



**ARCTIC SCIENCE
MINISTERIAL**



Report of the 2nd Arctic Science Ministerial

CO-OPERATION IN ARCTIC SCIENCE – CHALLENGES AND JOINT ACTIONS

Berlin, Germany, 25–26 October 2018

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INTRODUCTION AND BACKGROUND

The rapid changes happening in the Arctic are impacting the fragile Arctic ecosystem and have deep impacts on the people living there. Arctic changes are also impacting the global system such as influencing the climate system or sea levels changes. There is a sense of urgency among decision-makers and awareness in the public opinion regarding the global importance of changes taking place in the Arctic. These challenges demand for coordinated and carefully planned collective efforts, as no country can work in isolation in this difficult environment, under harsh working conditions.

Science Ministers, or their representatives, from Austria, Belgium, Canada, China, Czech Republic, Denmark, Faroe Islands, Finland, France, Germany, Greenland, Iceland, India, Italy, Japan, the Netherlands, Norway, Poland, Portugal, Republic of Korea, Russian Federation, Singapore, Spain, Sweden, Switzerland, United Kingdom, the United States of America and the European Union, leaders and delegates from the Arctic Indigenous peoples' organisations Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International, Inuit Circumpolar Council, Russian Association of Indigenous Peoples of the North and Saami Council and representatives of the international science organisations with interests in Arctic research (Association of Polar Early Career Scientists, Group on Earth Observations, International Arctic Science Committee, International Arctic Social Sciences Association, International Council for the Exploration of the Sea, Sustaining Arctic Observing Networks, University of the Arctic, UN

Environment Programme and World Meteorological Organization) are gathering to discuss further cooperation for supporting and enhancing Arctic science. The meeting builds on the first Arctic Science Ministerial (ASM) held in Washington, DC in 2016¹, which declared a long-term objective to deepen international collaboration to enable nations to address large-scale research questions and increase the pace of discovery. The second Arctic Science Ministerial (ASM2) is discussing progress made from the Washington ASM as well as ideas for new efforts that can further international cooperation and help increase the pace of our understanding of the rapidly changing Arctic.

This interim report presents a summary of the contributions provided by the participating countries, indigenous and science organisation prior to the ASM2. After the Ministerial it will be supplemented with the outcome of ASM2 and made available in printed form.

¹ https://www.arctic.gov/publications/other/supporting_arctic_science.html





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SCIENCE SUMMARY

SCIENCE SUMMARY

The second Arctic Science Ministerial (ASM2) aimed to promote the results of the projects presented at the first ASM and to foster further scientific cooperation among a wide number of countries and representatives of Indigenous Peoples and international organisations with Arctic interests. The ASM2 focused on three themes where an improved and better-coordinated international scientific effort can provide clear opportunities to advance the understanding of the impact of rapid Arctic changes and to respond to major societal challenges in the Arctic and globally. A significant note of progress from the ASM1 meeting is the increased participation of the Arctic Indigenous Peoples and international science organisations that provided important content and discussions to the ASM2. The themes for ASM2 were:

1. STRENGTHENING, INTEGRATING AND SUSTAINING ARCTIC OBSERVATIONS.

FACILITATING ACCESS TO ARCTIC DATA, AND SHARING ARCTIC RESEARCH INFRASTRUCTURE

2. UNDERSTANDING REGIONAL AND GLOBAL DYNAMICS OF ARCTIC CHANGE

3. ASSESSING VULNERABILITY AND BUILDING RESILIENCE OF ARCTIC ENVIRONMENTS AND SOCIETIES

ABOUT THIS DOCUMENT

This Science Summary presents a synopsis of the contributions provided by the following: Canada, China, Czech Republic, Denmark, Faroe Islands, Finland, France, Germany, Greenland, Iceland, India, Italy, Japan, the Netherlands, Norway, Poland, Portugal, Republic of Korea, Russia, Singapore, Spain, Sweden, Switzerland, United Kingdom, United States of America, European Union (EU), Gwich'in Council International (GCI), Inuit Circumpolar Council (ICC), Russian Association of Indigenous Peoples of the North (RAIPON), Saami Council, Association of Polar Early Career Scientists (APECS), Group on Earth Observations (GEO), International Arctic Science Committee (IASC), International Arctic Social Sciences Association (IASSA), International Council for the Exploration of the Sea (ICES), Arctic Council Indigenous Peoples Secretariat (IPS), Sustaining Arctic Observing Networks (SAON), University of the Arctic (UArctic), UN Environment (UNEP) and the World Meteorological Organisation (WMO). It is based on the input describing both the progress achieved after ASM1 and new research activities in relation to the themes of ASM2. The documents received from countries and Indigenous and international organisations were analysed and initiatives categorised within the three themes of ASM2 by the Science Advisory Board. This categorisation is not univocal and countries and organisations may have a different opinion. Contributions and initiatives proposed ranged from small localised and concentrated short-term efforts of a few researchers to large multi-national multi-agency long-term programmes with several hundred professionals involved. This document is a higher-level summary of these contributions including summary tables and word clouds highlighting key words across all contributions. It is not exhaustive but rather aims to provide an overview to identify areas of major interests and to help catalyse further cooperation aiding in the advancement of Arctic science. For the sake of transparency all the inputs provided to the ASM2 are available for consultation by the ASM2 participants.

