

The contribution of a new joint European research icebreaker capacity to environmental monitoring and policy relevant research in Polar Regions with special emphasis on the Arctic





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Contents

Glossary	2
Aim of the report	6
Introduction	7
Contributions	8
Contribution to Polar Research by Sustained Monitoring and In Situ Measurement	8
Contribution to European Research	9
Contribution to International Polar Marine Research and Research Services	9
Contribution to Space Technology	10
Contribution to European Maritime, Environmental and Polar Policies	11
Development of European Public Goods and Services	12
EC Arctic Strategy	13
Europe and the Arctic Rim Countries	13
Sustained Observing Networks in the Arctic	14
Support for Decisions Affecting Polar Regions (with Special Emphasis on the Arctic)	14
Perspectives	15
AURORA BOREALIS Contribution to Science, Policy, Industry and Society	16
References	17

ACIA, the Arctic Climate Impact Assessment project (http://www. acia.uaf.edu/), is an international project involving the Arctic Council and IASC. ACIA is the world's most comprehensive and detailed regional climatic and ultraviolet radiation assessment. ACIA evaluates and synthesizes knowledge on climate variability, climate change, and increased ultraviolet radiation, as well as their consequences.

Arctic Council, (http://www. arctic-council.org/index.php/en/) is a high level intergovernmental forum to promote cooperation, coordination and interaction among the Arctic States. It involves Arctic Indigenous communities and other Arctic inhabitants on common Arctic issues, in particular relating to sustainable development and environmental protection in the Arctic. Arctic Council Member States are Canada, Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, Russian Federation, Sweden, and the United States of America.

ARCODIV, the Arctic Ocean Biodiversity (http://www.arcodiv. org/), is a Census of Marine Life project aimed at coordinating research efforts to examine the diversity in each of the three major realms: sea ice; water column; and sea floor, including fish, mammals & birds.

Arctic ROOS, the Arctic Regional Ocean Observing System (http:// arctic-roos.org), has been established as a legacy of the IPY 2007-08 by a group of 14 member institutions from nine European countries working actively with ocean observation and modelling systems for the Arctic Ocean and adjacent seas. Arctic ROOS aims to promote, develop and maintain operational monitoring and forecasting of ocean circulation, water masses, ocean surface conditions, sea ice, and biological/ chemical constituents.

AMAP, the Arctic Monitoring and Assessment Programme (http:// www.amap.no/), has a primary function to advise governments of the eight Arctic countries on matters relating to threats to the Arctic region from pollution. It covers associated issues such as persistent organic contaminants, heavy metals, acidification, petroleum hydrocarbon pollution, environmental consequences and biological effects in the Arctic resulting from global climate change, as well as stratospheric ozone depletion (biological effects due to increased UV-B, etc.). It also evaluates the effects of pollution, combined with other environmental stress factors, on ecosystems and the health of humans living in the Arctic.

CAFF, the Conservation of Arctic Flora and Fauna working group (http://arctic-council.org/working_ group/caff), addresses the conservation of Arctic biodiversity, habitats and ecosystem health.

CliC, Climate and Cryosphere (http://clic.npolar.no/), is a project of the World Climate Research Programme promoting research into the cryosphere, and its interactions with other parts of the global climate system.

CODATA (http://www.codata. org/about/index.html) is an interdisciplinary Scientific Committee of the International Council for Science (ICSU), which works to improve the quality, reliability, management and accessibility of data of importance to all fields of science and technology.

EEA, the European Environment Agency (http://www.eea.europa. eu/about-us), is an agency of the European Union. Its task is to provide sound, independent information on the environment. Currently, the EEA has 32 member countries.

EMSO, European Multidisciplinary Seafloor Observatories (http:// www.esonet-emso.org/emso/) is a European-scale network of seafloor observatories around European waters from the Arctic to the Black Sea, including the Mediterranean Sea, constituting a widely distributed infrastructure for long-term monitoring, mainly in real-time, of environmental processes related to ecosystem life and evolution, global changes and geo-hazards. EMSO will deliver multi-parametric, long-term (years) time series addressing the seabed and the water column. EMSO observatories will be equipped with a common set of sensors for basic measurements, and further sensors for specific purposes.

EIONET, the European

environment information and observation network (http://www. eionet.europa.eu/about), aims to provide timely and qualityassured data, information, and expertise for assessing the state of the environment in Europe and the pressures acting upon it. Through EIONET, the EEA coordinates the delivery of timely, nationally validated, high-quality environmental data from individual countries.

EPPR, the Emergency Prevention Preparedness and Response working group (http://eppr.arcticcouncil.org/), fosters international cooperation on environmental protection and sustainable development in the Arctic. The goal of the Working Group is to contribute to the protection of the Arctic environment from the threat or impact that may result from an accidental release of pollutants or radionuclides. In addition, the Working Group considers issues

Glossary

relating to the consequences of natural disasters and how to respond to them.

EUMETSAT, the European Organisation for the Exploitation of Meteorological Satellites (http://www.eumetsat.int/Home/ Main/AboutEUMETSAT/index. htm?l=en), has a main purpose to deliver weather and climaterelated satellite data, images and products 24 hours a day, 365 days a year. This information is supplied to the National Meteorological Services of the organisation's Member and Cooperating States in Europe, as well as other users world-wide. EUMETSAT is an international organisation and was founded in 1986.

Euro-Argo (http://www.euro-argo. eu/) is the European component of a world-wide in situ global ocean observing system (http://www. argo.net/) based on autonomous profiling floats. Argo is a global array of 3,000 free-drifting profiling floats that measures the temperature and salinity of the upper 2000 m of the ocean. This allows, for the first time, continuous monitoring of the temperature, salinity, and velocity of the upper ocean, with all data being relayed and made publicly available within hours of collection.

EuroGOOS, the European Global Ocean Observing System (http://www.eurogoos.org/), is an association of national governmental agencies and research organisations dedicated to European-scale operational oceanography within the context of the intergovernmental GOOS, the Global Ocean Observing System. EuroGOOS has 34 members, providing operational oceanographic services, and carrying out marine research, from 16 European countries. Many of the member agencies of EuroGOOS offer a large variety

of operational oceanographic products, both for the national coasts of their countries and for larger sea areas. Products include forecasts, oceanographic databases, and bathymetric maps.

