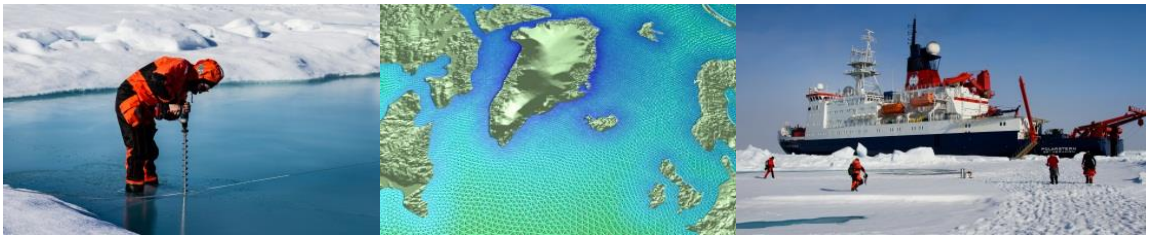
Arctic ECRA

Strategy and Work Plan

"Advancing European Arctic climate research for the benefit of society"



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EXECUTIVE SUMMARY

The Arctic climate is changing at a rate, which takes many people – including climate scientists – by surprise. The ongoing and anticipated changes provide vast economic opportunities; but at the same time they pose significant threats to the environment. Important decisions will need to be made in the coming years which take into account economic, societal and environmental issues. In this context, a reliable knowledge base, on which decisions can be based, is a prerequisite to provide sustainable solutions.

It is increasingly being recognised that what happens in the Arctic does not stay in the Arctic. A prominent example is the proposed atmospheric link between Arctic sea ice decline and the severity of cold European winters. Therefore, Arctic climate change is likely to affect the weather and climate of Europe.

It is argued that gaps in our scientific understanding and predictive capabilities are still hampering the evidence-based decision-making processes by stakeholders. There is an urgent need to accelerate progress in building a reliable knowledge base, and it is recommended that the EU funds collaborative research that aims to provide answers to the following three central issues:

- Why is Arctic sea ice disappearing so rapidly?
- What are the local and global impacts of Arctic climate change?
- How to advance environmental prediction capabilities for the Arctic and beyond?

Arctic ECRA is one of four Collaborative Programmes of the European Climate Research Alliance (ECRA). It aims to advance Arctic climate research for the benefit of society by raising awareness of key scientific challenges, carrying out coordinated research activities using existing resources, and writing joint proposals to secure external funding for coordinated, cutting-edge European polar research and education projects.
Arctic ECRA is a network of climate research institutions from different European countries and provides a breadth of expertise including theory, observations, modelling, operational forecasting and logistics. It is unique in its flexibility and responsiveness to new ideas, new results and emerging challenges. The network is backed by access to large-scale infrastructure such as icebreakers, polar stations, aircraft and supercomputing facilities. Furthermore, Arctic ECRA scientists develop and run some of the most advanced regional and global climate models. Arctic ECRA is an inclusive organisation that is open to new participants.

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The European Climate Research Alliance (ECRA)

In October 2011 a group of leading climate research organizations from eight European countries established the European Climate Research Alliance (ECRA). ECRA constitutes a powerful network for tackling the scientific challenges of climate change that require a concerted effort.

ECRA helps to coordinate the capacities of the individual members in a targeted manner through collaborative research programmes. Optimized exchange and sharing of personnel resources, modelling capacity, expeditions and research infrastructure is expected to further our understanding of the complex Earth system and find meaningful adaptation strategies for Europe.

The Arctic ECRA programme, created under the umbrella of the European Climate Research Alliance (ECRA) and the European Polar Board (EPB), aims to strengthen the scientific and technological capabilities for carrying out Arctic climate research within Europe. It aims to strengthen collaboration in scientific work, sharing of infrastructure and exchange of students, scientists and technicians.

Arctic ECRA

- One of four Collaborative Programmes of the European Climate Research Alliance (ECRA)
- Aims to advance Arctic climate research for the benefit of society
- Breadth of expertise in Arctic climate research including theory, observations and models
- Flexible and responsive to new ideas, new results and new challenges
- Access to large-scale infrastructure (e.g. ice breakers, polar stations and research aircrafts)
- Availability of some of the most advanced global and regional climate models

1. Introduction

The polar regions react more strongly to anthropogenically driven changes than any other region on Earth. The shrinking sea ice cover in the Arctic Ocean, the loss of ice from the Greenland ice sheet and pan Arctic glaciers, the rapid retreat of Northern Hemisphere snow cover, the thawing of permafrost, the changes in the hydrological cycle in the northern hemisphere and the impacts on biodiversity and ecosystem functioning, are all areas of particular concern. Global climate models demonstrate that polar regions play a crucial role in the climate system – what happens in the Arctic does not stay there. This explains the growing concern about rapid Arctic climatic change and its relevance for future development weather and climate in European and beyond.

There is an urgent need for increased observations in the Arctic, for open exchange of data and for improved modelling and prediction capabilities of polar weather and climate. Most of the processes in the polar regions are still poorly understood which is largely due to the fact that science operations in the polar regions are technologically and logistically very demanding and cost-intensive.

The Collaborative Programme (CP) “Arctic Climate Stability and Change” (Arctic ECRA) aims to provide an institutional platform for Arctic climate research in Europe. The Programme focuses on specific research topics that will be addressed through collaboration between Arctic ECRA members. Arctic ECRA will integrate the scientific guidelines of relevant strategic organisations such as the European Polar Board (EPB), the Scientific Committee on Antarctic Research (SCAR) and the International Arctic Science Committee (IASC) but also national priorities, and identify the requirements and priorities of research in areas of critical developments for Europe’s society. The central objective of Arctic ECRA is to contribute to the development and dissemination of knowledge needed to formulate adaptation strategies and national policies related to climate change and globalization in the Arctic.

Participation in these joint projects is open to all interested research institutions. In this framework, specific memoranda of understanding between relevant scientific International Organizations (e.g. EPB, IASC, SCAR) and networks (e.g. SAON, SIOS, INTERACT) will be considered for implementing scientific strategies.

2. Mission Statement

Arctic ECRA aims to advance Arctic climate research for the benefit of society by

- Raising awareness of key scientific challenges,
- Carrying out coordinated research activities using existing resources, and
- Writing joint proposals to secure external funding for coordinated, cutting-edge European polar research and education projects.

3. Key Scientific Questions

Centred about the overarching theme of *Arctic sea ice decline,* it is proposed to carry out research that helps to address the following key issues:

- Why is Arctic sea ice disappearing so rapidly?
- What are the local and global impacts of Arctic climate change?
- Advancing environmental prediction capabilities for the Arctic and beyond.

The listed issues are based on collective consensus following extensive discussions among some of the leading European climate scientists and scientific institutions during three Arctic ECRA workshops held in 2012 and 2013.

4. Research Plan

4.1 Challenge 1: Why is Arctic sea ice disappearing so rapidly?

4.1.1 Overview

The Arctic sea ice is responding to changes in the overlying atmosphere and the underlying ocean. Arctic sea ice loss has been staggering, especially in summer when more then half of the sea ice coverage has been lost during the last 30 years. To the best of our knowledge the Arctic has had perennial ice, that is all year ice cover, in most regions, for more than the last 1000 years, and presumably even for the last 30 million years. A number of different factors have contributed to the recent sea ice decline, most of which are believed to be connected to anthropogenic warming. It will be crucial to improve our understanding of the causes of recent rapid sea ice decline and provide reliable projections of its future development.

There are a number of mechanisms that are thought to have contributed to the loss of Arctic sea ice including changes in atmospheric heat transport, oceanic heat transport, radiation, sea ice concentration and sea ice export out of the Arctic. The relative contributions of the mechanisms appear to have changed in time and are spatially dependent. Generally, ice loss will be amplified by the warming of open water areas by solar radiation, thus melting more ice (ice-albedo feedback). The presence of pronounced stable stratified atmospheric boundaries is also believed to contribute to Arctic amplification. The potential for re-growth during winter is especially uncertain given that new sea ice types that may form more effectively in the large areas of open water have emerged in late summer. While the observational data give us some idea of the ongoing changes, observational gaps prevent us from developing a deeper quantitative understanding.