ASM2 Science Advisory Board

- Karin Lochte (GER, Chair)
- Tuula Aarnio (FIN, Ex Officio)
- Jenny Baeseman
(Baeseman Consulting)
- Tim Eder (GER, Ex Officio)
- Kelly Falkner (USA)
- Attilio Gambardella
(EC, Ex Officio)
- Larry Hinzman (IASC)
- Kirsi Latola (FIN)
- Svein Mathiesen
(UArctic Institute of Circumpolar Reindeer Husbandry)
- Volker Rachold (GER, Ex Officio)
- Andrea Tilche (EC)
- Huigen Yang (CHI)

↑ **Figure 1: Keywords describing initiatives contributing to the ASM2 Themes.**
Word Clouds are based on frequency of keywords from titles and descriptions of initiatives submitted by participating countries/organisations.



3. ASSESSING VULNERABILITY AND BUILDING RESILIENCE OF ARCTIC ENVIRONMENTS AND SOCIETIES

Word Clouds are based on frequency of keywords from titles and descriptions of initiatives submitted by participating countries/organisations.

THEME 1

STRENGTHENING, INTEGRATING AND SUSTAINING ARCTIC OBSERVATIONS, FACILITATING ACCESS TO ARCTIC DATA, AND SHARING ARCTIC RESEARCH INFRASTRUCTURE

Research and observations are essential for predicting the evolution of changes in the Arctic and their impacts on regional to global scales. The Arctic is a complex system, and it remains a challenge to monitor it – even more so due to its vastness, low population density, and extreme conditions. Costly research infrastructures are usually required to observe the processes in the Arctic. Costs can be reduced by sharing research infrastructure and observing systems, but also by making data freely and openly available in a timely manner. Cooperation among countries, research institutions and communities is therefore mutually beneficial for the partnering entities.

Existing national and international observing and research efforts are not yet fully able to meet the demand for comprehensive and integrated information on the Arctic. There is a need to enhance coordination and collaboration on Arctic observations ranging from those by an individual to high-tech autonomous systems. The demonstration of the benefits and the value of an integrated Arctic observing system is essential to justify the required long-term investments. Significant advances from the first ASM have happened in this realm.

PROGRESS TOWARDS AN INTEGRATED ARCTIC OBSERVING SYSTEM

The development of sustained long-term Arctic observations is progressing, with new national and community-based initiatives contributing to filling gaps and improving our understanding of the Arctic. International and regional efforts continue to work toward integration, but more support is still needed.

- **Arctic Observing Summit** – The international Arctic Observing Summit (AOS)¹ is an avenue for providing guidance for an international network of Arctic observing systems. A significant improvement in Arctic observation and monitoring has already been achieved through major programmes by different nations, but the key messages from AOS need to be considered for the future. For example, at the AOS in

June 2018, participants from 26 countries and several Arctic Indigenous People's organisations highlighted the societal benefits of accessible data and sustained observing systems. They submitted a call to action to the Arctic Science Ministerial that can be considered a basis for improving Arctic observation systems:

- There is an urgent need to progressively shift key observing system components – including community-based observations – from short-term research funding to sustained, operational infrastructure support;
 - A properly resourced, comprehensive effort is needed to identify strengths and gaps in the current set of systems, sensors, networks, and surveys used to observe the Arctic;
 - Observing and data systems, at different spatial and temporal scales, should emerge from co-design, co-production, and co-management processes with relevant stakeholders and rights-holders embracing free, ethical, and open data sharing, adhering to the “FAIR” data principles (Findable, Accessible, Interoperable, Reusable); and
 - To build an Arctic Observing System that is comprehensive, coordinated, sustainable, and fills current observational gaps, all existing assets and activities, including indigenous knowledge, must be leveraged to the greatest extent.
- **Sustained Arctic observing** – Since ASM1, the Sustained Arctic Observing Network (SAON) and the US lead a group of experts from multiple sectors to develop the Arctic Observations Assessment Framework which is a value-tree framework for future assessments of the societal benefits of Arctic observations and the development of a pan-Arctic observing system consisting of 12 societal benefit areas, 41 sub-areas, and 163 key objectives. The EU's Impact Assessment on a Long-Term Investment

