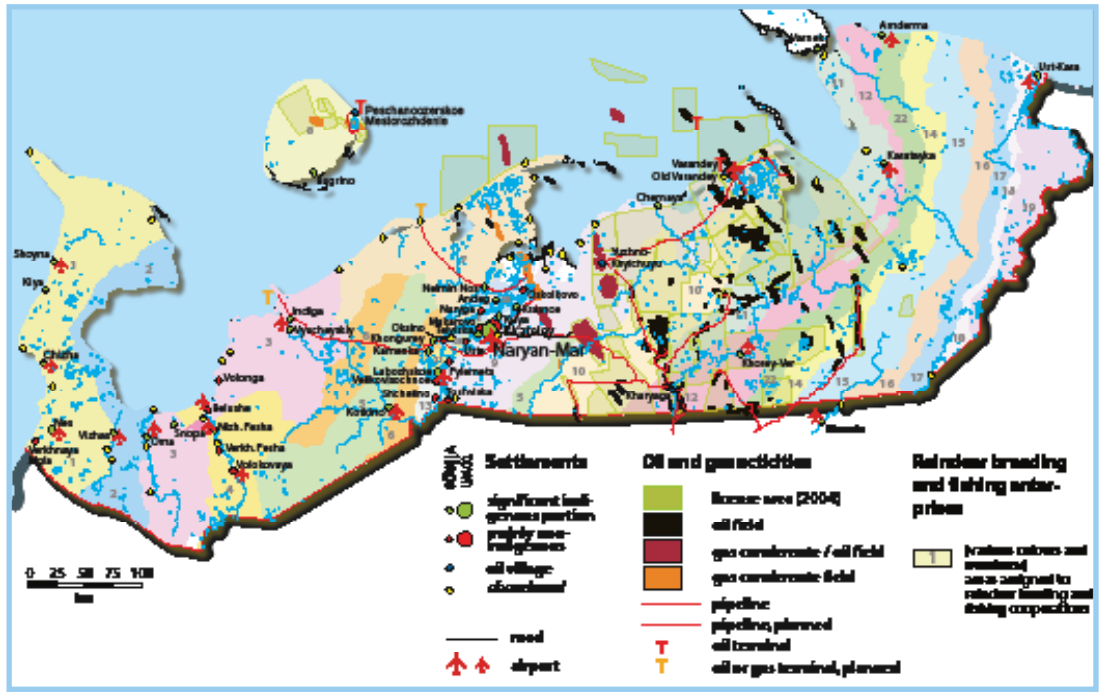


FIGURE 1: Overview map of infrastructure, traditional and modern land use in the Nenets Autonomous Okrug.

Nomadic people migrating north. Photo: Øyvind Ravna

- ➔ In areas where future oil development is expected, people fear the negative impact it will have on traditional land use. In areas where oil development has been a reality for some time, people notice this negative influence but at the same time see an improvement in the economic situation and the social security system as a result of investments by oil companies.
- ➔ Traditional land users have little or no influence over most aspects of the development of oil and gas installations, beyond providing minor technical recommendations.
- ➔ The high consumption of traditional food among traditional land users indicates the indigenous population's high degree of vulnerability in the event that traditional sources of subsistence are reduced or eliminated. The permanent replacement of traditional food by market food will seriously affect the health and the general well-being of the indigenous population.
- ➔ Environmental regulations are not satisfactory, as there are no effective mechanisms of control. There is a serious lack of control over the use and misuse of the environment; companies unlawfully use tracked vehicles on summer pastures, pollute lakes and rivers, etc.
- ➔ Only a few companies fulfil their legal obligations towards indigenous peoples. In recent years the trend shows that such obligations are no longer included in licence agreements.

Outlook

The project has had a strong outreach component as a result of its online interactive GIS database. The MODIL-NAO database is the first GIS database of this kind, fully employing the most recent Google Earth applications for the purpose of promoting public debate about land use issues. Technical upgrades of the applications are expected to be carried out on an annual basis.

The original project idea was to track developments over a number of years, and to extend the investigated area to encompass the whole of the NAO. Yasavey has plans to do so, provided that funding can be found. One of the goals of the MODIL-NAO project was that it would serve as a pilot project for similar, future projects in other areas of the Russian North or at the international level.

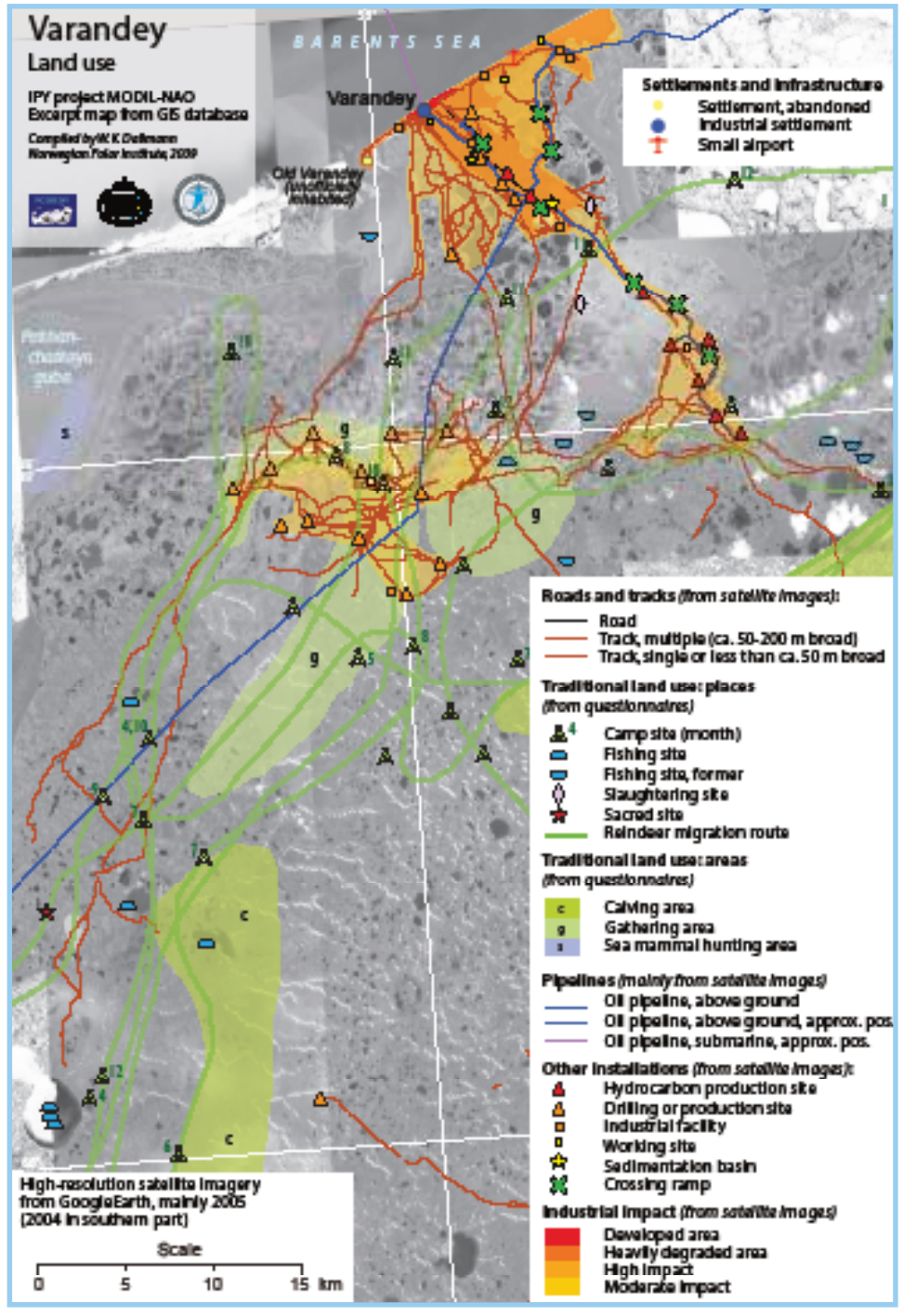


FIGURE 2: Detailed map of area close to the oil terminal Varandey, excerpt from MODIL-NAO database, superimposed onto a satellite image from GoogleEarth. The map shows an example of the type of detailed map data contained in the project's database, which is available on the Internet. The selected map data shows oil facilities, classification of the physical degradation of the tundra (both obtained through satellite image interpretation), and indigenous land use (obtained from a survey). Although partially degraded areas are still used by reindeer herders, the high number of abandoned fishing places close to the oil rigs is striking.

Research and communication on climate change and adaptation strategies

By Eiliv Larsen and Gudmund Løvø

Photo: Katrine Husum

ARCTIC NATURAL CLIMATE AND ENVIRONMENTAL CHANGES AND HUMAN ADAPTATION: FROM SCIENCE TO PUBLIC AWARENESS (SCIENCEPUB)

Project owner: Geological Survey of Norway (NGU)
Project manager: Eiliv Larsen
Total budget: NOK 20 million
Doctoral fellowships: 2
Post-doctoral fellowships: 3
Dissemination measures, public and user-oriented: 81
Mass media coverage: 128
Articles published in scientific and scholarly journals: 21
Books published: 1
Presentations published from international meetings/conferences: 91
Other reports and lectures from scholarly fora: 37
Home page: http://www.ngu.no/sciencepub

The SciencePub project was an extensive communication and research project that set itself high goals in terms of promoting research, communication and education across disciplines and institutions. The aim of making research and communication equal, integrated components of the project with separate and common goals was both innovative and challenging. Today, at the end of the project, it is generally agreed that the project succeeded in achieving this aim. The close integration of research and communication on an equal footing from day one of the project has enhanced the contribution towards a lasting legacy of knowledge.

Today it is expected that the effects of future climate change will first be noticed in the Arctic. The SciencePub project has mapped natural climate variations from the Ice Age and conducted a thorough analysis of how the pioneer settlement in Finnmark adapted to the tremendous changes that followed. Under the SciencePub project further understanding of the future was sought through the study of past events.

Project design

The project was organised as a field-based research and communication consortium in which participants from 10 Norwegian institutions took part. In addition, there was extensive collaboration with foreign, in particular Russian, colleagues.

The project organised 17 land expeditions and marine voyages. These set out to northwestern Russia, Finnmark, Svalbard and several other areas in the Barents Sea, as well as to the northern areas of the Norwegian Sea.

Under the project geological methods were used to study past climate variations. These were compared with archaeological investigations to find out how ancient people adapted to these changes. Students were also educated in the fields of geology, archaeology and journalism, and extensive education and outreach activities were carried out in the form of communicating research results and descriptions of the various steps in the research processes. The attitudes of journalists and scientists towards climate issues were also studied under the project.

Researchers and disseminators collaborated across all subjects, disciplines and cultural boundaries. A considerable amount of the work was conducted in small cross-disciplinary groups out in the field, in laboratories or through exhibition-related activities. All efforts carried out have had geological, archaeological and communication aims. As data was collected on past climates and humans, disseminators were busy educating media students, working on exhibitions, as well as reporting on ongoing field work and popularising research results.

Challenges encountered during the project

From the outset, the main challenge facing the project was to get the diverse groups of participants to function together so that a synergy effect could be achieved. The key was to ensure that all participants had equal ownership of the substance of the project and its results.

The project was successful in this respect because all the participants from the various professional fields had been involved right from the start, from the day discussions began about whether or not to apply for IPY funding. All the project partners participated in defining the content and objectives of the project. This also helped to clarify the various elements of the project for the participants, which was essential to ensuring that the cross-disciplinary potential was utilised to the full. In many ways it can be said that the SciencePub project was a good lesson in project collaboration.

Findings – from the Ice Age to the present day

The methods used to reconstruct past oceanic climates have been significantly improved. Micro-fossil studies cover more modern-day climate situations than previously. Thus, the basis for understanding past climates has been strengthened under the project, although it is still difficult to reconstruct ocean temperatures below approx. +2^{O}C.

Research carried out under the project demonstrated that it is not only surface water masses that can warm up very rapidly, but also deep water masses. Investigations on the continental margin, west of Svalbard, the Barents Sea and the fjords in North Norway, show rapid and intense temperature fluctuations during the last 2 000 years (Figure 1). It has also been shown that the fjords in North Norway went from having a full Ice Age climate to the climate of today in the course of just 200 years, i.e., oceanic circulation acquired full interglacial conditions in a very short time.

In order to understand natural climate boundary conditions, significant work was carried out to reconstruct how the glaciers varied throughout the last Ice Age. These studies were restricted to northern Russia and western Svalbard.

Ample deposits from this period are available in these areas. The glaciers were in contact with the sea, and therefore potentially crucial for ocean circulation. It has been demonstrated that the maximum ice extent reached during the last Ice Age was greatly delayed in the east compared to western areas, and that the ice had melted and receded a great deal before it reached its maximum position in the east (Figure 2). The study also showed that the ice was somewhat more extensive in Russia than previously assumed.

In both Svalbard and Russia, there was an extremely complex interaction between fast flowing ice along the main drainage routes and slower moving ice in between.

In addition, it was found that the drainage of the large lakes, which had been dammed up by the glaciers in Russia, provided the sea with less water volume and extended over a longer period of time than previously thought. This means that our understanding of the effect on the climate of the interaction between the glaciers and the ocean must be given greater nuance.

As the ice receded, human immigration began. Comprehensive reconnaissance, as well as extensive excavations and analyses, have provided more detailed insight into how people in the pioneer age related to the receding ice, sea level fluctuations and temperature changes.

In East Finnmark, settlement patterns and technology were studied in detail. It is now clear that the people in the area managed to meet the challenges of climate change encountered during the pioneer age without having to change their robust technology or their financial or social structures.

Investigations in northern Russia also showed somewhat unexpectedly that at the time of the Last Glacial Maximum people chose to live close to the glaciers because of the good hunting opportunities there. Perhaps global warming was the greatest challenge for them as it is for us?