Eurostat, EU statistical office (http://epp.eurostat.ec.europa. eu/portal/ page/portal/eurostat/ home/), is a Directorate-General of the EC. Its main responsibilities are to provide the European Union (EU) with statistical information at European level and to promote the integration of statistical methods across the Member States of EU, candidate countries and EFTA countries.

EPB, the European Polar Board (http://www.esf.org/researchareas/polar-sciences.html), is Europe's strategic advisory body on science policy in the Arctic and Antarctic. It is a platform for European engagement in international science programmes, and provides strategic science policy advice to the European Commission and international bodies.

GMES, the Global Monitoring for the Environment and Security service (www.esa.int/esaLP/ SEMRRIODU8E_LPgmes_0. html), is a joint initiative of the European Commission and the European Space Agency (ESA) for the establishment of a European capacity for Earth Observation. In practice, GMES comprises a complex set of systems which collects data from multiple sources (earth observation satellites and in situ sensors such as ground stations, airborne and sea-borne sensors), processes this data, and provides users with reliable and up-to-date information.

GEO, the Group on Earth Observations (http://www. earthobservations.org/about_geo. shtml), is a coordinated effort to build a Global Earth Observation System of Systems, or GEOSS. GEO was launched in response to calls for action by the 2002 World Summit on Sustainable Development, and by the G8 leading industrialised countries. These high-level meetings recognised that international collaboration is essential for exploiting the growing potential of Earth observations to support decision making in an increasingly complex and environmentally stressed world.

GEOSS, the Global Earth Observation System of Systems (http://www.earthobservations. org/geoss.shtml), has been set up by GEO on the basis of a 10-Year Implementation Plan for the period 2005 to 2015. The Plan defines the nine "Societal Benefit Areas" of disasters, health, energy, climate, water, weather, ecosystems, agriculture and biodiversity. GEOSS will provide decisionsupport tools to a wide variety of users. This 'system of systems' will proactively link existing and planned observing systems around the world, and support the development of new systems where gaps currently exist. It will promote common technical standards so that data from the thousands of different instruments can be combined into coherent data sets.

GOOS, the Global Ocean Observing System (http://www. ioc-goos.org/), provides accurate descriptions of the present state of the oceans, including living resources. It also provides continuous forecasts of the future conditions of the sea for as far ahead as possible, and the basis for forecasts of climate change. GOOS is a system of programmes, each of which is working on different and complementary aspects of operational ocean observation capability for all of the world's nations.

HELCOM, the Baltic Sea Protection Committee (http://www. helcom.fi/), is a governing body that works to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental cooperation between Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. One of the main roles of HELCOM is to act as a regional environmental focal point, providing information about the state of, and trends in, the marine environment, and the efficiency of measures to protect the Baltic Sea.

IABP, the International Arctic Buoy Programme (http://iabp. apl.washington.edu), with 28 participating institutions and agencies, maintains a network of drifting buoys in the Arctic Ocean.

IASC, the International Arctic Science Committee (http://iasc. arcticportal.org/), encourages and facilitates cooperation in all aspects of Arctic research, involving all countries engaged in Arctic research and all areas of the Arctic region. IASC promotes and supports leading-edge multidisciplinary research in order to foster a greater scientific understanding of the Arctic region and its role in the Earth system.

IES, the Institute for Environment and Sustainability (http://ies.jrc. ec.europa.eu/), is one of the seven European Commission's Joint Research Centres (JRC). Its task is to provide scientific and technical support to EU policies for the protection of the European and global environment. Connected to partner organisations in the EU and at the global level, IES helps provide sustainable solutions to today's global environmental challenges by encouraging partnerships. INSPIRE (http://inspire.jrc. ec.europa.eu/index.cfm/pageid/48) is a 2007 Directive, establishing an infrastructure for spatial information in Europe to support Community environmental policies, and activities that may have an impact on the environment. INSPIRE is based on the infrastructures for spatial information established and operated by the 27 Member States of the European Union. The Directive addresses 34 spatial data themes needed for environmental applications, with key components specified through technical implementation rules. This makes INSPIRE a unique example of a legislative "regional" approach.

IPAB, the International Arctic Buoy Program (http://www.ipab.aq/), is a network of drifting buoys in the Southern Ocean, in particular over sea ice, to provide meteorological and oceanographic data for realtime operational requirements and research purposes.

IPY, the International Polar Year (http://www.ipy.org/), is a large scientific programme focused on the Arctic and the Antarctic from March 2007 to March 2009 involving over 200 projects, with thousands of scientists from over 60 nations examining a wide range of physical, biological and social research topics.

IOC, the Intergovernmental Ocean Commission (http://ioc-unesco. org/) of UNESCO, promotes international cooperation and coordinates programmes in marine research, services, observation systems, hazard mitigation, and capacity development in order to learn more and better manage the nature and resources of the ocean and coastal areas.

MyOCean (http://www.myocean. eu.org/) proposes a first model of governance for a Marine Service organization. Its conducts observations, analysis, reanalysis, and forecasts describing the physical state of the ocean and its primary biogeochemical parameters.

OSI SAF, the Ocean & Sea Ice Satellite Application Facility (http:// www.osi-saf.org/), provides meteorological and oceanographic communities of EUMETSAT Member and Cooperating States with comprehensive information derived from meteorological satellites at the oceanatmosphere interface. The OSI SAF complements in situ data, and provides with continuously increasing temporal and geographical resolution level.

OSPAR Convention, the

conclusion of the Convention for the protection of the marine environment of the North-East Atlantic (http://www.ospar.org/ html_documents/ospar/html/ OSPAR_Convention _e_updated_ text_2007.pdf), is the current legal instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic. Annex VI to the Convention provides for cooperation in monitoring programmes, joint quality assurance arrangements, the development of scientific assessment tools, such as modelling, remote sensing and risk assessment strategies, and the preparation of assessments. Arctic waters are covered under Region I and constitute approximately 40% of the OSPAR maritime area.