¹ <http://www.arcticobservingsummit.org>

on Arctic Observations (IMOBAR) project builds on this framework and will provide policy makers with evidence to support long-term investments in Arctic observing systems by analysing the costs and societal benefits of Arctic observing systems of a selected number of essential variables. The Arctic Observations Assessment Framework will be of benefit to the many countries contributing to the SAON process. Germany, Switzerland, Greenland, Denmark, France, Russia, Iceland and China, among other countries, have increased their efforts in supporting SAON. The Group on Earth Observations (GEO) is working to connect the demand for sound and timely environmental information with the supply of data and knowledge about the Earth so that decisions and actions, for the benefit of humankind, are informed by coordinated, comprehensive, and sustained Earth observations. Their polar efforts are concentrated in the GEO Cold Regions Initiative, which SAON is part of.

- **Regional observing** – Many regional observation programmes continue to evolve and lead to important discoveries. This includes the Distributed Biological Observatory² and the Svalbard Integrated Arctic Earth Observing System (SIOS)³. Many countries already contribute to these regional programmes and more being invited to join, such as the invitation for Russia's Barentsburg Station to become part of SIOS. The EU is helping to coordinate regional efforts with their INTAROS project aimed at developing an integrated Arctic Observation System (iAOS) by extending, improving and unifying existing systems in the different regions of the Arctic. WMO has many efforts working toward coordinating global Earth observations relevant for the Arctic, such as the Global Cryosphere Watch which provides authoritative, clear, and useable data, information, and analyses on the past, current and future state of the cryosphere, or the Polar Challenge which is working to stimulate new technological advances for under ice observations.
- **National observing activities** – There is a noticeable increase in national monitoring and observing programmes. The new US National Science Foundation initiative “Navigating the New Arctic” is a major commitment to accelerating the pace of research in order to tackle the challenges and opportunities associated with wide-scale, rapid Arctic change by fostering innovation in observing and data sharing. It is guided by the co-production of knowledge between local and indigenous communities and partnerships at the local and state government, interagency and international levels. The German project “Frontiers in Arctic Marine Monitoring” (FRAM) is a modular network of fixed-point and mobile sensor platforms in the Fram-Strait and Central Arctic Ocean contributing new capacities for year-round ocean observations. Multidisciplinary observatories tethered to ice-floes of the German MIDO project provide freely available, real-time data on atmosphere, sea-ice and ocean. Spain is creating a Spanish Arctic Observatory. The Czech Republic has been monitoring ice-free regions of Svalbard since 2007 looking at factors impacting vegetation cover and how that influences ground temperature. The Faroe Islands have several monitoring programmes helping to better understand their marine environment. The Republic of Korea's Arctic Ocean Observing System (K-AOOS) aims at strengthening international collaboration and access to data and their Circum-Arctic Permafrost Environment Change Monitoring (CAPEC) project has added new observational node sites in Iceland and Russia. Poland is expanding its oceanographic, meteorological and glaciological observations at Hornsund with the RV Oceania. A new Norwegian centre focusses on observing the aurora, ionosphere, and the coupling of Earth with space. Russia's Ice base “Cape Baranov” and Tiksi station carry out comprehensive monitoring of a variety of earth system components. Two new tasks have emerged within the suite of US observing activities to support sea ice forecasting and wildfire detection. Many other countries, such as China, India, the Netherlands and Sweden, are also increasing their observation efforts.

² <https://www.pmel.noaa.gov/dbo/>

³ <https://sios-svalbard.org>



- **Community-based observing** – Community observing and training activities are also gaining momentum. The US-lead Local Environmental Observer (LEO) Network is a group of 2500 local observers and topic experts in 552 communities worldwide who share knowledge about unusual animal, environment, and weather events using an innovative software tool. The US is also supporting the EyesNorth effort to develop a set of best practices for community-based observing. Canada established the Rangers Ocean Watch and the new Biodiversity Rangers programme and has just launched a new effort to include Indigenous Peoples, particularly youth, in community-based monitoring activities.
- **Indigenous Knowledge** – Incorporating Indigenous Knowledge into scientific observation frameworks is increasingly important and necessary. To keep track of the work being done in this area, the Inuit Circumpolar Council (ICC) and partners have created a web-based atlas infrastructure⁴ to inventory and map community-based monitoring and Indigenous Knowledge initiatives across the circumpolar North and has expanded the atlas to include an Inuit Mental Health and Wellness map. The Indigenous Peoples Secretariat (IPS) of the Arctic Council also works to coordinate activities with respect to indigenous knowledge.

