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SETTING SCIENCE AGENDAS FOR EUROPE

EPB Strategic Position Paper

European Research in the Polar Regions:

Relevance, strategic context and setting future directions in the European Research Area

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The European Polar Board (EPB) is Europe's strategic advisory body on science policy in the Polar Regions. Established in 1995, it acts as a voice and high-level facilitator for cooperation between European national funding agencies, national polar institutes and research organisations. The EPB is concerned with major strategic priorities in the Arctic and Antarctic and has members from national operators and research institutes in 20 countries. The Board is taking a central role in the coordination and management of Polar Initiatives at a European level. Major focus areas are the implementation of a new Polar Framework MOU, the launching of joint research programmes such as PolarCLIMATE, the coordination of Polar research Infrastructures, and policy issues in the context of the European Research Area for the polar regions. The EPB is actively liaising with major polar programmes outside Europe including those in the USA, Russia and Canada. It has also been involved in discussions with other international agencies such as the World Meteorological Organization and in international research cooperation and Environmental monitoring in the Polar Regions.

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Contents

Foreword

It is becoming increasingly clear to European society that the Polar Regions are a key driver of the Earth's climate and the functioning of the oceans. European research activities in the Polar Regions (Arctic and Antarctic) significantly contribute to the understanding of the global climate system and its direct impact on European populations and the environment. The magnitude and scope of the science that is undertaken in these regions crosses many disciplines including oceanography, geosciences, physics, biology, space sciences and astronomy, as well as environmental sciences, socio-economic sciences and humanities. The regions cover a vast area and the investment from national polar programmes of European countries is significant, exceeding 300 million euros per year[1].

Research in the Polar Regions needs to be enhanced in the context of the European Research Area. Europe has to improve its efforts in polar research by addressing new ways of coordinating, structuring and investing in a collaborative way to maximise impacts and ensure that the highest quality scientific results are obtained and transferred into the policy domain. Efficiency, high quality, and justification of enhanced and sustained investment in national polar programmes with direct societal and economic connections are crucial elements of a future European polar research strategy, as well as close cooperation between national polar research programmes and future EC Framework Programmes. It is imperative to fully integrate research in the Polar Regions into the European Research Area, oriented towards aiding society through forecasting and knowledge creation.

Major priority issues identified in this report can be summarised as the following:

- The Polar Regions have a significant impact on the regional climate of Europe.
- Research in the Polar Regions is multidisciplinary and crosses many domains.
- The results of successful European polar science programmes in crucial fields have significant socio-economic implications.
- European polar research is characterised by significant differences in scale and scope between national polar programmes and the disparity between the approaches of small versus large countries.
- European supranational funding is important to provide an order of magnitude difference in implementation of research beyond national sources.
- The research assets that are involved require continuous and significant investment and coordination.
- The human and social dimensions of research in the Polar Regions are critical components of the interconnected system and need to be continuously integrated with natural sciences.
- The legacy of the International Polar Year 2007-2008 involving over 50,000 scientists and 60 nations resulted in an explosion of ideas and clusters of research groups. A major issue is the sustainability of these efforts into the future for the benefit of society.
- The political dimension of carrying out research in the Arctic will become increasingly complex and polar research is an important factor in the relations between Europe and other nations.
- The public's affinity towards the Polar Regions, especially by young people, can be enhanced by increasing the visibility of polar research in traditional media and in the newer forms of social media.

This keynote position document by the ESF European Polar Board defines a broad strategy for investment in research activities in the Polar Regions for the long term benefit of Europe. It highlights mechanisms to advance the mutual coordination of countries with national interests towards a common goal of advancing European research for future generations. This document points to critical issues related to integrating polar research into the mainstream of the European Research Area, and establishing a close link with future European Commission Framework Programme 8 and national polar funding agencies. It highlights the need for integrating activities and enhancing links with international partners, aimed at answering global scientific questions of importance for society and the social economic consequences of the dynamic Earth system.

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1. The European Polar Consortium: Strategic Coordination and Networking of European Polar RTD Programmes, FP6, Coor -1.1, Project Reference: 517842

Summary of High-level Recommendations

1. In order to understand the ongoing changes in Polar Regions, the European Polar Board recommends the development of integration and investment in monitoring and observations, research and modelling.
2. The European Polar Board recommends strengthening international cooperation to ensure cutting-edge science and the long-term availability of reliable technological means, capable of covering the maximum possible area.
3. The European Polar Board recommends that greater attention is paid to the human aspects of life in the Arctic as a valuable element to the EU for establishing itself as an important regional actor on the Arctic scene.
4. The European Polar Board recommends the establishment of guidelines for polar education and outreach, and to enhance the communications activities at all levels.
5. The European Polar Board recommends that the operational coordination of European polar research infrastructures will improve the information to policy makers and the public of future climate and environmental threats.
6. The European Polar Board recommends the establishment of a close link with EC Framework Programme 8 and national funding agencies and highlights the need for integration of activities.

1. Relevance of European Research in the Polar Regions

The Polar Regions (Arctic and Antarctic) are of special importance to the world and they are changing rapidly. The two regions can provide us with an insight into fundamental Earth system processes that are of crucial importance for the environment and climate of the Earth as a whole. In the Polar Regions important processes originate and can provide an early warning of climatic changes. Both regions are an international heritage to humankind, but are very different in physical nature and in political organisation. This chapter highlights the priority issues and challenges facing the future development of research in the Polar Regions, embedded into the broad European research strategy.

The global setting of the Polar Regions

Antarctica is a continent surrounded by an ocean. It is regulated by the Antarctic Treaty to which a number of European nations are signatory states. In contrast, the Arctic region is an intra-continental ocean surrounded by national territories inhabited by indigenous peoples and subjected to national laws. The Arctic Ocean contains Exclusive Economic Zones of the surrounding states, including some European states.

European research activities in the Polar Regions (Arctic and Antarctic) significantly contribute to understanding the global climate system and its direct impacts on European populations. The regions cover vast and sensitive geographical areas and the investment from national programmes is very significant. Research in the Polar Regions needs to be at the heart of the European Research Area.

There is no doubt that changes in the Polar Regions are of great significance at the global level, such as having far-reaching effects on atmospheric and ocean circulation. The accelerated ice melt in the Polar Regions is expected to affect significantly rises in sea level and global circulation patterns. Changes in ocean currents, temperature conditions, ice cover and reduction of permafrost regions will have impacts on marine and terrestrial ecosystems, resulting in changes in species' distribution ranges and migration patterns. For some species, survival will be difficult, whereas others will enjoy better living conditions. The Arctic has experienced the greatest annual warming of all regions on Earth, by 2°C to 3°C since the 1950s. Predicted further temperature increases range from 2°C to over 5°C and a sea level increase of 60–70 cm is expected, according to conservative estimates, by the end of this century (see Figure 2).