PAntOS, Pan-Antarctic Observations System (http:// pantos.siena-space.org/), compiles details about existing or planned observational networks over the Antarctic in various scientific disciplines covered under the umbrella of the SSG/ PS. The PAntOS Group's main goal is to address the scope and implementation strategies for the follow-on development of the multidisciplinary Pan-Antarctic Observations Network encompassing the Antarctic Continent and the surrounding Southern Ocean.

Polar View (http://www.polarview. org) is an earth observation or satellite remote-sensing programme, focused on both the Arctic and the Antarctic. It offers integrated monitoring and forecasting services in the Polar Regions Polar View, and is supported by the European Space Agency (ESA) and the European Commission, with participation from the Canadian Space Agency.

SAON, the Sustaining Arctic Observing Networks (http://www. arcticobserving.org/), was set up in 2007 by the Arctic Council. It was formed to help develop long-term Arctic-wide observing capabilities to provide free, open, and timely access to high-quality data. Such data will help provide societal benefits on a pan-Arctic and global level.

SCAR, the Scientific Committee on Antarctic Research (http:// www.scar.org/), is charged with the initiation, promotion and coordination of scientific research in Antarctica. SCAR also provides international and independent scientific advice to the Antarctic Treaty System and other bodies.

SCAR-MarBIN, the Scientific Committee on Antarctic Research Marine Biodiversity Information Network (http://www.scarmarbin. be/), compiles and manages existing and new information on Antarctic marine biodiversity by coordinating, supporting, completing and optimising database networking.

SEIS, the Shared Environmental Information System (http://

ec.europa.eu/environment/seis/), is a collaborative initiative of the EC and the EEA to establish together with the Member States an integrated and shared EUwide environmental information system (http://eur-lex.europa.eu/ LexUriServ/LexUriServ.do?uri=CO M:2008:0046:FIN:EN:PDF). This integrates existing data gathering activities relating to EU environmental policies and legislation.

SIOS, the Svalbard Integrated Arctic Earth Observing System (http://www.unis.no/20_ RESEARCH/2080_SIAEOS/default. htm), aims to establish an Arctic Earth Observing System in and around the Svalbard archipelago. It is integrating information about geophysical, chemical and biological processes from existing research and monitoring activities into four observation platforms. These are land-based, sea-based, glacier/ice-based and space/airbased.

SOOS, the Southern Ocean Observation System (http://www. scar.org/soos/), is an international network launched as a 4th IPY legacy to share physical oceanographic data, and to build a data portal that provides easy access to multidisciplinary data from the Southern Ocean. The SOOS data system relies on existing data centres (e.g. the CLIVAR & Carbon Hydrographic Data Office, CCHDO, for hydrographic and tracer data, the thermal data assembly centres for XBT data, and the Argo data system). SOOS is co-sponsored by SCAR, SCOR, the Census of Antarctic Marine Life (CAML), the Partnership for Observation of the Global Oceans (POGO)3 and the Global Ocean Observing System (GOOS).

SWIPA, the Snow, Water, Ice and Permafrost in the Arctic

Assessment (http://www. arctic-council.org/index.php/ en/environment-a-climate/159swipa), was formally delivered by AMAP to the 7th Arctic Council Ministerial Meeting in Nuuk on 12 May 2011. SWIPA key findings are for example that the past six years (2005-2010) have been the warmest period ever recorded in the Arctic.

WCRP, the World Climate Research Programme (http:// www.wcrp-climate.org/), provides analysis and prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society.

WMO, the World Meteorological Organisation (http://www.wmo. int/pages/index_fr.html), is a specialised agency of the United Nations. It is the UN's authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the oceans, the climate it produces, and the resulting distribution of water resources. WMO has a membership of 189 Member States and Territories (on 4 December 2009).

Aim of the report

This report examines how a pan-European research vessel such as the AURORA BOREALIS (AB), with unique technical capabilities, would serve as an observational platform for integrated studies on climate change in the Polar Regions. It will do this by acquiring physical, biological, geological and chemical data and deployment of instrumentation for monitoring.

Another purpose is to demonstrate how Europe and its global partners would benefit from acquired knowledge to:

- Advance research and the understanding of climate change and related processes in Polar Regions
- Help develop European environmental and maritime policies and services
- Promote international cooperation in the Arctic
- Contribute to polar policy advisory mechanisms and support for decisions affecting the sustainability of Polar Regions
- Advance industrial sectors such as space and telecommunications

These five objectives include the most important existing policy and scientific monitoring activities in the Polar Regions, in which AURORA BOREALIS (AB) could contribute to advance knowledge. A set of different programmes and networks are given in each chapter as examples.

Greater emphasis has been given to the Arctic because it is of more interest for Europe from a political and economic point of view. However, it is important to note that AB could operate equally well in the Antarctic and be applied there for monitoring research crucial for understanding the effects of climate change. As it is, the AB Science Plan does include the Antarctic as well.

The report will not embrace interoperability, intellectual property rights, or data archive and management. Those topics are covered by different international and intergovernmental groups and committees such as **CODATA**. However as a pan-European operation, AB enhances to science data management, and systems such as **GEOSS**.

Joint monitoring programmes for the Arctic Ocean need appropriate ice-going research vessels to complement data that can be collected by, for example, remote sensing. A problem is that available ice margin vessels are not adapted to enter the Arctic during all seasons, many existing vessels are subject to operational constraints by their respective nations. There are not enough <u>heavy</u> research icebreakers in Europe that are able to penetrate the deep Arctic. The German POLARSTERN 1 (or the planned POLARSTERN 2), as well as the Swedish ODEN, are not available to work all year round in the Arctic (or in the Antarctic). Both vessels could operate for three months during the Arctic summer, and in exceptional cases for an extended period during mild winters, too. Even though current observations indicate that multi-year sea ice in the Arctic is retreating, there can still be heavy ice conditions during winter in those regions. In Antarctic waters most of the coastal sea ice around the east of the continent is multi-year perennial ice in summer and winter. It covers the continental shelf and has not been explored yet, because of the lack of suitable vessels.