⁴ <http://www.arcticcbm.org/index.html>

ENHANCED COOPERATION AND NEW ACTIVITIES FROM SPACE AGENCIES

Data from past, current and future satellite missions are critical to better understanding the Arctic and to provide much needed input for modelling of Arctic processes.

- **Satellite data tools and uses** – To help access, analyse and share that data, the European Space Agency has established the Polar Thematic Exploitation Platform allowing for easier discovery and access to large volumes of Copernicus Sentinel satellite data and comprises toolboxes, provisioning of virtual machines, processing resources, plus functionality to allow deployment of user defined workflows and processing environments. COPERNICUS, the EU Earth observation programme, is developing an Arctic dedicated webpage aimed at supporting scientists in finding adequate products and information with direct links to the portfolios of the Copernicus Services or Sentinels products. The Finnish Arctic GEOSS satellite data centre plans to give Arctic research actions a sufficient level of free to use data capacities to accelerate knowledge production from Arctic observations. An example of practical use of this data is the collaboration between Chinese and Greenlandic researchers who completed the latest high-resolution (30m) Greenland remote sensing image map (2014-2015) which is used in local resource management, research and improved welfare of the Greenlandic people.
- **New and follow-on missions** – The next generation of Canada's RADARSAT-1 and RADARSAT-2, the RADARSAT Constellation Mission will launch in late 2018 for three main uses: maritime surveillance (ice, surface wind, oil pollution and ship monitoring); disaster management (mitigation, warning, response and recovery); and ecosystem monitoring (agriculture, wetlands, forestry, permafrost monitoring related to climate change, and coastal change monitoring). The US and Germany launched the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission in Spring 2018 to continue tracking Earth's water movement including ice sheets and glaciers, and sea level rise. The US NASA IceBridge airborne science mission is collecting altimetry, radar, and other

geophysical data to monitor and characterise the Earth's polar sea ice, glaciers, and continental ice sheets with the primary goal of extending the record of ice altimetry begun by NASA's Ice, Cloud and land Elevation Satellite (ICESat-1, 2003-2009). ICESat-2 was launched in September 2018 and will continue to measure changes in the height of the Earth's polar land and sea ice that aides in assessing ice elevation changes and sea ice thickness; the measurements are also relevant for forest height assessments e.g. in permafrost regions, Arctic cloud studies, and measurements of ocean topography for sea level changes.

INTERNATIONAL ACCESS TO INFRASTRUCTURE

Expensive research infrastructures are usually required for observations in the Arctic. Costs can be reduced by sharing research infrastructure and observing systems. Cooperation among countries, research institutions and communities is therefore mutually beneficial for the partnering entities.

- **International agreement** – Since the ASM1, at the Arctic Council's ministerial meeting in May 2017, the Foreign Ministers of the Arctic states, including the Ministers of Greenland and the Faroe Islands, signed an agreement where the Arctic countries commit themselves to enhanced cooperation in the areas of research, education, data, sample and personnel exchange, access to research facilities and access to Arctic areas. The legally binding "Agreement on Enhancing International Arctic Scientific Cooperation" entered into force on May 23, 2018 and Denmark holds the responsibility for initiating follow-up activities.
- **Icebreakers** – The new EU Arctic Research Icebreaker Consortium (ARICE)⁵ project will develop strategies for the optimal use of existing Arctic research icebreakers to share and jointly fund operational ship time, provide trans-national access to six research vessels, and improve research services by partnering with the maritime industry on a "ships and platforms of opportunity" programme. The UK is building the new RRS Sir David Attenborough icebreaker which should be ready for the 2019 field season.

⁵ <https://www.arice.eu>

- **INTERACT** – The International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT)⁶, supported by the EU, aims for a geographically comprehensive compilation of terrestrial research infrastructure throughout the Arctic and adjoining forest and alpine regions. Now with 79 research stations under the INTERACT umbrella it is a fundamental building block and one-stop-shop for research projects, programmes and organisations requiring access to northern lands, data and services, and includes a rapid response capability to potential hazards.
- **EU-Polar-Net** – The EU-PolarNet⁷ project has launched an online European Polar Infrastructure database which includes detailed information on European stations, vessels and aircraft, and an up to date inventory of European logistical capabilities in the polar regions.
- **National activities** – In addition to the larger international efforts of sharing infrastructure, many nations have their own programmes to enhance cooperation. The Netherlands contributes internationally by hosting the European Polar Board⁸. Canada is working to establish the Experimental and Reference Area of the Canadian High Arctic Research Station (CHARS ERA) as a Flagship Monitoring Observatory Site, and as a hub for interdisciplinary research open to international researchers.
- **National funding** – Since ASM1 many countries have increased their Arctic research budgets. Sweden raised its climate research budget by 13 million Euro, increasing funding for polar research infrastructure and the icebreaker RV Oden and its planning for a new fleet of vessels. In 2018, for the first time, the Italian Budget Law included specific resources for Arctic research and establishes the 2018-2020 Arctic Research Programme. Denmark has launched a call for projects for: 1) monitoring and mapping of long-range transport pollution in Arctic ecosystems and human