The latest global IPCC-type models (CMIP5) have improved in simulating the recent loss of Arctic sea ice, especially in terms of its areal extent. However, the observed reduction in ice thickness from the 1960's to the 1990's (or the related loss of ice volume) is still underestimated.

Staggering changes are not only confined to the Arctic Ocean. The decline of Northern Hemisphere snow cover in spring is even more dramatic than that for Arctic sea ice. In order to get a more comprehensive system understanding it will be important, therefore, to consider snow cover and permafrost changes as well.

4.1.2 Selected research challenges

- Observations and reliable simulations of the poleward atmospheric heat transport
- Understanding the role of cloud processes and vertical mixing in determining radiation changes
- Observations of oceanic heat transport in Fram Strait, Barents Sea and Bering Strait
- Observation of sea ice export through the Fram Strait
- Understanding heat fluxes above and below the Arctic sea ice in the Arctic climate regime
- Representation of the observed Arctic changes in climate models

4.1.3 Selected activities

- Improving observations of heat transport in the atmosphere and ocean
- A drift station, at least 1 year, in the central Arctic Ocean, with a multi-sensor Programme (MOSAiC)
- Assessment of the representation of polar key-processes in coupled models

4.2 Challenge 2: What are the local and remote impacts of Arctic climate change?

4.2.1 Overview

Local impacts

The strong Arctic sea ice loss has already created additional surface warming through positive feedbacks as well as increased UV radiation penetrating into the upper ocean. A consequence of this surface warming is an increased energy flux from the ocean to the atmosphere. Furthermore increased precipitation and continental run-off leads to a freshening of the Arctic Ocean that causes a stronger stratification and less deep ocean ventilation. Furthermore, the Arctic Ocean is developing into a system with predominance of one-year over multi-year ice that causes ecosystem shifts and biodiversity loss. Some organisms are replaced by species from lower latitudes due to reproduction failure when the onset of ice melt is changing by a few weeks and hence certain ice algae are lost as a source of food. Another issue is the increased CO_2 uptake by the ocean leading to acidification and influencing marine food webs and ecosystems.

Retreating sea ice offers economic opportunities since oil and gas reserves are getting more accessible for exploitation: Furthermore, the Northern Sea Route (and to a lesser extent Northwest Passage) can be used to substantially shorten shipping routes from Europe to China (by about 20-25%). Increased economic activities in the high north will increase the human impacts on Arctic ecosystems through increased emissions (e.g. aerosols) and increased risks of environmental disasters such as oil spills.

Given the opportunities and risks associated with rapid Arctic climate change, it will be crucial to provide the knowledge base required by stakeholders to make informed decisions.

European impacts

There is evidence that Arctic amplification has strong implications for the weather and climate of the Northern Hemisphere (NH) mid-latitudes, including Europe. Increased temperature in the Arctic directly leads to an increasing loss of snow cover in spring and summer over the NH over much of the last century. In contrast, the NH snow cover in boreal autumn and winter has increased over the 20th century, since a warmer atmosphere is able to hold more moisture and hence produces greater snowfall in autumn. This trend is particularly prominent in October of the last 20 years.

Arctic amplification associated with sea-ice loss, reduced spring snow cover, and increased autumn snow cover was linked to changes in mid-latitude stationary Rossby waves that increase the probability of persistent extreme weather events, such as droughts, floods, heat waves in summer, and cold snaps in winter. Observational data suggest that very low sea ice extent in summer and autumn enhances the probability of anomalously cold temperatures in Europe in the following winter. Decreased winter sea ice coverage, accompanied with

increased surface temperatures leads to decreased westerly flow over Eurasia, resulting in less maritime and more continental climate in Europe.

Global impacts

The freshening of the Arctic Ocean outflow can affect the Atlantic overturning circulation with possible global consequences. Furthermore increased release of methane from the Arctic Ocean and melting permafrost can influence the global climate system due to methane's role as a potent greenhouse gas. Melting of the Greenland ice sheet and glaciers increases the global sea level and therefore can have a severe impact on coastal communities worldwide.

4.2.2 Selected research challenges

- Provision of good spatial and temporal observational coverage of physical properties such as salinity and thermal structure of the Arctic ocean and its ecosystem changes
- Understanding of the causes of ecosystem changes
- Adaptation of the indigenous communities
- Quantification of the methane release from the Arctic ocean and land areas
- Understanding of teleconnections between Arctic sea ice cover and global circulation
- Prediction of mid-latitude extreme events connected to Arctic sea ice cover change (seasonal prediction to centennial changes in frequency and intensity)

4.2.3 Selected activities

- Modelling of impacts of rapid Arctic sea ice cover decline on the mid-latitude climate in a coordinated effort with a set of different regional and global climate models
- Improvement of parameterisations of regional and global climate models with a focus on Arctic processes
- Coordinated efforts to observe and monitor the physical and ecosystem changes in the Arctic ocean and land areas

4.3 Challenge 3: Advancing environmental prediction capabilities for the Arctic and beyond

4.3.1 Overview

A research plan on exploring the potential of Arctic climate predictability needs to identify critical components in the process of carrying out a prediction. Furthermore, it is worth to revisit the difference between projections and predictions.

Projections of possible future Arctic climates are readily available from the CMIP5 effort and from the regional downscaling project CORDEX. Those climate projections are normally not initialized with observations. Instead, recent climate states are generated with the help of external forcing such as solar variability, volcano eruptions and aerosols. This procedure does not take into account the inherent decadal and inter-decadal variability. As a result, possible climate trajectories for the near future, i.e. for the coming 10-20 years, show large differences among the different GCMs compared to the long-term warming trend.

The step from "climate projection" to decadal "prediction" of the Arctic requires a suitable initialization of the climate components, which incorporates the state of decadal and inter-

decadal variability. Prediction is then to be carried out with an adequate number of repeated simulations ("ensemble prediction") reaching for example 10 years into the future. Depending on geographical location, ensemble members will differ on the future climate, thus providing robustness of the prediction.

Predictability (the potential capability to predict) studies typically show highest predictabilities in surface air temperature over the northern North Atlantic. Over land, away from coastal areas, only a few areas can currently be significantly predicted on a local scale. That picture improves much when allowing for prediction of continental size spatial averages.

Decadal prediction systems can easily be used to carry out dynamical sub-seasonal and seasonal predictions.

4.3.2 Selected research challenges

- Exploration of the value of improved initialization techniques
- Identification of observational needs for forecast initialization, model development and model assessment
- Identification of relevant processes and sources of predictive skill to guide future model development
- Understanding the implication of the new Arctic climate regime for seasonal and decadal predictions
- Establishing communication with stakeholders to better understand interactions between forecast probabilities and decision making

4.3.3 Selected activities

- Carry out "perfect model studies" to further explore the limits of potential predictability
- Improve ensemble prediction systems (representation of initial and model uncertainty)
- Use multi-model approaches to identify model short-comings
- Explore the potential of high resolution for decadal prediction, potentially improving predictability over inland areas and providing more detailed information for decision support tools
- Support forecast users in their capability of risk management in the light of remaining uncertainties.

5. Strategies to Achieve the Goals / Implementation mechanisms

5.1 Key objectives

The Collaborative Programme provides a strategic vision for integration of research capacities for Arctic climate research. It aims to:

- Work towards a long term, durable integration and optimised, shared use of present resources, including collaborating in the development of advanced research infrastructures for polar climate research.
- Improve the long-term observation capacity in the Arctic and Antarctic and data sharing.
- Improve modelling and prediction capabilities
- Initiate and execute large fundamental and comprehensive cooperation for Arctic climate research on a European level.
- Improve joint training, education and outreach activities.
- Provide advice to policy makers, funding agencies and the general public with respect to Arctic climate change.