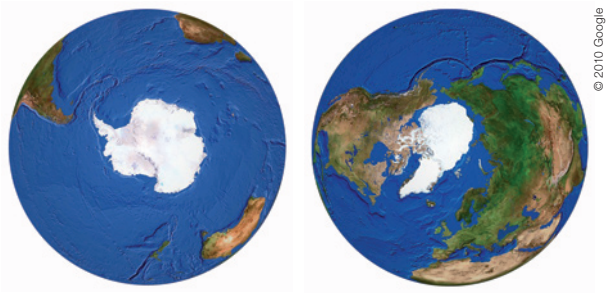


Figure 1. Antarctica and Arctic views.

In addition, climate change has major social impacts especially in the Arctic. If the rapid retreat of the Arctic sea ice continues, there will be a dramatic increase in the accessibility of regions in the high North in the course of only a few years. This will open up new opportunities in economic sectors such as the fisheries, tourism, oil and gas and transport. Maritime transport between Europe and Asia through the northern sea route may become feasible in only 5–10 years' time. In the longer term, we can expect to see transport routes straight across the Arctic Ocean in summer. Such scenarios will present new opportunities for economic activity, but will also make new demands on marine management, monitoring systems, emergency response systems, search and rescue services, and require closer international cooperation. Global warming can potentially determine new accessibility conditions to hidden Arctic resources.

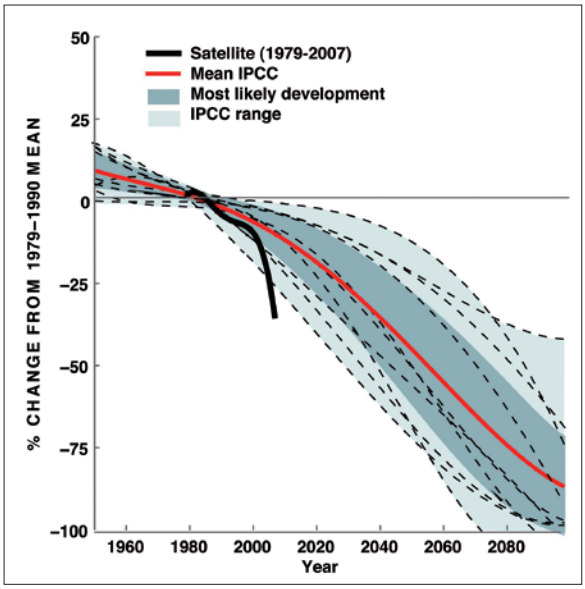


Figure 2. Arctic sea-ice loss in September 2007 compared to IPCC modelled changes using the SRES A2 CO_2 scenario (IPCC high CO_2 scenario).

The exposure and exploitation of such resources require the development of an international regime based on the improvement of the present regulations of exploration, accessibility, exploitation and liability.

Polar research in the Earth system context

Earth system science comprises studies of individual processes and their interactions at all levels in five major spheres: the biosphere, geosphere, atmosphere, hydrosphere/cryosphere and the anthroposphere (see Figure 3). Polar research encompasses all of these aspects of Earth system science. European nations have traditionally been very active in polar research and have built up an expertise and infrastructure for this research that is unparalleled world-wide. Research is directed both to the Arctic and Antarctic which facilitates bipolar comparisons of climate, adaptation strategies of organism and biodiversity. Major emphasis is placed on palaeoclimate research (ice cores, sediment cores), observation of ocean current systems (thermohaline circulation, deep water formation), atmospheric research (ozone concentration, airborne transport of pollutants), biological resources (krill, fish stocks, biodiversity), research on permafrost regions, and socio-economic impacts of a changing polar system on indigenous populations and on economy. In this framework health and climate change are becoming of growing importance. In addition, because the harsh environment is a unique laboratory for natural sciences it is an ideal testing ground for the development of new technologies for remote observations and systems functioning under extreme conditions.

The most recent assessment report AR 4 from the UN Intergovernmental Panel on Climate Change (IPCC 2007) made it clear that a better understanding of the feedback mechanisms between the cryosphere and climate, clouds, carbon cycle, biosphere and the ocean circulation is needed to improve climate scenarios. These mechanisms have been very poorly quantified in the Polar Regions, which are therefore of particular interest in the context of Earth system science.

The relevance for Europe

European countries acknowledge the cost and complexity of performing science in Polar Regions and recognise the potential for cost-effective operations through increased cooperation on logistics and infrastructure, based on the fact that the countries of Europe have different and complementary infrastructures and logistical resources in Polar Regions, as elaborated in chapter 3.

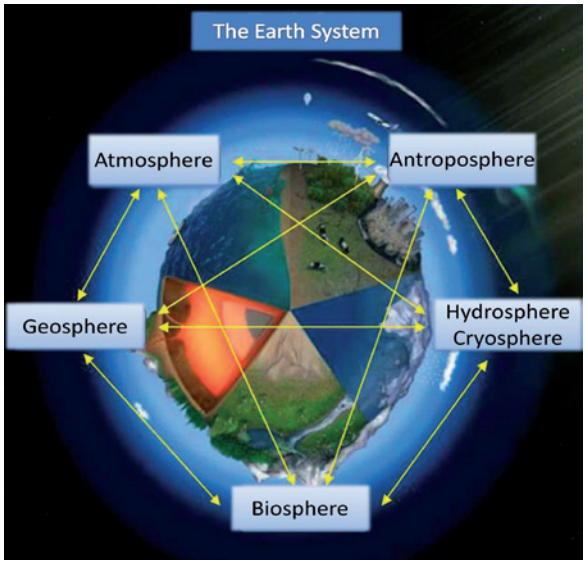


Figure 3. The modellisation of the five major spheres (biosphere, geosphere, atmosphere, hydrosphere/cryosphere and the anthroposphere) constitutes the Earth system.

New challenges within the humanities and social sciences will emerge as a result of the major changes that are taking place in the Polar Regions, and particularly in the Arctic. These changes may have considerable impacts on individuals, communities, and the economy of the states. Human activity is putting pressure on the environment in these regions. There are unresolved issues related to national claims on continental shelf and sea areas and the utilisation of resources that involve international law. Dialogue and international agreements based on scientific evidence are key elements for finding solutions. Research in this field must generate insight into these challenges and identify potential responses, as discussed in chapter 4. Polar research is expected to provide a significant contribution to knowledge for the climate debate; therefore it is important to encourage polar researchers to play the role of experts in the public debate, giving them the appropriate skills to do so. Dissemination activity must be targeted towards the public administration in order to provide a better basis for decision-making. In addition, communication of environmental knowledge and findings to the general public in a way that holds its attention is valuable and will help stimulate interest in scientific training and research. These issues are outlined in chapter 5.