health 2) biodiversity and sustainable exploitation of living resources and 3) development of the knowledge base on national and international environmental regulation. Portugal extended its PROPOLAR call for Antarctic research in 2013 to include Arctic research campaigns.

- **International funding** – To enhance international collaboration efforts specific funding calls and sources are needed. The EU has committed 28 million Euro for projects dealing with the topics of Polar Climate, GEOSS⁹ Initiatives in the Arctic Region, and Coordination of European Polar research. The “LC-CLA-07-2019: The changing cryosphere: uncertainties, risks and opportunities” call it will provide an additional 41 million Euro. There are also important bilateral efforts such as the new Arctic Bursaries Programme between the UK and Canada, which fosters UK participation in Canadian projects. ASM 2 is intended to stimulate additional opportunities for leveraging and cooperative investments.

INCREASED DATA ACCESS AND CYBERINFRASTRUCTURE

Many nations have increased their efforts to share data and develop new cyberinfrastructure to support Arctic research.

- **National data efforts** – Denmark’s user-driven web-portal, Isaaffik, provides information and support for use of infrastructure and vessels, assistance on arctic travel, enhancement of safety during fieldwork, and an overview of Arctic educational programmes. The Italian Arctic Data Center has recently set up a user interface with visualisation and download of atmospheric data. Japan expands its Arctic Data Archive System with web services for search and download capability, data visualisation in quasi-real time and plans to include geographic information systems into the platform by 2020. Sweden is working to digitise older data including 100+ years of land-based and marine research data since 1980.

⁶ <https://eu-interact.org>

⁷ <https://www.eu-polar.net/eu>

⁸ <http://www.europeanpolarboard.org>

⁹ <https://www.earthobservations.org/geoss.php>

The US National Environmental Satellite, Data, and Information Service (NESDIS) Arctic mission is to provide data for Arctic waters, land, and atmosphere including delivery and evaluation of imagery and products from satellites for research and operational needs; it contributes to a range of international data portals and networks. The Chinese Earth Big Data Science Project launched in February 2018 aims to establish an international Earth big data science centre committed to promoting and realizing Earth big data technology innovation and providing comprehensive one-stop macro decision support; it includes focal research areas for the Arctic, the Antarctic and the Qinghai-Tibet.

- **International data efforts** – International activities to share data across national and disciplinary boundaries include the Arctic Spatial Data Infrastructure project of the eight Arctic countries aiming to modernise the use and reuse of existing data and it has created an internationally harmonised basemap that provides a unified topographic view over the entire Arctic. SAON and the International Arctic Science Committee (IASC) will develop a blueprint for a structure or “architecture” to better connect existing data resources. Their goal is to set the foundation for a fully developed Arctic data system that will use an open data policy and standards to allow users to find, access, and reuse data critical for research and for mitigating risk to humans and infrastructure.

INCREASED COOPERATION ON NEW OBSERVATION TECHNOLOGY AND METHODS

The need to continue to develop innovative technological tools and new methods for advanced observation in the remote and harsh Arctic environment is increasingly recognised with many nations at the forefront of creating such tools.

- **New technology** – A new technique of solar-sky-moon photometry for monitoring atmospheric aerosols has helped to constitute the first comprehensive dataset with respect to aerosol properties from remote sensing at the AWIPEV base in Ny-Ålesund. As a result of international collaboration, Chinese researchers led the development a new method for the measurement of meltwater runoff on the Greenland ice sheet surface, showing that current regional models overestimated the actual runoff on the ice surface. US researchers are developing an Autonomous Underwater Vehicle (AUV) that can travel long distances with sensors that have the capability of surveying oil spills at high latitudes and under ice and are helicopter-portable, allowing rapid response to incidents. They plan to refine sensors, develop new underwater gliders, improve the engineering of floats to maximise operations for the Arctic and develop the capability of under ice navigation. Japanese researchers have developed the Continuous Soot Monitoring System (COSMOS) which is now regarded as the standard measurement technology for black carbon and have initiated research on a new Autonomous Underwater Vehicle (AUV) for observations under sea ice.
- **Harmonised methods** – In addition to developing new approaches, the need to standardise methods and protocols between institutions and various disciplines also requires efforts to reconcile differences. The Italian-led Monitor and investigate Arctic along Longitudinal Transects (MELT) project is working to standardise measurements, methodologies, and terminology for the research of boundaries of different environmental components (e.g. ocean-atmosphere interface). The US has a national effort to enhance multi-agency participation in new and existing activities to improve best practices, coordination, and synthesis of Arctic observations.