In order to achieve its key objectives the Collaborative Programme will exploit existing 'own' resources (e.g. expertise and infrastructures) from participating European climate research institutions. The Programme will also aim to attract additional third party funding to increase its capacity and impact while ensuring coherence with other activities in the same fields.

5.2 Task Teams as a way of operating within Arctic ECRA

Three thematic task teams are maintained to ensure continued innovation for the benefit of Arctic ECRA.
The task teams are:

- “Arctic climate modelling” with expertise in Arctic climate modelling, prediction and projection (lead. Ralf Doescher),
- “Arctic observations” with expertise in the physical processes, dynamics and observational systems (lead: Vito Vitale), and
- “Arctic drifting platforms” with planning capacity for major international joint observational campaigns (Jean-Claude Gascard).

The task teams collaborate on the main challenges identified by Arctic ECRA.

5.3 Workshops

The Arctic ECRA community will meet regularly during workshops (1-2 times a year). The aim of the workshops is to present status of research activities and achieved results on the key scientific questions, and at the same time to share information on emerging topics, on-going plans, landscape and perspectives for the European polar research.
During workshops Arctic ECRA shall stimulate discussions and provide new insights as basis for development of infrastructure and projects in the Arctic.
They will be relevant for prioritised research needs, for solving the identified observation challenges associated with scientific questions that society has identified as important, for

development and improvement of the long-term monitoring, to discuss best practices and technological improvements, to develop international joint campaign planning, to investigate new use of research infrastructure (RI) and data on the basis of previous research.
Workshops will contribute to further develop ideas, identify new emerging topics, set up thematic working groups, promote data sharing and scientific integration, discuss funding opportunities.
Workshops will also provide a forum for early career scientists to present and discuss their results.
Finally, workshops will represent a forum where international collaboration is developed and where information about existing relevant national and international activities will be shared.

5.4 Coordinated Research activities

Facilitating the coordination of research activities is one of the central aims of the European Climate Research Alliance.
The mutual exchange of information on on-going and planned research activities of each participant will be crucial. In particular, research results already obtained by participants can be shared, thereby avoiding duplication and loss of research time. Secondly, parties can benefit from each other's already developed expertise in addressing the key challenges. Table III in the Annex will serve as a starting point for the exchange of information and will be put online in the Arctic ECRA CP section of the ECRA website to be continuously updated.
Joint research activities of major European climate research centres to address the challenges outlined above will be carried out. This is the added value of the CP effort−leaving the whole greater than the sum of its parts. It will result in the optimisation of the workflow, the enhancement of the critical mass for each research task, and will greatly facilitate the dissemination of the results. To initiate and establish common research projects topically focused side meetings will be held during the workshops. Collaboration can be on a small bilateral scale or in a larger consortium. Institutional funding will serve as the primary basis to support coordinated research activities; however, joint attempts will be made to pursue external third party funding.

5.5 Funding

Arctic ECRA will actively pursue third party funding at the European level to assist the network by seeking financial support for European cooperation and interaction between European researchers. A proposal called "Arctic Climate Processes for Better Predictability" (ACPRED) for a COST action has been submitted in September 2013 to establish a network of experts to advance Arctic prediction capabilities. The COST action aims to support research initiatives by financing meetings, exchange of scientists, publication costs and other expenditures related to strengthening the network.
Additionally, the entire ECRA network has been successful in attracting funding from the European Commission (EC) in the last call of the FP7 theme "Environment". The proposal called "REsearch network for forward looking activities and assessment of research and innovation prospects in the fields of Climate, Resource Efficiency and raw mATErials" (RECREATE) has been granted by the EC in spring 2013. RECREATE is a policy support network that will collect and analyse strategic information about medium and long term research and innovation trends and prospects, and will carry out forward looking analysis in the areas of climate action, resource efficiency and raw materials as described in the Commission proposal for Horizon 2020.

Even more important, Arctic ECRA is also aiming at becoming an important contact point to initiate European research projects within the upcoming Horizon 2020 framework programme of the European Commission (EC). A Science Briefing in the European Parliament has been held on April 24th 2013 to inform policy makers about Arctic climate change, the underlying mechanisms, impacts and predictability. Since Arctic ECRA comprises leading experts on Arctic climate change in Europe it is an ideal nucleus to initiate research proposals with the "Climate action, Resource Efficiency and Raw Materials" challenge of the upcoming Horizon 2020 program.

5.6 Research Infrastructures

The remoteness of the Arctic, the challenges of harsh weather and wintertime conditions and the inaccessibility of the central Arctic Ocean due to the sea ice implies that field based research to obtain the measurements required to solve key science challenges is expensive and difficult. The scarcity of wintertime observations in the central Arctic is a major factor preventing us from making progress in our understanding and modeling of the Arctic climate system. We need to improve and harmonize spatial and temporal coverage of the observational system, using a hierarchy of stations from basic one's to supersites. Due to complexity and costs to manage observations in a so hostile environment, sustainability of such effort is intrinsically connected with progress in Arctic climate science. Technological innovations and development of remotely operated autonomous systems will provide important advances in Arctic observation capabilities. At the same time it is clear that various existing types of platforms and measurement/monitoring stations remain an important part of the observing system. Given these challenges, Arctic ECRA strives to share and support existing infrastructure within an open access policy, and to push for joint planning and implementation of new infrastructures.

Development and implementation of "Svalbard Integrated Earth Observing System" (SIOS) ESFRI initiative will contribute to establish in the crucial area of Svalbard Archipelago and surroundings an important node in the envisaged "Sustaining Arctic Observing Networks" (SAON). SIOS will have a significant contribution on reducing the fragmentation of the European research landscape, representing one of the most important multi-lateral structures for scientific cooperation in the Arctic at European level, and providing a natural catalyst and attractive element for the European research landscape in the polar areas. SIOS will also facilitate coordinated activities across the Fram Strait and more integration of activities performed at the two side of it (Greenland and Svalbard).

Several activities in the World Climate Research Program (WCRP) and the World Weather Prediction Program (WWRP) focussing on polar predictability have been launched. Comprehensive and sustained measurements, extending from the ocean through the sea-ice into the atmosphere are needed to initialize forecast and to provide the process-level understanding which is to improve our modelling capabilities of the Arctic weather and climate.

A very important planned activity is the *Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC).* This international drifting research station in the Arctic Ocean, which has been developed by the Atmospheric Working Group (AWG) of the International Arctic Science Committee (IASC), is a Sustained Arctic Observing Network (SAON) activity. In the framework of MOSAiC it is planned to deploy a manned drifting station in the sea ice in the far western Arctic Ocean; it will drift with the transpolar drift towards the Fram Strait over the course of 1-2 years. This Arctic ocean drifting station could serve as a Super Site Station

together with already existing Land Supersites in the network of the International Arctic Systems for Observing the Atmosphere (IASOA), SAON and SOIS.
A target deployment date of autumn 2018 with research vessel POLASTERN has been proposed for MOSAiC to measure a large range of physical, chemical, and radiative processes, involving ocean, sea ice, land-surface, snow cover, clouds, and aerosols. On the land super sites, long-term measurements of several key climate parameters from the surface level up to the ozone layer have been performed for decades. Such comprehensive data sets are available from very few sites in the Arctic and the data are continuously fed into global networks.
This network of stations including the Arctic Drifting station as a new temporary supersite over the Arctic Ocean offers excellent conditions due to its accessibility and international and multidisciplinary character. This approach forms a network of international long-term atmospheric monitoring and observation platforms supported by all research institutions and thus to realize a network of supersites, allowing investigations of the complex Arctic System with a multidisciplinary approach.