A dedicated pan-European research vessel would provide a strong impetus for coordinating and structuring the European Research Area in the field of polar research. Scientific outcomes and new knowledge would accumulate rapidly. A pan-European vessel would also enable the collection of long-term observations urgently needed to understand important processes related to climate change.

The EC Communication "EU and the Arctic region" (2008) notes that AB would, as a new research infrastructure, support the integration of Arctic research in the European agenda and would coordinate efforts in different maritime sectors with relevance to the Arctic such as environment, transport, health and energy.

AB would concretely

- Boost the provision of in situ and real time measurements, in areas still poorly covered by data,
- · Further the development Arctic technologies,
- Provide ground verification for satellite data,
- Support the space and telecommunication industries,
- Contribute to the coordination of European research. By pooling resources AB would
- Create new knowledge,
- Help establish and maintain an environmental monitoring system in the Polar Region,
- Deliver data supporting decision making for the Polar Regions by centralising and coordinating new data,
- Help further scientific collaborations between European Countries and the Arctic Rim Countries.

The task of monitoring is to collect and transform field data into meaningful information for the benefit of society. **IOC**, the Intergovernmental Oceanographic Commission of UNESCO, United Nations Educational, Scientific and Cultural Organisation (IOC UNESCO, 2010) has produced a comprehensive pamphlet advancing major arguments why it is necessary to monitor the Arctic Ocean. The reasons include:

- 1) Monitoring conservation and management of natural resource
- 2) Monitoring changes in the ecosystem
- Monitoring the Arctic Ocean and providing regular, reliable information to guide Arctic shipping safely
- Monitoring the Arctic Ocean to understand key indicators and drivers for climate change
- Monitoring for Industry, energy and economic development.

Analysis of global environmental change requires better understanding of the physicochemical processes of our Planet. It is crucial to obtain reference data as a baseline and to monitor and understand changes in the Earth's system and the effects of climate change due to human-induced pressure on our physical environment (http://www.earthobservations.org/about_geo.shtml).

Climate change effects are more pronounced in the Polar Regions than in many other regions of the world. A regional focus is needed, but there are currently important knowledge gaps about the cryosphere and its interaction with the other compartments of the global climate system. According to **CliC**, a project of **WCRP**, the World Climate Research Programme, there is no global research programme focussing on the role of the cryosphere. Limited access during the wintee, and the lack of specialised jointly operated infrastructures, mean that the polar region is still one the most under-sampled and uncovered areas of the world.

Environment and climate policies will need increasingly sound and up-to-date data from the Polar Regions. A vessel that is dedicated to polar expeditions io the deepsea basins of the Arctic during all seasons of the year could contribute to filling these data gaps. The planned European research icebreaker AURORA BOREALIS (AB) is a unique technological innovation that can help meet the challenges. AB would acquire new scientific reference data from undersampled polar areas. By doing so, this infrastructure would support environmental monitoring in the fields of research and policy, with applications for industry and society at the European and international level. The monitoring activities of the AB would run alongside its scientific programme. Part of the monitoring can be carried out independently of the specific scientific missions using, for example, automatic recorders. Other parts of the monitoring would have to be specifically integrated with the science plan of the vessel.

Definition of Monitoring

In this document the term environmental monitoring means regular observations in space and time in the Polar Regions with special focus on the Arctic, aiming to identify natural and human-induced trends and changes for the benefit of a wide range of users.

The monitoring encompasses the atmosphere, cryosphere, ocean (physics, biology and chemistry), the seabed (biology and chemistry), as well as processes such as weather and climate, pollution, ecosystem dynamics, sedimentation, gas exchange through sea/air interface etc.

Contributions

Contribution to Polar Research by Sustained Monitoring and In Situ Measurement

IPY, the International Polar Year (2007-2009), was a major catalyst for polar research, across all disciplines. It was recognised that Polar sciences today still lack the critical all-year-round observations and experiments in the central Arctic Ocean. Weather and ice conditions prevent the penetration of research vessels into heavy pack ice during the dark seasons when critical climatic, biological and oceanographic processes occur.

According to ACIA, the Arctic Climate Impact Assessment project, a wide range of knowledge gaps in different research fields in the Polar Regions exist, which require sustained monitoring programmes (ACIA, 2005).

Example 1 – ice thickness

It is known that sea ice regulates heat, moisture, and salinity exchanges between the polar oceans and the atmosphere. Changing ice conditions in the Arctic will affect atmospheric processes such as the formation and persistence of clouds, the transport and disposition of solar radiation, and large-scale patterns of variability in the atmospheric pressure fields, that play a central role in global climate (Integrated Climate Data Centre, http:// icdc.zmaw.de/cryosphere.html?&L=1).

Currently the thickness of sea ice, and its spatial extent, as well as the portion of open water within the ice in response to changes in weather and climate, are not well mapped. Although the impact of sea ice on the global climate is recognised, its influence on the system is not understood because seasonal and regional changes are still unknown. However, a more detailed understanding and representation of these processes in global climate models is essential for improving predictions of future climate (ACIA, 2005).

For Antarctic sea ice, computational algorithms deriving sea ice thicknesses from satellite data are still in a developmental stage and data validation is in progress. Ice thickness data from ground-based surveys and surface elevation, combined snow depth, and ice elevation, reveal a more complex relationship between surface elevation and the sea ice thickness than predicted by simple isostasy using satellite laser altimetry. Moreover, the existence of areas flooded by sea water at the ice surface-snow interface makes the Antarctic different from the Arctic. This suggests that thickness algorithms based on positive ice elevation may need re-evaluation and adjustment for the Antarctic flooded condition with negative ice elevation. Reliable estimates for seasonal and regional variations in the Antarctic sea ice can be accomplished if the baseline thickness of the Antarctic sea ice is accurately predicted (Ozsoy-Cicek, B. et al. 2011).

Mapping the sea ice also has application for shipping, as new sea routes will open up in the Arctic for trade, tourism, or emergency responses.

Example 2 – Biological processes

The role of the Arctic and the Antarctic in the global carbon cycle, its diversity in marine and sea ice life, and the adaptation mechanisms of living systems to cold environments, are still poorly understood.

