The Research Council of Norway

Norwegian polar research

Research policy 2014–2023

The Research Council of Norway

The Research Council of Norway is a national strategic and funding agency for research activities. The Council serves as a chief source of advice on and input into research policy for the Norwegian Government, the central government administration and the overall research community. It is the task of the Research Council to identify Norway's research needs and recommend national priorities. The Council utilises specifically-targeted funding schemes to help to translate national research policy goals into action. The Research Council provides a central meeting place for those who fund, carry out and utilise research and works actively to promote the internationalisation of Norwegian research.

Content

Preface

The changes taking place in the polar regions do not merely affect those regions themselves, they affect our entire planet. The Arctic and the Antarctic are two of the last large areas of virtually untouched nature on Earth. These harsh regions have a special place in Norwegian history, with the achievements of the explorers Fridtjof Nansen and Roald Amundsen, extensive hunting and fishing activity and, not least, research activity, which is steadily increasing. Climate change and the prospect of increased human activity in polar regions offer both challenges and opportunities. Norway is one of the world's leading polar nations, and as such we have particular responsibility for and interest in acquiring knowledge as a basis for sustainably managing polar resources and safeguarding these unique environments. With our outstanding polar researchers, Norway also has the potential to make a significant contribution to the international knowledge effort in the field.

Norwegian polar research is predominantly Arctic-related to enable us to safeguard our proximal polar regions. Nevertheless, it is important to enhance research in and on the Antarctic, both to generate knowledge about the continent of Antarctica and its role in global systems and to maintain Norway's economic and political interests there. Polar research questions must be examined to a greater extent from commercial, social science and humanities perspectives as well.

This policy document articulates the ambitions of and sets the direction for the Research Council of Norway's polar research efforts for the next decade. Norway must engage in comprehensive international collaboration and promote fruitful interaction between the national and international polar research communities. New and existing infrastructure must be optimally utilised and new generations of polar researchers must be recruited. Norway must also promote effective coordination of research activities in Svalbard and enhance the capacity and quality of Antarctic research.

I would like to thank the Norwegian National Committee on Polar Research, which has played a key role in drawing up this polar research policy, as well as other external contributors. We have received important and constructive input through dialogue meetings and consultative statements. We look forward to the work of achieving the policy's long-term priorities and objectives through the relevant Research Council funding schemes and across disciplinary, thematic and sectoral boundaries. In this way the Research Council will help Norway to strengthen its role as one of the world's leading nations in polar research and as an important contributor to knowledge of global interest.

Arvid Hallén
Director General

Introduction

Photo: Ruth Astrid L. Sæter

Changing polar regions – new opportunities and new challenges

Global warming and increased human activity are causing changes to occur more rapidly in the polar regions. Changes in the climate and the environment have considerable impacts, posing new challenges to and generating new opportunities for countries, communities and individuals alike. An extensive body of knowledge is necessary for solving these challenges and exploiting these opportunities.

The polar regions are part of the global system, as a driver of important natural processes and as a location of early warning of global climate change. In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) concludes that human influence is the most important cause of climate change from 1950 to the present.[1] Anthropogenic greenhouse gas emissions have led to ocean warming, snow and ice melt, and a rise in global sea level. These trends are expected to continue.

Climate change has impacts on species distribution and living conditions. Species living in polar regions are affected by many factors. Long-range transboundary pollutants are transported into the polar regions by air and ocean currents and accumulate in the food chain. Species are simultaneously affected by local pollution and industrial activity.

The retreating Arctic ice cover creates a potential for increased economic activity. New sea routes can be established, and natural resources will become more accessible for extraction and harvesting on land, in the ocean and below the seabed. The economic potential is vast, which may lead to conflicting interests among various actors as well as challenges in developing policy.

Various fora for cooperation on the polar regions have been established, with focal points ranging from international trade, regional cooperation, cultural exchange and the rights of indigenous peoples, to the environment, education and research.

[1] Working group 1 report: The Physical Science Basis.

Eriophorum (often called cottongrass) is a hardy plant commonly found on the Arctic tundra. Photo: Shutterstock

Actors in the private and public sectors are joining forces to find effective solutions for sustainable utilisation of resources. Increased access to and activity in the Arctic will require clarification and agreement on the delimitation of maritime boundaries.

Norwegian polar research – objectives and status

Objectives

The objective of polar research is to enable Norway to fulfil its special responsibility for acquiring the knowledge needed to implement policy, management and economic activity in the polar regions. At the same time polar research is intended to generate fundamental knowledge about the Arctic and the Antarctic. Research on polar regions will provide deeper insight into processes of crucial importance for the Earth's environment and climate. Norway has a longstanding tradition of polar exploration and we have a particular responsibility for and interest in polar research, not least because our prosperity is linked to inter alia economic activity in the polar regions.

Status

Polar research is carried out by research groups throughout the country, including Svalbard, and encompasses all sectors performing research. Polar research has undergone a tremendous development in recent decades, fuelled in part by Norway's extensive activities in connection with the International Polar Year (IPY 2007–2008) and the strong national prioritisation of the High North. Extensive infrastructure has been established nationally and internationally, and cooperation between researchers in Norway and researchers in other countries has been strengthened. An important trend is the growing number of centres for research and innovation addressing Arctic issues.[2] This indicates that more and more attention is being targeted towards these issues and that Norwegian research groups are achieving success in open competitive arenas. All of this should bolster Norway's scientific position in polar research and enhance the knowledge base for management of polar natural resources.

Norway is one of the world's leading polar research nations and ranks fifth as measured by the number of papers published in the period 2009–2011, after major research nations such as the US, Canada, the UK and Germany.[3] In terms of research on the polar parts of the Arctic, Norway ranks third, after the US and Canada.

Norway's prominent role in Arctic research is primarily linked to its extensive climate and marine research activities, particularly in Svalbard and the adjacent sea areas, for which considerable infrastructure has also been built. Due to this concentration of research activity and accessible infrastructure, priority has not been given to certain other research areas.