2. Addressing Global Scientific Questions

The Polar Regions have a huge influence on, and are influenced by, the other parts of the Earth system. Thus, their study offers a unique opportunity to unravel some of the system's inherent complexity. It provides insights into the natural variability of the system and how it will respond to human induced challenge, and how humankind might manage and adapt to future changes. This chapter introduces the major scientific questions and makes recommendations for focal points of European polar research.

New challenges in polar research

The Polar Regions offer an unrivalled opportunity for research at the frontiers of knowledge, both for basic scientific and strategic reasons. The majority of polar research is focused on climate change as this has the most pronounced effects in these areas. In addition polar areas are of great interest for other research, such as studies of the northern and southern lights, pollution issues and, more recently, bio-prospecting. New technology also gives opportunities to carry out observations that a few years ago were impossible. An example at the physical and biological frontiers is research into **sub-glacial environments**. One of the most amazing and exciting discoveries about our planet in recent years was the unexpected finding of another 'world' beneath the Antarctic ice cap, a system of rivers and lakes which has been separated from the surrounding world for hundreds of millennia. This finding of sub-glacial environments is profound, akin to discovering another planet in the solar system. Another particularly exciting aspect of the sub-glacial environment (probably unique to the Antarctic) is the prospect of new forms of life inhabiting the sub-glacial lakes, adapted to extreme conditions and providing new insights into microbial evolution with the additional possibility of discovering completely new compounds of value to industry or medicine.

Crustal structure and the geology under the ice are virtually unknown and may provide insights into the evolution of the continental crust beneath Antarctic and Greenland ice caps. For instance, the Gamburtsev Mountains are a huge mountain range (as large as the European Alps in extent and height) positioned deep in East Antarctica.

The polar deep sea ecosystems are similarly unknown in respect of their biodiversity and adaptation to this extreme environment. In particular the deep Arctic Ocean is suspected to harbour living communities hitherto unknown to science. The scarcity of food in the ice-covered ocean presents a particular stress for survival. Recently hydrothermal activity was discovered in the Arctic Ocean and it is an open question whether this could sustain comparable communities as in other ocean regions.

The inner Antarctic continent is the wildest, coldest and driest desert on Earth. Astronomers have for decades been attracted by the clear skies and the opportunity to install state-of-the-art astronomical facilities. The atmosphere above the highest domes of the Antarctic continent offers the best conditions for **astronomical investigations** at high angular resolution in the near thermal infrared and sub-millimetre-ranges. Concordia station at Dome C, located about 1200 km from the sea coast and an elevation of 3202 m, is an extremely promising location for the establishment of a European astronomical observatory in Antarctica.

Climate change and impacts in Polar Regions

Climate change is a major issue for both Polar Regions. It is manifested in the decrease in the extent and thickness of Arctic sea ice, permafrost thawing, coastal erosion, changes in ice sheets, ice shelves and in seasonal snow cover, and altered distribution and abundance of species. The Antarctic Peninsula has been identified as a 'hot spot' of regional temperature rise causing significant changes in ice cover and in the ecosystem. Nevertheless, the changes expected for Antarctica are still relatively small compared to the more dramatic changes in the Arctic.

Feedback from polar processes to the global climate can potentially accelerate global warming and cause

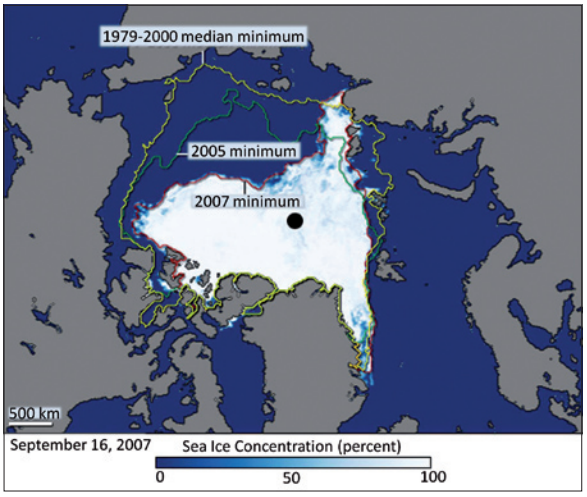


Figure 4. Extent of Arctic sea ice during the annual minimum of the climatological year 1992-2006 (white); contours of the minimum area in 2005 (blue) and 2007 (red) are superimposed on.

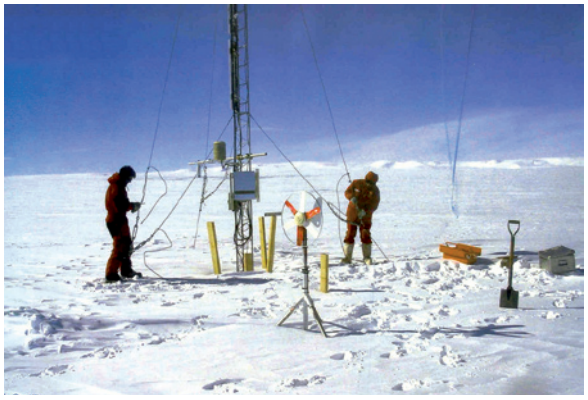


Figure 5. Researchers assembling a mast for atmospheric physics measurements in Antarctica, Victoria Land.

more rapid rise in sea level. Consequences for biodiversity and polar ecosystems are likely to be severe as these regions are home to very special and highly adapted organisms, many of which are endemic and occur exclusively either in the Arctic or Antarctica.

Thermohaline circulation: One of the key features of both Polar Regions is their role in the global heat balance and in the connected mechanisms driving the atmospheric and oceanic circulation. The coverage and the seasonal variation of sea ice plays a crucial role on this balance. In the oceans, differential heating between high and low latitudes determines differences in temperature and salinity distribution which are the bases of the thermohaline circulation (THC). THC is a crucial element for heat transport at the global scale and profoundly influences atmospheric circulation and the Earth's climate. It is known from palaeo-records that there have been enormous changes in the atmospheric and oceanic circulation patterns over geological time and that these changes may have occurred over relatively short time spans.

Global energy balance: Processes that govern energy transfer between the different layers of the polar atmosphere and between the atmosphere and space are important for the global energy balance. Despite the fact that atmospheric processes in the Polar Regions differ both qualitatively and quantitatively from those at lower latitudes, parameters from lower latitudes are often used in models and to calibrate satellite data.

Climate impact on terrestrial ecosystems: Research on terrestrial and freshwater ecosystems should focus on measuring, understanding and predicting complex interactions between species in response to environmental changes. This will permit to estimate the consequences of changes in ecosystem structure and function for provision of ecosystem services. It should address changes from local scales that are necessary for the planning of adaptation strategies by local residents, to changes at global scales that contribute to the need for mitigation.

Climate impact on marine systems: Climate change may lead to changes in the distribution patterns of microorganisms, zooplankton, fish, mammals and seabirds and more knowledge is needed on how rapidly such changes take place. Furthermore, the timing of reproduction at various trophic levels may be affected by climate change causing disruption of predator-prey relationships or patterns of competition amongst species. The stronger such indirect effects are, the more difficult it is to predict the overall impacts on the system.