Significant decreases in the extent, thickness, and seasonal duration of sea ice, in the Arctic basin and along the Antarctic Peninsula, have severe ecological consequences for the sea ice biota. Habitat loss and changes in productivity, species composition, and community structure of the under-ice community are not fully understood. Also changes in hydrography due to climate warming have an impact on the sea ice ecosystem (http:// www.marbef.org/wiki/Sea_ice_ecosystems).



Figure 1. Diversity of marine life in the Arctic, from the sea ice to the deep sea floor. Taken from ARCODIV, the Arctic Ocean Diversity Project (http://www.arcodiv.org/index.html); for the Census of Antarctic Marine Life consult SCAR-MarBIN, the Scientific Committee on Antarctic Research Marine Biodiversity Information Network (http://www.scarmarbin.be/).

Shelf-basin transport in the Arctic is relatively poorly understood and is hypothesized to play a significant role in the global carbon system. Multiyear studies supported by icebreakers are needed.

In the Antarctic, knowledge of the biodiversity has been hampered by the relative inaccessibility of the region. Sampling is often restricted to the shelf, or close to locations of scientific bases. This makes it more difficult to determine actual distribution patterns. The same problem is encountered in pelagic work, which is frequently dictated by routes of logistical supply rather than by scientific considerations. Little is known about the fauna of the deep sea (Griffiths, H. J., 2010).

Extensive year-round observations onsite, which depend strongly on icebreaker support for transects and the deployment of measurement systems, can significantly enhance understanding of ecological processes. A ship such as AURORA BOREALIS (AB) would provide a platform to accomplish such programmes and yield new scientific results. It would have all the required features including strong ice-breaking capability, dynamic positioning in closed sea-ice cover, advanced ice-forecasting and management with autonomous, multiple helicopter support, along with the ability to deploy Remotely Operated Vehicles (ROV) and Autonomous Underwater Vehicles (AUVs) for sub-ice surveys and the modularised mission specific laboratory systems.

Contribution to European Research

Beside its ability to reach the deep Arctic, AB is designed to serve as an oceanography platform for many maritime research programmes and joint European research initiatives, with focus on the maritime Arctic. One of them is **SIOS**, the Svalbard Integrated Arctic Earth Observing System, with the aim of establishing an Arctic Earth Observing System in and around Svalbard archipelago. This project aims to organise all existing infrastructures and research and monitoring activities into four observation platforms: land-based, sea-based, glacier/ice-based and space/air-based. In this context AB could operate as the marine arm of SIOS and be part of the building block of a Sustained Arctic Observing System, **SAON**.

Shifting ice and icebergs make it difficult to deploy sea surface equipment over long periods, and restrict access for research vessels. Therefore other EU funded projects relating to the placement of monitoring instruments could make use of AB, for example Euro-Argo and EMSO.

Another project on the **ESFRI** (European Strategy Forum on Research Infrastructures) roadmap is **Euro-Argo**, the European component of a world-wide in situ global ocean observing system based on autonomous profiling floats for the continuous monitoring of the temperature, salinity, and velocity of the upper ocean. Euro-Argo estimates that some 3,000 floats are required to reach this objective. The battery powered floats have an operational life of 3 to 5 years. That means that about 800 floats must be deployed per year to maintain the target array. The data are transmitted in real time by satellite to data centres for processing, management, and distribution. In order to maintain the 3,000 floats, the deployment of 250 European floats per year is needed. Currently the target has not been reached.

AB would also serve as a platform for **EMSO**, the European Multidisciplinary Seafloor Observatories project. EMSO plans to widen the employment of seafloor observatories in the Arctic for long-term monitoring of environmental processes related to ecosystem life and evolution, global changes and geo-hazard.

A Memorandum of Understanding between SIOS, EMSO and AB has been established in early 2010.

Contribution to International Polar Marine Research and Research Services

AB with its capacity to enter into the deep Arctic would help advance understanding of the Arctic and to map it. It would thereby contribute to **GOOS**, the Global Ocean Observing System, and related programmes for establishing an operational ocean observation capability for all of the world's nations by providing regular information from the polar areas. Europe would contribute in the strengthening of international cooperation and interoperability of diverse data sets in the Arctic with AB. A wide range of international research programmes and agreements rely on in situ measurements directly from research vessels or via buoys, moorings or gliders deployed from vessels. They are essential to validate and calibrate satellite data.

Today only a small number of buoys, ice tethered profilers, and coastal stations, are operational in the Arctic. They are monitoring sea level pressure, surface air temperature, sea ice motion, thickness, and temperature, snow depth, ocean temperature and salinity, and ocean circulation. There is also a small tide gauge network in the Arctic Ocean, which provides information on sea levels. However none of those parameters are measured all the year round, so the data needed to track seasonal changes in the Arctic and to detect changes occurring in the marine environment is lacking. This data is also needed for improving climate models.

In this chapter not all existing monitoring programmes in the Arctic (or of the Antarctic) are covered. Some examples are presented to illustrate the potential use of AB for different purposes.

One example is IABP, the International Arctic Buoy Programme with 28 participating institutions, agencies and institutes. IABP works together to maintain a network of drifting buoys in the Arctic Ocean with a spacing of 200×200 km. The programme will provide meteorological and oceanographic data for real-time operational requirements and research purposes including support to the World Climate Research Programme (WCRP) and the World Weather Watch (WWW), both programmes of the WMO, the World Meteorological Organisation.

Data from the IABP has many uses, such as forecasts of weather and ice conditions, validation of satellites, validation and assimilation into numerical climate models, and tracking the source and fate of samples taken from the ice. It is clear that AB can strongly support IABP by the deployment of ice drifting buoys in the Central Arctic Ocean, or by collecting data in Arctic Ocean regions lacking buoys.

A sister programme of IABP, the International Arctic Buoy Program, is the WCRO/SCAR **IPAB** International Programme for Antarctic Buoys that aims to maintain a network of drifting buoys in the Southern Ocean, in particular over sea ice, to provide meteorological and oceanographic data for real-time operational requirements and research purposes.

IPAB data are used for many purposes such as research in Antarctic climate and climate change, forecasting weather and ice conditions, validation of satellite measurements, forcing, validation, and assimilation into numerical climate models or for tracking the source and fate of samples taken from the ice.