THEME 2

UNDERSTANDING REGIONAL AND GLOBAL DYNAMICS OF ARCTIC CHANGE

Recent years show a continual decline of summer sea ice and snow extents, and also increasing net loss of mass from Greenland's ice sheet. In the absence of sea ice and snow, solar energy is not reflected but rather absorbed at the exposed land and sea surfaces. The absorbed energy contributes to delayed ice growth in fall and earlier ice melt in spring and so amplifies temperature increases. Thawing of permafrost leads to potential further increases in greenhouse gas emissions. All these changes – and their dynamics – affect ocean and atmospheric circulation, thereby impacting the global climate. Even a small increase in air temperature can thereby trigger greater system warming over time, making the Arctic among the most sensitive areas to climate change on Earth.

The full impacts of a warming Arctic, including deep ecosystem changes (both on land and the ocean), have not yet been fully assessed and quantified. Understanding and responding to this challenge requires joint efforts of the global community.

INCREASED PREDICTIVE CAPABILITIES AND SKILLS

Improved predictions of Arctic changes are prerequisite for developing adaptation measures. Several major international projects are underway with the aim to better predict future Arctic changes.

- **MOSAIC** – The international Multidisciplinary drifting Observatory for the study of the Arctic Climate (MOSAIC)¹⁰ is the first year-around expedition in the central Arctic with the focus to explore the mechanisms acting in the coupled climate system and investigate environmental wintertime conditions in the Arctic Ocean. Its goal is to improve regional and global climate models and weather forecast models. Much progress has been achieved since ASM1 and the drift of the German R/V Polarstern across the Arctic Ocean is planned from September 2019 until September 2020; the programme will involve 60 institutions from 16 nations. Russia and China will contribute to the research and provide fuel and key logistical support to R/V Polarstern. Among the many US contributions to MOSAIC are a suite of

instruments that will be installed on R/V Polarstern to study the atmospheric boundary layer and its interactions with the sea ice surface. The UK, Norway, Japan, Netherlands, Sweden and further countries (in total 17 countries), will participate by sending researchers at various points during the expedition, contributing with science projects and processing data.