Earth system modelling: Earth system modelling poses a computational, technical and scientific challenges that must be linked together to make realistic projections as effectively as possible. It is important to incorporate improved understanding of processes and feedback mechanisms in the Polar Regions into Earth system models as quickly as possible. It is also important to downscale global scenarios for the Polar Regions, and to carry out studies using a hierarchy of models of varying resolution and complexity.

Ocean acidification: The uptake of CO_2 by the ocean is an important factor for future carbon dioxide concentration in the atmosphere. The cold waters of the Polar Regions are most effective in the uptake of CO_2. When this dense, cold water sinks after further cooling the CO_2 is rapidly transported into the deep ocean. The uptake of CO_2 acidifies the sea water and this affects a number of biological processes. Since the Arctic and Antarctic ecosystems generally contain only a few species in large numbers, it is important to quantify how these species are affected by ocean acidification.

Figure 6. Grey-headed albatross in the Antarctic Ocean. Grey-headed albatross (*Thalassarche chrysostoma*) are circumpolar birds living in the southern latitudes.

Figure 7. Navigation in the Antarctic Ocean, Ross Sea.

Sea ice: With constantly shrinking sea ice cover in the Arctic, the energy balance and feedback between air and water will change. This makes it important to understand how a thinner and weaker ice cover responds to wind and precipitation. Since sea ice is also an important habitat for many polar species its reduction has profound impacts on the polar ecosystem as a whole.

Glaciers and ice sheets: The hydrological changes associated with the retreat of glaciers and ice sheets have a direct effect on sea level rise. Such processes can be studied using a combination of field studies and modelling. In the Antarctic, the floating ice shelves drive unique geophysical processes that are also closely linked to the renewal of bottom water in the world's oceans. So far the estimations of loss of ice masses from the polar ice sheets have high uncertainties. A better understanding of how rapidly ice sheets and glaciers can change, including the importance of melt water for acceleration of ice movement, is important for climate scenarios and predictions of sea level rise.

Permafrost on land and under water: The thawing of the terrestrial permafrost results in considerable changes in landscape dynamics as well as in the social domain. Measurements of temperature, ice content of permafrost, and of annual thaw depths in different parts of the polar regions provide much needed data for models that can give more reliable projections of how climate variability will affect the permafrost and vice-versa. Thawing of carbon-rich permafrost soils, especially in the Arctic enhances greenhouse gas fluxes to the atmosphere. Furthermore, thawing of the permafrost and a rise in sea temperature may result in melting of gas hydrates both onshore and offshore, with subsequent methane emissions and the risk of rapid enhancement of the greenhouse effect.

Polar tele-connections: Links between processes in Arctic and Antarctic climate systems have been identified in paleo-records and indicate intimate inter-hemispheric exchange. The "bridge" between the two polar areas is via oceanic and atmospheric connections. Therefore a bipolar perspective in polar research is necessary.

Other science related issues

Upper Atmosphere/space physics: The Polar Regions are particularly suitable for studies of the middle and upper layers of the atmosphere, where the influence of space factors is strongest. In the interplanetary space, the solar wind interacts with Earth's magnetic field and plasma around the Earth. This interaction in the space surrounding the Earth originates from the Earth's magnetosphere. This region is continuously changing; changes appear through a variety of phenomena observed from Earth that also are known as magnetic sub-storms. Among the phenomena observed from Earth during a sub-storm there are the enlargement of the polar cap, the increase of electrojet currents, the occurrence of auroral emissions, etc. Phenomena occurring in ionosphere and magnetosphere regions are related to climatic changes and could be indicators of dangerous situation for the ground based and airborne electric plants and electronic equipments. Such research is also being applied to the emerging discipline of "Space Weather". The effects of Space Weather can range from damage to satellites to disruption of power grids on the Earth, so improved knowledge in this area is vital for modern society.

Maritime transport in the Polar Regions: New sea routes will be opened up by melting sea ice in the Arctic, and tourist cruise vessels are likely to visit both Polar

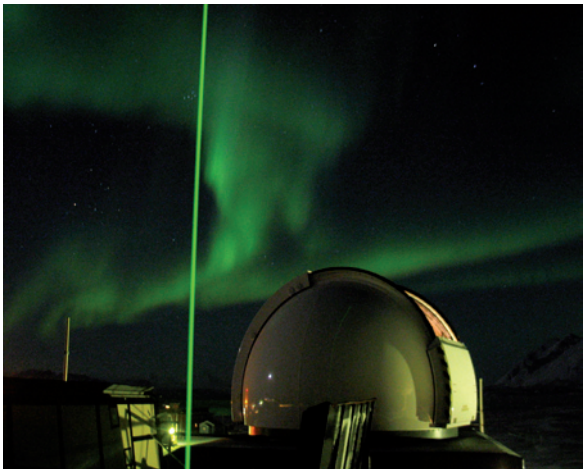


Figure 8. Green light beam of a Lidar. Lidar (Light Detection And Ranging) is an optical radar that measures properties of the atmosphere through scattered light. In the Polar Region, Lidar is mainly used for studying the climatology of aerosol and stratospheric ozone.

Figure 9. Spitzbergen landscape.

Regions more frequently. Thus issues relating to maritime transport will become increasingly important. Three research areas are particularly relevant in this context. Firstly, there will be a need for technological Reasearch & Development on vessels operating in these areas. Secondly, an increase in the volume of maritime transport will result in local pollution, which will not only affect marine life but also reduce the reflectivity (albedo) of snow and ice surfaces locally. Thirdly, shipping will break up the ice surface, exposing larger areas of open water. This is also expected to have a positive local feedback effect on melting due to reduction of albedo.

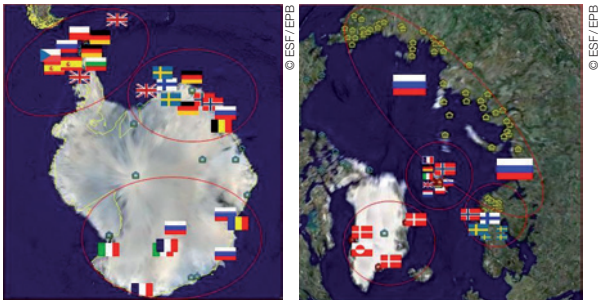
Bio-prospecting: Bio-prospecting is the search for and use of bioactive molecules and substances from living organisms for commercial purposes. The biotechnology based on polar genetic and molecular aspects covers several key areas including enzymes, anti-freeze proteins, bioremediation, pharmaceuticals and other health related applications such as dietary supplements and cosmetics. The commercialisation of research results based on marine bio-prospecting often requires a long-term perspective, a cross-disciplinary approach, business expertise, sufficient capital and a willingness to take risk.