Year-round access to the Central Arctic Ocean would provide unique opportunities for the deployment of instrumentation in areas where there are currently important gaps in the monitoring of the Arctic Ocean system.

Other environmental monitoring programmes that would benefit from AB are:

- EuroGOOS, the European Global Ocean Observing System, committed to European-wide operational oceanography services (forecasts, oceanographic databases, and bathymetric maps) in six regional sea areas, among them the Arctic and the Baltic.
- EuroGOOS operates within the context of the intergovernmental GOOS, the Global Ocean Observing System, which aims to provide permanent observations, modelling and analysis of marine and ocean variables to support operational ocean services worldwide.
- Arctic ROOS, the Arctic Regional Ocean Observing System strives to develop and maintain operational monitoring and forecasting of ocean circulation, water masses, ocean surface conditions, sea ice and biological/chemical constituents in the Arctic under the GOOS Regional Alliance for the Arctic.
- SOOS, the Southern Ocean Observation System, will facilitate sharing of physical oceanographic data and recovery of biological and ecological data (e.g. net tows; acoustics; phytoplankton) and historical sea ice observations. SOOS aims to make effective

use of National Antarctic Data Centres and SCAR's Standing Committee on Antarctic Data Management (SC-ADM), following the SCAR data and information strategy.

Contribution to Space Technology

Space technologies have been serving the maritime community for over 30 years, measuring many marine surface variables, and have improved meteorological forecasts. Today satellite technology is becoming increasingly important for a wide range of maritime activities, helping to improve maritime safety and surveillance, navigation accuracy, and marine environmental monitoring.

Though Earth observation satellites provide a unique opportunity to observe the oceans, with coverage and availability that in situ measurement networks could never achieve alone, the polar areas pose problems. Heavy cloud cover often limits the use of imagery in visible light from satellites, and necessary data accuracy is still not fully achieved. The ocean is opaque for electromagnetic radiation, and so knowledge of the three-dimensional structure of the oceans requires the combined use of satellite observations, in situ observations, and ocean numerical models, through assimilation techniques.

The European satellites include Envisat, the four satellites of the Sentinel-1 series for GMES, and the research satellite CRYOSAT-2. CRYOSAT-2, launched in 2010, is a three-year radar altimetry to determine variations in the thickness of the Earth's continental ice sheets and marine ice cover. By helping to produce more accurate data, AB would indirectly support the production of services for safe and efficient navigation, tracking of pollution etc.

Meteorological satellites [compare list of products under the Ocean and Sea Ice Satellite Application Facility (EUMETSAT OSI SAF)] could make use of a vessel that can penetrate deep into the polar ice-pack to reach areas previously inaccessible outside the summer time window.

An important facet is the ground-verification potential of commercial satellites in telecommunication. This brings huge potential for the development of new products and markets in the field of telecommunication. It could catapult Europe into a leadership position.

Also for GNSS, the Global and regional satellite navigation systems for accurate positioning, AB could serve as a positioning tool. By doing so, GNSS could also contribute to the observation of the Arctic for scientific purposes. Improvements in visibility and positional accuracy are needed, as currently geostationary satellites do not reach 75° N.

Contribution to European Maritime, Environmental and Polar Policies

The implementation of the Marine Strategy Framework Directive (**MSFD**) 2008/56/EC, as environmental pillar of the Integrated EU Maritime Policy (**IMP**), is now under way. In different working groups, the Commission and the Member States discuss the anticipated environmental status of marine waters by 2020. A healthy marine ecosystem is a precondition for its producing goods and services, i.e. for supporting economic development, jobs and eco-innovation. The Directive is the first concerted attempt by the EU to apply an ecosystemsbased approach to the regulation and management of the marine environment, marine natural resources, and marine ecological services. It has the potential to become the principal source of marine environmental management measures in the EU (R. Long, 2011).

The MSFD builds on a regional approach (Article 4). In the preamble, environmental concerns relating to climate change are amplified in the Arctic waters, and since these are regarded a neighbouring marine environment they are of particular importance for the European Community. Thus the possible need for action to ensure the environmental protection of the Arctic is made explicit (Recital 42 of Directive 2008/56/EC). This reasoning is reinforced by the fact that three European Member States, Denmark (with Greenland), Finland and Sweden, have territories in the Arctic. In addition two Arctic states, Iceland (a candidate Member State of the EU) and Norway are members of the European Economic Area. To emphasise the role of the EC in the Arctic, the EC published its communication of the Arctic (compare chapter "EC Arctic Strategy").

Ambitious goals need extensive monitoring for climate and seasonal forecasting and marine safety (e.g. marine operations, oil spill combat, ship routing, defence, search & rescue). Data from AB could help to develop a European polar component in this marine knowledge infrastructure, with high-quality marine data for both public authorities and businesses.

In addition, AB could help to

- Support the extension of the ambitious goals of the MSFD to arctic sea,
- Provide new information for developing the protection of the polar marine environment,
- Increase the scientific knowledge of the status of the Arctic,
- Help indirectly to shape governance models and structures for the managemeng of marine waters,
- Provide a platform for research that supports interaction between all sea-related and cross-sectorial policies in the EU,

 Enhance Europe's capacity to deliver research on climate change, and on the state of the marine environment supporting sustainable use of polar seas. It can also improve maritime safety in polar waters.

AB could contribute to the research supporting the implementation of the OSPAR Convention, which extends to Arctic waters and in which the European Community is a party. Concepts and approaches developed for AB may also be relevant in the Baltic Sea (HELCOM) and the Convention for the Black Sea (see Figure 2).