5.7 International collaboration and links with other initiatives

The impacts of climate change are borderless and therefore climate research is an international challenge and can only be addressed by working together on an international level. ECRA will act as a facilitator to develop a science driven research agenda for the Arctic region and as a means to build a consensus on a European level.
Arctic ECRA will endeavour to establish links with other research programmes, organisations and initiatives wherever feasible ensuring coherence with other activities in the same field, with the primary aim to answering the scientific questions outlined above. Many Arctic ECRA participants already take leading roles in these programmes. A number of relevant initiatives already exist and are mentioned below without claiming to be exhaustive.
Research carried out in the framework of Arctic ECRA should contribute to international research programmes, such as:

Acronym	Name	Website
CLIVAR	Climate Variability and Predictability	www.clivar.org
GEOTRACES	An International Study of Marine Biogeochemical Cycles of Trace Elements and their Isotopes	www.geotraces.org
ISAC	International Study of Arctic Change	www.arcticchange.org
WCRP - PCPI	World Climate Research Programme - Polar Climate Predictability Initiative	
WMO **> PPP** **> IPD** **> IPI**	World Meteorological Organization > Polar Prediction Project > International Polar Decade > International Polar Initiative	www.wmo.int www.polarprediction.net www.internationalpolarinitiative.org
NSF polar strategy	National Science Foundation Polar Strategy	www.nsf.gov/attachments/125895/public/oac_vision_doc.pdf
NSF Arctic modelling strategy	National Science Foundation Arctic modelling strategy	www.iarc.uaf.edu/sites/default/files/publications/reports/IARCTP10-0001.pdf

Research infrastructures and observations are essential tools to enable excellent research, especially in a challenging environment such as the Arctic. Of importance to mention in this context are:

Acronym	Name	Website
ACTRIS	Aerosols, Clouds, and Trace gases Research InfraStructure Network	www.actris.net
AMAP	Arctic Monitoring and Assessment Programme	www.amap.no
Arctic ROOS	Arctic Regional Ocean Observing System	www.arctic-roos.org
ASPeCT	Antarctic Sea Ice Processes & Climate,	www.aspect.antarctica.gov.au
CBMP	Circumpolar Biodiversity Monitoring Program	www.arcticportal.org/en/caff/cbmp
FARO	Forum of Arctic Research Operators	www.faro-arctic.org
GEOSS	Global Earth Observation System of Systems	www.earthobservations.org/geoss
INTERACT	International Network for Terrestrial Research and Monitoring in the Arctic	www.eu-interact.org
NDACC	Network for the Detection of Atmospheric Composition Change	www.ndacc.org
SAON	Sustained Arctic Observing Network	www.arcticobserving.org
SIOS	Svalbard Integrated Observing System	www.sios-svalbard.org

Partnerships with many other organisations and institutions dealing with Arctic issues in a broad sense will be sought, such as:

Acronym	Name	Website
	Arctic Council	www.arctic-council.org
IGFA	Belmont Forum	www.http://igfagcr.org/index.php/belmont-forum
NCE RCE	Arctic-Net	www.arcticnet.ulaval.ca
ACSNet	Arctic Climate System Network	www.iasc.info/home/networks/arctic-climate-system-network-acsnet
APECS	Association of Polar Early Career Scientists	www.apecs.is
ARCUS	Arctic Research Consortium of the United States	www.arcus.org
CAPSNet	Canadian Advanced Polar Science Network	
European Commission	European Commission Directorate General: > Research & Innovation > Environment > Maritime Affairs and Fisheries > Climate Action	www.ec.europa.eu /dgs /research /environment /maritimeaffairs_fisheries /clima

EEA	European Environment Agency	www.eea.europa.eu
EPB	European Polar Board	www.esf.org/research-areas/polar-sciences.html
IASC > BipAG	International Arctic Science Committee (and its different working, action and advisory groups) > Joint IASC/SCAR Bipolar Action Group on Science Cooperation	www.iasc.org
IPCC	Intergovernmental Panel on Climate Change	www.ipcc.ch
JPI Climate	Joint Programming Initiative Climate	www.jpi-climate.eu
JPI Oceans	Joint Programming Initiative Oceans	www.jpi-oceans.eu

The role of the Arctic in global climate change is also addressed in Model Intercomparison Projects (MIPs) as coordinated efforts of the international climate research community. Such MIPs provide the scientific base for climate change projections in IPCC reports and beyond. Arctic-ECRA is well interconnected with major MIPS such as CMIP5 (http://cmip-pcmdi.llnl.gov/cmip5/) and CORDEX (http://wcrp.ipsl.jussieu.fr/cordex/about.html).
CORDEX and its sub-project Arctic-CORDEX are carrying out coordinated and standardized Arctic climate simulations as dynamical interpretation of global climate model runs. The goal is to improve regional climate change adaptation and impact assessment by a better quantification and understanding of Arctic change uncertainty. Analyses of model-generated climate datasets are a major challenge to be addressed by the international community. Arctic ECRA provides leading contributions to the CORDEX set of model simulations and analysis.

5.8 Outreach

Climate change in the Arctic is a topic of global importance. An essential element and justification for Arctic ECRA is to communicate Arctic climate science, its results and methods and the linkages between changes in the Arctic and regional and global changes and challenges. Arctic ECRA aims to reach a wide range of audiences, the general public to a wide range of audiences, to the general public, to the young generation, to public and private stakeholders on global and regional scales.
The strong evidence for polar amplification and the rapid speed of on-going changes is perhaps the most visual evidence of climate change, and communicates that we are already changing our planet in dramatic ways. Communicating our results will thus help to generate awareness of the challenges climate change poses to humanity, hence becoming an important scientific underpinning policy action to adapt to and to mitigate against climate change. Climate change in the Arctic impacts geopolitics, transport routes, access to natural resources and changes in harvestable marine and terrestrial bio-resources, and various other economic sectors both within the Arctic and outside through the connectivity between the Arctic and the global climate system.
Arctic ECRA will engage in and organize outreach efforts of various types:

- ECRA will generate popularized science products in various formats, collaborate with mass media or other outlets, on various platforms tailored for different audiences. Much emphasis will be placed on engaging the young generation both in terms of

science knowledge, but also in understanding and becoming engaged in the scientific process. Attracting young persons to polar science is an important objective. Furthermore, Arctic ECRA is the ideal networking platform for senior scientists from different areas entering the field of Arctic climate research.

- Arctic ECRA will develop a series of activities directed towards public and private decision makers. We aim to produce briefing documents for policymakers, organise assessments and interaction with national and European policymakers in support of their work, noting that Arctic ECRA is at its core an activity for developing policy relevant science, without engaging in activities that are policy prescriptive. Arctic ECRA will develop forecasting and prediction tools and organise workshops and conferences specifically for user communities of those sectors (public and private) that have a particular stake in the on-going and future changes in the Arctic.
- The infrastructure challenges involved in Arctic research invite widespread innovations and developing new and emerging techniques. Thus it is a special task for Arctic ECRA to stimulate such innovations and developing activities and platform wherefrom such innovations can be tested and utilised. This requires coordinated efforts and communication between the science realm and the industrial innovations.

5.9 Education

Arctic ECRA will foster joint activities in post-graduate education and training of young scientists through a selected number of activities:

- Provision of a framework for the exchange of students between partner organisations
- Support and organisation of summer schools and joint training courses at graduate and post-doctoral level
- Opportunities to present and discuss results at Arctic ECRA workshops and conferences

Furthermore, funding opportunities (e.g. through the Marie Curie Initial Training scheme) will be actively pursued.

6. Management and Governance

The Arctic ECRA Collaborative Programme is coordinated by a joint Steering Committee of the European Climate Research Alliance and the European Polar Board, constituting the Arctic ECRA Steering Committee.
The Arctic ECRA Collaborative Programme adheres to the general ECRA governance and ECRA Collaborative Programme governance with the following additions:

- The Arctic ECRA Steering Committee (AESC) is composed by one representative of the institutions and organizations participating in the Collaborative Programme and by a maximum of three members or external experts appointed by the EPB Plenary Assembly and agreed by ECRA on the basis of proposals by the AESC itself and the requirements of the scientific programme.
- The Chairman of the EPB is a member of the AESC, as well as at least one member of the EPB Executive Committee identified by the Committee itself.
- The AESC reports to the ECRA Executive Committee and EPB Plenary Assembly. Both bodies approve the budget and the annual report and make recommendations on future activities.