Pollutants: Detection of pollution in the Polar Regions is indicative of the global diffusion of pollutants. Studies are needed to clarify the mechanisms of their environmental dispersal and their accumulation in different organisms. Because of the simple structure of polar ecosystems and the special adaptations of polar species, studies of the effects of pollutants on polar life may be particularly informative. The use and release of new industrial substances poses a great threat to polar ecosystems.

Figure 10. Convoy to Concordia Antarctic station, *Dome C*. Concordia is an all-year research station situated 3,233 m above sea level at Dome C on the *Antarctic Plateau*. It is located 1,100 km inland from the French *Dumont D'Urville* research station, 1,100 kilometres inland from Australia's *Casey station* and 1,200 kilometres inland from the Italian *Zucchelli station* at *Terra Nova Bay*. The *Geographic South Pole* is 1,670 kilometres away. The convoy leaves every year from Dumont D'Urville station to bring, in about 10 days, provisions and heavy equipment to Concordia station.

3. Supporting the Polar Science through World Class Research Infrastructures and Logistics

Polar research is characterised by a high degree of interdisciplinary, international cooperation and a requirement for sophisticated infrastructure and logistic support. The European States individually maintain a large number of observatories and research stations both in the Arctic and Antarctic. Polar observatories are of crucial importance for the detection and analysis of changes occurring in the Polar Regions and are the bases for modelling of future scenarios. This chapter analyses the present situation and provides guidelines for supporting European polar science by optimised use of infrastructures.



Left: Geographic distribution of the European scientific stations in Antarctica.
Right: Geographic distribution of the European scientific stations in the Arctic.

Because of the rapid environmental changes occurring in the Polar Regions, especially in the Arctic, enhanced observation is urgently required. The European States individually maintain a large number of observatories and research stations both in the Arctic and Antarctic. However, the coordination of these research facilities is relatively weak and a comprehensive assessment of the polar system and ongoing changes is not sufficiently developed. A European framework for optimised observations at the Polar Regions has to connect existing monitoring activities, harmonise and standardise measurements and provide access to the data and information gathered. Such coordinated European observation and monitoring strategies will significantly improve polar science. It will also raise international interest and help promote collaboration with international partners. A coordinated European observation strategy is also essential in the framework of the international process of Sustaining Arctic Observation Networks (SAON), promoted by the Arctic Council.

Logistics

Research in the harsh polar environment requires logistics and support of the highest quality, security and efficiency. In most cases this is beyond the capability of a single nation and the successful execution of polar projects requires coordinated, multinational efforts. Each national European polar research programme runs logistic systems able to provide support to national research teams in a wide range of scientific fields. Combining the logistic networks and concentrating the efforts on specific geographical stations (hubs) could strongly improve and widen European capacity. It would facilitate the integration of research teams at the European level and provide a more comprehensive and effective support to international cooperation with non-European partners.

Excellent and successful examples of such attempts are DROMLAN and DROMSHIP, providing logistic support between South Africa and East Antarctica. While international organisations like COMNAP (Antarctica) and FARO (Arctic) guarantee that European efforts are well linked to their international partners, there is still scope to improve efficiency and avoid costly duplication. The entire system has to be optimised for reasons of finance, security and scientific exchange.

Infrastructure

Research stations: European countries maintain a number of terrestrial research stations on the Antarctic continent with regional focuses on Dronning Maud Land, Antarctic Peninsula and Victoria Land. Recent additions of state-of-the-art research stations are Neumayer III (Germany), Halley V (United Kingdom), Princess Elizabeth Station (Belgium) and Concordia (France and Italy) which enable European and international researchers to carry out world-class science on globally relevant questions. Svalbard is an important location for Arctic research for several European nations including Russia; more recently, South Korea, China and India opened their own stations. SCANNET is a network of field sites that originated from Scandinavian cooperation, but has expanded to become an international circum-arctic network of 32 research stations in the FP7 supported INTERACT project, which will be a major asset for terrestrial Arctic research.

Many of the terrestrial stations are increasingly acting in the capacity of long term Earth observatories for baseline monitoring of chemical, atmospheric, geophysical, biological and astrophysical parameters. National polar authorities should design workable mechanisms to share the extremely costly facilities in the Arctic and Antarctic. Such a collaborative system should evolve in stages. Already several multinational facilities have been set up (see Box 1) and such efforts should be extended.

Research vessels: Dedicated research vessels capable to operate all year round under any weather conditions in the central Arctic Ocean and in the Southern Ocean are

3. Supporting the Polar Science through World Class Research Infrastructures and Logistics

Box 1: Examples of existing European multinational polar facilities:

- The French-Italian Concordia station provides common infrastructure and project management, and is science driven and logistically managed over a geographic area of more than 500,000 square km
- Ny-Ålesund/Svalbard cluster of facilities hosted by Norway provides excellent facilities for research collaboration and access to extensive infrastructures
- AWI/IPEV (Germany/ France) joint station at Ny-Ålesund with common management and project planning
- Sweden and Finland share Nordenskiöldbasen in Dronning Maud Land, Antarctica, with the research stations Wasa and Aboa

vital marine infrastructures for polar research. The fleet of ice breaking vessels operated by European nations is a major asset of European polar research. Their operation is already partly coordinated amongst institutions and linked to international partners via organisations like COMNAP in the Antarctic and FARO in the Arctic. However, in order to achieve fully optimised use of these ships further coordination efforts towards shared use of ships are needed. New ship capacity is needed especially for Arctic research and new ice-breakers are being constructed within Europe. Technical and preliminary studies for the building of up-to-date all weather multipurpose scientific icebreaker (AURORA BOREALIS) have been funded by the German BMBF and by the EC's Framework Programme 7 as a preparatory phase project connected to the ESFRI roadmap. It is advisable to ensure that the new ship capacities are to a certain extent complementary and that the scientific payload can be exchanged between different vessels. Such questions of multinational use of ship time and interoperability of equipment are presently being addressed by the EC Framework Programme 7 project EUROFLEETS.

Figure 11. The Aurora Borealis icebreaker was endorsed by the European Polar Board in early 2000. The vessel provides unique capacities to carry out interdisciplinary research in almost 90% of polar waters in any season and weather conditions. The model underwent severe tests for both frontal and lateral ice-breaking capabilities in Hamburg and in Finland at the Aker Arktic's towing tank.

Observing systems: Automated observing systems are increasingly employed to obtain measurements over larger time and space ranges and in inaccessible locations. These systems include automated under-ice vehicles, remotely operated vehicles, observatories, moored systems or ice-tethered buoys. They provide long-term data essential for modelling and for assessments of trends and oscillations of ecosystem parameters.