Figure 2. Garcia, C. B presentation "The integrated management of human activities under the Marine Strategy Framework Directive", European Commission (DG ENV) Greenwich, 3 June 2009 (http://www.google.de/url?sa=t&rct=j&q=european%20integrated%20maritime%20 policy%20msfd&source=web&cd=t&ved=0CCEOFjAA&url=http%3A%2F %2Fvww.thegreenwichforum.co.uk%2F_data%2Fassets%2Fpowerpoint_doc%2F0014%2F314132%2FCarlos-Berrozpe.ppt&ei=nS7KTrr8BMS2hQfy-o3nD&u&g=AFQjCNEN_HVtJyLfdmEZfGedP9RFoGvNtg)

Data delivered by AB would not only further the scientific understanding in the Arctic, but would also help to develop products and new services, either directly or indirectly. One of those European services in which data of AB could be fed in is **GMES**, the Global Monitoring for the Environment and Security, conceived to deliver information on the state and dynamics of the ocean as well as sea ice. This initiative is a true joint European undertaking: it includes ESA, which develops the space component (i.e. Sentinel missions) of this observation infrastructure, the Member States, responsible for the in situ components, and the European Environment Agency (EEA).

It is intended that users will be provided with information through services dedicated to a systematic monitoring and forecasting of the state of the Earth's subsystems. There will be six thematic areas: marine, land, atmosphere, emergency, security and climate change. Policy makers and public authorities, the major users of GMES, will use the information to prepare environmental legislation and policies with a particular focus on Climate Change, monitor their implementation, and assess their effects (www.esa.int/esaLP/SEMRRI0DU8E_ LPgmes_0.html).

Single projects are partly financed through the 7th Framework Programme for Research and Development of the European Union. For example **MyOCea**, is the marine component of the GMES services, and is also linked to climate change. Such dedicated projects could take advantage of novel data sets in model analyses and predictions, including simulations for improved safety and efficiency of maritime transport and naval operations. The data would also contribute to climate variability studies and forecasts, by providing a better understanding of the ocean and its ecosystems.

Polar View is an example of a monitoring activity that focuses on both the Arctic and Antarctic, and uses Earth-observation data from multiple satellites. It needs in situ measurement and observations to develop forecast models, and to improve the reliability of sea-ice charts and forecasts, as well as ice-edge and iceberg monitoring.

Both Polar View and GMES aim to facilitate sustainable exploitation and management of marine resources, such as offshore oil reserves and fisheries, or lessen the impact of environmental hazards, such as oil spills, support safe and cost-effective marine operations, and improve resource management and sustainable economic growth in the polar environment.

The data that AB would deliver has to be stored accessibly, and in a format that allows open use. Thus it should fit into the general infrastructure framework specified by the INSPIRE Directive (2007/2/ECs. INSPIRE aims to enable the sharing of environmental spatial information and to develop spatial data sets and services. The actual data from the AB could be distributed through the **EIONET**, which is a partnership network of the **European Environment Agency** (EEA), its member, and cooperating countries. The network supports the collection and organisation of data, and the development and dissemination of information concerning Europe's environment. Finally the data management of the AB should fulfil the visions and principles of the **Shared Environmental Information System** (SEIS) that strives to ensure accessibility, and joint production and use of environmental data.

One of the main international bodies for producing information on the arctic is the Arctic Monitoring and Assessment Programme (AMAP), which is an international organisation established in 1991 to implement components of the Arctic Environmental Protection Strategy. AMAP has been instrumental in producing assessments of the state and trends of the Arctic environment such as the 2011 AMAP Report on the Impact of Black Carbon on Arctic Climate, and the **Snow, Water, Ice and Permafrost in the Arctic** (SWIPA 2011). Results from AB would feed directly into the preparation of such reports that are used by the Arctic Council for policy development.

If the AB is able to maintain routine collection of long data series, some of this information could also be developed into Sustainable Development Indicators maintained by Eurostat and fed into the EU Sustainable Development Strategy.

EC Arctic Strategy

Europe and the Arctic Rim Countries

In 2008 the EC published for the first time a Communication on Arctic Strategy (Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee and the Committee of the Regions, Brussels, 10.10.2007 - COM(2007) 575 final).

Under item 2.3 "Research, monitoring and assessments" EC Communication "EU and the Arctic region", the EC produced a set of action recommendations. One action is to cope with the deficiency of long-term monitoring, coordination and data availability for Arctic research. Another action item is the coordination of efforts in different research areas relevant to the Arctic, such as environment, transport, health and energy, as well as the development of Arctic technologies. The finalisation of AB was also mentioned.

As a true pan-European initiative with Russia as a consortium partner, AB would support the integration of European Arctic research considerations, enhance monitoring capabilities of the Arctic, and support international efforts and research cooperation to preserve the pristine Arctic environment to create the basis for its sustainability. AB would have the capability to ensure continuity in space measurements, as well as long-term measurements, and contribute to the establishment of the Arctic component of Global Earth Observing System of Systems. By doing so, AB would help establish an ERA for polar research and a Sustained Arctic Observing Network.

The availability of the AB as a platform for deploying monitoring instrumentation would create the condition for connection and cooperation with international research programmes. The deployment of monitoring instrumentation from AB would support the scientific work of the Arctic Council, organised in six expert working groups. At least three of those panels would be beneficiaries of the data collection of AB.

These are AMAP, focusing on monitoring, assessing and preventing pollution in the Arctic along with climate change. CAFF treating issues on biodiversity conservation and sustainable use, and EPPR discussing issues relating to prevention of and preparing for emergencies and living conditions for Arctic residents. The AMAP 2010 scientific report on Greenland ice sheet status identified, for example, major gaps of knowledge in basic understanding of coupling between ocean and marine based ice sheet fronts. The report on Snow, Water, Ice and Permafrost in the Arctic (SWIPA 2011) provides further details across the Arctic. The reports recommend the validation of climate models more systematically with in situ observations, which would require better monitoring capabilities to develop more reliable scenarios. Also ACIA, Arctic Climate Impact Assessment project, reports that research, observation, monitoring and modelling is needed to refine and extend its existing findings.

Sustained Observing Networks in the Arctic

The International Polar Year (IPY) 2007-2008 created a unique opportunity to stimulatd cooperation and coordination of Arctic research, and increased awareness of the importance of the Arctic region.

In view of the rapid changes in the polar realm and the increasing scientific and political interests in understanding the processes, the need for a well-coordinated and sustained Arctic Observing Network was identified. Such a network is necessary to address scientific and societal questions that have been identified in many scientific workshops and high profile conferences.