The AESC will play a role in the following frames:

- To create additional synergies between the Arctic ECRA participating institutions and other EPB members and relevant Polar scientific organizations.
- To promote and coordinate joint high-profile scientific and technological initiatives in priority fields relevant to the Arctic ECRA's priority actions.
- To facilitate the development of participation and capacity building of the smaller Polar Organizations.
- To detect the complementarities and the specificity of the European Polar infrastructures and to offer a forum for implementing the coordination and the interoperability among the participating members.
- To maximise the shared use of the European Polar stations and facilities and to develop code of conduct.
- To implement the MoU «Polar Framework» signed in Brussels on June 2009.

Appendix

I. Arctic ECRA Participating Institutions

Arctic ECRA is currently composed of members from 23 research institutions. Each participant has a wide experience in Arctic research and has currently on-going research activities in this filed, funded by institutional, national or European resources.

Alfred Wegener Institute for Polar and Marine Research (AWI), DE: The AWI carries out polar and marine research in the Arctic and Antarctic as well as in the high and mid latitude oceans. The AWI also carries out terrestrial polar research: it provides key contributions in the field of atmospheric physics and chemistry; the dynamics of ice sheets and on permafrost soils. The institute coordinates German polar research and makes available to the national and international scientific community important infrastructure, e.g. the research ice breaker "Polarstern" and research stations in the Arctic and Antarctic.

Arctic Research Centre, Aarhus University, DK: The ARC is a recently established cross-faculty Centre to foster multidisciplinary research in marine, limnic, cryosphere, contaminants, atmospheric and health research in the Arctic. It also has the remit to develop education in Arctic issues that includes international education programmes. The ARC is part of the Arctic Science Partnership (ASP), and is active in the coordination and research activities taking place at key field research stations in Greenland.

Bjerknes Centre for Climate Research (BCCR), NO: The BCCR is a climate research institute established in Bergen in 2000. It has four partners, the two main partners are the University of Bergen (own description) and Uni Research, while the IMR and NERSC are the two other (own description). Uni Research is the second largest research company in Norway, and has extensive experience in managing and performing basic research and applied research projects, where running the Norwegian Earth System Model and regional coupled models are among the main activities. Uni Research also performs field observations of sediment cores and oceanographic properties in many regions, including Arctic waters.

British Antarctic Survey (BAS), UK: BAS carries out research in both the Arctic and the Antarctic and has key expertise in the fields of polar atmospheric science (surface to high atmosphere, physics, chemistry and dynamics), sea ice, polar ocean physics and dynamics, polar marine ecosystems, ice sheet dynamics and polar climate variability (recent and palaeoclimate timescales). BAS provides the UK science community and international collaborators with access to polar infrastructure, including two ice-strengthened ships, a fleet of five aircraft and permanent research facilities in both the Arctic and Antarctic.

The Catalan Institute of Climate Sciences (IC3), SP:
IC3 is divided into research units and laboratories, e.g. the Climate Forecasting Unit (CFU). The CFU carries out research to forecast global and regional climate variations from one month to several years into the future (seasonal-to-decadal predictions) at a global scale. This includes understanding the sources of predictability, formulating probabilistic forecasts with dynamical and empirical methods, performing a thorough forecast quality assessment, interacting with a range of users, and combining and calibrating the predictions formulated by

the various sources of climate information. The unit members also investigate the impact of future climate variability on socio-economic sectors, and the management of those impacts via the development of climate services for renewable energy.

Centre National de la Recherche Scientifique (CNRS), FR:
CNRS is the largest fundamental research organization in Europe and carries out research in all fields of knowledge within seven institutes. CNRS encourages collaboration between specialists from different disciplines in particular with the universities thus opening up new fields of enquiry to meet social and economic needs. CNRS has developed interdisciplinary programs, which bring together various CNRS departments as well as other research institutions and industry. CNRS is leading the Arctic Activities in France, e.g. The French Arctic Initiatives including six sub-topics.

Danish Meteorological Institute (DMI), DK: DMI is the national meteorological service for Denmark, Greenland and the Faeroe Islands. DMI carries out observation and operational forecast for Greenland and Arctic region, including sea ice monitoring and forecasting. DMI has also extensive experience in Arctic climate research: It has developed and maintained state-of-the-art global and regional models for the climate system of atmosphere, ocean, sea ice and recently also Greenland ice sheet, uncoupled and/or coupled; It carries out simulations of climate changes in global, Arctic region, and Greenland ice sheet, and researches of processes leading to these changes. DMI provides in-depth information and advice on climate and climate change to governmental institutions and the general public.

European Polar Board, European Science Foundation (ESF), FR: The European Polar Board (EPB) is Europe's strategic advisory body of the European Science Foundation 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. The current 26 funding organizations of the European Polar Board include, Bulgaria and the Czech Republic. The EPB integrates the Russian Federation as an associated country.

Finnish Meteorological Institute (FMI), FI: FMI is a research and service agency under the Ministry of Transport and Communications. The main objective of the FMI is to provide the Finnish nation with the best possible information about the atmosphere above and around Finland, for ensuring public safety relating to atmospheric and airborne hazards and for satisfying requirements for specialized meteorological products. For these tasks it operates highly complex monitoring and modelling systems.Its Arctic Research Centre (ARC) is located at Sodankylä provideing ideal facilities for versatile observations of arctic low temperature conditions. The research work at ARC currently focuses in the polar ozone and Arctic snow coverage under the influence of global warming. As an additional feature auroras are studied at the Helsinki group of Arctic Research division.

Institut polaire français Paul Émile Victor (IPEV), FR: The IPEV is a governmental support agency providing a legal framework and the human, logistical, technical and financial resources to the development of French research in Polar Regions. IPEV operates 2 stations in Antarctica (1 of them jointly with Italy), 3 stations in the French Subantarctic islands and 1 station in Spitsbergen (jointly with AWI), IPEV collaborates with AWI to manage and conduct research activities in Svalbard (AWIPEV station, Spitsbergen). IPEV also operates the R/V Marion Dufresne (all oceans) and the polar vessel L'Astrolabe in the Southern Ocean.

Italian National Research Council (CNR), IT:

CNR institutes and researchers, carry out research in the Arctic and Antarctica, providing key contributions in the field of atmospheric physics, marine sciences, terrestrial ecosystems, geology, paleo-climate and dynamics of ice sheets. DSSTTA coordinates CNRs polar research and makes available to the national and international scientific community the research station at Ny Alesund (Svalbard) Dirigibile Italia and observing platforms as Amundsen Nobile Climate Change Tower. CNR, through DSSTTA provides the coordination and management of scientific activities of the Italian National Antarctic Programme (PNRA), largely contributing to reinforce the bi-polar perspective into the Italian polar research community.

Institute of Marine Research (IMR), NO: IMR carry out polar research in the Arctic with focus on climate variability and impacts on marine species and ecosystem. An important task of IMR is to provide advice to Norwegian authorities on aquaculture and the ecosystems of the Barents Sea, the Norwegian Sea, the North Sea and the Norwegian coastal zone. For this reason, about fifty percent of the activities are financed by the Norwegian government. With a staff of almost 700 IMR is Norway's largest centre of marine science. IMR operates 5 research vessels, which are at sea for a total of 1600 days a year.

Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), IT: ENEA is a governmental research agency, whose activities are targeted to research, innovation technology, and advanced services in the fields of energy. The Technical Unit Energy and Environmental Modelling carries out, amongst other activities, research on climate. In particular, activities are dedicated to the development of instrumentation for atmospheric remote sensing, and the measurement of atmospheric parameters for studies on climate change at high latitudes and in the Mediterranean. ENEA is also in charge of the logistics of the Italian Antarctic Programme.