Antarctic research is vital to understanding global processes linked to e.g. ocean currents, ice, rise in sea level and atmospheric conditions. There are stringent requirements for planning and logistics when conducting research in the Antarctic in order to overcome obstacles relating to long distances, harsh climatic conditions and less fixed research infrastructure. Norwegian Antarctic research is relatively modest in volume. Norway ranks 21st in research on this region as measured by the number of papers published in the period 2009–2011. An increase in both funding and international cooperation is needed to strengthen Antarctic research.

The most recent mapping of polar research activities shows that researchers in Norway lag behind researchers in leading nations with regard to citation frequency.[4] Although Norway ranks fifth in terms of the number of publications, it ranks 14th in terms of its relative citation index. While there are many complex reasons for this, there is indisputably room for improvement.

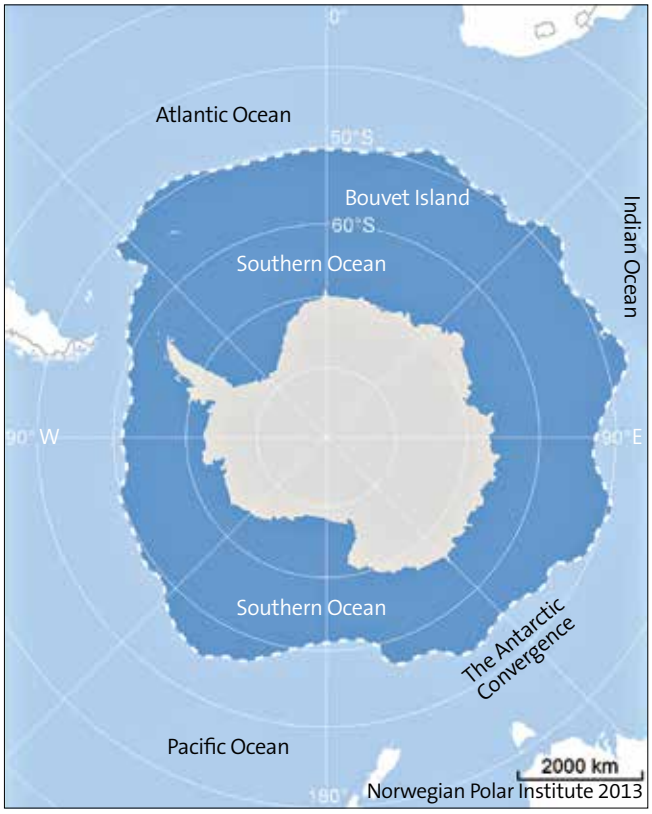
Framework for the polar research policy

What does polar research encompass?

This polar research policy encompasses activities ranging from basic research to applied and industry-oriented research in and on the polar parts of the Arctic and Antarctic. Polar research includes thematic areas such as climate, the environment, geology, natural resources, the societal and industrial challenges, geopolitics and culture, and is thus not a separate discipline. The term "industrial challenges" does not include all industry-relevant research in polar areas, but focuses on the particular problems that arise as a result of natural conditions in polar regions.

[2] Centres of Excellence scheme (SFF), Centres for Research-based Innovation scheme (SFI), Centres for Environment-friendly Energy Research scheme (FME), and Nordic Centres of Excellence scheme (NCoE).
[3] Nordic Institute for Studies in Innovation, Research and Education (NIFU) report 3-2012.
[4] NIFU report 3-2012.

The polar regions are exposed, cold and challenging. Yet, we humans have "always" been fascinated by these geographical extremities, and over the years we have built a long and proud polar research tradition. The Arctic fox is a species we now know a lot about. Photo: Carsten Egevang



With regard to the Antarctic, this policy document covers the area south of the Antarctic Convergence.

With regard to the Arctic, this policy document covers the shaded (dark blue and grey) area on the map.

In the context of this policy, the geographical term "Arctic" refers primarily to the polar part of the Arctic, including Svalbard, Jan Mayen, the northern part of the Norwegian Sea, the Barents Sea, the Greenland Sea and the Arctic Ocean. Furthermore the geographical term "Antarctic" refers to the area south of the Antarctic Convergence. This encircles Antarctica, and is where cold, northward-flowing Antarctic waters meet and mix with the warmer waters of the sub-Antarctic. Its position varies, but it normally lies between 50° S and 60° S. The Antarctic Treaty applies to the area south of 60° S. However, this policy also includes the sub-Antarctic islands such as Bouvet Island and South Georgia, which may at times be north of the Antarctic Convergence.[5]

National policies

This polar research policy must be viewed in the context of relevant white papers and policy documents. The most central documents are: *Long-term perspectives – knowledge provides opportunity* (Meld. St. 18 (2012–2013) Report to the Storting); *The High North – Visions and strategies* (Meld. St. 7 (2011–2012) Report to the Storting); *Svalbard* (Report No. 22 (2008–2009) to the Storting); *Norwegian Climate Policy* (Meld. St. 21 (2011–2012) Report to the Storting); the management plans for the Barents Sea–Lofoten area and for the Norwegian Sea; *An industry for the future – Norway´s petroleum activities* (Meld. St. 28 (2010–2011) Report to the Storting); and the sectoral research strategies for the 21st century, including HAV21, MARITIM21, OG21 and KLIMA21.

The Norwegian National Committee on Polar Research has also drawn up two reports that provide important input for priority-setting for polar research in the future: *Industry and polar research – a national initiative for a common future) and Norwegian research activities in Antarctica 2013–2022*.

International framework

Large parts of the Arctic region are under national sovereignty and are thus subject to national legislation, while activities in the Antarctic are regulated by treaties and

[5] This definition is in keeping with Report No. 42 (1992–1993) to the Storting on polar research.