In this context **SAON**, the Sustaining Arctic Observing Network composed of representatives of international organisations, agencies, and northern residents, has been formed to develop ideas on how to achieve longterm Arctic-wide observing activities. SAON is aware that there is a need to fill spatial, temporal and disciplinary gaps in observing records, and to strengthen the sustainability of observing programmes to create a more comprehensive, system-wide view of the Arctic and its connections to lower latitudes (SAON report, 2008).

For this reason, a multidisciplinary research infrastructure covering all important observation elements of the coupled Earth System in the Arctic is a very valuable tool for quantifying on-going global change, and verifying the capability of Earth System models to predict future changes. Europe, with its contribution from AB as pan-European research platform, would become an important partner and enhance inter-governmental cooperation in Arctic observation. In addition Europe would have a role in the establishment of an observational framework for the Polar Regions. A first step was taken when the EPB, the European Polar Board, became a member of the SAON Initiating Group in 2007. In the Antarctic SCAR, the Scientific Committee on Antarctic Research, is developing a similar approach to that of SAON: the Pan-Antarctic Observations System, a network built on existing national and international observing efforts for the delivery of easily accessible and reliable pan-Antarctic observation.

Support for Decisions Affecting Polar Regions (with Special Emphasis on the Arctic)

Global activities affect the Arctic environment. At the same time changes in the Arctic environment have global consequences. Hence, the global community must be engaged in improved monitoring of the Arctic to better understand the changes and their effects. Social and economic issues will also have to be considered. The current lack of observations, process studies, and cryosphere modelling, affects the political assessment of, for example, climate change processes and their impacts. There is a need for information that can demonstrate impacts and the linkages between complex systems. A strategy on how to curtail the knowledge gap and how to efficiently coordinate and pool acquired scientific data from regional to global scale is essential.

Maintaining monitoring systems all over the planet with enough coverage in time and space is expensive, and requires European and international cooperation. There is a need to use jointly operated platforms that exploit existing assets, as well as establishment of new programmes that better meet the requirements.

By establishing AB as a coordinated scientific observatory for sustained long-term environmental monitoring in the Arctic, the vessel would bridge the scientific and political gap, providing researchers and policy makers with a unique tool for data collection and for strategic decisions.

Via the contribution of novel observations, AB would help to address some of the grand challenges of climate and biodiversity change, pollution control, and protection of the polar environment.

Europe must take responsibility and join forces with its neighbours to tackle the strategic challenges of the 21st century, not only because of its regional vicinity to the Arctic, but also because of its knowledge in the management of sustainable development and its long lasting endeavour in research in the polar realm.

Perspectives



One of the most important achievements of the International Polar Year 2007-2008 was in attaining a new level of knowledge about the Polar Regions. This made it possible to draw a preliminary conclusion that the processes determining the environmental changes of Polar Regions may be predictable at a decadal time scale. However, practically exploiting this predictability requires a coordinated continuation of long-term observations and studies that started during the IPY, and comprised its legacy.

The WMO activities in the Polar Regions are coordinated through the WMO Executive Council Panel of Experts on Polar Observations Research and Services (EC-PORS). EC-PORS has proposed to WMO to develop a Global Integrated Polar Prediction System (GIPPS) and to continue the development of the Global Cryosphere Watch (GCW).

This initiative has the potential for providing a framework for enhanced coordination of and support for all these initiatives. The need for further consideration and elaboration of this initiative was endorsed by the 60th session of the WMO Executive Council in 2008, by the 25th Assembly of IOC UNESCO in 2009, and the Arctic Council in its Tromsø Ministerial Declaration of 2009.

In parallel, an International Polar Decade (IPD) has been suggested on the occasion of a dedicated workshop at the Arctic and Antarctic Research Institute (AARI) in St. Petersburg, on 14 and 15 April 2011, at which the EPB, several meteorological services of Russia, Norway, Canada, and USA, as well as members from the **WMO**, **EC**, **EAA**, **IASC**, **IOC** and IASSA (the International Arctic Social Sciences Association) attended. In the case of IPD, AB as unique research vessel has great potential to be one of main platforms to support monitoring systems in the Arctic and the Southern Ocean.

AURORA BOREALIS Contribution to Science, Policy, Industry and Society

AB would bridge gaps in Arctic and Antarctic research

- Assess the state of the Arctic, and Antarctic
- Monitor environmental effects all year round over a range of measurements including both living (census of marine live, health status) and non-living resources, with quantification of pollution and ocean acidification in the polar oceans
- Define and make use of scientific marine indicators
- Gain new insight in the climate change processes in the Arctic and Antarctic

AB would help to reduce costs

- Reducing costs via pooling monitoring programmes and verification of data
- Costs of environmental degradation (litter, oil spills, invasive species, chemicals, loss of natural resources)
- Mitigation costs protecting human population against negative effects of environmental degradation

AB would link to different industrial sectors such as

- Calibration of remote-sensing data for commercial Earth observations and tele-communication satellites and meteorological satellites
- Testing bed for innovative devices (sensors etc.)
- Pooling and assessing of the scientific and technical requirements
- Adapted monitoring frequency and compatibility in view of existing monitoring and needs
- Monitoring targets (how to cover the data gaps in the dedicated regions)
- Establish research services e.g. ice management, sea ice mapping

AB would bridge the gap between research and policy, translating research results into policy development (stakeholders and general public)

- Give high visibility to Europe
- Coordinate effectively national polar and marine research priorities and agendas by contractual access, even for nations with no capacity for their own polar programme
- Provide meteorological and oceanographic data
- Track pollution or other events relevant for climate in the polar realm
- Acquire baseline data for several European agencies and European directives
- Provide a unique platform for intergovernmental collaboration

• Contribute to an integrated and sustained observation system in the Arctic (SAON) and PAntOS in the Antarctic

AB would contribute to society and the Public Understanding of Science

- Bring processes and changes into public visibility
- Virtual access on a unique ship with expeditions to remote areas
- Data for teachers
- Hands-on experience and training for young researchers on a floating university
- Creation of new goods and applications (information and services for society) for the use of the end customer

AB would be able to undertake Search and Rescue Operations in case of emergency

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