Climate knowledge and policy

The SciencePub project generated a great deal of new knowledge about climate change. It also posed questions relating to our professional and private roles as researchers and journalists in our handling of this issue. The results provide food for thought. At Oslo University College, the norms and values of journalists and researchers dealing with the climate issue were examined closely. The survey shows that journalists strive to a large extent to retain a balance when reporting on climate issues. Researchers view objectivity as an absolute criterion, but they allow themselves to be more politically active than journalists. It appears that researchers do not believe that this influences their objectivity as professionals. Journalists are educated and trained to know that their work and journalistic integrity will be compromised if they become politically involved and they are therefore more cautious. Nevertheless, there is some indication that a minority of journalists appreciate the severity of the climate crisis and experience the requirements of the journalism profession in Norway as more of a strait-jacket. Perhaps the norms need to be re-evaluated to give these journalists more leeway.

Lasting legacy of knowledge

All new knowledge that is generated and communicated, both in scientific journals and in the form of popular science publications, contributes to the creation of a common legacy of knowledge. Under the SciencePub project a long list of scientific and popular science articles and lectures was produced, as well as numerous media articles. The project participated in a number of museum exhibitions, as well as in Norwegian Science Week and established a project website, which includes blogs from the field work and cruises.

The SciencePub project provided education for journalism students as well as students studying for a bachelor, master's or doctoral degree in geology, archaeology or media studies. In addition, a number of young researchers were awarded post-doctoral fellowships. These students and researchers came from six Norwegian institutions, in addition to Stockholm University and Herzen University in St. Petersburg. Thus, the project provided the foundation for the careers of several young polar researchers, who will influence their professional field for years to come.

The students of journalism gained insight into geological and archaeological research processes and methods, which they will take with them into their future careers.

Extensive communication activities

The researchers learned a lot about communication, knowledge that they will be able to bring to new projects. In partnership with the Trondheim Science Centre, a geological laboratory targeted towards adolescent pupils was developed. The laboratory was used by lower secondary schools in Trondheim and Bergen, and will continue to be used after the end of the project period by schools in Steinkjer, Tromsø and Longyearbyen respectively.

A number of lectures were given at upper secondary schools for pupils and natural science teachers, and teachers also joined the field expeditions. A national climate competition for pupils was also organised in which the first prize was participation in field work in Russia. The prize went to two girls from Bergen. Last, but not least, the SciencePub project is involved in a project entitled Polarskolen.no ("Polar school"), which will adapt film and photographic material collected in connection with International Polar Year for use in schools.

As mentioned above, the SciencePub project was a good lesson in project collaboration, made possible by the fact that all those involved felt that they had proprietary interest in the project and its results. The project accomplished a lot in the fields of research and communication, but achieved most in terms of establishing effective collaboration across the two. This is something that will be useful in future projects.

Five geologists from four different countries study sediments deposited approx. 60 000 years ago in an ice-dammed lake in Russia. Photo: Gudmund Løvø

Geologists study a beach ridge on the west coast of Svalbard. The investigation shows that the sea level is rising in this area. Photo: Heidi T. Ryen

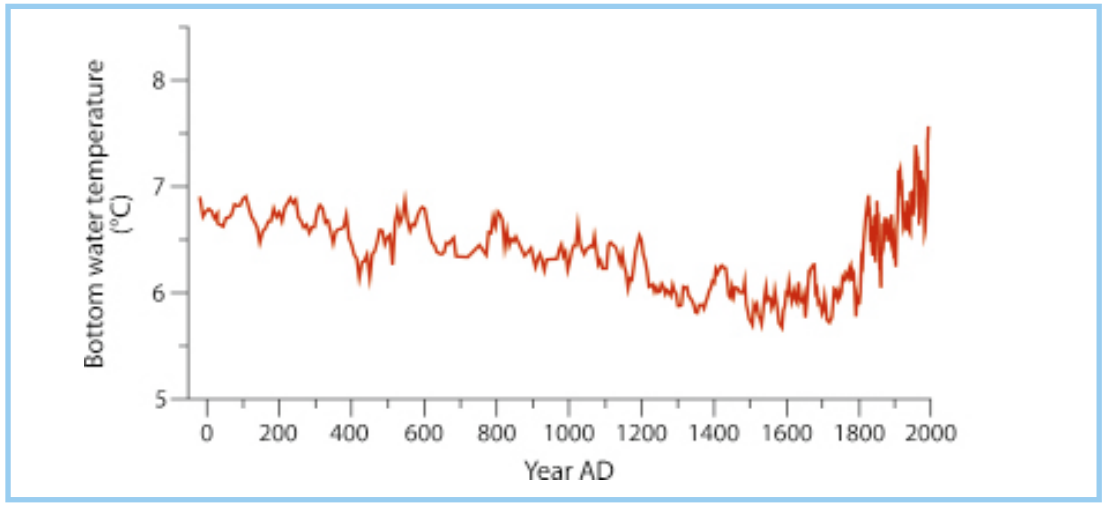


FIGURE 1: Bottom water temperatures in Malangsfjorden over the past 2 000 years. Cooling towards the Little Ice Age approx. 1300–1700 AD and warming to the present day is extremely pronounced. Provided by Hald et al. (in press).

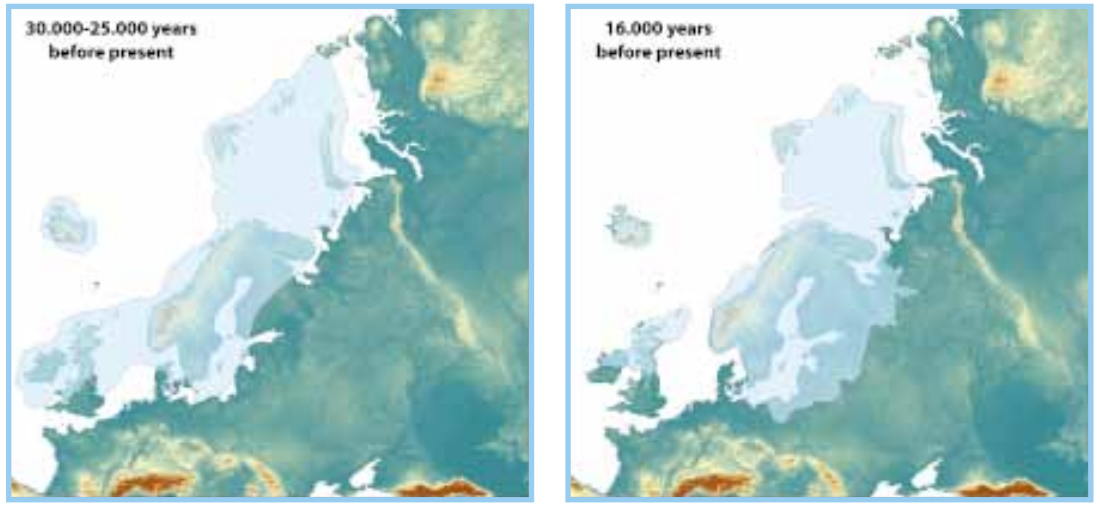


FIGURE 2: The Last Glacial Maximum was delayed by approx. 10 000 years in the eastern parts of the ice sheet as compared with the western parts. When the ice finally reached its maximal position in the east, it had already been melting and receding in the west for a considerable period of time. Provided by Larsen et al. (2010).

Ice Age research in the Ural Mountains – on "unusual" glaciers and mammoth hunters

By John Inge Svendsen, Øystein Strand Lohne and Jan Mangerud

Photo: Øystein Lohme

THE ICE AGE DEVELOPMENT AND HUMAN SETTLEMENT IN NORTHERN EURASIA (ICEHUS II)

Project owner: University of Bergen (UiB), Department of Earth Science
Project manager: John Inge Svendsen
Total budget: NOK 8 million
Dissemination measures, public and user-oriented: 18
Mass media coverage: 18
Articles published in scientific and scholarly journals: 33
Books published: 15
Presentations published from international meetings/conferences: 82
Other reports and lectures from scholarly fora: 12
Home page: http://www.gyllencreutz.se/ICEHUSII.html

The Ural Mountains have remained ice free for more than 50 000 years. Not even during the extremely cold final stage of the last Ice Age, when Svalbard and the Norwegian mainland were encapsulated in thick ice, did sizeable glaciers form in the Ural Mountains. Analysis of sediment cores can shed light on the vegetation history and tell us something about why the glaciers in the Urals behaved differently from those further west.

Surprising contrasts in the north

Research carried out in northern Russia (Figure 1) has revealed some sharp contrasts between east and west in terms of climate development, glacier variations and human occupation. During the Last Glacial Maximum some 20 000 years ago, when ice 2 000 metres thick covered the Barents Sea and the Scandinavian ice sheet reached northern Germany, the glaciers in the Polar Urals appear to have been surprisingly small.

During the early stage of the last Ice Age, around 90 000 years ago, the situation was quite different. At that time an even bigger ice sheet came into existence over the Barents and Kara Seas, and this time it reached far into the Russian mainland. The advancing ice front blocked the large northbound rivers (Pechora, Ob, and Yenisei) forming huge ice-dammed lakes that spilled over the low water divides towards the Aral, Caspian and Black Seas.

Despite the bone-dry climate of the long-lasting ice-free periods, the northern landscapes were lush and hosted herds of herbivorous animals.

Along the foothills of the Ural Mountains stone tools and remains (bones) have been found belonging to humans who crossed the Polar Circle more than 40 000 years ago, i.e. 30 000 years before the first Stone Age humans followed the retreating ice edge to Norway (Figure 2). At the dwelling sites remnants of reindeer, bears, woolly rhinoceroses, bison, horses and other animals were found. However, it appears that the woolly mammoth was the most important prey. Who were these hunters and do the sites represent temporary or more long-lasting settlements?

Hypotheses need to be tested

Various research findings have been generated through several projects supported by the Research Council of Norway since 1993. The many observations that have been made over the years, and in particular the interpretations and reconstructions, have changed the overall understanding of the development of the Ice Age to a considerable degree. Nevertheless it is important to subject these hypotheses to adequate testing to further refine understanding of these findings.

Field investigations have been carried out in an area that is several times the size of Norway, so it is clear that the picture is far from complete. The challenge was to find the way in which the working hypotheses could best be tested, and the results from archaeological excavations and the mapping of former ice sheets and drainage bound together.

Idea for an IPY project

When the IPY programme was launched, the project decided to find out if geological archives in the lakes of the Ural Mountains could be used to test the working hypotheses. It was hoped that sediment cores from such basins would provide continuous records of the natural environment and climate against which to compare and correlate observations.

Previous attempts had revealed that most of the lakes on the lowland had not been formed until the permafrost started to thaw some 15 000 years ago. In the valleys of the

Hauling the equipment is heavy work. Photo: Herbjørn Presthus Heggen

Alexei drilling sediment cores.
Photo: Herbjørn Presthus Heggen

Ural Mountains there are many "bedrock lakes" that are more stable than those formed in unconsolidated gravel and till on the lowland. The challenge was to find lakes that existed as long ago as the period when humans were hunting mammoths.

Field work was begun in the Polar Urals using the coal mining town of Vorkuta as a base. Vorkuta, which was one of Stalin's most notorious forced labour camps, is situated on the windswept tundra on the western flank of the mountain range. During the late winter of 2007 a lake situated a few hours' drive by caterpillar vehicle from Vorkuta was cored. Heavy Russian motorised drilling equipment that could core deep into the bottom sediments from the frozen lake was used. However, that year the mild weather started much earlier than usual, and in mid-April both equipment and personnel had to be evacuated. Some cores had been retrieved but they revealed that the lake had only existed for some 11 000 years. Older lakes needed to be found to test whether the hypothesis about old lakes was true.

Challenging and successful

A decision was taken to examine the largest lake in the Polar Urals, Lake Bolshoye Shuchye, which is situated deep in the mountain chain (Figure 1). Transport to the lake took place in converted military weasels and took about 13 hours. The previous seismic surveys showed that a water depth of 140 m and it became clear that there was at least 130 metres of soft silt and clay beneath the lake floor.

The Russian equipment that was originally intended for use had the capacity to core thick strata, but not in such deep water. US equipment designed for these conditions was beyond the financial means of the project. Instead an Austrian company was engaged to produce a coring rig that could cope with the deep water. However, the ambition of coring the whole sequence had to be abandoned.

The new coring operation, which was carried out during the summer of 2009, proved very demanding. That year the lake ice did not break up until July. However, more than a hundred metres of cores were brought up, the longest of which were 24 metres long. This was close to the maximum capacity for the type of equipment being used.

Achievements

The geological results indicate that the main valleys in the central part of the mountain chain have remained ice free for more than 50 000 years. Not even during the extremely cold final stage of the last Ice Age when Svalbard and the Norwegian mainland were encapsulated in thick ice did sizeable glaciers form in the Ural Mountains. However, traces were found of a large ice cap that existed 60 000–70 000 years ago.

The lake cores are now being used to try to find out why the glaciers in the Urals behaved so "differently" as well as to determine what the environment was like during the period when Ice Age humans took shelter along the mountains. Most of the analytical work remains to be done and the cores may reveal further surprises. In cooperation with French and Russian archaeologists a chronology of human visits to the area has been established and it may soon be possible to solve the riddle of whether these humans were Neanderthals or modern humans.