Svalbard is a natural research laboratory attracting many scientists, such as these geology students on an excursion. Photo: Eva Therese Jenssen/the University Centre in Svalbard

conventions. Important conventions for the polar regions are: the United Nations Convention on the Law of the Sea; the Geneva Convention on the Continental Shelf; and the Convention on Biological Diversity (CBD). Treaties and conventions that apply specifically to the Antarctic include: the Antarctic Treaty, which regulates all activity on the world's southernmost continent; the International Convention for the Regulation of Whaling; the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR); and the Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol). For the Arctic, the following organisation and treaty play a key role: the Arctic Council, which is an intergovernmental forum for Arctic cooperation, and the Svalbard Treaty, which ensures Norwegian sovereignty in Svalbard and regulates the signatories' rights of industrial activity, hunting and fishing.

The role of the Research Council of Norway

The Research Council seeks to promote the highest possible quality in Norwegian polar research through open competition for funding and by encouraging national and international research cooperation. The Council also seeks to facilitate more innovative and pioneering polar research.

This polar research policy will help to achieve the objectives of relevant Research Council strategies.

The polar research policy is closely related to the Research Council's Research Strategy for the Arctic and Northern Areas (forskning.nord.to), as Arctic research lies within the strategy's scope. However, the polar research policy document provides a more concrete description of research challenges in the polar parts of the Arctic compared to the forskning.nord.to strategy, and covers Antarctic research as well. It does not cover research related to the Norwegian mainland, with the exception of pan-Arctic studies, for example of people and living conditions.

Vision and objectives for Norwegian polar research

Photo: Lucie Strub-Klein/the University Centre in Svalbard

Vision

Norway will strengthen its role as one of the world's leading nations in polar research and as an important contributor to knowledge of global interest.

Objectives

- Results from Norwegian polar research will be of relevance and benefit to society and support knowledge-based, sustainable environmental and resource management, industrial and social development, and policy development.
- Norwegian polar research will be at the forefront in areas in which Norway has special qualifications, expertise and competitive advantages and in areas of national priority.
- Norwegian polar research will achieve success in international competitive arenas through a high level of activity and production, high quality, visibility and influence.
- Norwegian research in and on the Antarctic will be strengthened.

It is presumed that Norwegian polar research will comply with the highest environmental standards to limit the footprint on these unique polar environments to the greatest possible extent. Research activities will follow the guidelines drawn up by the National Committees for Research Ethics in Norway.

The bearded seal is a common species of seal in Svalbard. Photo: Geir Wing Gabrielsen/Norwegian Polar Institute

Thematic priority areas

Photo: Shutterstock

Norwegian interests in the polar regions are diverse, thus Norwegian polar research must encompass a broad scope of scientific approaches and thematic areas. The Arctic and Antarctic represent natural laboratories where studies of systems and organisms with entirely unique characteristics and adaptations can provide insight into fundamental biological and physical processes and mechanisms. The distinctive character of polar research adds valuable input to basic research and scientific debate in many fields. Changes occurring in the Arctic may have wide-ranging impacts on the environment and natural surroundings as well as major economic and security-related consequences for countries, societies and individuals. It is therefore imperative to strengthen interdisciplinary research to clarify complex issues, while at the same time ensuring the continued high quality of discipline-specific research.

Research groups specialising in areas of strategic importance for Norway need to be strengthened, and those working in the international forefront of research must be able to maintain their leading positions. In addition it may be advisable to establish new scientific areas and expertise considered strategically important in the long term.

International interaction

The political and economic importance of the polar regions continues to increase. Foreign, security and defence policy analyses are vital to Norway, which has major resources and strong interests in the polar regions. Relevant questions include: How do the relevant stakeholders work together to develop polar policy? How are states, societies and individuals affected by environmental and climate change, access to new technology and increasing commercial activity?

Ensuring peaceful development of the region in a manner that promotes responsible management of resources and the environment will require the stakeholders to find legal and agreement-based solutions across a wide range of issues. There is a need for more knowledge about the various stakeholders' understanding of issues relating to the management of the polar regions and the rights of indigenous peoples.

Polar bears are marine mammals that spend much of their lives hunting seals on sea ice. Photo: Shutterstock

Adélie penguins in Antarctica. Photo: Harvey Goodwin/Norwegian Polar Institute

More systematic knowledge is needed about the new conditions for economic activity that are emerging in the wake of rapid environmental and climate change. It is equally important to define which restrictions are needed in order to prevent undesirable changes in the environment and climate, particularly in the Arctic. Key issues to study include potential conflicts of interests resulting from these restrictions, as well as new governance and negotiation challenges that may lie ahead. Knowledge about the role of trade and industry, and multinational corporations in particular, in managing and utilising the natural resources of the polar regions is essential as part of the basis for developing policy and designing resource management regimes. In light of this, it will also be useful to understand more about the influence of geopolitics on market forces and dynamics. The political and economic development of the polar regions must be viewed in the context of regional and global development trends.

Research on conditions that can help to avert an escalation in conflict levels or a decrease of international cooperation will provide important insights to the broader debate on international relations. The same applies to studies of conditions that promote the ability of states to effectively negotiate issues such as the delimitation of international maritime boundaries and fisheries-related negotiations. Potential shifts in fish stock migration patterns may pose challenges for international resource management bodies, for instance in the apportionment of fishing rights in cases where fish migrate across multiple national jurisdictions. There is enhanced value added in studies of politically relevant issues when the answers also inform the broader scientific debate. This applies to e.g. how global agreements can strengthen regional measures for search and rescue operations, oil pollution emergency preparedness and fisheries management.

PRIORITY RESEARCH TOPICS:

- **Geopolitical issues relating to change in the polar regions.**
- **The development of polar policy in collaboration between stakeholders at the international, pan-Arctic and national levels.**
- **Regimes for management of resources and the environment, preparedness and security in the polar regions.**

A changing climate and an environment under pressure

The polar regions are affected by global changes in the physical and chemical composition of the atmosphere and the oceans. The temperature in the Arctic is rising rapidly and the long-term rise is expected to exceed the global average. Multiyear ice comprises a diminishing proportion of the Arctic ice cover, which has significantly thinned and shrunk over the past 30 years. The Arctic glaciers are melting, the temperature of the permafrost is rising, the rate of coastal erosion is accelerating, and the distribution of species is changing. Deposition of soot on the ice and snow cover causes increased heat absorption, intensifying the melting.