Remote sensing from airplanes or from satellites provides the necessary spatial coverage of large region in conjunction with ground measurements that are essential for improvement and validation of models. They include polar aircrafts equipped with measuring systems for atmospheric components, ice surface and thickness as well as remote observations from satellites. The European Economic Interest Grouping "Geophysika-EEIG" (2001-2007), was a successful initiative providing a multinationally managed research platform for airborne experiments in the polar stratosphere. The recently launched CryoSat, an ESA satellite monitoring variations in the extent and thickness of polar ice, provides for the first time comprehensive data for the assessment of ice sheets and sea ice volumes.

New technologies

The design and implementation of new scientific technologies and platforms are major drivers to overcome present limitations in the Arctic and Antarctic. Such developments often require a multinational approach due to their complexity and costs. Several proposals for large polar research infrastructures are listed on the ESFRI roadmap (see Box 2).

At the national level a range of new technologies is being developed. For instance new ice drilling techniques are designed to access sub-glacial lakes or explore the bottom beneath the Antarctic or Greenland ice sheet. Automated systems capable of operating under ice and exploring the ice-covered deep ocean are being developed. New telescopes and upper atmosphere sounding equipment have been also implemented taking advantage of the unique characteristics of transparency and

Figure 12. DLR Falcon and M55-Geophysica at the ARENA ARCTICA's Hangar, Kiruna, Finland, during the EUPLEX Campaign. The FP5 EUPLEX (European Polar Stratospheric Cloud and Lee Wave Experiment) project aimed to answer key questions relating to Arctic stratospheric ozone depletion, using the Russian stratospheric aircraft M55-Geophysica, able to fly at over 21,000 m within polar stratospheric clouds.

stability of the deep-Antarctic atmosphere. These techniques promise new insights into a completely unknown world.

Added value by cooperation on a European level

Europe's polar research organisations and agencies should develop networks in the context of strategic priorities, with synergistic international sharing of resources, particularly to enhance coordination of European polar programmes and utilisation of polar research facilities.[1] Existing national expertise, priorities, infrastructures and capacities identified over the last few years provide a basis to improve the scientific capacity by optimising cooperation and mutual integration in strategically important areas. European collaboration can advance the idea of a core mechanism to allow researchers access to national platforms in a general way.

Almost all European stations can be thought of as nodes of scientific networks that could represent platforms of excellence for the development of specific research themes and studies for polar change processes.

The wide spread visibility of European polar research in the international programmes in Arctic and Antarctica highlights the excellence of the European polar institutions and the ability of European national polar agencies to promote partnership for carrying out large international projects. To develop and coordinate the ability of European countries to catalyze scientific international capabilities is an added value of European research that creates scientific alliances with variable geometry to face the highest challenges of modern science.

Data derived from an assemblage of research facilities dedicated towards observation of polar systems have to be easily accessible. The development of joint data policies, data management systems and data centres is an important step to underpin international climate policies and advice. Such data will be a major contribution to e.g. the Intergovernmental Panel for Climate Change (IPCC), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and other future assessments of global change.

Box 2: Projects with polar aspects listed on the ESFRI roadmap

- AURORA BOREALIS – A technologically and conceptually new icebreaking research vessel with unparalleled capabilities for working all year round and sea floor drilling in the ice-covered ocean.
- EMSO – European-scale network of multidisciplinary seafloor observatories for long-term real-time monitoring of geo, bio and hydrosphere processes; one high Arctic station is planned between Svalbard and Greenland.
- SIOS – A coordinated High Arctic observations network in and around Svalbard on the basis of existing and new systems.
- LIFE WATCH – Infrastructure for research on the protection, management and sustainable use of biodiversity including polar biodiversity.
- EUROARGO – European component of a worldwide *in situ* global ocean observing system.
- EISCAT 3D – European incoherent scatter radar system for geospace studies.

Figure 13. Concordia station, Antarctica.

1. See also FP6 EC project EUROPOLAR ERA-NET: Polar Alert: Information delivery and policy support for European governments on the Polar Regions, Deliverable 5.6

4. Integrating Social and Economic Impacts and the Human Dimension

The Arctic is characterised by considerable variations in population, climate, culture and community life. The physical area of interest encompasses lands stretching from the taiga-tundra boundary to the polar deserts and includes life on glaciers and life in permafrost regions; it also includes the rivers, lakes, ponds and wetlands of the Arctic and the stretches of rivers outside the Arctic that are necessary to understand environmental and ecosystem process within it. This chapter focuses on the northern human dimension as crucial element for any policy of Arctic environment preservation.

The Arctic is home to indigenous and other permanent human residents in thousands of large and small communities, many of which are European. Many of these communities live in harmony with the environment, and have developed their own cultural heritage. Only recently have the Arctic areas been recognised as an early warning system for changing climate and its impact on relations between society and the environment.

The Arctic also features abundant natural resources such as marine fisheries, wildlife, oil and gas. Many Arctic landscapes are pristine; their flora and fauna are adapted to the cold, and are largely undisturbed by human physical activity, although such areas can be impacted by contaminants transported from a long distance. In other areas however there is extensive exploitation of biological and mineral resources.

The predicted changes of Arctic climate and environment are likely to have diverse impact on the economy of the Arctic region and on Arctic residents. Permafrost based infrastructure (buildings, roads, and other infrastructures), as well as pipelines and waste disposal are under threat at rising temperature. Anticipated changes in global and Arctic climate are likely to result in increased contaminant transport to the Arctic. Circumpolar health problems such as those associated with changes in diet are expected especially for those population used to traditional foods that may become less available. Changing snow conditions are likely to adversely affect reindeer and caribou herding. For many Inuit, reduction of sea ice resulting in retreat of the hunted animals could disrupt or even destroy their hunting culture. The increasing number of tourists is creating a serious pressure on its fragile environment.

The newly emerging opportunities and associated emerging threats for Arctic people increase the number of policy areas in which EU involvement is relevant and necessary. New research programmes focused on social, cultural, political, and economic change in the Arctic area will advance the development of an EU Arctic policy, as expressed in the Arctic Communication of the EU[1]. These programmes will also support the European Commission's goal to embed and secure knowledge development for the needs of the society and to maximise Europe's scientific potential in all dimensions, including global cooperation.

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Figure 14. Arctic Council: Senior Arctic Officials meeting, 19-20 November 2008, Kautokeino, Norway.
A typical costume of the Sami indigenous population.

To improve future climate impact assessments to evaluate rates and ranges of changes in Arctic biota, and to the health status of arctic people, a more detailed systematic documentation of indigenous knowledge is crucial (ACIA Report 2007). The ESF EUROCORES Programme BOREAS, is a European initiative to identify through vernacular architecture, and household dynamics, similarities and differences in the way that northerners interrelate with their landscape.

If Europe wishes to have a pro-active and systematic approach to the Arctic, encompassing all of the relevant policy areas, integration of humanities and social science research is urgently needed. The integration of European socio-cultural, economic, historical, and policy studies under one coordinated research area (programme) will be a way to act in a constructive and convincing way toward its member states, Arctic and non-Arctic, as well as toward non-EU Arctic countries.