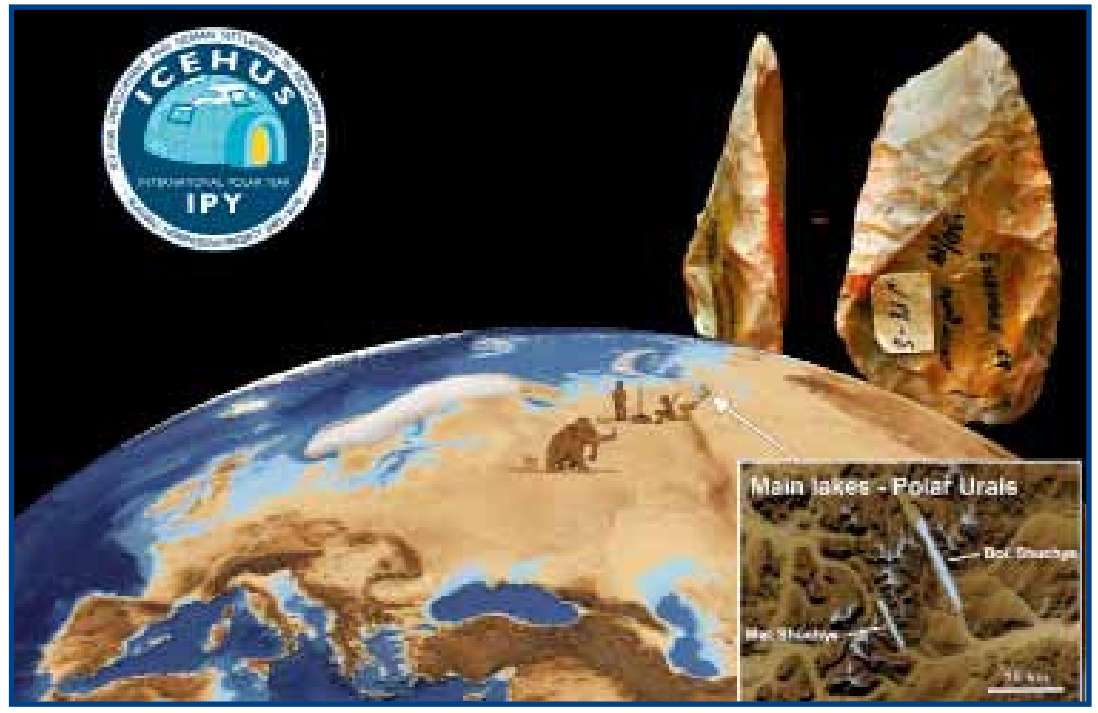


FIGURE 1: Field work took place in the polar Urals and adjacent lowland areas on both sides of the mountain chain.
Figure: Eva Bjørseth

FIGURE 2: Our knowledge of the Ice Age people and how the landscape has changed over time is partly based on field studies of uncovered strata, including archaeological sites and discoveries of bones and objects.

Different understandings of "security" in the context of oil and gas activity in the Arctic

By Gunhild Hoogensen Gjørv

Photo: Yasavey

THE IMPACTS OF OIL AND GAS ACTIVITY ON PEOPLES IN THE ARCTIC USING A MULTIPLE SECURITIES PERSPECTIVE (GAPS)

Project owner: University of Tromsø (UiT)
Project manager: Gunhild Hoogensen Gjørv
Total budget: NOK 6 million
Doctoral fellowships: 2
Post-doctoral fellowships: 1
Dissemination measures, public and user-oriented: 2
Mass media coverage: 3
Articles published in scientific and scholarly journals: 6
Presentations published from international meetings/conferences: 12
Other reports and lectures from scholarly fora: 11
Home page: http://www.ipygaps.org/

On the basis of interviews in several local communities as well as document analyses and cooperation with researchers across a wide range of disciplines, this project has developed a solid analytical foundation for how security is articulated and created around natural resource industries in the Arctic.

What does "security" mean to you?

This was the core question of the IPY GAPS project, which involved research activities in Norway, Canada and Russia.

The concept of "security" can elicit many different responses, ranging from positive feelings about community safety or individual well-being to negative ideas about restriction of liberties, "homeland security" or the use of militaries by the state. The wide range of possible responses reflects the concept's long and varied history. At its core, security is about identifying, prioritising, and protecting that which we value and ensuring its viability for the future.

Security has long been, and is increasingly, a concept employed in the Arctic region. This notion of security has been heavily influenced by over 40 years of Cold War rhetoric, which invoked images of the military, protection of borders and the Arctic region as the potential pathway for nuclear exchange between the superpowers. During the Cold War it became common to understand "security" in this way, as a matter for states, not for people.

More recently the notion of "energy security" has assumed a more central role as states seek security of access to oil and gas in a global context of uncertain markets and politically unstable oil and gas exporters (Middle East). This is an area in which the Arctic states such as Canada, Norway, and Russia have something to offer.

Greater focus on human security

In the 1990s human security and environmental security came more to the fore. Human security, which focused on individuals and was defined loosely as "freedom from fear, freedom from want" was popularised in the 1994 UN Human Development Report. Human security was promoted by both the Canadian and Norwegian governments as an important part of their foreign policy profiles, in part through the Lysøen declaration, in which Norway and Canada agreed to focus on a variety of important human security issue areas. These included land mines, child soldiers, and the impacts of war on women and children. However, tucked into this agreement on human security, without any explanation, was also "Arctic cooperation".

What did the Arctic have to do with human security? The human security concept was not used in relation to Canada and Norway. Human security has a normative agenda to make individual, "everyday" security concerns relevant and visible, and to make room to hear marginalised voices, highlighting health, food, economic, environmental, community (identity), personal and political security of individuals and communities. Are security needs voiced in Norway, Canada and other Arctic nations not relevant?

Objective of the project

The overall objective of the GAPS project was to examine how security needs are articulated by communities and individuals living in the Arctic who have thus far been excluded from discussions about Arctic security, and to compare these views with state-based perspectives.

According to the GAPS project, security is achieved when individuals and/or multiple actors have the freedom to identify risks and threats to their well-being and values

(negative security), the opportunity to articulate these threats to other actors, and the capacity to determine ways to put an end to, mitigate or adapt to those risks and threats either individually or in concert with other actors (positive security).

Oil and gas production currently plays such a central role in the development of Arctic policies, security, and society that it made sense to examine the multiple security perspectives surrounding this important issue. Oil and gas development affects the economic security of communities, as well as their identities, health and environment. Under the project different actors were asked about what they valued for the future, what should be protected, why and how. This process required learning to communicate across languages/discourses, between state elites who speak a specific language of security connected to sovereignty and threats against the states and communities that speak about risks, development, and threats to identity, between research and policy, and between different research disciplines from natural to social sciences.

Project design

This was accomplished through the development of a series of comprehensive theoretical models focused on a multi-actor security framework that

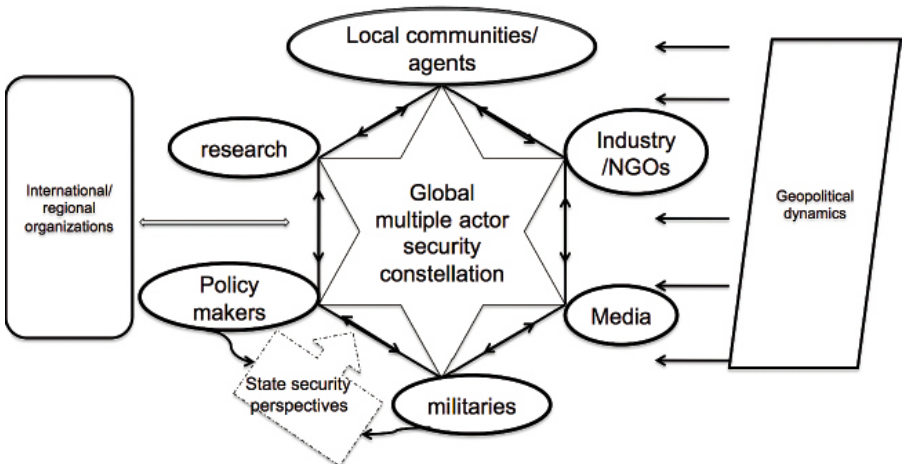
1. encompasses non-state actors (for example communities and research) and their security perspectives;
2. increases our understanding of the dynamics and tensions between different security perspectives;
3. identifies and makes visible the values that are important to the future of Arctic communities, and the actions taken at community levels, with regard to oil and gas development.

On the basis of interviews in communities such as Hammerfest, Lofoten, Murmansk, and villages in the Komi Republic (Russia), as well as document analyses, and cooperation with researchers across a wide range of disciplines (ecotoxicology, ecology, physiology, anthropology, geography and political science to name a few), the IPY GAPS project has been able to provide a solid analytical foundation for how security is articulated and created around natural resource industries in the Arctic.

But the process has not been without its challenges. Probably one of the greatest of these was posed by the concept of "security" itself, in that some people think it represents fear rather than a foundation for the future. Language and communication between people will always be one of the most interesting, and most difficult, features of a multi-actor perspective.

The IPY GAPS project has developed a basis from which to pursue the linkages between natural resource development, human impacts on the environment/climate, and human and social systems in the areas of energy, human health, identity, and environmental security. This knowledge will be shared through teaching and ongoing publications.

MULTIPLE ACTOR-BASED SECURITY MODEL



Documenting the Kven language and other minority languages in the northern areas

By Pia Lane

Photo: Pia Lane

THE LINGUISTIC AND CULTURAL HERITAGE ELECTRONIC NETWORK (LICHEN)

Project owner: University of Oslo (UiO)
Partner institutions: University of Tromsø, the University of Oulu and the Kven Institute in Børselv
Project manager: Pia Lane
Total budget: NOK 1.5 million
Dissemination measures, public and user-oriented: 1
Mass media coverage: 19
Articles published in scientific and scholarly journals: 4
Reports and lectures from scholarly fora: 6
Home page: http://www.hf.uio.no/iln/forskning/prosjekter/lichen/index.html

The objective of the LICHEN project was to document the Kven language, a language primarily spoken in Troms and Finnmark. As a result of the project a collection of sound recordings and transcripts of spoken language from Kven and Finnish-speaking areas from the period 1960 to 2009 is now available. This is one of the largest collections of its kind in the world, containing nearly half a million words in more than 76 hours of recorded material. The material will form the basis for developing the written Kven language, as well as a Kven dictionary and grammar.

Many languages in the northern areas are dying out

Linguistic suppression and heavy-handed assimilation policies have led to a situation where many languages in the northern areas are now in danger of dying out. Most of the minority languages are poorly documented. They have neither dictionaries nor a proper written language. The aim of the international LICHEN network is to develop electronic resources in order to document minority languages and cultures in the northern circumpolar region. The Norwegian LICHEN project focused on the Kven language.

The LICHEN network is an international IPY cluster. It is headed by the University of Oulu in Finland and comprises researchers from Canada, Finland, Norway, Scotland, and the US. The Norwegian project was headed by the Department of Linguistics and Scandinavian Studies at the University of Oslo. The Kven Institute in Børselv is coordinating efforts to develop a written Kven language, now using data from the Norwegian LICHEN project.

The Kven language

The main areas in Norway where the Kven language is used are Troms and Finnmark; more than 10 000 people in these two counties state that they speak Kven and/or Finnish, but the number of people that can read and write the Kven language is much lower. In April 2005 Kven was recognised as a separate language in Norway. Although its official name is Kven, many people say that they speak Finnish. In Øst-Finnmark in particular the use of the term 'Kven' remains the subject of heated debate. The Kven language is closely related to Meänkieli, a language spoken in northern Sweden, and to Finnish, but there are considerable differences in vocabulary and also some grammatical differences between the languages. However, many of the differences between Kven and Finnish have not been recorded, because sufficiently large collections of data have not been compiled before now.

Ethnographic fieldwork

Data was collected from the Kven-speaking areas of Finnmark in autumn 2008. The aim of the data collection was to make recordings of speech that was as close to everyday language as possible, a challenging task for researchers that are "outsiders". In autumn 2007 the project's field assistant Anna-Kaisa Räisänen, who was also doctoral fellow on the Finnish LICHEN project, spent time in a number of Kven-speaking areas in Finnmark. The project manager Pia Lane had informed her local contacts in advance, who welcomed Ms Räisänen and introduced her to people she could interview.

The interviews were partly structured to ensure that the same topics were covered with all the interviewees, but they did not follow a simple question-answer pattern. The interviews are therefore more like normal conversations. Some 39 of these conversations have now been transcribed, as have interviews conducted previously.

Tools

The aim of the Norwegian LICHEN project was to digitalise and transcribe old sound recordings in Kven, collect new data in order to test the tools being developed by the University of Oulu, and to make the sound recordings and transcriptions available for researchers. The lessons learned from processing the data on the Kven language will now be used to further develop the University of Oulu's electronic system so that it can be used for the documentation of other minority languages and cultures in the polar regions in other countries.

Photo: Vilfred Inglæ

Anna-Kaisa Räisänen interviewing Asgeir Samuelsen with his dog Quattro in Børselv, August 2007. Photo: Liisa Koivulehto, Ruijan Kaiku

Another important task for the Norwegian researchers in the future is to document the Kven language and culture by analysing and comparing old and new data. This will provide us with knowledge about how the language is changing and developing.

Particular challenges

The greatest challenge for the project was to coordinate efforts between geographically dispersed institutions. The solution was to provide training for the doctoral fellow on the Finnish LICHEN project Anna-Kaisa Räisänen, who in turn trained the transcription assistants in Oulu.

It became clear early on in the project that the University of Oulu's electronic system would not be completed by the time the Norwegian project was concluded. It was therefore decided to create a separate speech corpus, i.e., a collection of sound recordings and digital transcripts for the Norwegian project. This collection is called the Ruija Corpus and was developed by project manager Pia Lane in cooperation with the Text Laboratory at the Department of Linguistics and Scandinavian Studies, University of Oslo.

Most important finding

One of the objectives of the Norwegian LICHEN project was to acquire and process data material to enable the University of Oulu to develop and test its electronic language technology system.

In April 2010 another of the project's primary objectives was achieved when the Ruija Corpus was launched. The corpus is a collection of sound recordings and transcripts from Kven and Finnish speaking areas from the period 1960–2009 and is now available to researchers in password-protected form.

The Ruija Corpus is one of the world's largest minority language corpuses and contains nearly half a million words in over 76 hours of recorded material. It allows researchers to study how language and cultural expressions change over time. The data and research from this project are now being used as a basis for the teaching of the Kven language at the University of Tromsø and for the development of a written Kven language, as well as a dictionary and grammar for Kven.

Dissemination and further efforts

The project and the corpus have received much media attention. A corpus of this kind is a form of dissemination in itself, since it is now being used to develop the written Kven language and in the teaching of Kven. In the long term, parts of the material will also be openly available on the Internet by agreement with the interviewees.