Knowledge about the climate system lays the foundation for understanding the relationship between natural climate variation and anthropogenic changes, as

The calving of glaciers is becoming increasingly common. Shown here is Spitsbergen's Kronebreen glacier. Photo: Geir Wing Gabrielsen/Norwegian Polar Institute

well as the impacts of climate change on nature and society. Knowledge about impacts forms the basis for research related to climate adaptation. Without a thorough understanding of the climate system and climate change, any knowledge about future impacts and appropriate measures to adapt and reduce emissions becomes highly uncertain.

Predicting how Earth's climate will develop in the future requires fundamental knowledge about the climate system and how it is linked to changes in mean and extreme values in climate parameters both past and future, locally and globally. Climate variations are the result of a combination of natural fluctuations and anthropogenic forcing. More understanding is needed in both areas. There is considerable uncertainty in climate projections related to the Arctic climate system. A key weakness in the climate models is that they cannot adequately predict changes in polar ice condition. Thus it is of crucial importance to expand research activities on the climate system.

The physical changes and the relationships in the polar regions can be understood from an Earth System Science (ESS) perspective, which draws from a number of scientific disciplines to study the Earth as an integrated system. The ESS perspective enhances understanding of the interactions between natural science and human-based factors that affect the Earth's development.

The atmosphere and earth's proximal space

In order to strengthen the connection between observations and theoretical models that describe meteorology, climate change and long-range transboundary air pollution, access to long time series for key variables is needed. The polar regions currently have few monitoring stations for observing the necessary parameters, and major methodological challenges remain for quantifying variables and processes with adequate precision. For the Arctic in particular, it is essential to study the interaction between the oceans/sea ice and the atmosphere to understand the dramatic decline in sea ice.

The anticipated rising activity level in the polar regions makes it important to have knowledge about background values in order to assess any impacts on the environment. Research activity in the polar regions needs to be viewed in an overall context to enable research infrastructure and data to yield the highest possible value added in relevant areas.

The polar regions are excellent locations from which to study the middle and upperlayers of the atmosphere, where the impact from space is the strongest. Considerable research activity in the fields of space and auroral research is carried out from Svalbard using available spacerelated research infrastructure. This research is vital for understanding interactions between solar winds, the ionosphere and the various layers of the Earth's atmosphere. Coordinated use of ground measurements, weather balloons, rockets and satellites is needed for studying microscale processes in the middle and upper atmospheres. This enables scientists to map and forecast ionospheric disturbances, which is vital for secure satellite navigation.

At a regional level, geophysical and atmospheric processes can intensify the impacts of climate change through feedback effects, causing e.g. ice and snow to melt faster. This, in turn, can have impacts on global-scale climate change. Understanding this reinforcing effect requires integrated studies of energy balance, atmospheric circulation, and sources of climate forcers and pollutants. Using new observation platforms such as remote sensing from satellites and modelling provides a better understanding of interactions in the Arctic. Knowledge about transport, deposition and climate effects of short-lived climate forcers (such as soot and ozone) is essential to understanding observed changes in the climate, including links with cloud processes, heat transport and changes in the cryosphere[6].

Glaciers and permafrost

The cryosphere is very sensitive to climate change. Understanding the processes and rates of change in ice cover and glaciers is critical knowledge for quantifying current and future changes in sea levels. Glaciers, ice caps and (in Greenland and Antarctica) ice sheets are losing mass through increased melting and the calving of icebergs. The dynamic response and its link to climate are still not well understood, which causes high uncertainty in calculating future changes in sea levels. The larger amount of fresh water from melting ice masses also has direct impacts on the marine environment, water circulation in fjords and the thermohaline circulation.[7] Diminishing snow cover in the Arctic, less snow cover on glaciers and a shorter season of snow cover all reduce albedo (the fraction of solar energy reflected back into space). This feeds back to the

[6] Areas where the physical environment is predominantly snow, ice and permafrost.

[7] Ocean circulation driven by density gradients (determined by salinity and temperature).

Measurements such as these at Ny-Ålesund quantify the methane gas released when permafrost thaws. Photo: Christiane Graef

Melting ice masses, such as here in Svalbard's Hornsund fjord, affect the marine environment. Photo: Ruth Astrid L. Sæter

climate by affecting the Earth's energy balance. Reduced snow cover also has regional effects on thermal conditions in the ground and for the vegetation.

Permafrost exists on land as well as in continental shelves. When permafrost thaws, greenhouse gases such as methane and carbon dioxide (CO_2) are released, adding to the global emissions of greenhouse gases. The hydrological changes resulting from thawing permafrost will have significant impacts on the vegetation. Little is known about the extent to which changes in permafrost affect the stability of large mountainsides and seabed slopes and related processes of landscape formation. Measurements of temperatures and ice content in permafrost, as well as annual measurements of thaw depths in Arctic landscapes, provide necessary data for modelling the impacts of climate change on the permafrost. Fossils in permafrost provide a valuable archive for analysing past climate and species diversity. The thawing of permafrost affects infrastructure and has negative impacts on the preservation of cultural heritage.

Red saxifrage, one of the world's northernmost species of plant. Photo: Norwegian Polar Institute

Oceans and seabeds

The Arctic marine areas comprise deep seas, shallow areas (continental shelf areas) and coastal zones. The Arctic Ocean has not been studied or surveyed to any great extent. Boosting research efforts in this area will provide a better understanding of the geological history of the deep ocean of the Arctic and adjacent areas. This is important for mapping geological resources and understanding the climatic history.

It is important to gain a better understanding of the significance of ocean currents for physical and biochemical processes and natural variability in the marginal zones of the Arctic Ocean, the northern part of the Norwegian Sea and the Barents Sea. The energy balance and interactions between air and sea will be altered when the Arctic sea ice cover shrinks. Reduced sea ice, higher ocean temperatures and greater amounts of freshwater melt-off from glaciers alter the thermohaline circulation, which has major implications for the climate and marine environment. Changes in the extent of and seasonal variation in sea ice cover will have significant impacts on ecosystems and society alike.