1. Arctic Communication of the EU, 20.11.2008, COM(2008) 763 final.

5. Reaching Out and Communicating to the Public

This chapter explores the importance of establishing communication to a broad audience with help of the media, the training of young people and young researchers and the strategic communication to policy makers. Dedicated polar communication must touch all societal levels and age groups by bringing together the input of polar scientists, educators, teachers, media and stakeholders and the public.

Communicating polar changes to a broad audience

The high costs of infrastructure or environment protection and other direct economic impacts of climate change demonstrate to everyone that understanding changes occurring in Polar Regions is of high relevance to the lives of citizens.

Polar exploration and discoveries have always stimulated the imagination of the public. Scientists, journalists and teachers are some that have always been able to capture the interest of the public and young people, and to convey the beauty of the Polar Regions and the fascination of Polar research. Both the Arctic and Antarctic are understood to be a crucial part of mankind's heritage and as such hold a special place in the heart of many citizens.

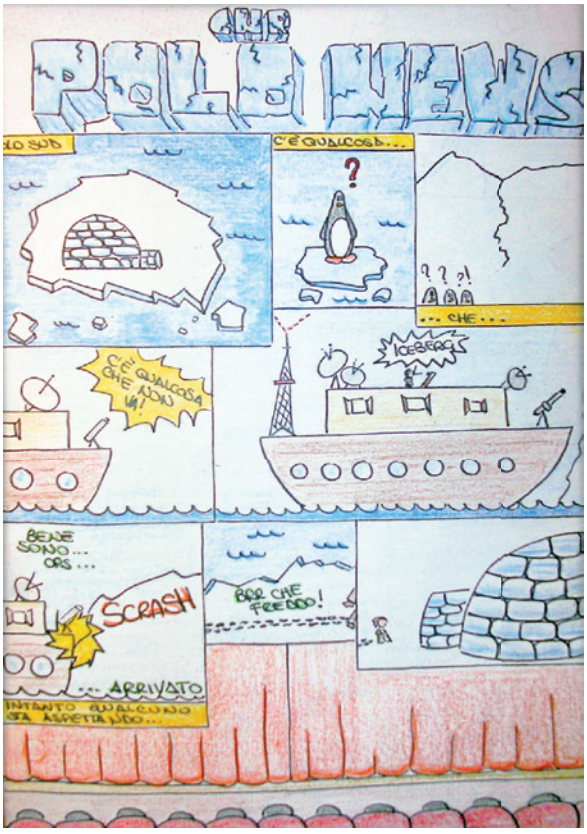

Figure 15. Detail from a hand-made brochure on polar issues edited by young students after a meeting.

The International Polar Year (IPY) has provided an important set of outreach categories ranging from the creation of classroom materials to the organisation of artistic events, from science training events to fairs and festivals. In particular, educational material can, at a relatively low cost, be translated and adapted to the different European countries and even to developing countries where there may be a serious lack of appropriate educational materials, and made available on the Internet.

Strategic communication and connection to policy

The support and guidance of policy makers to help reach decisions in educational, financial and governance issues must be an important component within the portfolio of communication dedicated to polar issues. There is an increasing need to extract important and validated results from polar research programmes to transfer advice to policy makers, alerting key constituencies on emerging threats. This will add significant value to the broader public and to politicians, and be a justification for the financial investments that are required to sustain these efforts in the Arctic and Antarctic. In this respect it is necessary that the polar research community should seek to speak with one voice. A suitable platform for this exchange and coordination can be provided by the European Polar Board.

Education and training of young people and young researchers

Polar education and outreach are important to attract and develop the next generation of polar scientists that will have to tackle the grand challenges ahead. IPY provided an opportunity for early career professionals to assume an active role and to enhance engagement in science and outreach activities by establishing the Association of Polar Early Career Scientists (APECS). UNIS in Svalbard provides university-level education in Arctic studies; the University of the Arctic (UArctic) is an international cooperative network based in the circumpolar region; the International Antarctic Institute (IAI) is a global consortium of universities and agencies that provide university-level education and conduct research in Antarctic studies. These are examples of best practice for dedicated education in the polar sciences.

6. The Polar Regions – Critical Components of the European Research Area

This chapter highlights the vital integration of combined and well coordinated research efforts in the Polar Regions and the recognition that they form critical components of the European Research Area. Future European polar research strategy should be based on coordination and connection between nationally funded polar research programmes and research infrastructures. A synergistic cooperation with the European Commission's Framework Programme and national programmes will be an important vehicle for developing a strategic research agenda. A full integration addressing the scientific grand challenges and the development of joint programmes oriented towards aiding society through forecasting, knowledge creation and innovation is required.

Towards a European polar research strategy

The European Commission through its Arctic communication and the subsequent endorsements by Heads of State in the European Council has elaborated and highlighted the importance of energy, security and environmental issues together with future governance and stability of the Arctic Basin and the critical importance of the populations of the Arctic. Research is an area where significant progress can be made in relation to advancing international relations. There is also the resonance of these research activities with policies at the European level such as maritime policy and the European environmental regulation and climate and emission targets.

As society increasingly appreciates the importance of the Polar Regions as a driver of the Earth's climate and the functioning of the atmosphere and oceans, it is time for Europe to address new ways of coordinating, structuring and investing in a collaborative way to ensure the highest quality scientific research and the transfer of results to the European policy domain. In this context it is important to maintain the convening power and role of the European Polar Board as a facilitator between the key national stakeholders and organisations involved in managing European polar research activities.

Specific high-level requirements to strengthen European polar research

Establishing dynamic partnerships and multinational coordination: If European nations are to sustain the International Polar Year's momentum into the next decades, they need to look towards dynamic partnerships between national programmes and supranational

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mechanisms. National programmes need to integrate European perspectives in their strategies and proactively invest in joint research or infrastructure initiatives. Co-designing and implementing polar research calls and connected actions between the European Commission and national agencies will result in an order of magnitude greater impact both politically and financially. The PolarCLIMATE research programme generated by the European Polar Board as an outcome of EUROPOLAR ERA-NET was one of the first examples of such a joint undertaking. Complementarities between such European nationally supported calls and the European Commission Framework Programme 8 may ensure that European polar research is established as a fundamental part of the European Research Area.

Developing joint funding programmes on grand challenges: Research questions in the Polar Regions are of such significant magnitude and scope to justify them as candidates for such types of endeavours. The supranational connection between the European Polar Board, National Research Councils and the European Commission in matters of European polar research would be an important step forward. A future European polar research strategy should explore its contribution to policies such as the European maritime, climate change and transportation policies.

Enabling forward resource planning and prioritisation of research themes: As countries plan their investments, mechanisms to engage in multiyear forward look planning between polar programmes should be addressed in order to have a more robust forecast of expenditures and commitments linked to ongoing programmes. This process should include elements of common scientific themes and prioritisation. A standard charter of European quality control on observations could be introduced across the European polar programmes for Arctic and Antarctic to maintain and encourage a higher level of comparability between national programmes.