Karlsruhe Institute of Technology (KIT), DE: The Karlsruhe Institute of Technology – founded in 2009 by the merger of the former Karlsruhe Research Centre and the former University of Karlsruhe – combines the mission of a state-run university with that of a national research centre in the Helmholtz Association. Its staff of over 9000 makes KIT one of the world's largest research institutions. KIT's major research areas are Energy, Climate and Environment, Nano- and Microtechnologies, Elementary Particle and Astroparticle Physics, Mobility Systems, Information and Robotics, and Humans and Technology. KIT's Institute for Meteorology and Climate Research coordinates the German Helmholtz Programme on Atmosphere and Climate.

Laboratoire d'Oceanographie et du Climat (LOCEAN), FR

LOCEAN is a laboratory with research focus on processes of ocean variability and their interactions with climate variability. LOCEAN studies a wide range of scales ranging from those of the vertical mixing and those internal to the planetary movements waves. Research conducted in the laboratory aims to deepen the understanding of ocean dynamics and its impact on climate change and major chemical compartments (especially carbon in its inorganic and organic forms) in conjunction with bio-geochemical cycles.

Nansen Environmental and Remote Sensing Center (NERSC), NO

The Nansen Center is an independent research foundation founded in 1986 and affiliated with the University of Bergen, Norway. The Nansen Center conducts basic and applied environmental and climate research with interdisciplinary scientific expertise in satellite remote sensing, modelling and data assimilation. Its research foci are in Earth sciences,

particularly covering topics such as physical and biology oceanography, meteorology, sea ice/cryosphere studies, hydrology and climate studies, including remote sensing in all these themes.

Norwegian Polar Institute, NO
The Norwegian Polar Institute is Norway's central governmental institution for scientific research, mapping and environmental monitoring in the Arctic and the Antarctic. The Institute advises Norwegian authorities on matters concerning polar issues, and is Norway's competent environmental authority in Antarctica. The Norwegian Polar Institute is a directorate under the Ministry of Climate and Environment. The Ministry defines the scope and sets the tasks for Institute.

Swedish Meteorological and Hydrological Institute (SMHI), SE: SMHI's interest in the Arctic is founded by Sweden's geographical location as part of the Arctic, and by the need to understand Arctic changes and its impact on global and Swedish climate. Objectives are to improve the description of Arctic processes in climate models and the generate knowledge to inform climate change adaptation in societal sectors, and decision making. SMHI is carrying out research at the frontier of regional climate modelling and is actively participating in global climate modelling efforts (as a leading partner in the EC-Earth consortium). Model development and process understanding as well as climate projections and decadal prediction are integral components of the modelling strategy. In that set-up, the Arctic is a key research area for SMHI.

The Royal Netherlands Institute for Sea Research (NIOZ), NL: The NIOZ is the national institute for ocean sciences under aegis of the Netherlands Organization for Scientific Research (NWO). Seagoing research is pursued in the polar regions as well as the temperate Atlantic and Indian Oceans and in European coastal seas. Ever since the European Polarstern Study (1988-1989) there is active polar research in collaboration with the AWI and the BAS, focusing on the role of iron and other trace elements and their isotopes (www.geotraces.org), the uptake and biological effects of anthropogenic CO_2, and the role of viruses in the plankton ecosystem. Specialized equipment and laboratory containers are contributed to polar expeditions hosted aboard ice-breaker vessels of AWI and BAS. As off 2012 there is a Dirck Gerritsz Laboratory of NWO at the Rothera Research Station, Antarctica, of the British Antarctic Survey.

The Royal Netherlands Meteorological Institute (KNMI), NL: The KNMI carries out a wide variety of climate and weather related research, from fundamental to applied. Research topics include weather forecast improvements, satellite observations of the Earth and atmospheric composition, regional and global climate modelling and providing climate services. Part of the global climate modelling is focused at the Arctic region. Using the global Earth System Model EC-Earth, research includes Arctic climate feedbacks, seasonal to longer-term predictability and the effect of Arctic changes on the mid-latitudes (specifically Western Europe).

University of Bergen (UiB), NO: The University of Bergen is a young, modern university with about 14,500 students, and 3,200 staff. In addition to research and education in the traditional university disciplines, the academic profile of the University of Bergen has two major foci: marine research and co-operation with developing countries. The Bjerknes Centre for Climate Research is coordinated by the University of Bergen. . The University of Bergen

performs a full range of Arctic projects from detailed turbulence field campaigns in the boundary layers, to studies of the North Atlantic regional climate variability.

National Centre for Atmospheric Science (NCAS)/University of Reading, UK: The National Centre for Atmospheric Science (NCAS) is one of the Natural Environment Research Council's (NERC) research centres. The Centre increases knowledge of key environmental issues including: climate change, weather processes and atmospheric composition including air quality. NCAS is not based in one location. It is made up three science directorates (climate; weather; atmospheric composition) and four services and facilities distributed across many UK universities and related institutions.

II. Arctic ECRA Expertise, Facilities and Points of Contact

Arctic ECRA Members				
Institution	**COUNTRY**	**EXPERTISE**	**FACILITIES**	**Point of Contact**
Alfred Wegener Institute for Polar and Marine Research (AWI)	GERMANY	Polar atmosphere, interactions with sea ice, ocean and land Ice sheet dynamics and mass balance Biogeochemistry and physics of Arctic sea ice Polar benthic biota and ecosystem functioning Permafrost decline and coastal erosion Climate model development, climate dynamics and climate prediction Regional climate system model of the Arctic	RV Polarstern, AWIPEV research station (Svalbard), Samoylov station, polar research aircrafts POLAR5+6, ice core lab, NEC supercomputer computing facilities, Pangeae, ECHAM6-FESOM climate model, MITgcm sea ice-ocean model	**Thomas Jung** **Co-chair of Arctic ECRA** (Thomas.Jung@awi.de) Karin Lochte (Karin.Lochte@awi.de) Klaus Dethloff (Klaus.Dethloff@awi.de)
Bjerknes Centre for Climate Research (BCCR) **University of Bergen and Uni Research.**	NORWAY	Sea ice-ocean processes, sea ice-atmosphere interactions, storm tracks, climate model development, climate prediction, past Arctic climates, carbon and nutrient cycling.	NorESM climate model, MITgcm sea ice-ocean model, CAM atmospheric model with tracers, Norwegian supercomputing facilities.	Camille Li (Camille@uib.no) Eystein Jansen (Eystein.Jansen@uni.no) Lars Henrik Smedsrud Co-chair of Arctic ECRA (larsh@gfi.uib.no)
Institut Català de Ciències del Clima (IC3)	Spain	Monthly-to-decadal global climate prediction, analysis and prediction of extreme events, sea-ice modeling and prediction, development of climate services, development of impact models (health, energy, hydrology), atmospheric composition measurements, high-resolution climate and	EC-Earth climate and NEMO ocean forecast systems, LIM and GELATO sea-ice models, cluster computing facilities and training, network of ground-based instrumentation for measurements of atmospheric	Francisco J. Doblas-Reyes (francisco.doblas-reyes@ic3.cat), Virginie Guemas, (virginie.guemas@ic3.cat)

		ocean modeling, models for the impact of climate on human health.	composition in the Iberian Peninsula and the Canary Islands and several masts.	
Centre National de la Recherche Scientifique (CNRS)	France	All the scientific fields involved in Arctic studies. CNRS is leading the new French Arctic Initiative in which scientific expertise has been gathered in 6 main interdisciplinary themes: Permafrost, Climate: Ocean-Ice-Atmosphere, Ecosystems and Biodiversity, Geodynamics and Natural Resources, Human Impacts, Arctic Societies and Knowledge Systems, Governance and Geopolitics	Different national research facilities including research aircrafts and supercomputers,	Denis-Didier Rousseau (denis-didier.rousseau@cnrs-dir.fr) Michel Diamant (michel.diament@cnrs-dir.fr)
Danish Meteorological Institute (DMI)	DENMARK	Arctic and global climate system modelling, climate change simulation (CMIP5/IPCC scenarios) and high resolution dynamical downscaling; Greenland ice sheet modelling and interaction with climate system; Greenland weather observation, operational forecast, and surface mass balance simulation; Remote sensing of sea ice states (including ice concentration, drift and icebergs, etc.); Field campaign using in-situ and remote sensing instruments for hydrographical survey; Deploy Arctic moorings and process data; Sea ice operational forecast; Oil spill modelling.	EC-EARTH global Earth System model, HIRHAM regional climate model, HYCOM-CICE ocean and sea ice coupled model for Arctic ocean, CRAY-XT5 supercomputer computing facility, CORDEX regional IPCC/CMIP5 data server, standard weather stations around Greenland coast, a Hut in western Greenland coast (Qaanaaq) which can be used as logistics for field campaign, CTDs and IR radiometer (ISAR)	Shuting Yang (shuting@dmi.dk) Katrine Krogh Andersen (kka@dmi.dk)
Finnish Meteorological Institute (FMI)	FINLAND			Kari Luojus (kari.luojus@fmi.fi) Mikko Strahlendorff