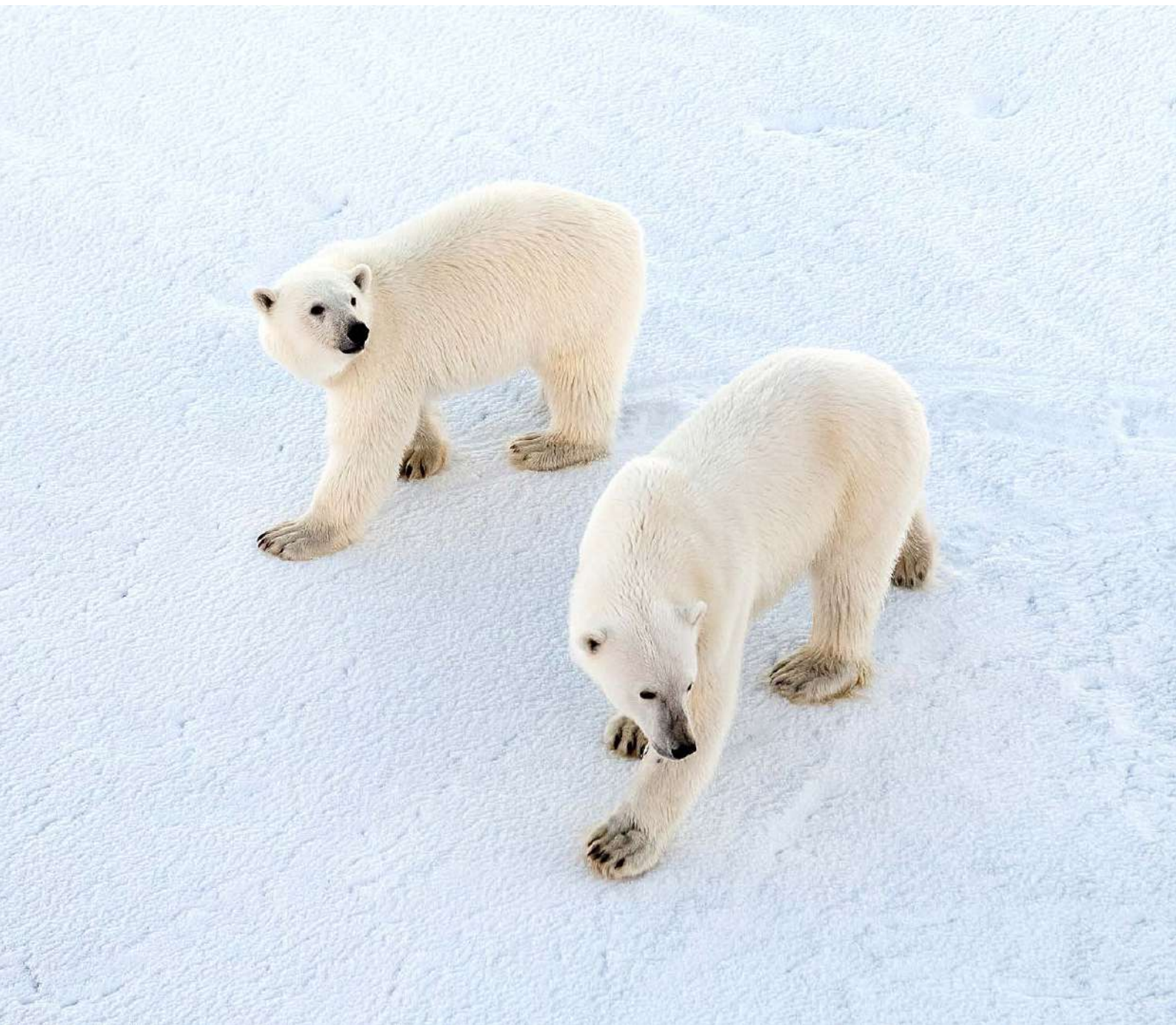
- **YOPP** – As one of the WMO's Polar Prediction Projects, the Year of Polar Prediction (YOPP)¹¹ is an internationally coordinated period (mid-2017 to mid-2019) of intensive observing, modelling, prediction, verification, user-engagement and education activities that will contribute to the knowledge base needed for managing the opportunities and risks that come with Arctic environmental transitions. The EU APPLICATE programme is a main contributor to YOPP by developing enhanced predictive capacity for weather and climate in the Arctic and beyond. In 2018, China's Ninth Arctic Scientific Expedition will contribute observations of atmospheric sounding and buoys and transmit its atmospheric sounding data to WMO in real time. As a contribution to YOPP, Canada launched the Canadian Arctic Prediction System (CAPS), a high-resolution atmospheric model that enables enhanced services to mariners through improved predictions of weather, ice and ocean conditions, including sea state in Arctic waters. The International Arctic Systems for Observing the Arctic (IASOA) Observatories have been identified as the locations at which there would be enhanced radiosonde launches during the YOPP Special Observing periods that will improve the quality of weather and sea ice forecasts, the prediction of weather phenomena over the Arctic Ocean and the accuracy of cold wave forecasts for Japan and the North American East Coast. The US also has a number of organisations and researchers involved in projects supporting YOPP including efforts for improved sea ice forecasting, short-term weather forecasts and data processing support. In total more than 22 countries are contributing to the YOPP.

¹⁰ <https://www.mosaic-expedition.org>

¹¹ <https://www.polarprediction.net>

- **Other prediction efforts** – In addition to MOSAiC and YOPP, there are a number of activities on the international organisation and national levels that are working toward improving our understanding of climate processes, mid-latitude atmosphere connections and general improvement of prediction. These research activities will develop and deliver improved climate products and services and valued information for decision making and societal benefit. The WMO, for example, is in the early stages of implementing an Arctic Regional Climate Centre (ArcRCC) to provide climate scale (monthly and

seasonal) information for temperature, precipitation and sea ice for all of the circumpolar Arctic. Many national and regional projects, such as Russia's efforts in the North Eurasian node of the Pan-Arctic Regional Climate Outlook Forum, already make strong contributions to this Centre. Other efforts are posed to contribute such as the EU's Blue-Action project is improving the ability to describe, model, and predict Arctic climate change and its impact on Northern Hemisphere climate, weather and their extremes. The Copernicus Arctic Regional Reanalysis project will combine all available surface and atmospheric



observations with a simulation model of the atmosphere (Numerical Weather Prediction model) to produce as accurate as possible estimates of the time evolution of the state of the atmosphere. The Norway-led Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies (ARCPATH) project is working internationally to address gaps and uncertainties that can improve the development of local and international adaptation measures. Germany's Transregional Collaborative Research Centre (AC)³ will investigate key processes contributing to Arctic Amplification and the major feedback mechanisms. The US, Norway,

Republic of Korea, Russia and Japan also have a number of modelling groups and projects working to enhance climate prediction.