Autonomous buoy for seismic reflection measurements – a future direction for marine geoexploration in the Arctic Ocean

By Yngve Kristoffersen, Ole P. Meyer and David Peddie

Photo: Yngve Kristoffersen

CONTINUOUS SEISMIC REFLECTION PROFILING BUOYS – A FUTURE DIRECTION FOR MARINE GEOPHYSICAL EXPLORATION OF THE ARCTIC OCEAN (SEISMIC BUOY)

Project owner: University of Bergen (UiB), Department of Earth Science
Project manager: Yngve Kristoffersen
Total budget: NOK 2.5 million
Dissemination measures, public and user-oriented: 5
Articles published in scientific and scholarly journals: 1
Other reports and lectures from scholarly fora: 3
Home page: http://www2.geo.uib.no/seisdrift_wiki/index.php

Experience from icebreaker expeditions into the Arctic Ocean indicates that about a quarter of the deep polar ocean basin will not be accessible with the towed equipment used for modern seismic reflection measurements, even if the survey icebreaker is assisted by a nuclear-powered icebreaker, which is a costly method of collecting data.

The IPY Seismic Buoy project, a technology development project, proposed developing an autonomous buoy to collect seismic reflection data from the Arctic Ocean north of Svalbard and particularly in high-priority but less accessible areas such as the Alpha Ridge (Figure 4).

Project design

Thanks to sea ice cover, ambient noise levels in the Arctic Ocean are below levels in the open ocean on a calm day. Good signal-to-noise ratios may therefore be obtained using a single hydrophone in the water instead of multiple sensors on a long seismic cable.

Seismic reflection measurements require an energy source. Russian and American scientists have found that detonators and electric sparker sources are simple to handle and operate reliably at low temperatures (-1.7°C in water). Since hundreds of shots are needed, detonators are impractical for unmanned operation, while a commercially available sparker powered by a 12-volt supply is a feasible alternative.

The Argos satellite system – which deals only with simple position, pressure and temperature data – cannot process the greater volumes of data involved in seismic data acquisition. The Iridium satellite system was first used for the transmission of buoy data from the Arctic Ocean in the spring of 2004. Transmission of seismic data from a one-channel seismic system is feasible only if recordings are limited to, say, frequencies less than 1 kHz of one second of travel time, starting at sea-floor reflection. This will record information about the acoustic layering of sediments down to roughly one kilometre below the sea floor.

The buoy is designed in modules, and we entered into a partnership with Christian Michelsen Research (CMR) in Bergen to develop prototype control electronics, while the Department of Earth Science, University of Bergen, was to deal with the energy supply issue. The control electronics included a central processing unit interfaced with GPS and Iridium, the sparker source, and analogue-to-digital conversion and storage of the hydrophone signal. It also had to be possible to remotely control the data acquisition via satellite. The buoy was to be powered by solar panels connected to a battery bank supplemented by a wind turbine. Up-time was limited to the part of the season with sufficient available sunlight.

Test Results

The buoy is placed on an ice floe upstream of the target area and activated (Figure 3). Data acquisition is controlled by the position information from a GPS receiver. When the ice floe has moved 50 meters from the last shot location, a new shot is fired and the signal from the hydrophone in the water is recorded for seven seconds. The analogue signal is converted to digital form and stored on an internal memory card.

Subsequently, the data string is retrieved and processed for detection of the seabed reflection and a data volume equivalent to one second of two-way travel time is extracted. This reduced data set is divided into 2-kilobyte telegrams and transmitted as "short burst" messages via the Iridium satellite connection to a server at CMR in Bergen. Battery voltage and temperature of the electronics are also logged and included in the information from each shot. The energy source is based on solar panels, a wind turbine and a battery bank. Recharging the capacitor bank of the system requires 85 watts for roughly two minutes and a later refill by short pulses.

Several tests of the two seismic buoys were carried out in the marginal ice zone north of Svalbard in 2008–2010. Each buoy was placed on the ice next to the hovercraft or on-deck in order to monitor the operation closely via a connected laptop computer. The spark electrodes were mounted on a frame and lowered to a depth of 5 m, with the hydrophone lowered to the same depth roughly 15 m away.

Figure 2 (top) shows seismic data from the test in 2009 on the continental slope north of Svalbard (Figure 1). The energy level of the sparker source is 4.6 kJ, which achieved a penetration of 400–700 milliseconds, corresponding to 400–700 m below the seabed. The sediments on the slope were glacial-marine, which are a mixture of coarse and fine material eroded and transported by glaciers and fine clay particles and biogenic matter transported by deep currents. Penetration increases with increasing dominance of fine sediments as water depth increases down the continental slope.

Large vessels use air guns as a seismic source. An air gun array produces most of its energy in the frequency range below 80 Hz, while the energy from our sparker source is above 60 Hz, yielding significantly better vertical resolution but less penetration. Also, the difference in energy levels between the two sources is several orders of magnitude. Nevertheless, when the project buoy data is compared with multi-channel seismic data from a nearby seismic line (Figure 2, bottom), the degree of improved resolution in the project seismic buoy dataset (0902) is clear and meets the project's expectations for the scientific

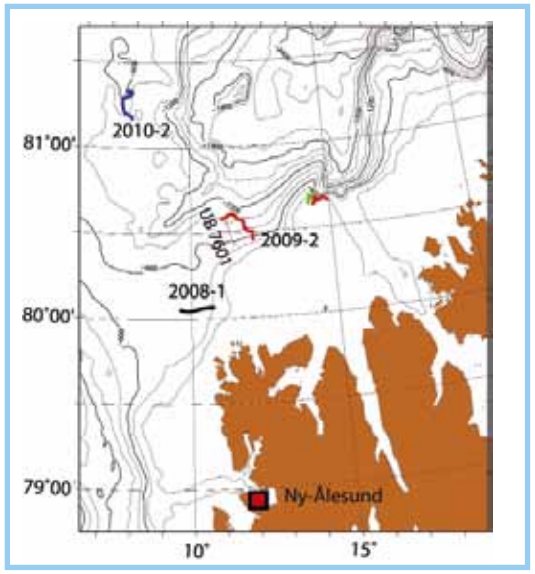


FIGURE 1: Map of drift tracks during tests. The data from buoy 2009-2 are compared with data from the multichannel seismic line UB 7601 and shown in Figure 2.

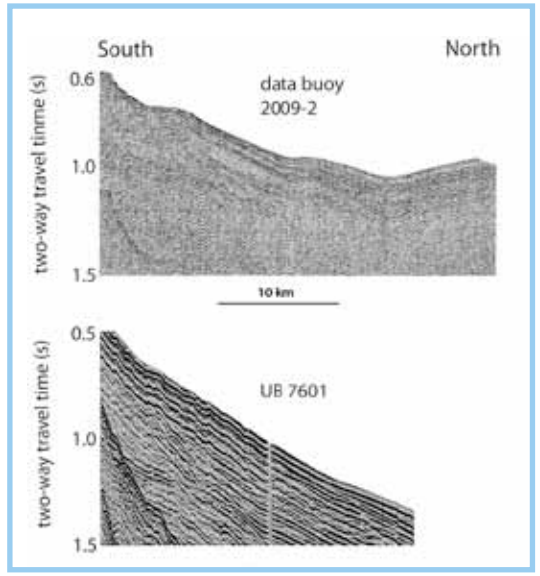


FIGURE 2: Seismic reflection data from buoy 2009-2 (upper panel) compared with a nearby multichannel seismic line acquired by a research vessel using air guns as the seismic source and recording with a 600-m-long. seismic cable.

value of autonomous data buoys. Equally encouraging are observations of persistant coherent reflections from within the water column which hold promise of the buoy as a tool for imaging of oceanographic processes in the same way as complex multi-channel seismic measurements in the open ocean.

Challenges

At first the energy was provided in three ways: battery, solar panels and wind turbine. Monitoring of the buoy showed that all cases of unstable operation could be traced to the battery voltage dropping below the 11-volt threshold. We increased the number of solar panels from three to six, but this remained insufficient on days with persistent low cloud cover. A wind turbine is a periodical supplement, but not sufficient. The solution turns out to be a fuel cell; an appropriate fuel cell model provides a continuous 90 watts with a consumption of just over one litre of ethanol per day.

Future deployments and cooperation

Experience to date indicates that the project's technical solution for an autonomous seismic buoy for collecting one-channel seismic data and transmitting it via the Iridium satellite system is working as intended and provides data of expected quality. The fuel cell provides sufficient energy and stable operation. For future buoy deployment, we have access to a hovercraft with a range up to at least 82° N north of Svalbard. For deployment and operation of the buoys in the inner parts of the Arctic Ocean, cooperation is being sought with icebreaker expeditions.

Researchers at the University of Hawaii and the Lamont-Doherty Earth Observatory, Columbia University, New York, have been involved in developing an autonomous echo sounding buoy. Synergies are obtained by using the same control electronics provided by CMR and a transmitter/receiver unit purchased commercially. The prototype was tested in the ice north of Svalbard in August 2010 with good results.

Photo: Yngve Kristoffersen

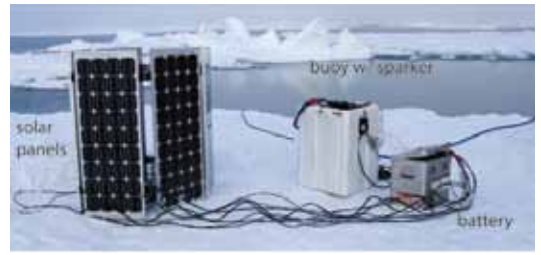


FIGURE 3: The autonomous buoy for seismic reflection data. The cable towards the edge of the ice floe (right) feeds power to the sparker electrodes in the water. The signals are picked up by the hydrophone and transmitted via the cable in the middle.

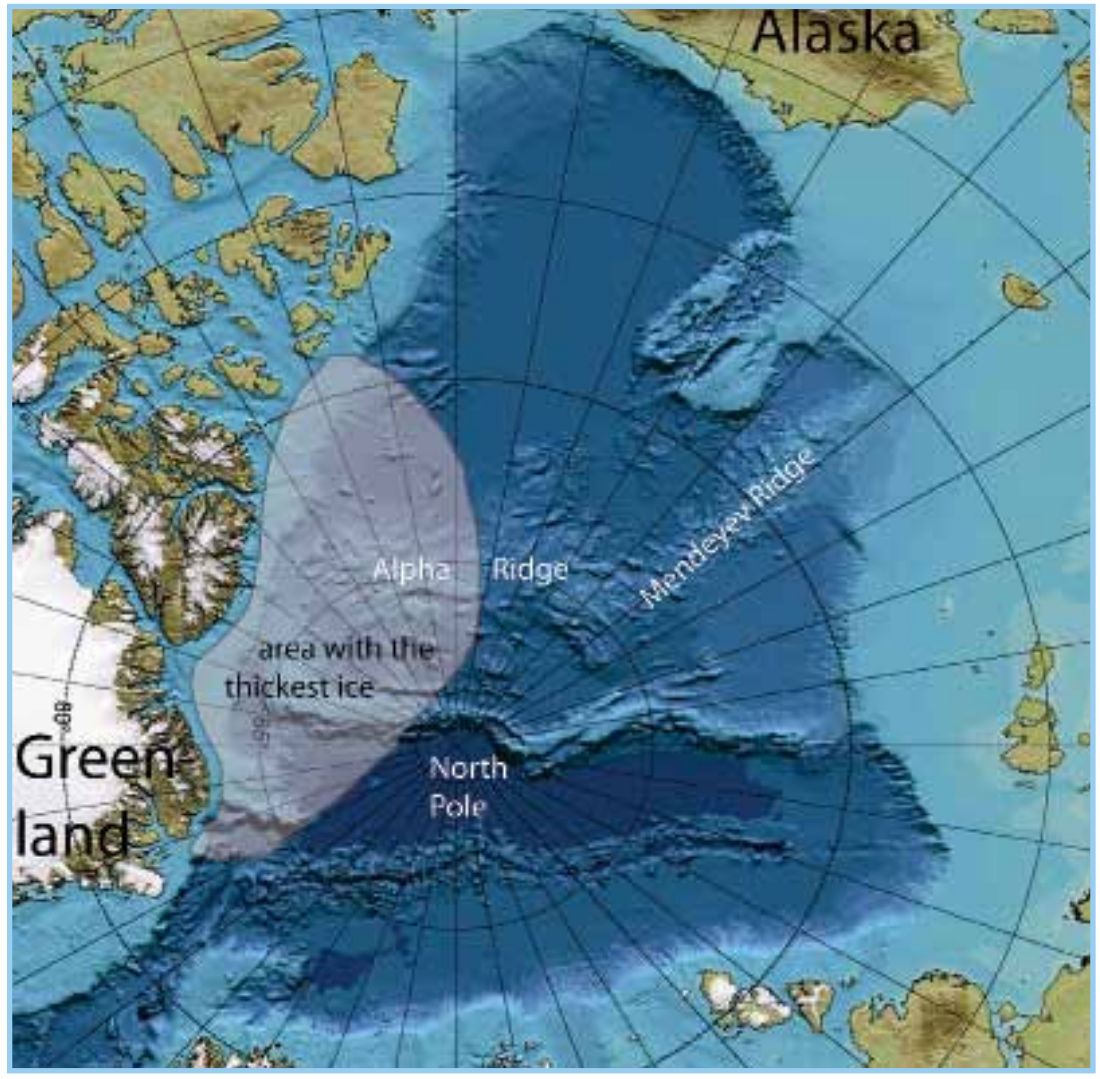


FIGURE 4: An autonomous buoy for seismic reflection measurements in the Arctic Ocean will be most useful for surveys over submarine ridges, plateaus and areas inaccessible by icebreaking vessels due to thick sea ice cover (>3 m).