The Southern Ocean is one of the world's least studied marine areas, yet it plays a vital role in deep ocean ventilation processes, the transport of inorganic nutrients, gas uptake and the global climate. In the Antarctic, the floating ice shelves drive unique geophysical processes that are also closely linked to the renewal of deep ocean water. Ocean currents are pivotal to climate development, so research should concentrate on processes that may contribute to altered circulation patterns.

Ecosystems

Natural variation, human-induced climate change, pollution, increasing commercial activity and tourism will entail changes at all levels of ecosystems, marine and terrestrial alike. Every part of the ecosystem will be affected, including microorganisms, flora, fauna, and species composition. A warmer climate in the polar regions will lead to severe reductions or outright disappearance of some species, while more temperate species will be able to establish themselves. This, in turn, will have consequences for the entire ecological system. It is important to enhance knowledge about reproduction, species composition and distribution, ecological processes and productivity. To achieve sound management of the ecosystems, it is critical to generate more knowledge about how adaptive the ecosystems are and how resilient they are to external pressures.

Sea ice is a habitat in itself, and changes in sea ice distribution may have major impacts on species dependent on this habitat. The melting of glacier fronts can also affect glacier-related ecosystems and species adapted to fjord ice.

Ocean acidification is considered to pose one of the most serious challenges to marine life. The polar marine areas are particularly vulnerable, since CO_2 is taken up more rapidly by cold water. In addition, the increasing amount of fresh water pouring into Arctic waters from rivers and melting ice reduces the oceans' capacity to neutralise the acidification. Acidification disrupts the formation of calcium carbonate in marine organisms, thereby affecting marine ecosystems.

Species composition in the Arctic tundra is highly significant for ecosystem function. Changes in hydrology and precipitation amounts and patterns may result in substantial changes in vegetation, which in turn has effects on snow cover and albedo and therefore on regional and global climate development. The polar regions store large amounts of carbon which could be a source of greenhouse gas emissions. Thus, there is a need to better understand the impacts of climate change on ecosystems with permafrost.

Pollution

Long-range transboundary pollution transported by air and ocean currents is the primary source of pollution in the polar regions. The Arctic is subject to more long-range transported pollution than the Antarctic, due in part to proximity to the polluting sources. Atmospheric transport is the fastest path of dispersion. Transport through ocean currents is a relatively slow process but is a primary means for compounds that are not fat-soluble and for radioactive pollution. Because local emissions are such a small factor, the Arctic can be considered a global reference area for pollution. Thus, knowledge about the extent of pollution and its environmental impact is crucial for international regulatory efforts. Observations and modelling are fundamental for enhancing understanding of how pollution is transported into and dispersed throughout the polar regions. Organic pollutants accumulate in the food web. There is more knowledge about levels and impacts on organisms in the Arctic than in the Antarctic, so comparable studies of levels of persistent[8] pollutants in the food web would be valuable. Climate change will affect the transport and turnover of both known and new pollutants.

Knowledge about the levels and impacts of known simple compounds is relatively good, whereas not enough is known about the interactive effects of a number of pollutants or the interactive effects of climate change, ocean acidification and pollutants.

The impact of local sources of pollution is minimal in both polar regions. In the Arctic, increasing commercial and tourism activity may result in greater local emissions. The elevated risk of oil spills from petroleum operations and shipping is considered the most serious threat. Increased soot emissions in the region may also hasten the melting of snow and ice and hence global warming in general.

The Arctic still faces challenges related to the risk of radioactive contamination from local sources in Northwest Russia. More knowledge is needed about source tracking, transport patterns, use of alternative measures and ethical aspects of managing risk and uncertainty.

People and cultural heritage

The Arctic is home to roughly 40 different ethnic groups with a wide variety of cultural and historical roots and economic bases. Climate change is threatening traditional ways of life and livelihoods. Infrastructure is also strongly affected by the rapid changes in climate. Arctic communities are under pressure from the global society's economic interests and activities, which are steadily advancing northwards. It is critical to learn more about how the changes in the Arctic will create winners and losers. This involves understanding

[8] Resistant to environmental degradation.

what influences choices between preservation and the utilisation of natural resources, and what this all means for potential measures to safeguard these communities' interests, cultures and future.

A key factor in maintaining the settlement at Longyearbyen, in keeping with political aims, will be the development of research-based commercial activities. Research can also help to establish critical loads for human activity in Svalbard and limit the environmental footprint on a fragile wilderness area.

In the polar regions there are cultural monuments from Norwegian and international economic activities, from the early exploration of the areas and from indigenous peoples' settlements and lives. Cultural heritage research provides insight into the past, present and near future. Climate change is causing challenges for the preservation of cultural monuments in the polar regions. Identifying and understanding these challenges and how to address them are important tasks in preserving cultural heritage in the Arctic and Antarctic. Norway must continue to play a major role in the established international research on polar cultural monuments.

Remnants of human activity at Camp Mansfield on Svalbard's Blomsterhalvøya. Photo: Kristen Ulstein

A Svalbard reindeer grazing in summer. Photo: Bjørn Franzen/Norwegian Polar Institute

Despite the harsh climate, human activity in the polar regions is increasing. Photo: Per Frejvall

PRIORITY RESEARCH TOPICS FOR A CHANGING CLIMATE AND AN ENVIRONMENT UNDER PRESSURE:

- **Links between the biosphere, geosphere, atmosphere, cryosphere and hydrosphere to enhance Earth system models with a polar perspective.**
- **The polar climate system and its interactions with the global system.**
- **Processes that control the polar ecosystems.**
- **Changes in ocean circulation and interactions with climate.**
- **Dispersion, effects and interactions of long-range transboundary and local pollution.**
- **Impacts of climate change and increased commercial activity on Arctic communities.**
- **Potential scenarios and critical loads for the development of human activity in Svalbard.**
- **Stronger foundation for preservation of cultural monuments in the polar regions.**

Retrieving a hydrophone buoy. Photo: Jan Durnick

Natural resources and industrial activity

Increased access to the polar regions opens up opportunities to utilise economic resources as well as new sea routes. Industrial development must proceed with caution and be based on a sound understanding of the potential consequences and measures to address the challenges. New knowledge and technology development is essential in a number of areas if the opportunities are to be realised safely and cost-effectively, with the least possible environmental impact. Research needs comprise the entire chain from basic research to applied research to the development of products and services. There will also be a need to identify potential conflicts relating to interests and use of land and sea when multiple actors and industries look to operate in the same area. Through research-based innovation, polar research can help to promote value creation in the form of new services and products for society and by establishing new commercial activities.