				(mikko.strahlendorff@lvm.fi)
Italian National Research Council (CNR)	ITALY	Polar Atmosphere radiation and energy budget, ABL dynamics, mass and heat exchange at air-snow-ice interface, transport and climate effects of aerosols, modelling interactions between arctic ecosystems and climate variability, processes in the stratosphere, Paleoclimate, Mercury Marine Sciences Oceanography, Climate change on marine circulation and C cycle; Marine biodiversity, benthos & adaptation strategies; Bio-acoustics; Marine geology; Gas Hydrates, Pollution Terrestrial Ecosystems permafrost, resilience to climate change, hydrological cycle in the Arctic, microbial communities, CO2 and CH4 fluxes Climate Change Monitoring through satellite observations; dynamics of ice sheets; Development of new technologies to investigate polar environment (UAV, USV, ROV, sensors)	Dirigibile Italia Research station (Svalbard); Amundsen-Nobile Climate Change Tower (Svalbard), access to national supercomputing facilities; EC-Earth global climate model.	Vito Vitale (V.vitale@isac.cnr.it) Jost von Hardenberg (j.vonhardenberg@isac.cnr.it)
Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)	ITALY	Radiative budget of the atmosphere Characterization of atmospheric aerosols and their role in climate Stratospheric processes	Instrumentation installed at the Network for Detection of Atmospheric Composition Change at Thule (76.5°N, 68.8°W), Greenland. The station is managed by the Danish Meteorological Institute	Alcide Giorgio di Sarra (Alcide.Disarra@enea.it) Giandomenico Pace (giandomenico.pace@enea.it)
Karlsruhe Institute of Technology (KIT)	GERMANY	Atmospheric composition and dynamics; Clouds and aerosols; Middle and upper	Ground-based, airborne and satellite instrumentation for	Bjoern-Martin Sinnhuber (Bjoern-

		atmosphere; Remote sensing; Chemistry-climate modelling	measurements of atmospheric composition, clouds and aerosols; long-term atmospheric composition monitoring at sub-arctic site (Kiruna, Sweden); high performance computing centre	Martin.Sinnhuber@kit.edu)
Norwegian Polar Institute	NORWAY			Harald Steen (Harald.Steen@npolar.no)
Swedish Meteorological and Hydrological Institute (SMHI)	SWEDEN	Coupled Arctic climate modelling for ocean, atmosphere and sea ice, soil and vegetation. Global climate modelling, climate projection and climate prediction.	Rossby Centre at SMHI is the Swedish climate modelling centre, including scientific and technical expertise and capabilities. Climate models for community use.	Ralf Doescher (Ralf.Doescher@smhi.se) Torben Koenigk (torben.koenigk@smhi.se)
The Royal Netherlands Meteorological Institute (KNMI)	THE NETHERLANDS	Polar atmosphere, interactions of the coupled ocean, sea ice, atmosphere system, polar climate feedbacks, climate predictability, teleconnections The fully coupled Earth System Model EC-Earth includes all relevant Arctic components, and will even include fully interactive dynamical ice sheets in the near-future	EC-Earth climate model, based on IFS (atmosphere), NEMO (ocean), LIM (sea ice), TM5 (atmospheric composition), LPJ (dynamic vegetation), GRICE (ice sheet, near-future)	Richard Bitanja (Bitanja@knmi.nl) Wilco Hazeleger (Wilco.Hazeleger@knmi.nl)
National Centre for Atmospheric Science (NCAS)/University of Reading	UK	Sea ice modelling & processes, seasonal-decadal climate variability and predictability, climate model development, Arctic-mid-latitude teleconnections, coupled Arctic processed (fluxes & dynamics), coupled data assimilation,	Hadley Centre climate models: HadGEM/GAM, HiGEM. NEMO, Access to Cray XE6 high performance computing (HECTOR)	Jonathan J. Day (J.J.Day@reading.ac.uk)

		ocean reanalysis, Arctic marine access		
Arctic Non-ECRA Members				
Institution	**COUNTRY**	**EXPERTISE**	**FACILITIES**	**Point of Contact**
Arctic Research Centre, Aarhus University	DENMARK	The Arctic Research Centre (ARC) is a new initiative launched in 2012, with a core group of researchers covering terrestrial, limnic, marine, cryopsheric, atmospheric, contaminants and health research in the Arctic.	The ARC is a central hub to research opportunities in Greenland and in other regions through the Arctic Science Partnership (ASP). Key facilities include field stations and the necessary logistical expertise at Nuuk, Station Nord and Zackenberg.	Lise Lotte Sorensen (lls@dmu.dk)
British Antarctic Survey (BAS)	UK	Polar ocean physics and dynamics Polar atmosphere – surface to thermosphere Polar climate variability (proxy and instrumental records) Sea ice and its interaction with the atmosphere and ocean Ice sheets and their interaction with the ocean Polar marine ecosystems Global and regional climate modelling	RRS James Clark Ross, UK Arctic Research station (Svalbard), DHC6 Twin Otter research aircraft, ice core labs, HadGEM global climate model, WRF and Met UM regional climate models.	John King (jcki@bas.ac.uk) Jeremy Wilkinson (jpw28@bas.ac.uk)
European Polar Board, European	FRANCE			Roberto Azzolini (RAzzolini@esf.org)

Science Foundation (ESF)				
Institut Polaire Français (IPEV)	FRANCE	No scientific expertise (IPEV is a support agency) but the institute can provide expertise in logistical issues in polar regions, protection of the environment associated to human/scientific activities in polar regions.	RV Marion-Dufresne, and the following research stations: AWIPEV (Svalbard), Dumont d'Urville (Terre Adélie, Antarctica), Concordia (Antarctic Plateau), Crozet, Kerguelen and Amsterdam Islands (Subantarctic)	Yves Frenot (Yves.Frenot@ipev.fr) Alternate tbd (dirpol@ipev.fr)
Institute of Marine Research (IMR)	NORWAY	Polar ocean physics, dynamics and thermodynamics Polar ocean variability (from seasonal to multi-decadal) Ocean interaction with the atmosphere and ice. Ocean acidification and impacts on marine organisms. Polar marine ecosystems (phytoplankton, zooplankton, fish, marine mammals and benthos). Downscaling global climate models, regional modelling (ROMS) on scales from Atlantic to fjords, transport modelling (e.g. pollution, fish eggs and larvae, salmon lice), ecosystem modelling.	IMR operates 5 vessels equipped for oceanographic and biological sampling as well as fish trawling: RV G.O. Sars, RV Johan Hjort, RV Håkon Mosby, RV Fritjof Nansen and RV Dannevig. IMR has laboratory facilities for biological experiments including ocean acidification experiments on zooplankton and fish. IMR operates general ocean circulation models (ROMS), downscaling climate models, bio-physical models, individual-based models for fish and ecosystem models.	Harald Loeng (Harald.Loeng@imr.no) Randi Ingvaldsen (Randi.Ingvaldsen@imr.no)
Laboratoire d'Oceanographie et du Climat (LOCEAN)	FRANCE			Christine Provost (cp@locean-ipsl.upmc.fr) Jean Claude Gascard