The dynamic continental margin between the Mid-Atlantic Ridge and Bjørnøya (Bear Island)

By Johannes Schweitzer

Photo: Geir Wing Gabrielsen

THE DYNAMIC CONTINENTAL MARGIN BETWEEN THE MID-ATLANTIC-RIDGE SYSTEM (MOHNS RIDGE, KNIPOVICH RIDGE) AND THE BEAR ISLAND REGION (CONTINENTAL MARGIN)

Project owner: NORSAR
Partner institutions: University of Bergen (UiB), University of Oslo (UiO), Alfred Wegener Institute for Polar and Marine Research (AWI), Germany, University of Potsdam (UP), Germany, Polish Academy of Sciences and University of Warsaw (UW), Poland
Project manager: Johannes Schweitzer
Total budget: NOK 6 million
Post-doctoral fellowships: 1
Dissemination measures, public and user-oriented: 2
Articles published in scientific and scholarly journals: 9
Presentations published from international meetings/conferences: 41
Other reports and lectures from scholarly fora: 31
Home page: http://www.norsar.no/c-24-International-Polar-Year.aspx

The transition area between the continental shelf and the deep ocean is known as the continental margin. Its formation and evolution through geological times are primarily the result of tectonic plate motions and sedimentation.

The Continental Margin project was part of the international IPY project consortium "Plate Tectonics and Polar Gateways in the Earth System", which sought to investigate the structure and evolution of the oceanic access gates to the polar regions. The main goal of the project was to increase the understanding of the continental margin between the Mid-Atlantic Ridge and Bjørnøya.

Project plans

The plan was to uncover the processes behind the evolution of the margin, including natural catastrophes, such as strong earthquakes and underwater landslides. The investigation included detailed mapping of the Earth's crust and upper mantle structure using advanced active seismic experiments, supplemented by the analysis of seismic data from local and regional earthquakes. It was anticipated that earthquakes in the region would provide crucial information for the estimation of the stress-field and the definition of active faults.

Installation of instruments and data collection

Data collection commenced with a field experiment in autumn 2007. Some 12 ocean-bottom seismometers (OBSs) were installed on the sea floor west of Bjørnøya from M/S Horyzont II, and were collected in August 2008. One instrument was lost during recovery. In autumn 2007, two new broadband seismometers were installed at Hornsund and on Hopen Island. Both stations remain in operation and are part of the global network of high quality stations that monitors the Earth's seismicity.

In May 2008, the Norwegian Coast Guard transported 13 seismic stations to Bjørnøya. The stations were installed as a small seismic antenna (array) and were demobilised at the end of September 2008. In August 2008, the University of Bergen, the Institute of Geophysics (IGFPAS) at the Polish Academy of Sciences, and the University of Warsaw conducted several seismic reflection and refraction experiments along two profiles close to Bjørnøya. To increase the number of measuring points along the profiles, additional OBSs were installed from M/S Håkon Mosby, while land-based seismometers were placed along the Bjørnøya coast from M/S Horyzont II.

Analysis

Analysis of the project data concentrated on seismicity in the region and the crustal structure along the two profiles, beneath Hornsund, and in the area where the OBSs had been deployed.

The structure of the sedimentary layers along the northern profile was studied by the University of Bergen in the context of the general structure of the crust along both profiles, and analysis of the data from the small dynamite explosions along the southern profile was carried out in Poland. The thickness of the crust underneath the OBSs was investigated by the Alfred Wegener Institute, while a detailed study of the Earth's crust and mantle structure beneath Hornsund, conducted by the University of Warsaw, confirmed earlier results regarding the thickness of and boundary between the upper and lower crust.

Data from all the OBSs and land stations were used at NORSAR to obtain more accurate locations for hundreds of earthquakes along the Mohns and Knipovich Ridges. Seismicity on the ridges is also expressed by episodes of thousands of small events (swarms), too weak to be

Instruments and solar panels for one of the 13 elements of the seismic array on Bjørnøya. Photo: Johannes Schweitzer

The new seismic station at the Polish Polar Station Hornsund. Photo: Johannes Schweitzer

Deployment of an OBS from M/S Horyzont. Photo: Daniel Volmer

observed by the permanent land stations. The observations from the array on Bjørnøya were also included in NORSAR's catalogue of automatic seismic events.

Results to date

The results from the project indicate that Bjørnøya is a key location for monitoring seismicity in the entire region and that a future, permanent seismic array on Bjørnøya would significantly improve seismic monitoring capability between the Norwegian mainland and Svalbard.

Several thousand small, local events recorded by the Bjørnøya array were investigated by NORSAR and the University of Potsdam. Most of them were found to be caused by strong sea waves crashing on the northern coast of Bjørnøya. A few small, natural tectonic earthquakes were also located in the island's southeast coastal area.

On 21 February 2008, one of the strongest earthquakes recorded in Norway over the past 100 years occurred in Storfjorden, east of Spitsbergen. Storfjorden lies outside the actual project region, but many of the temporary stations had excellent observations of the event and provided additional, high quality material for several detailed studies. The earthquake started an aftershock sequence, consisting of several thousand small and larger events, on a previously unknown fault. This activity is still ongoing (June 2011).

Further activities

Some of the airgun shots and small dynamite explosions used for the reflection and refraction profiles described above were also observed by the permanent seismic stations on Spitsbergen and in Finnmark. Such observations are crucial for defining the absolute travel-times of the seismic waves, as the exact position and time of these events is known. For NORSAR, these observations were important as additional constraints for a new three-dimensional seismic model of the Earth's crust in the region.

Over the past few years the project participants held five meetings to organise their collaborative efforts and discuss the results. Numerous talks and posters have been presented at national and international meetings and conferences. All the partners involved will continue to analyse data from the project, and discussions about new, joint projects in the Arctic have already begun.

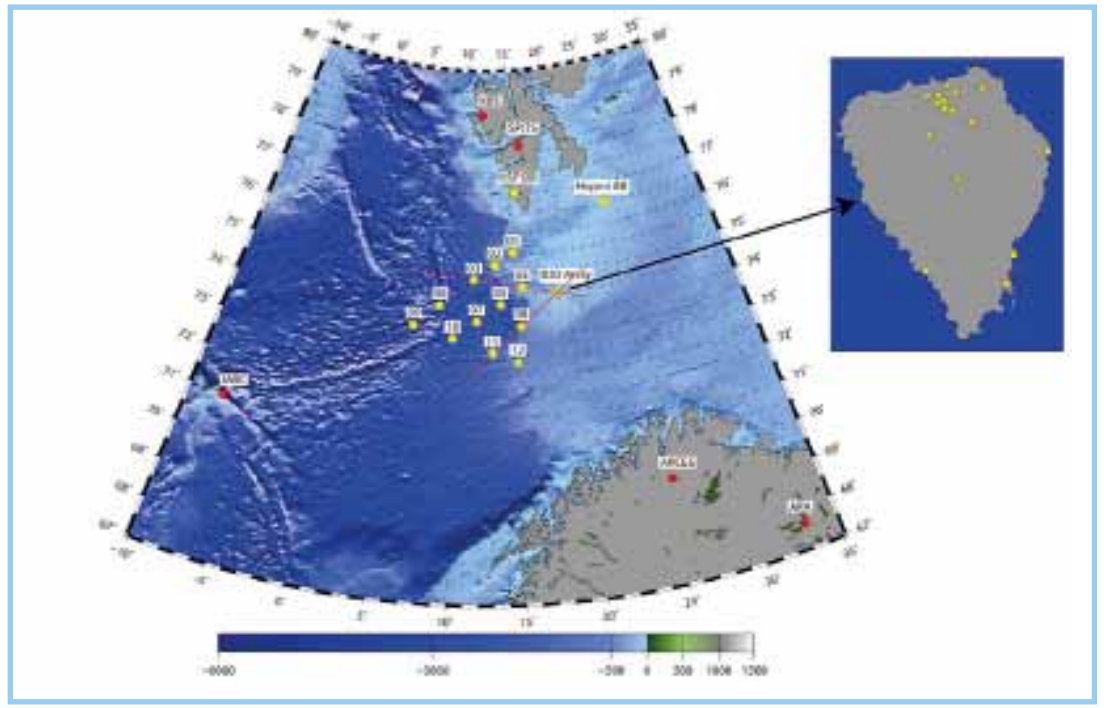


FIGURE 1: Map of the project region showing the location (yellow symbols) of the 12 ocean-bottom seismometers, the new broadband stations on Hornsund (HSP BB) and Hopen Island (Hopen BB), and permanent seismic stations in the region (red symbols). The two red lines note the two reflection and refraction profiles. The map to the right shows the position of the 13 stations of the Bjørnøya array (yellow triangles), and the Polish stations installed on the coast (yellow squares). Figur: Myrto Pirli

PROJECT PARTNER (INSTITUTE)	MAIN PROJECT TASKS
NORSAR, Norway	Project management, coordination of field experiments, data analysis
University of Bergen (UiB), Norway	M/S Håkon Mosby, seismic reflection and refraction experiments, data analysis
University of Oslo (UiO), Norway	Interpretation of geological processes
Alfred Wegener Institute (AWI), Bremerhaven, Germany	Ocean-bottom seismometers (OBSs), data analysis
University of Potsdam (UP), Germany	seismiske stasjoner på Bjørnøya, dataanalyse
Polish Academy of Sciences, (Institute of Geophysics (IGFPAS)) and University of Warsaw, (UW), Poland	M/S Horyzont II, new seismic station at the Polish Polar Station Hornsund, seismic refraction experiment, seismic stations on Bjørnøya, data analysis

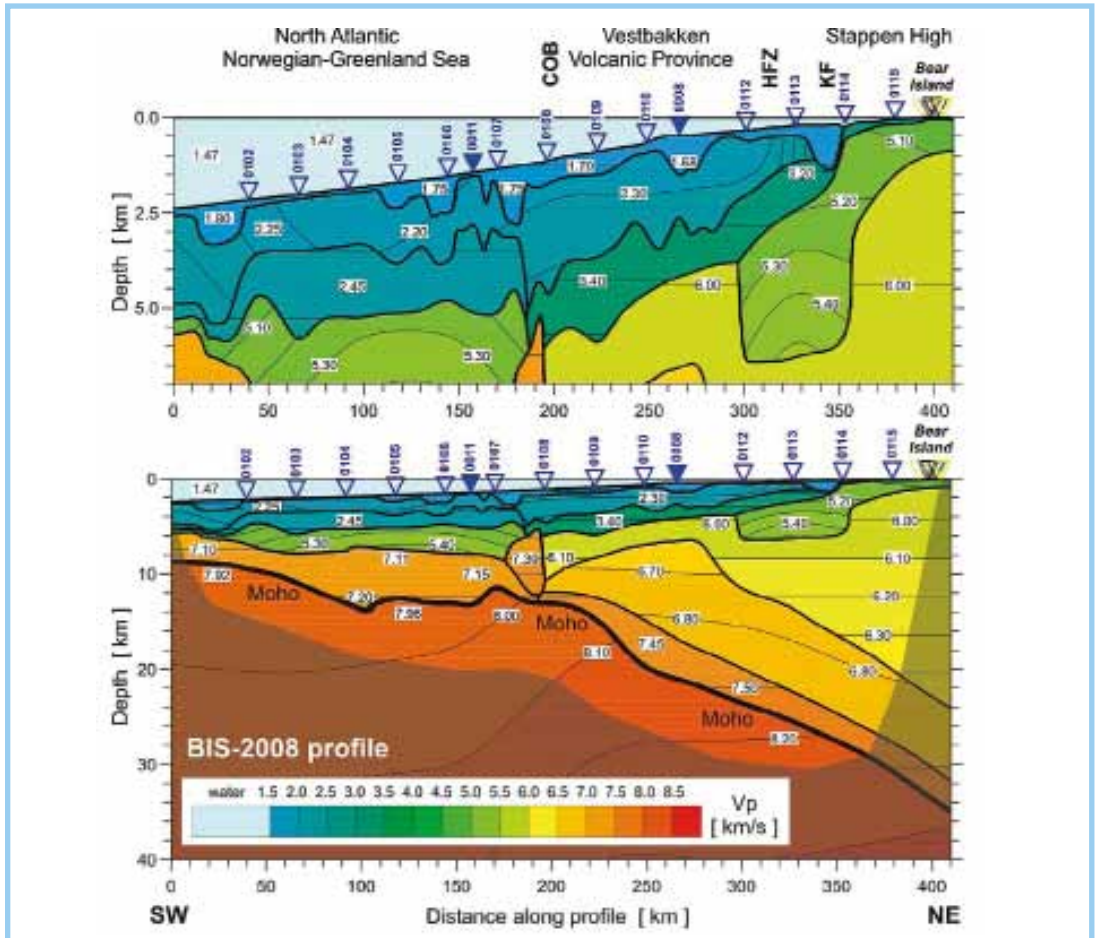
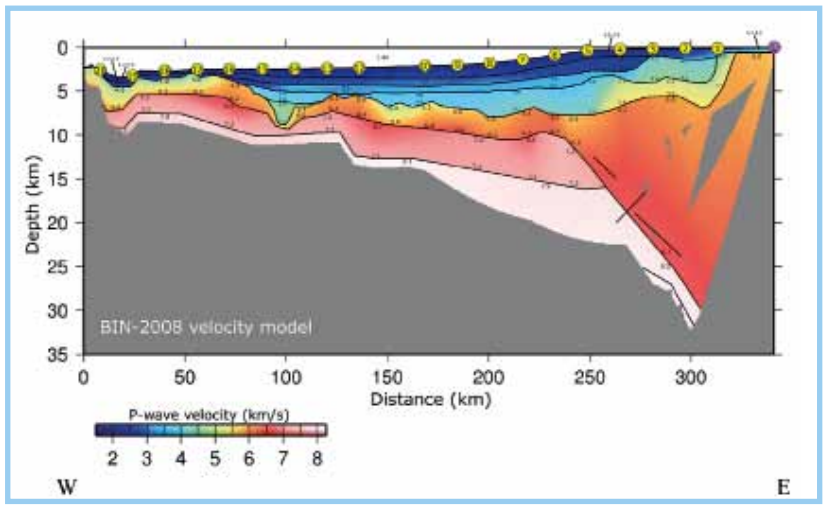