Petroleum activities

A substantial portion of the world's undiscovered petroleum resources are estimated to be located in the Arctic. The scope of petroleum operations, however, will depend on access and profitability. The uncertainty of estimates makes research related to identifying and understanding the petroleum resources essential for defining the activity level. Greater access due to reduced Arctic ice cover will facilitate better understanding of geological and geophysical processes. Norway is a world leader in offshore oil and gas production and is highly advanced when it comes to Arctic technology.

Petroleum field development in the Arctic will face challenges such as cold climate and icing problems, the polar night, increased disruption of atmospheric communications and navigation, and safeguarding vulnerable Arctic ecosystems. The

long distances and vast marine areas also comprise a significant challenge to Arctic petroleum activities. Greater knowledge about ocean currents, meteorological conditions, ice and icy conditions, and methods for notification of and dealing with sea ice and icebergs are all necessary for developing sound solutions for the entire production chain, from exploration and drilling to offshore production and transport.

Operations in the Arctic must be founded upon integrated, risk-based environmental management and follow stringent emissions requirements. Polar research must contribute to developing knowledge and technology that reduce the risk of unforeseen incidents and ensure high HSE standards. Environmental monitoring, a deeper understanding of petroleum activities' impacts on ecosystems, and oil spill response must be given priority in a region where nature's ability to decompose spilled oil, for instance, is diminished due to low temperatures, ice and limited sunlight for parts of the year.

Maritime operations

The increasing maritime activity in polar waters calls attention to a number of technological challenges, such as the design and construction of vessels, maritime operations in ice-covered waters, and operational challenges due to extreme weather conditions. Other challenges involve communication and navigation systems under shifting atmospheric conditions and risk management. There is also a need for improved data and a reliable forecasting system for weather and climate-related conditions such as ocean currents, low-pressure systems, ice formation and ice drift, and as a basis for developing operational procedures, risk management and HSE procedures in general. Extreme climatic conditions also affect materials and instrumentation, which in themselves are significant research areas in a polar context. The vulnerability of the polar environments calls for stringent emissions requirements, whether discharged to air or sea, as well as good environmental monitoring systems.

Reductions in ice cover are presenting the Northeast Passage in particular as a potential future shipping route. In addition, marine tourism is taking advantage of these conditions to move steadily farther north. Better routines for monitoring and search and rescue will be important so that this development can proceed safely. The Arctic Council has established cooperation agreements between member states on preparedness for search and rescue as well as oil spill response. In the Antarctic, search and rescue cooperation is also in place. Achieving adequate preparedness in the polar regions will require an expanded range and faster response times.

Fisheries and biomarine resources

How the marine ecosystems develop as the climate changes will depend heavily on biological interactions, physical and chemical conditions, and the utilisation of biological resources. Observations and modelling will be fundamental to understanding ecological development. In-depth knowledge of the relationships between various levels in the food web is vital, including marine ecosystems' production cycles and productivity.

Utilising marine resources will require new technology in a number of fields. This applies to traditional fisheries as well as to harvesting species lower in the food web.

Sustainable management of herring stocks ...
Photo: Institute of Marine Research

... and potential for increased harvesting of krill in the Antarctic.
Photo: Institute of Marine Research

Maritime activity is expected to increase in Arctic waters – and the need for knowledge will grow accordingly.
Photo: Geir Wing Gabrielsen/Norwegian Polar Institute

How are the penguins of Antarctica affected by climate change? This is just one area where polar research can provide new knowledge. Photo: Shutterstock

In the Antarctic, for instance, there is great potential for increased harvesting of krill. Any resource exploitation, whether in the north or in the south, must be carried out in a sustainable fashion, which entails a better understanding of the impacts of harvesting lower levels in the food web on the ecosystem as a whole. Essential to this will be the development of fishing equipment that can select for specific species, sizes and volumes, while also ensuring high quality.

The marine areas of the Arctic and Antarctic feature interesting biological diversity. Efforts are increasing to identify biologically active components from marine organisms, with the goal of finding compounds or genetic products useful in areas such as medicine, food, animal feeds, industrial processes and biofuels. Marine organisms have developed different strategies to ward off infection than terrestrial organisms. Special enzymes enable cold-adapted organisms to have high activity levels at low temperatures.

Mineral extraction

Rising standards of living and urbanisation in populous countries have brought higher demand for minerals, driving prices up. The Arctic has a varied geology with many types of resources. Research to identify and understand prospective areas is crucial for the levels of activity. The relatively new field of subsea mining is gaining attention internationally. Deposits of minerals and metals in Norwegian waters may be substantial. Mining them may have major environmental impacts, so it is important to identify and document deepsea biological diversity and ecosystems.

Extracting minerals, ores and rare earth elements may entail major environmental consequences such as erosion, sinkhole formation, loss of biodiversity, and the contamination of soil, groundwater, seawater and fresh water. It will be imperative to develop research-based methods of utilising waste and by-products to minimise contamination levels at acceptable costs.

Travel and tourism

The polar regions are considered exclusive, exotic destinations, and the number of tourists visiting the regions is rising rapidly. Cruise tourism in the Antarctic and Arctic has grown significantly in recent years, and Svalbard is more accessible as a travel destination than ever before. One consequence of this is that the Arctic is becoming a year-round tourist destination, which opens up opportunities for developing new, attractive tourism products. This growth, however, has a downside related to e.g. the environmental impact of activity onshore and in polar waters, and potential conflicts between actors using the polar regions. It is also important to understand the effects of the travel and tourism industry on local communities and economies, including effects on other commercial activities and the development of infrastructure.