				(Jga@locean-ipsl.upmc.fr)
Nansen Environmental and Remote Sensing Center (NERSC)	NORWAY			Lasse Pettersson (Lasse.Petterson@nersc.no)
The Royal Netherlands Institute for Marine Research (NIOZ)	THE NETHERLANDS	Iron and other trace elements and their isotopes; CO2 uptake and effects on biota; virus -plankton interactions	Ultraclean CTD sampling system of 24 x 27L samplers, with own ultraclean lab container; winch with 10 km clean Dyneema CTD hydrowire; 2 more ultraclean analytical lab containers with FI-CL analyzers for trace metals; large volume CTD/Rosette 24 x 25L for non-contamination-prone isotopes etc sampling; CO2 lab container comprising 4 Vindta analyzer systems; nutrients lab container comprising 2 autoanalyzers; flow cytometers; deck incubators; ultraclean 180 m^2 home laboratory with HR-ICP-MS.	Hein de Baar (Hein.de.Baar@nioz.nl) Micha Rijkenberg (Micha.Rijkenberg@nioz.nl)

III. Presently ongoing activities of each participant

(to be updated in regular intervals)

Institution	Ongoing research activities (e.g. EU projects, National projects, institutional projects)
Alfred Wegener Institute for Polar and Marine Research (AWI)	international projects: ACCESS, ArcRisc, SATICE: Arctic Ocean Sea-ice and Ocean Circulation Changes Using Satellite Methods, "Pan-Arctic georeferenced ecological data base", INTERACT: International Terrestrial Arctic Collaborative Network, ABYSS- Assessment of Bacterial Life and Matter Cycling in Deep-Sea Surface Sediments, ICE2SEA- Estimating the future contribution of continental ice to sea-level rise, PAGE21-Changing Permafrost in the Arctic and ist Global Effects in the Century, SIOS; national projects: MODINI "Model initialization by partially couple spin-up", MiKlip - Towards regionally focused decadal climate predictions (TORUS), RACE: Regional Atlantic Circulation and Global Change; institutional projects: REKLIM (Regionale Klimaänderungen/Regional climate change)
Arctic Research Centre, Aarhus University (ARC)	
Bjerknes Centre for Climate Research (BCCR)	EU projects Past4Future, Carbochange; National projects – EarthClim, Deccen, BlueARC, OCCP; Institutional projects - Practice, Regscen, Dynawarm
British Antarctic Survey (BAS)	UK national Arctic programme (projects ACCACIA and TEA-COSI). EU FP7 ACCESS project. US ONR MIZ project. Participation in Norwegian DriftIce project.
Centre National de la Recherche Scientifique (CNRS)	The French Ministry of Higher Education and Research mandates CNRS to structure and coordinate the French community working in the Arctic. A new national program, named French Arctic Initiative has been launched in 2012 with the first national conference early June 2013 designed to release a white paper about French Arctic Research from which scientific priorities will be defined. CNRS labs are also individually involved in EU projects, and collaborative actions on the different scientific fields
Danish Meteorological Institute (DMI)	EU projects: COMBINE (inclusion of ice sheet in Earth System Models), Ice2Sea, OSISAF, MyOcean I and II (SST&Sea Ice TAC), POLARVIEW, THOR, NACLIM, ESA CCI projects (CCI-ice sheet, CCI-Sea Ice and CCI-SST), ICEMAR, SMOSICE; NordForsk (Nordic Council of Ministers) projects: SVALI, DEFROST National projects: Center for Regional climate change in Earth System (CRES), Greenland Climate

	Research Centre (GCRC), NAACOS, LOMROGIII; Institutional projects: Greenland-SYNOP, DMI-HIRLAM SMB
European Polar Board, European Science Foundation (ESF)	
Finnish Meteorological Institute (FMI)	
Institut Polaire Français (IPEV)	Some 80 research programs are selected every year by IPEV on the recommendation of its international Scientific Committee, of which 75% is conducted in Antarctica or in the Subantarctic Islands and 25 % in the Arctic. Topics of research include Glaciology, Meteorology, Atmospheric Sciences, Astronomy, Coastal Oceanography, Geology, Biology, Ecology, Physiology and Psychology. Some 20 projects are long term observatories.
Italian National Research Council (CNR)	Climate Change Tower Integrated Project (CCT-IP - inst. Project), SIOS-PP (EU project), specific research projects at Ny Alesund (see SSF RIS database for details)
Institute of Marine Research (IMR)	
Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)	National projects: “Observations of changes in chemical composition and physical properties of polar atmospheres from NDACC stations”, supported by the Italian Antarctic Program; “ARCTICA - ARCTic research on the Inter-connections between Climate and Atmosphere”, supported by the Italian Ministry for University and Research.
Karlsruher Institut für Technologie (KIT)	Selected current projects: EU Project RECONCILE (Arctic stratospheric ozone loss); German DFG project SHARP (Stratospheric change and its role for climate prediction); German VERDI project (Vertical distribution of ice in Arctic clouds); Helmholtz initiatives REKLIM (Regional climate change) and ESKP (Earth System Knowledge Platform)
Laboratoire d’Oceanographie et du Climat (LOCEAN)	
Nansen Environmental and Remote Sensing Center (NERSC)	
Norwegian Polar Institute	

Swedish Meteorological and Hydrological Institute (SMHI)	EU projects: COMBINE aims to improve global climate models for better climate predictions and projections. ECLISE is analysed and providing climate scenario data for research aimed at establishing climate services in Europe. EMBRACE aims to make targeted improvements to key process failings in present-days Earth System Models EUPORIAS and SPECS advances climate prediction on the seasonal to decadal timescale with the aim of identifying problems in climate prediction and developing and delivering reliable predictions of the future climate to public and private stakeholders. GENESIS provides ensemble regional climate data for groundwater modelling across Europe HEALTHY FUTURES provides high-resolution regional climate simulations for eastern Africa IMPACT-2C considering, simulating and analyzing climate conditions under EU's 2-degree goal. IS-ENES2 deals with a wide range of climate modelling infrastructure improvements. Selected National Swedish projects: ADSIMNOR aims to improve the understanding of climate change in the Arctic and its impacts in northern Sweden. MISTRA-SWECIA is an interdisciplinary research programme on climate, impacts and adaptation. The programme brings together researchers in the fields of climate science, economics, life sciences and social sciences.
The Royal Netherlands Institute for Marine Research (NIOZ)	GEOTRACES International Polar Year; DYNALIFE 2009 Amundsen Sea and Pine Island Glacier, Antarctica; Role of iron and manganese in sea-ice 2010-2012, field work at Scott Base, Antarctica; GEOTRACES West Atlantic Ocean section Iceland to Falklands; GEOTRACES Iron and major nutrients Process Study during IceARc Arctic expedition August-October 2012; GEOTRACES and virus-plankton interactions, Rothera Research Station, 2012-2015, Antarctica; Mediterranean Sea and Black Sea, 3 cruises in summer 2013; GEOTRACES Central Arctic (2015), proposal submitted; GEOTRACES Fram Strait 2016, proposal submitted.
The Royal Netherlands Meteorological Institute (KNMI)	Arctic climate feedbacks (national), Arctic seasonal predictability (national), Arctic seasonal climate changes and feedbacks, sea-ice and snow feedbacks

National Centre for Atmospheric Science (NCAS)/University of Reading	Arctic Potential Predictability on Seasonal to inter-annual time scales (APPOSITE)(NERC, UK). The Environment of the Arctic: Climate, Ocean and Sea Ice (TEA-COSI)(NERC, UK). Centre for Polar Observation and Modelling (Cryosphere theme of NERC). Realistic sea ice melt in climate models using field observations and theory (NERC). Calculating the rate of AABW formation using new theory, fine-scale modelling, and observations (NERC project at UoR and BAS).