FIGURE 2: Seismic velocity model along the southern profile showing gradual thickening of the crust from left (Southwest) to right (Northeast). The boundary between the Earth's crust and mantle is called the Moho. The upper part of the figure offers a zoomed-in view of the complex crustal structure. Figure: Wojciech Czuba, Institute of Geophysics, Polish Academy of Sciences, Warsaw

FIGURE 3: Seismic velocity model along the northern profile showing gradual thickening of the crust from left (West) to right (East). Pink colours denote velocities between 7 and 8 km/s and are typical of the transition between the Earth's crust and mantle. Yellow symbols note the positions of the 20 OBSs placed along the profile, while the violet L notes the location of the land stations on Bjørnøya.
Figure: Audun Libak, UIB



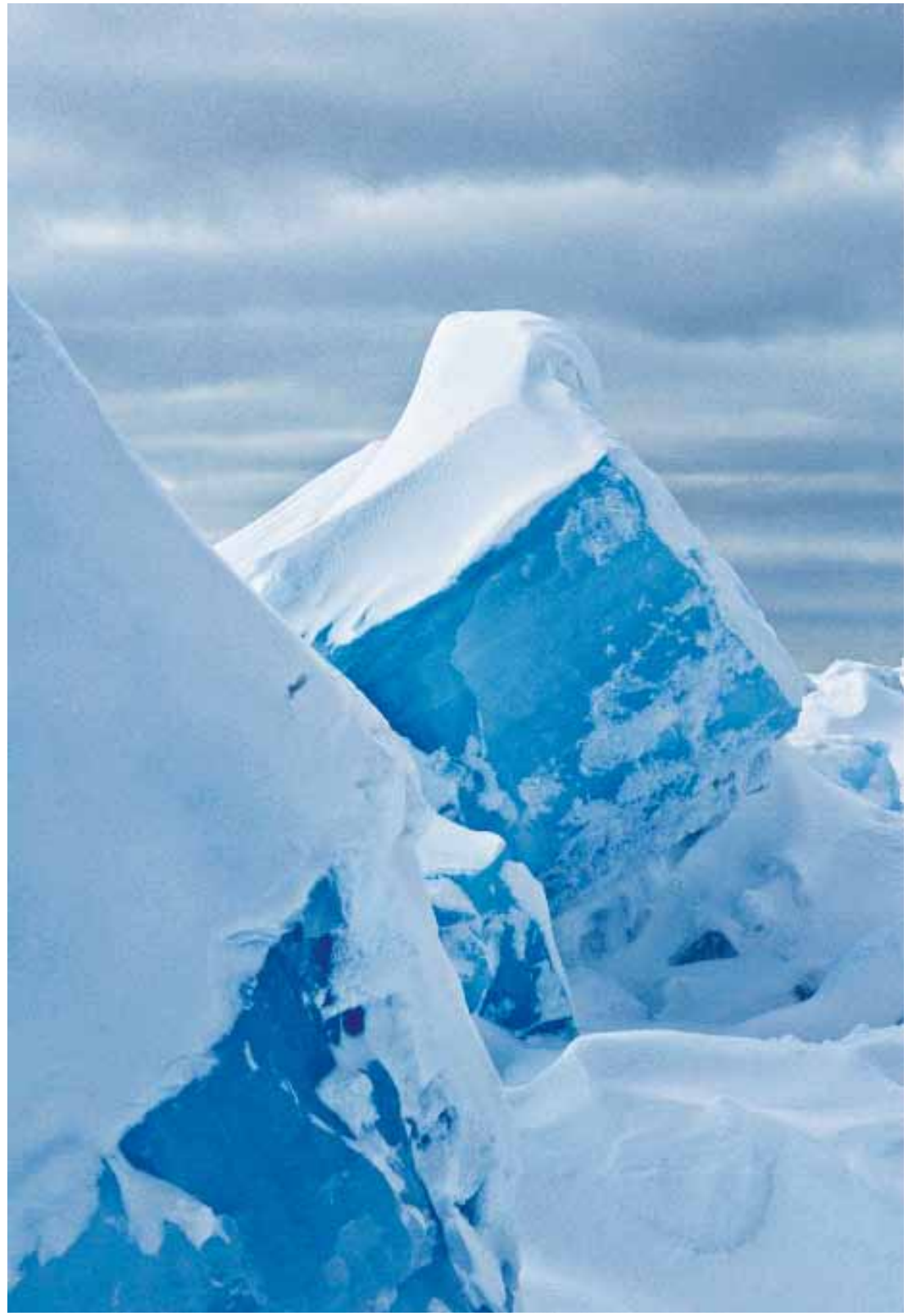


Photo: Rudi Caeyers

Southern and Northern Lights not identical

By Nikolai Østgaard

Photo: Bjørn Jørgensen / Samfoto

INTERHEMISPHERIC CONJUGACY EFFECTS IN SOLAR-TERRESTRIAL AND AERONOMY RESEARCH (IPY-ICESTAR)

Project owner: University of Bergen
Project manager: Nikolai Østgaard
Total budget: NOK 5 million
Doctoral fellowships: 1
Dissemination measures, public and user-oriented: 14
Mass media coverage: 50
Articles published in scientific and scholarly journals: 20
Other reports and lectures from scholarly fora: 78
Home page: http://web.ift.uib.no/Romfysikk/RESEARCH/PROJECTS/IPY_ICESTAR/

Most auroral research has focused on the aurora borealis, the Northern Lights, but a similar phenomenon occurs over Antarctica: aurora australis or the Southern Lights. Few studies of the aurora have included both hemispheres, a gap which the IPY-ICESTAR project addressed by investigating how the solar wind and the interplanetary magnetic field interact with the Earth's magnetosphere and ionosphere and affect the two polar regions differently. The project has yielded sensational findings, such as new knowledge about the relationship between the northern and southern auroras.

The IPY-ICESTAR project had four main goals:

1) examine whether the aurora in the north and south are different or not
2) run the EISCAT Svalbard radar for one year
3) examine the effects of energetic particle precipitation
4) build a Space Suitcase and organise a conference for space scientists and journalists.

Aurora in the north and south

Using global imaging from space of the auroras in the north and south, the IPY-ICESTAR project discovered that auroral breakups are usually asymmetric in the two hemispheres. This can be explained by the orientation of the interplanetary magnetic field. The project also showed that the dayside aurora is controlled by the interplanetary magnetic field and that the theta aurora can exist in only one hemisphere. It also demonstrated that the proton aurora is controlled by solar wind dynamic pressure, switching the proton aurora on and off.

The polar boundaries of the aurora in north and south also behave differently during substorms. This can be explained by different responses of the ionospheres in the north and south to increases of the magnetospheric plasma drift caused by processes in the magnetotail.

The project's most conspicuous achievement was being highlighted on the cover of the July 23, 2009 issue of the prestigious journal Nature, with a featured article in which Karl Magnus Laundal and Nikolai Østgaard presented simultaneous images from north and south to reveal a total asymmetry. The two auroras were not mirror images, as previously believed.

The project researchers interpret this as signatures of electrical currents running along the magnetic field lines between north and south. Different exposure to sunlight in the two hemispheres can lead to such interhemispheric currents, which have never been observed simultaneously in the south and north. As conjugate imaging of the two hemispheres is rare, it is not known how common these currents are, but this discovery will definitely motivate further studies.

This study also reveals how interpretation of data from only one hemisphere may not necessarily apply to the opposite hemisphere. Knowledge about the aurora and processes in the upper atmosphere is based solely on data from the north.

EISCAT – one year of continuous data

One year of continuous data was obtained by the EISCAT radar on Svalbard. Since such radars are technically advanced and require a great deal of energy (20% of the power supply in Longyearbyen), this one-year run required a tremendous effort by the EISCAT team. This has never been achieved before, and was the focus of a great deal of media attention. Continuous data are extremely valuable as they may reveal trends in the upper atmosphere with greater certainty.

EISCAT provides measurements of temperatures, velocity and electron density. Figure 1 shows the 12 months of data (March 2007 through February 2008). An international team of scientists has reported that:

The project was featured on the 23 July 2009 cover of the prestigious journal Nature.

The enormous EISCAT antenna in Adventdalen on Svalbard.
Photo: Kristen Ulstein

- → the upper atmosphere is colder than predicted by models
- → the chemical composition of the upper atmosphere is undergoing unexpected long-term changes
- → higher solar wind speeds produce much higher temperatures in the upper atmosphere
- → space debris from the destruction of a Chinese satellite was tracked with high precision.
- → Exciting work ahead:
- → A major earthquake occurred in the last month of the continuous run, so the researchers are planning to investigate if there is any trace or precursor in the upper atmosphere data.

The continuous EISCAT measurements have inspired continuous operation of similar radars (in Alaska). IPY-ICESTAR was also the inspiration for the new US incoherent radar in Antarctica as well as the EISCAT 3D initiative.

Stratospheric signatures of energetic particle precipitation

A subproject focused on energetic particle precipitation and its effects on the chemistry of the stratosphere. Eight years of satellite microwave observations, with special emphasis on IPY, were analysed and reported in papers and at international conferences.

The Space Suitcase

The IPY-ICESTAR project's primary dissemination measure was the development of the Space Suitcase for lending to schools at no cost. Designed to stimulate interest in polar research and science at upper secondary schools, the suitcase contains five instruments connected to a laptop used to obtain simple measurements of sunspots, aurora, electrical currents and radio waves in the atmosphere as well as cosmic rays.

A brochure and a poster describing the IPY-ICESTAR project and the Space Suitcase were sent to educational institutions in Norway, including more than 500 upper secondary schools. Each student group borrowing the suitcase is to report its findings to the project researchers.

In 2008, the researchers launched the Space Suitcase in connection with their participation in the ARCSUN video conference focusing on the polar regions. The conference organisers at the Barrow Arctic Terrestrial Observatory in Alaska linked up with IPY-ICESTAR researchers in Svalbard and with the Kiruna Geophysical Observatory. Longyearbyen School was the first school to borrow the suitcase.

Inspired by the Space Suitcase, several other institutions have now developed similar versions. The Norwegian Centre for Space-related Education (NAROM) prepared four suitcases (without camera and laptop), and a Swedish version has been developed for 18 upper secondary schools in northern Sweden. The IPY-ICESTAR manual and list of instruments have served as the basis for developing all these versions.

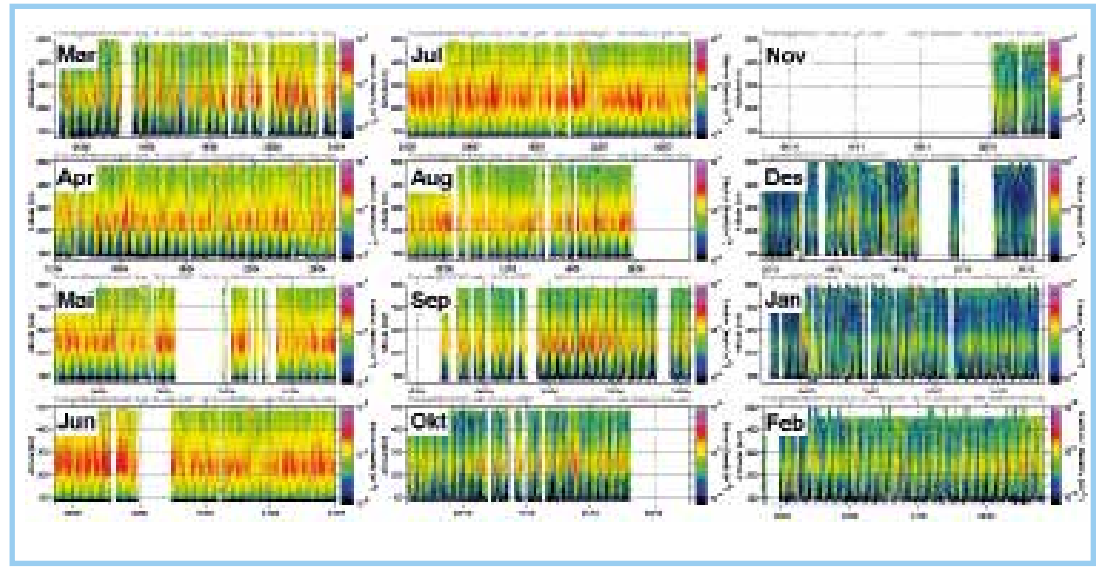


FIGURE 1: The 12 months of data from the European Incoherent Scatter (EISCAT) system.

Conference for journalists and space scientists

In September 2008 IPY-ICESTAR researchers organised a one-day conference for roughly 60 space-related scientists and journalists at the Soria Moria conference centre in Oslo. Presentations were given by all the space science groups in Norway, and then journalists presented their experiences of interviewing the scientists. Finally, there was a panel discussion with both groups represented.

Instruments included in the Space Suitcase.

PAGE
180–191

OUTREACH AND EDUCATION PROJECTS

IPY focused special attention on education, outreach and communication (EOC) activities, at both the national and the international level. In addition to efforts carried out under the research projects, a separate call for funding of EOC projects was announced, targeted towards, not only science instutions, but other actors in this field. A total of nok 14 million was allocated and distributed between 22 projects.

Achievements of the education and outreach projects supported by IPY

By Kristen Ulstein, Research Council of Norway

The framework document for the International Polar Year 2007–2008 (IPY) attached considerable importance to education and outreach. Therefore, all IPY science projects were required to have Education, Outreach and Communication (EOC) plans. Funding was also set aside for national EOC measures as well as coordinated international project to profile IPY.

The honeycomb chart of international IPY projects featured a column for dedicated EOC projects under the auspices of research institutions and others. The Norwegian IPY Committee allocated a total of NOK 14 million to EOC projects, most of which was awarded via a special funding announcement in autumn 2006. The Research Council received 67 grant proposals by the submission deadline, and awarded grants to a full 22 projects. These projects have been successful – individually and as a whole – in drawing attention to and generating interest in IPY and polar research, thereby helping to achieve key IPY objectives.