PRIORITY RESEARCH TOPICS:

- **Facilitate research-based development of knowledge, technology and services for petroleum extraction in the polar regions throughout the entire production chain, from exploration to production to transport.**
- **Improve forecasts by scaling and adapting models for atmosphere, weather and ice conditions.**
- **Develop technological solutions for cost-effective, environmentally sound fisheries in the polar regions.**
- **Contribute towards the research-based development of knowledge and technology for mineral extraction in the polar regions.**
- **Develop technological solutions for vessels and installations in the polar regions, and enhance knowledge about consequences of increased industrial activity.**
- **Enhance the knowledge base for environmental impacts and measures to address the challenges of increased industrial activity.**

Tourism is expanding in the polar regions – such as here in Svalbard's Kongsfjorden. Photo: Geir Wing Gabrielsen/Norwegian Polar Institute

Cross-cutting priority areas

Photo: Anna Pustogvar

International research cooperation

International cooperation is essential to enhancing quality and capacity in Norwegian polar research and ensuring that Norway has access to international knowledge production. International cooperation is a prerequisite in a number of research areas, including the climate, environment, the oceans and policy development, due to the international nature of the questions addressed. International research cooperation is a fundamental principle of the Antarctic Treaty.

Conducting research in the Antarctic is costly. Optimal results are achieved when research groups collaborate, utilise each other's infrastructure and drawn upon each other's expertise. In the Arctic, cooperation with the US and Canada is particularly vital for ensuring high quality in research. Research cooperation with Russia is essential for e.g. promoting effective joint management of the environment and shared natural resources. Key countries in the EU and major nations such as China and Japan make important contributions to international polar research and are thus important research partners for Norwegian researchers. Moreover, Nordic research cooperation can help to strengthen Norway's position internationally. In addition, the Research Council has signed a number of bilateral cooperation agreements that incorporate polar research.

Polar researchers in Norway are engaged in extensive, high-calibre international cooperation in many fields. This was confirmed in the international evaluation of Norwegian climate research[9] and the survey of Norwegian marine research.[10] Another indicator of the level of Norwegian research is the high success rate of Norwegian polar researchers under the Environment (including Climate Change) theme of the EU Seventh Framework Programme for Research and Development. Polar research is incorporated into all priority areas of the new EU Framework Programme for Research and Innovation, Horizon 2020, as part of the research activities to address environmental and climate challenges. Effort will be made to help Norwegian researchers to achieve even greater success under the new framework programme.

Research institutions from roughly 20 nations engage in research activity in Svalbard. The most recent white paper on Svalbard[11] highlights the fact that Svalbard is the most research-intensive part of Norway, and also the most international part. Research is an important element in management policy for Svalbard, and together with education is one of three priority

[9] Norwegian climate research. An evaluation. (2012)
[10] NIFU report 12-2013.
[11] Report No. 22 (2008–2009) to the Storting.

Research rockets can be launched into the northern lights from Andøya and Svalbard.
Illustration: Trond Abrahamsen/ARR

Providing more grants for fieldwork in the polar regions is one measure for promoting recruitment of new researchers. Here an example of polar bear research in the field in Svalbard. Photo: Magnus Andersen/Norwegian Polar Institute

areas for activity in Svalbard. Svalbard is to be further developed as a platform for Norwegian and international research with clear-cut Norwegian scientific leadership and presence. The Svalbard Science Forum (SSF) is an important tool for scientific and practical coordination of research activities in Svalbard. The Svalbard Integrated Arctic Earth Observing System (SIOS) is an international project on the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap. All key research institutions with research infrastructure and activities in Svalbard are involved in SIOS. The objective of SIOS is to coordinate, make accessible, upgrade and further develop observation systems for Earth system research in Svalbard. Both SSF and SIOS are thus important building blocks for further developing Svalbard as a platform for international research cooperation.

Norway takes active part in an array of international fora to advance Norwegian research interests and help to shape the international research agenda. Large-scale research programmes are developed within the framework of these bodies to improve coordination and deal effectively with the logistical challenges and costs of polar research. Such programmes also direct countries' efforts towards the major cross-cutting research questions.

PRIORITY AREAS:

- **Facilitate increased cooperation with leading international research groups and within research areas of strategic importance to Norway.**
- **Enhance international research cooperation through participation in, and interaction and task sharing with, international programmes and activities, including the EU Framework Programme Horizon 2020, relevant Joint Programming Initiatives (JPIs) and Nordic initiatives.**
- **Strengthen and target bilateral cooperation on polar research with countries, research actors and in areas of national interest to Norway.**
- **Improve coordination of sharing of data and infrastructure in the polar regions.**
- **Encourage Norwegian research groups to take on leadership roles in international cooperation to a greater extent.**

Recruitment

The increasing focus on research in the polar regions and use of existing infrastructure means it will be necessary to strengthen researcher training. This is made even more pressing by the fact that a major generational shift will be taking place in scientific and technical positions in the polar research disciplines at the universities and independent research institutes in the near future. New recruitment is therefore essential to ensuring continuity and further development. Recruiting junior researchers may entail increasing the number of doctoral and post-doctoral positions and grants, establishing researcher training initiatives and improving the general framework for polar research. Establishing new tenure-track positions at universities and university colleges may be an effective measure here. The research institutions should be encouraged to cooperate with industry and the public sector on researcher training.

The polar research activities of recent years, including the Norwegian projects under IPY 2007–2008, have included a considerable number of research fellowship positions. It is important to help these researchers to make use of their expertise in polar research as they pursue their careers. In addition to recruiting junior researchers and ensuring that they remain in this research field, effort should be made to recruit established researchers from the various disciplines encompassed by polar research. Costs related to travel and logistics pose constraints on the full utilisation of research capacity, and grants for polar field research should therefore be further increased.