Cost effective utilisation and operation of polar research infrastructure: The high cost of operations and logistics for research stations, vessels and aircraft in

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Figure 16. The Consortium started in early 2005. Its first action was to carry out a deep survey of European polar infrastructures and programmes. The infrastructure survey produced the most comprehensive overall assessment of European polar capacity by the European Commission.

the Polar Regions requires a more coordinated approach between European countries. Models for sharing and mutual opening of platforms will be essential in the future to justify public investments and to enable appropriate support to countries with operations in the Arctic and Antarctic. The use of shared platforms and the creation of regional hubs of scientific excellence around dedicated polar stations may become increasingly relevant to European polar operations for supporting the research priorities in the coming years.

Maintaining and expanding international relationships: European countries have already strong bilateral relations with Russia, Canada and the United States. Further joint research initiatives should be explored that could promote European and third country polar research partnerships and joint research calls, as well as shared usage of logistic resources and research infrastructures. These relationships should be extended from a bilateral to a multilateral level with the possibility for creating venues for the planning of logistical and programmes between groups of European countries and key international partners.

Structuring European research activities in the Polar Regions

Strategies and regulations of national polar programmes do not differ sufficiently[1] to exclude future agreements on common procedures and targets. Most of the European polar nations have national strategies in polar areas and centralised management and funding, which are primary factors to ease convergence and harmonisation.

Over the last few years the European Polar Board Consortium (EUROPOLAR ERA-NET) was funded as a project by the European Commission under Framework Programme 6, coordinated by the French Polar Institute (IPEV) in association with the ESF. This has made significant steps towards the convergence and integration of European efforts focusing on enhancing the cooperation between national funding agencies and the collective usage of research infrastructures. A European polar memorandum of understanding (**'Polar Framework agreement – EPC Memorandum of Understanding'**) was signed by 27 agencies and ministries in June 2009. It is an appropriate mechanism to engage with a large grouping of countries and funding / operational agencies within a strategic research partnership. A variable geometry open environment should be encouraged allowing for opportunities at a bilateral or multilateral level dependent upon the theme and issue concerned. The Polar Framework agreement – Memorandum of Understanding reflects this flexibility and openness.

Enhancement of coordination and investments within the context of future polar programmes will have to take into account the differences in the research financing and support systems across Europe. New models resulted in a test of the common peer review system and to which degree common scientific priorities have been identified and funding has been allocated. Successful models such as the EPICA collaboration demonstrates that pooling of funding is possible under certain carefully managed circumstances and that shared usage of infrastructures is a cost effective way forward.

The proposed EU-POLARIS initiative of the European Polar Board on the effective coordination of Antarctic research stations aims at a more effective future planning and support to scientific networks that will be established under joint programmes. Existing relationships between funding agencies established at a bilateral level over several years are helpful in fostering trust and understanding best practices.

Multilateral Agreements and Consortia. Multinational and interconnected long-term planning with

1. FP6 EC project EUROPOLAR ERA-NET: Assessment on European Polar Programmes

6. The Polar Regions – Critical Components of the European Research Area

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Figure 17. Signature of the *Polar Framework agreement – EPC Memorandum of Understanding*, which was signed by 27 agencies and ministries in June 2009.

foresight between European countries is a potentially very powerful approach and will significantly contribute to establish collaborative programmes and policies. One of the needs for some countries in the RTD landscape is to facilitate transactions of research funding across borders, to overcome scientific and logistical obstacles. Another hindrance, partially related to the previous point, is a general fragmentation of scientific activities and infrastructures which may cause overlapping and increase of costs of research in the Polar Regions. Nevertheless, there is an indicative trend of national polar programmes and activities in Europe becoming more integrative. Bilateral agreements are relatively common; however it would be desirable to encourage the development of European multi-lateral partnerships, with common priorities and elements of shared investment. This is particularly important in building future joint programmes. In this respect, the possibility of connected planning and long-term prioritisation of research topics and investments at a European level needs to be further examined and test cases pursued.

High-level Recommendations

1. In order to understand the ongoing changes in climate and environment, the European Polar Board recommends development, integration and investment in monitoring and observations to detect changes in the Polar Regions and their major drivers; research to understand causes of changes in Polar Regions; modelling to predict future changes in Polar Regions.
2. The European Polar Board recommends strengthering international cooperation to ensure cutting-edge science and the long-term availability of reliable technological means, capable of covering the maximum possible area. In particular the European Polar Board recommends maintenance of the high level of European polar infrastructure, improved joint use of polar ships and stations, investment in groundbreaking new technologies and development of a number of outstanding scientific networks in polar studies.
3. Recognising that the Arctic is an increasingly important theme in the global policy debate about human adaptation to future environmental change, the European Polar Board recommends that greater attention is paid to the human aspects of life in the Arctic as a valuable element to the EU for establishing itself as an important regional actor on the Arctic scene.
4. Recognising that education and outreach activities should be an essential part of any national European polar research programmes, the European Polar Board recommends the establishment of guidelines for polar education and outreach, and enhance the communications activities at all levels.
5. The European Polar Board recommends that the operational coordination of European polar research infrastructure is tested at a scale which will significantly enhance scientific excellence, researcher mobility, and international cooperation. It recommends harmonised data collection to inform policy makers and the public of future climate and environmental threats.
6. Recognising that the polar research should be fully integrated into the mainstream of the European Research Area, the European Polar Board recommends the establishment of a close link between EC Framework Programme 8 and national funding agencies and highlights the need for integration of activities. In particular it recommends:
   - establishment of dynamic partnerships and multinational coordination;
   - development of joint funding programmes on grand challenges;
   - resource planning and prioritisation of research themes both in the Arctic and Antarctica and encouragement of a higher level of comparability between national programmes.

Conclusions

This document highlights the priorities and challenges facing the future development of research in the Polar Regions, embedded into the broad European research strategy that will benefit society and provide social and economic development. As society increasingly appreciates the importance of the Polar Regions as the driver of Earth‘s climate and functioning of the oceans, it is time for Europe to address new ways of coordinating, structuring and investing in a collaborative way to maximise the impact of research and ensure that the highest quality scientific results are obtained and transferred into the policy domain. This keynote position paper by the European Polar Board defines in broad terms why we should invest in research activities in the Polar Regions for the long term benefit of society in Europe and how this can be achieved. It highlights mechanisms to advance the mutual coordination of national research in countries with interests in polar science. This document points to critical issues related to integrating polar research into the mainstream of the European Research Area, establishing a close link with EC Framework Programme 8 and national funding agencies. It highlights the need for integration and enhancement of the European polar community’s links with international partners, with the aim of answering global scientific questions of importance for society and the social economic consequences related to the dynamic of the polar systems.

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