TV/FILM

The Norwegian IPY programme chose to focus on visual communication channels for profiling polar research. The polar areas are still exotic for most people, and the natural surroundings are stunning – and a bit threatening. Data collection and expeditions have their logistical challenges and dramatic situations can arise. Polar research is therefore well suited to TV and film productions.

Just the TV productions financed by IPY alone have been seen by 1.5–2 million viewers. In addition, productions by the Norwegian Broadcasting Corporation (NRK) that focused on IPY – particularly two documentaries about the voyages made by the heirs to the Scandinavian thrones to Svalbard and Greenland – had high viewer ratings.

The luckiest (?) journalist in the world, Unni Ødegård of NRK, with an ice core. Ødegård accompanied scientists on the first half of the Norwegian-US Antarctic Traverse to the South Pole. Photo: Jan Gunnar Winther

The documentary film "Chasing the polar storm" was seen by 580 000 people at its first screening. The search was undertaken on board a plane crammed with equipment. Photo: Christian Mallaun

NRK accompanied the Norwegian-US traverse to the South Pole

"I must be the luckiest journalist in the world!" blogged project manager Unni Ødegård of NRK in Tromsø. Thanks to funding from IPY she was able to accompany researchers on the first half of the Norwegian-US Antarctic Traverse (TASTE-IDEA) during the 2007–2008 season, which started at the Norwegian Troll Station and nearly reached the South Pole. One purpose of the expedition was to collect climate data.

This multimedia project from NRK featured a webpage and blog on the nrk.no website, as well as five episodes for the popular-science programme Schrødingers katt, aired in January/February 2008. The webpage quickly attracted a large number of users, who checked in to find details on the day's events, photos and video clips. The webpage had over 200 000 hits during the most active period. The project also broke technological barriers – never before had there been reports like these from the Antarctic Plateau.

The webpage and blog helped to promote the TV series, which was heavily advertised before each episode was aired. Both the journalist, Unni Ødegård, and the expedition leader, Jan-Gunnar Winther, were frequent guests on television talk shows and radio shows, generating even more publicity. Even though Ødegård was flown out midway, the webpage followed the expedition until it concluded near the South Pole, with the researchers themselves blogging and taking pictures.
www.nrk.no/sydpolen (In Norwegian only.)

In search of Arctic storms

The documentary on the Norwegian IPY-THORPEX research project is another film project that received support from IPY and which garnered a lot of attention. For three weeks in February and March 2008, some 25 researchers gathered on the island of Andøya in Northern Norway to search for polar low-pressure systems. Among them was a German team with a specially-built plane to fly the researchers into the low-pressure systems to collect data, most importantly, on temperature, wind strength and humidity.

This was the first time the entire lifecycle of a polar low-pressure system has been documented "from cradle to grave" with scientific measurements. The film builds up suspense about whether the researchers will manage to get the measurements they need, thus making scientific history. Viewers are also introduced to Harald Figenschou, one of the few people to survive a shipwreck in extreme weather caused by a polar low-pressure system. He helps us to understand just how important this research is. One of the main objectives of the project was to gain a better understanding of this and other weather phenomena in order to improve the accuracy of weather forecasts in the Arctic region.

When the 54-minute-long documentary was aired for the first time on NRK1 in December 2008 it attracted 580 000 viewers. It has since been aired many times and seen by another several hundred thousand viewers. A shorter version of the documentary is available, and a 15-minute-long play was written based on the film.
www.ipy-thorpex.no/

Research and environmental monitoring in Ny-Ålesund

Film producer Olav Høgetveit received support for a TV documentary on the research being conducted in Ny-Ålesund on Svalbard. The 50-minute-long film was aired by NRK as part of the lead-up to the UN Climate Change Conference in Copenhagen in November 2009.

Høgetveit and his co-director Sverre Krüger had already visited Ny-Ålesund many times and had amassed a considerable amount of footage on the research activities there. The documentary combines this unused footage with new footage and interviews with key players in Copenhagen about the relationship between research activities on Svalbard and international climate policy.

An incredible sea voyage to Antarctica

Wildlife filmmaker Arne Nævra and explorer Stein P. Aasheim undertook a sailing expedition to Antarctica, which became the subject of three-part documentary series aired on NRK1 in spring 2008. The series was later aired on NRK2 in 2008, 2009 and 2010.

IPY, however, got the first footage. The voyage was the subject of a lengthy segment in an episode of the popular-science programme Schrødingers katt celebrating

Arne Nævra. Photo: Naturbilder

Arne Nævra and Stein P. Aasheim on South Georgia Island. Photo: Naturbilder

the launch of the International Polar Year on 1 March 2007. In January 2007 NRK broadcast a series of radio documentaries made underway during the voyage. The objective of the project was to spread knowledge about Antarctic ecosystems, generate interest in the polar areas and give the general public a better understanding of the history, flora and fauna of the Antarctic and sub-Antarctic region.

The voyage began in the Falkland Islands and continued on – via South Georgia – to the Antarctic Peninsula. Here the team went ashore, visiting historical sites connected to Norway's economic activities in the area as well as natural hot-spots. A glossy coffee table book *Antarctica – An Incredible Voyage!* also documents the expedition.
www.naturbilder.no/

Polar film festival in Tromsø

The Tromsø International Film Festival (TIFF) received support from IPY to put together a special polar film programme. Launched in 1991, TIFF is now Norway's largest film festival.

The festival is held each January, and polar film was the main focus in 2008. In summer 2007 TIFF got an early start on celebrating polar film by holding screenings at the Nordic Youth Film Festival, the Verdensteatret cinema and the silent film festival in Tromsø. Historical polar films, Norwegian feature films, international feature films and documentaries, and short films were shown. According to head of the festival Martha Otte, the films screened in connection with IPY were of extremely high quality and the festival was able to introduce the audience to a number of films which they would not have otherwise had the opportunity to see. Forty-six films were shown at 94 screenings and viewed by well over 7 000 people.
www.tiff.no

EXHIBITS

Although the three exhibits that received support from IPY are very different, they have all succeeded in presenting the initiative in general and specific IPY science projects in particular to a wide audience. Thus far, the overall number of visitors to the exhibits totals some 500 000. Several other exhibits associated with IPY have also been held, including a photo exhibit from an expedition to the South Pole and an art exhibit featuring pictures of microfossils from sediments found in Ny-Ålesund.

Klima X – award-winning climate exhibit in Oslo

In 2009 the Norwegian Museum of Science, Technology and Medicine won a prestigious US award for its IPY outreach project – the Klima X exhibit. Visitors to the museum had to put on waterproof rubber boots before entering the exhibit, which won the Roy L. Shafer Leading Edge Award for Best Visitor Experience. Each year the Association of Science-Technology Centers (ASTC) presents the Leading Edge Awards in three categories to one of its 2 500 member science centres.

The Klima X exhibit showed visitors the causes and effects of climate change, introduced them to research in the field, and helped them to understand how political choices, technology and consumer behaviour can minimise the negative impacts. When ice melts it turns into water. Visitors experienced this firsthand as they waded through water over their ankles in the 400m2 exhibit space.

Klima X was opened on 11 December 2007 by Norwegian Prime Minister Jens Stoltenberg and Dr Rajendra Pachauri of the Intergovernmental Panel on Climate Change (IPPC), who was in Norway to receive the Nobel Peace Prize with Al Gore. The exhibit – which drew at least 350 000 visitors – closed in December 2009.

Among the visitors were more than 100 000 schoolchildren. In 2008 alone over 500 classes participated in the educational programme targeting lower-secondary and upper-secondary school pupils. The museum also held a Klima X lecture series. Due in great part to its winning the Leading Edge Award, the exhibit drew a large number of visitors from other museum facilities.
www.tekniskmuseum.no

Fridtjof Nansen exhibit in Trondheim

The NTNU Museum of Natural History and Archaeology presents polar treasures from its collection in the exhibit "Death or the West Coast of Greenland". Taking Fridtjof Nansen's dramatic expedition over the Greenland ice sheet in 1888–1889 as a starting point, the exhibit displays items from this journey as well as 18th century objects from Greenland belonging to the collection of Bishop Gunnerus, one of the founders of the Royal Norwegian Society of Sciences and Letters.

Opened in February 2008, the exhibit gives visitors insight into the background for the expedition and the people and preparations involved. The exhibit focuses on the arduous journey across the ice sheet and how Nansen and his crew wintered with the Inuit in Good Hope. While there, Nansen studied Inuit culture, presenting his observations with great insight and respect in books published in the wake of the expedition. The exhibit also illustrates continuity in the Inuit hunting and handicraft traditions.

Thus far, some 100 000 visitors have seen the exhibit, which will remain open through 2011, the 150th anniversary of the birth of Fridtjof Nansen. The exhibit is affiliated with IPY in terms of its funding, and via its presentation of several of the IPY science projects – both in the exhibit itself and through a series of popular-science lectures.
www.ntnu.no/vitenskapsmuseet/doden-eller-gronlands-vestkyst

Touring exhibit of Sámi miniature artworks

The touring exhibit Hommage à Iver Jåks: Small Works that Reflect Great Artistry opened at Tromsø Art Gallery in August 2008 and has since been on the road. A large audience has viewed the exhibit and the response has been overwhelmingly positive. It is perhaps the most unique IPY outreach project.

This touring exhibit pays homage to and commemorates the Sámi artist Iver Jåks (1932–2007), and is a

Klima X was an interactive exhibit. Visitors answered questions with the help of rubber boots which they were given at the entrance.
Photo: Norwegian Museum of Science, Technology and Medicine.

Samuel Balto was a Sámi from Karasjok recruited in 1888 by 26-year-old Fridtjof Nansen to take part in an expedition to Greenland. His kayak was one of the objects that attracted attention at the NTNU Museum of Natural History and Archaeology exhibit Death or the West Coast of Greenland. Photo: Kristen Ulstein

collaboration between Nordnorsk Kunstnersenter (the Artists' Center of Northern Norway), RiddoDuottarMuseat – the Sámi Museum, the Sámi Artists' Center, and the Savio Museum. In addition to the artworks, 30 of which are mounted on bases, the exhibit package includes a video, a 60-page catalogue and banners – all packed in crates for transport.

A total of 62 artists – several of whom were students of Jåks at the art school in Kabelvåg – contributed miniature works. Jåks is best known for his small sculptures, which are heavily influenced by the traditional Sámi handicraft duodji and which comprise the starting point of the exhibit. His smallest sculpture measured an incredible 2x2x2.5 cm, and none of the works in the exhibit are larger than 20x20x20 cm.
www.nnks.no

The touring exhibit Hommage à Iver Jåks: Small Works that Reflect Great Artistry.
Photo: Nordnorsk Kunstnersenter (the Artists' Center of Northern Norway).

INTERNET

Web portal for reindeer husbandry

Thanks to support from IPY, a web portal was launched for reindeer herding communities. Among other uses, the portal serves as a platform for communicating the results of the IPY EALÁT Project and other activities related to reindeer husbandry in the Arctic.

The portal is a non-commercial channel to communicate knowledge about circumpolar reindeer husbandry and is targeted towards research and educational institutions at various levels, national authorities, the Arctic Council, reindeer herders and organisations. The project reaches out to young people through its focus on school and technology.
icr.arcticportal.org/ealat

BOOKS AND DOCUMENTATION

IPY has spawned a wide array of book projects. Only the projects that were awarded grants under the funding announcement for EOC projects are described here. The projects span a broad scope from children's books to an encyclopaedia. There is also a good deal of professional literature. However, the most common genre of polar literature is richly illustrated books on expeditions, several of which were published during IPY and which are tied to IPY science projects to a greater or lesser extent.

Miro with the dogs. Photo: Thomas Ulrich

Two boys on a journey back to the Ice Age

The fathers of eight-year-old Torjus and Miro are geologists and researchers in East Greenland. In summer 2008 the two boys were allowed to join their fathers' expedition and experience firsthand one of the most remote areas on earth. With financial support from IPY, the two boys and their parents wrote a children's book about their experiences. They were accompanied on the expedition by the award-winning Swiss nature photographer Thomas Ulrich. In the book The Journey to the Ice Age readers learn about musk oxen, the Inuit, mosquitoes, icebergs and visible climate change – and not least about the two boys' exciting adventures. The book also features interesting facts about animals and nature in the region, expeditions, geology and changes the earth has gone through.

Published in Norwegian in September 2009, the book was printed in 6 000 copies. It has received excellent reviews and is available at every library in Norway, thanks to the purchasing programme under Arts Council Norway. A five-episode miniseries for NRK's popular-science programme for children, Newton, was also made based on the book. The Journey to the Ice Age has been translated into English and publishing is being negotiated.
www.reisentilistiden.no

Children's book on the Svalbard rock ptarmigan

Cappelen Damm publishing house has published a series of children's books on animals in the Arctic. First out were books on the Arctic fox, the walrus, the polar bear, and snow, ice and climate. Ptarmigan researcher Åshild Ønvik Pedersen of the University of Tromsø thought that the Svalbard rock ptarmigan also deserved its own book, so she sought funding from the Norwegian IPY programme to research and write one.

The Norwegian-language website Norsk Polarhistorie (the Polar History of Norway) was launched during IPY. Funding made available for communication activities under IPY has helped secure photographic documentation of 50 years of polar history for the future.

One of the historical photographs. The Norway Station (Fimbul) was established on the coast of Dronning Maud Land, 35 kilometres from the ice edge. The research station was built in 1956/7 and a few months later it was already buried under the snow. This photograph was taken on 17 May 1957. The expedition lasted until summer 1960.

The children's book on the Svalbard rock ptarmigan was launched at the Svalbard Museum in September 2009. The book documents the lifecycle of a ptarmigan hen for an entire year. According to co-author Kirsti Blom, "It is a story of birth, survival and death." Blom has long experience of co-writing children's books with researchers. The researchers tell her everything they know about the subject, and she makes a story out of it. The entire series on animals in the Arctic has been produced in this way.