The mission of the University Centre in Svalbard (UNIS) is to carry out research and offer teaching that takes advantage of its geographical position and use of Svalbard as a natural laboratory. The cooperation agreement between UNIS and Norwegian universities specifies the role of UNIS as the universities' Arctic extension of their educational programmes. UNIS should be further developed as an arena for cooperation and its role in recruitment to Norwegian polar research should be expanded. This will be dependent on the ability of the mainland universities to create an adequate recruitment pool.

PRIORITY AREAS:

- **Increase recruitment to polar research by strengthening researcher training.**
- **Establish researcher training initiatives, such as graduate-level researcher schools in disciplines of relevance to polar research.**
- **Expand the financial framework for funding of operating expenses and research fellowships for projects involving field research in the polar regions.**

Research infrastructure

Infrastructure

Well-developed research infrastructure enables researchers in Norway to conduct high-quality research and cooperate with top international research communities. Norway has extensive polar research infrastructure in both the Arctic and the Antarctic, which will now be enhanced with the addition of a new ice-class vessel. It will allow researchers to access new areas and will be equipped with advanced modern equipment for observation and sample collection. Thus, the research vessel represents a major step forward for Norwegian polar research. Infrastructure of this type will help Norway to achieve its vision of being one of the world's leading nations in polar research. Infrastructure is also a platform for international research cooperation and requires resources and funding for operations. The Research Council's Norwegian Roadmap for Research Infrastructure is a key instrument for funding new, larger-scale, national and international infrastructure projects.

In the Arctic, Svalbard is a research platform of high international calibre, with permanent research and monitoring stations in Ny-Ålesund, Longyearbyen, Svea, Hornsund, Barentsburg, Bjørnøya and Hopen. The SIOS project will help to coordinate and facilitate access to research infrastructure in Svalbard, and will make an important contribution to the pan-Arctic observation system, Sustaining Arctic Observing Network (SAON). Research aircrafts operate from Svalbard, and several countries make considerable use of research vessels in the Barents Sea, the Norwegian Sea and the Greenland Sea. For example, Norway and Russia collaborate on annual comprehensive monitoring cruises in the Barents Sea.

In the Antarctic, Norway has the Troll research station, as well as a field station on Bouvet Island and the Tor field station at Svarthamaren in Dronning Maud Land. Norway collaborates with 10 other countries on the research infrastructure project "Dronning Maud Land Air Network" (DROMLAN). Such cooperation is important to ensure cost-efficient, environmentally sound research activity. Norway also participates in and conducts own research cruises in Antartic waters.

Key phenomena and processes in proximal space can only be studied from the polar regions. Norway has world-leading space-related infrastructure in both the Arctic and the Antarctic, and is thus uniquely equipped to carry out comparative studies of the two polar regions. The fishing fleet and other industry actors have a potentially larger role to play in the context of future data collection.

Efficient data management is the key to integrating activities across national, institutional and disciplinary boundaries. Data collected with the help of public funding must be made available to other researchers. This means that the data must be adequately documented, searchable through open channels and stored, to the greatest possible extent, in data centres with long-term capacity.

Fieldwork to measure the quantity of methane in the wetlands of Brøggerhalvøya, Spitsbergen. Photo: Mette M. Svenning/UiT The Arctic University of Norway

Long time series

Long, quality-assured data series are critical to studying long-term changes in nature. They are important resources in research programmes and a key element of all environmental monitoring. Thus, they are also essential for industrial activity and sustainable management of resources.

Norway maintains some of the world's longest biological, hydrological, meteorological, oceanographic and seismic time series, but still does not have sufficient or long enough time series covering key climate and environmental parameters. Changes in the climate will entail a need for new and more extensive monitoring. There are a number of international strategies for integrated environmental monitoring, as well as conventions that stipulate requirements relating to the scope and quality of the measurement activities.

Satellite data can cover vast areas, but provide limited information and must be combined with high-resolution methods for collecting detailed field data. A modern monitoring system combines a range of observation platforms with modelling systems for quality assurance, prediction and understanding. Satellite observations and observations from air, ocean and ground-based instruments integrated into modelling systems form the basis for modern process studies and for climate and environmental monitoring. This requires further development of new, integrated observation technology for the atmosphere, land and ocean that is specially adapted to the polar regions. New observatories and systems must have international links and fulfil both research and management purposes. National and international cooperation is essential to ensure optimal use of resources.

PRIORITY AREAS:

- **Contribute to the maintenance of important well-established observation stations and data series, and that both national and international users have open access to old and new data.**
- **Encourage an adequate degree of temporal and spatial monitoring coverage (observations and models).**
- **Develop environment-friendly technology for both remote and in situ measurement.**
- **Establish SIOS as a platform for improved observation systems.**

Dissemination of research findings

Polar research addresses questions of importance for trade and industry, the government administration and the general public alike. Active dissemination of research results is vital to raising awareness of the importance of polar research among the public at large and to ensuring that the results are put to use. Increased communication of findings may also help

Troll is Norway's research station in Antarctica, and is in operation year-round. Photo: Peter Leopold/Norwegian Polar Institute

to encourage more young people to pursue a career as a polar researcher. Dissemination activities must be tailored to the specific target groups.

It is primarily through publication in scientific journals that Norway can make its mark as a polar research nation. The most recent survey of polar research shows that polar researchers in Norway lag behind the leading countries in terms of citation frequency, so there is room for improvement.[12] Encouraging cooperation with the best international researchers and more innovative research will help to boost the citation frequency.

Polar research is carried out in a variety of disciplines which could benefit greatly from each other's research results. Thus, scientific dissemination across disciplines should be facilitated and encouraged. The Research Council will play an active role in compiling polar knowledge.

[12] NIFU report 3-2012.

PRIORITY AREAS:

- **Encourage dissemination of results from polar research to various target groups to ensure that the research results are put to use.**
- **Encourage more publication in recognised scientific journals to improve the citation frequency for Norwegian polar research findings.**
- **Use dissemination activities as an instrument for recruiting researchers to polar research in particular and to the mathematics and natural science disciplines in general.**

The Zeppelin observatory for atmospheric research and monitoring is located near Ny-Ålesund on Spitsbergen. Photo: Ove Hermansen/Norwegian Institute for Air Research

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