The book is illustrated with unique photographs that the authors collected from friends, photographers on assignment and other researchers. The first printing of the book on the Svalbard rock ptarmigan was quickly sold out, and a second printing was made. The book is available in Norwegian only and is suitable for children of all ages.
http://www.cappelendamm.no/

Overview of climate research during IPY

The Center for International Climate and Environmental Research – Oslo (CICERO) received support from the IPY programme to write a book that will give a cohesive, synthesised overview of the climate research conducted as part of Norway's contribution to IPY. The project will be completed once all of the research results are in. To make the findings accessible to a wide audience, the authors will discuss new research in the context of available knowledge about climate change in the Arctic and the Antarctic.

The aim is to give readers informative and graphic descriptions and illustrations. The book is intended for use in educational activities and as background information for the media. The book will be written and published in English, and possibly in Norwegian.
www.cicero.uio.no

Encyclopaedia on the Barents Region

The formal cooperation established between the northernmost administrative regions of Norway, Sweden, Finland and Northwestern Russia, based on the Kirkenes Declaration of 1993, is known as the Barents Region. There has, however, been cross-border cooperation in this region since time immemorial, but it has been largely ignored by historians who have written the official national histories.

The main aim of the IPY outreach project Barents Encyclopaedia is to remedy this situation. Researchers from several countries have written some 400 contributions to be published in book form in 2012. The approximately 700-page encyclopaedia on the Barents Region will be the first of its kind and will feature a large number of tables, diagrams and photos.
www.barentsinstitute.org

Photos documenting 50 years of polar history – from IGY to IPY

The Norwegian Polar Institute's photo collection documents large segments of Norwegian polar history, dating back as far as 1872. However, coverage of the period stretching from the International Geophysical Year 1957–1958 (IGY) through the 1990s is rather sketchy. The International Polar Year gave the institute an opportunity to do something about this. The aim of the project has been to collect and systematically archive photo materials from research expeditions in the Antarctic and research activities on Svalbard during the period. Some 20 000 photos – mostly slides – have been collected, scanned, registered and archived. Valuable photos which were on the verge of being lost have been saved for posterity, and the gap in the institute's collection has largely been filled.

Digitised photos are freely available for use for research purposes – contingent upon the photographer's consent. A number of photos have been published on the Norwegian-language website Norsk Polarhistorie.
www.npolar.no
www.polarhistorie.no (**Norwegian only**)

STUDENTS- AND EDUCATION PROJECTS

Adding to the efforts of the IPY Secretariat and the Education, Outreach and Communication (EOC) committees, educational projects receiving IPY support have helped to bring polar research to a large number of pupils – especially in lower secondary and upper secondary school. The effect of these activities can only be measured to a certain extent; for example, the long-term benefits of teacher training courses are hard to quantify. Also, much of the educational materials will have a long shelf-life, and experience has been gained that will benefit others.

Upper secondary pupils researched drifting sea ice in the Arctic Ocean

Fifteen pupils aged 14–18 were given the unique opportunity to learn a little extra maths and physics in connection with IPY – and to experience practical research in impressive surroundings. Thanks to the project Seismic Buoy and support from IPY, the pupils boarded the polar hovercraft R/H Sabvabaa for a weeklong trip, journeying from Longyearbyen to the drifting sea ice north of Svalbard. They drifted on the ice, like Fridtjof Nansen and his crew, and carried out the same types of measurements – using modern technology.

The pupils were selected on the basis of submitted applications, in close cooperation with the Norwegian Centre for Science Education. Of a total of 70 applicants, nine pupils and one teacher were selected in 2008 and six pupils in 2009. The pupils received a thorough introduction to polar history during a weekend seminar at the Fram Museum in Oslo.

Eight voyages were made from Longyearbyen to the sea ice with pupils on board the Sabvabaa. The vessel sleeps four (two young people and two adults), and it can operate in areas covered by sea ice from Svalbard up to 82° N for up to two weeks at a time. The voyages took place between late June and late August. The pupils were required to take a rigorous safety course, and strict safety routines were in place.

The pupils took part in seismic shooting and seafloor sampling; they drilled ice cores and took oceanographic measurements. They even ran into polar bears on several of the trips. It goes without saying that these experiences have left a lasting impression. Upon returning home, the pupils gave lectures at their schools, and were the subject of feature articles in several local newspapers.
www.IPY-klasserom.no

Some 15 fortunate school pupils were given the opportunity to join a research expedition north of Svalbard on board the polar hovercraft R/H Sabvabaa. Photo: Yngve Krisstoffersen

Schools investigate environmental pollutants in fish

For many years, the Norwegian Institute for Air Research (NILU) and the Norwegian Centre for Science Education have sponsored annual campaigns to involve schoolchildren in research. They have also collaborated on the development of the Environmental Education Network. The aim of the Global POP project, which received support from IPY, was to get schoolchildren all over the world to submit fish samples.

The participating pupils learned about correct scientific sampling of fish and were invited to take samples in their local environment. The pupils registered and published important field and sample data on a dedicated website, and labelled, packed and shipped their samples to NILU for analysis of dioxin levels. Participation in the project was not as widespread as anticipated. Fifty-five schools submitted a total of 160 samples of 24 types of fish consumed locally. The majority of the participant schools were from Europe – around half of them from Norway. The schools received feedback via the website.

The project demonstrated that schoolchildren can be used in research and environmental monitoring activities and that collaboration between schools and research institutions can benefit both parties. The pupils followed scientific protocol meticulously and learned how to conduct research in the natural sciences, while the researchers received a data set that they otherwise would not have acquired.

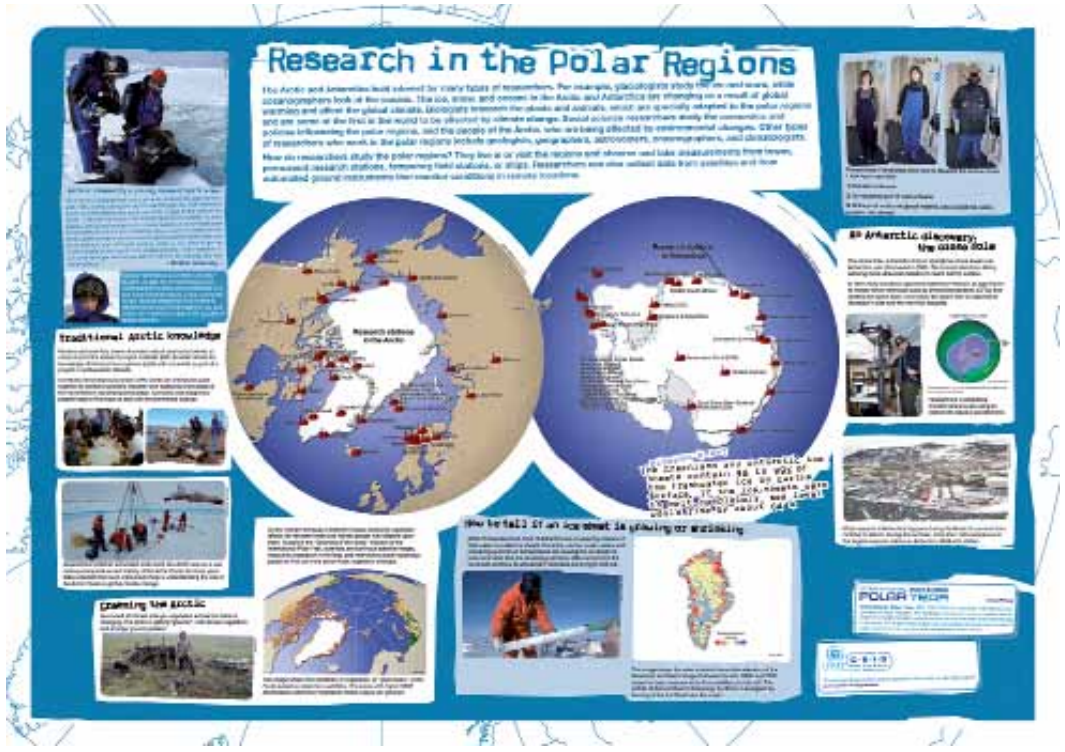
www.sustain.no/projects/globalpop

Polar science textbook – to hang on the wall

"Why, and how, are the polar regions and polar research important to all people on Earth?" This is the question addressed by a series of five classroom posters developed by UNEP/GRID-Arendal with support from IPY. Teachers, pupils and other interested parties can download these eye-catching, informative and educational posters free of charge from a dedicated website.

The aim is to enhance schoolchildren's knowledge about polar research and the International Polar Year. The posters may be downloaded in several formats and certain graphic elements from the posters may be downloaded as well. The website also features links to more information about the issues presented in the posters as well as to other reference materials. The posters are available in both English and Norwegian versions (see sample below).

www.grida.no/polar/ipy/2840.aspx



Bringing Norwegian space research into the classroom

The Norwegian Centre for Space-related Education (NAROM) is located at the Andøya Rocket Range in Northern Norway. During IPY, the centre hosted a wide array of activities targeting lower-secondary and upper-secondary school pupils (aged 13–18) under the Polar EduSpace project. The project has collaborated closely with the IPY science project ICESTAR.

A number of competitions related to polar science using satellite imagery were held in lower secondary schools in autumn 2007. Of the 50 pupils who submitted final reports, 11 were selected for a three-day visit in the field at Andøya. A field course was held for 15 teachers on Svalbard as well. Classes were also given the opportunity to visit the Engabreen glacier in connection with classroom activities using satellite images.

A main aim has been to show the pupils how researchers use satellite data in their work and to introduce them to remote sensing. In collaboration with the ICESTAR project and the University of Bergen, the PolarEduSpace project put together four instrument kits for schools to borrow and use for teaching purposes. By providing access to images from the SPOT 5 satellite, the project has enabled pupils to cooperate with glaciology students. A teaching module for remote sensing of glaciers was also developed.

www.sarepta.org
www.narom.no

Teaching about the Arctic System

The Norwegian Polar Institute received support from IPY for an education project targeting pupils from primary school through upper secondary school. The centrepiece of the project is a 64-page booklet entitled The Arctic System, published in both English and Norwegian. The booklet was sent to every school in Norway, and class sets of booklets could be ordered free of charge. Over 10 000 booklets have been distributed in Norway.

With a focus on the Norwegian Arctic, the project presents the Arctic as a continuous ecosystem and explains why it is especially important to conduct research and environmental monitoring there. The aim of the project was to reach as broad an audience as possible and increase interest in polar research in the natural sciences.

As part of the project, young artists shot videos in the field on Svalbard. The project also resulted in classroom posters, brochures, graph figures and lectures for teachers. The project launched its own website, which offers access to all of the educational materials as well as links to other informative websites about the Arctic.

Researchers representing eight IPY science projects also went on a lecture tour as part of the project, primarily targeting pupils in their first year of upper secondary school. A total of over 1 500 pupils attended the lectures in Kirkenes, Alta, Tromsø, Trondheim, Bergen and Oslo.

www.arcticsystem.no

COURSES

Course on Svalbard for government administrators

The annual Svalbard Course provides government administrators and other individuals who play a key role in Norwegian policy relating to and management of Svalbard with firsthand knowledge about the area. The course has been held each year since it was introduced in 1976 by Olaf I. Rønning, a professor in studies of the natural environment at the Department of Botany at the former college Den Allmennvitenskapelige Høgskolen in Trondheim.

For the special IPY Svalbard Course in 2008, participants took a two-week voyage on the M/S Kongsøy along southern and western Spitsbergen. The plan was to travel as far north as Sjuøyane and sail around them, but the amount and thickness of the ice made it impossible to go farther north than Verlegenhuken. There were 32 passengers on board the Kongsøy – 20 course participants, seven course leaders and lecturers, and five crew members – which posed a major challenge in terms of meals and sleeping accommodations.

The focus of the course was on the fourth International Polar Year; 13 IPY science projects were presented and the participants visited several of the research sites. Another important aim was to enhance participants' understanding of the management of Svalbard by sharing knowledge about the archipelago's nature and history. And as an added bonus, participants were able to experience the stunning and dramatic natural environment on Svalbard.

www.ntnu.no/nt/svalbardkurs (Norwegian only)

EXPEDITIONS

Five frozen students cross Spitsbergen

At the end of March 2007, a team of five international students from various scientific disciplines set out on a two-month-long expedition across Spitsbergen, the largest island in the Svalbard archipelago. The young scientists – who became known as the Frozen Five – wished to show young people how exciting polar research can be and how important the Arctic is for the global climate system.

The Svalbard Skiing Expedition started just after the opening of IPY. The students skied nearly 1 000 km, crossing high Arctic glaciers between 76° and 80° N, and reaching the tips of both southern and northern Spitsbergen. The objective of the expedition was twofold: to teach upper-secondary school pupils about the role of the Artic in the global climate system and what this means today and to demonstrate that research activities in Arctic areas can be very exciting, thereby motivating more young people to pursue a career as a researcher in the natural sciences.

The team went on a lecture tour before the expedition, and schoolchildren could follow the expedition via the Frozen Five website and blogs. Once they returned home, the team travelled around Norway for a month, giving lectures at upper secondary schools. The expedition also resulted in a photo exhibit and a 33-minute-long documentary for 10–12-year olds entitled, *Who Let the Dog Out?*
www.frozenfive.org

OTHER ACTIVITIES

Reindeer husbandry, climate change and society at large

The International Centre for Reindeer Husbandry in Kautokeino has been involved in two outreach projects associated with the IPY science project EALÁT at Sámi University College.

EALÁT-Outreach I has focused on the adaptive capacity of reindeer pastoralism to climate change in Finland, Norway, Russia and Sweden. Reindeer have major cultural and economic significance for more than 20 different groups of indigenous peoples in the region. Nomadic reindeer pastoralism is ancient and represents models in the sustainable exploitation and management of northern terrestrial ecosystems. It is based on generations of experience accumulated, conserved, developed and adapted to steadily changing climatic and administrative framework conditions.

The aim of the project is to disseminate Arctic reindeer herders' traditional knowledge to other reindeer herders, industrial enterprises and society at large in the Arctic regions of Norway and Russia. The project has resulted in a compilation of information from various reindeer herding societies, a series of workshops, a web portal, films, posters and books.
icr.arcticportal.org/ealat

Photo: Rudi Caeyers