- **Mid-latitude linkages** – Arctic change has the potential to affect millions of people through shifts in mid-latitude weather, but occurrences are intermittent. The US is leading an international effort with various organisations, including the Arctic Monitoring and Assessment Programme (AMAP), to foster workshops and symposia over the next 3 years to increase our understanding of the linkages between Arctic Change and mid-latitude weather. The US, Republic of Korea, India and the UK all have active research groups working on improving our understanding of these linkages.

INCREASED COOPERATION ON UNDERSTANDING THE ARCTIC SYSTEM

Major changes in the Arctic, with consequences for ecosystems, societies and the global climate system, are driven by the reduction of sea ice, glacial melt, permafrost thaw, alteration of ocean circulations and changes to the hydrological cycle. Understanding of these changes is also highly relevant for economic developments.

- **Sea ice** – The Republic of Korea is leading a 5-year project with the US, Norway, and Japan to improve our understanding of Arctic sea ice using satellite data. Norway is investigating interactions between Arctic sea ice cover and the sensitivity of the Greenland Ice Sheet; recent results showing that it could have major impacts on global ocean circulation. Spain, China and the US have projects to improve modelling of sea ice behaviour. The recently completed EU ICE-ARC project investigated the rapid loss of Arctic sea ice along with shifts in atmospheric and oceanic conditions and estimated the global economic and societal costs of sea ice loss. In partnership with Inuit, Canadian scientists together with Germany, UK and the US explore strategies and management options to protect the most likely last permanent ice-covered region in the Arctic Ocean, an area essential to ice-dependent species such as polar bears, beluga, narwhal, seals, walrus as well as the Inuit communities that depend on them for food. China is monitoring sea ice dynamics in key areas of north, east and west shipping lanes in the Arctic to understand the impact on Arctic shipping.



- **Marine ecosystems** – As sea ice changes in the Arctic, so does the behaviour of the Arctic marine ecosystem, yet we are still only beginning to understand life cycles of Arctic marine organisms. Several national and international efforts are underway to address these gaps. Norway has launched the Nansen Legacy project which aims to establish a holistic understanding of a changing Arctic Ocean and ecosystem which is needed for future sustainable resource management in the Barents Sea and the adjacent Arctic Basin. Russia has several projects looking at climate impacts on seals, walrus, beluga and other key fish species. In 2019, Switzerland will lead the GreenLand Circumnavigation Expedition (GLACE), a complete circumnavigation of Greenland looking at marine, terrestrial, atmosphere and cryospheric environments. Spain is starting a number of projects to understand the life cycle of main Arctic fish species as well as invasive crab species. The UK has new projects focusing on productive seasonal sea ice areas, the food web and whole ecosystem changes. To bring national level efforts together, the US held an international workshop to develop a shared, high-level conceptual model of the functioning of the Arctic Ocean considering key processes controlling the responses of Arctic marine ecosystems to current pressures and changes.
- **Arctic Ocean seafloor** – We know relatively little about the bottom of the Arctic Ocean, but efforts are ongoing to increase our understanding. The Republic of Korea, Norway and France are working together to collect a deep sediment core from the Svalbard fjords to provide insights into past, present and future climate changes. Canada and the US are mapping the Arctic Ocean seafloor. Italy is using samples collected from the Fram Straight to understand climate and environmental changes controlling the evolution of living organisms in the deep sea. Iceland has launched a new effort to map the ocean floor to aid in understating the ocean's natural resources and the protection of fragile ecosystems. Russia also has a project trying to better characterise the Arctic Ocean bottom including its geologic structure and gas hydrates reserves. The Republic of Korea, Denmark and the UK are looking at fossils from North Greenland to understand the evolution of life moving from sea to land. The Czech Republic is working to better understand the formation of dense algal mats in fjords around Svalbard that are thought to be over a billion years old. Germany collects data to establish a Pan-Arctic benthic biology baseline and to model potential ecosystem changes.
- **Ocean circulation** – Changes in the earth's temperature and associated changes in freshwater run-off have the potential to change Arctic ocean circulation patterns which can impact the whole planet. Freshwater discharge from the Arctic has thus been and continues to be an important area of study by many nations over recent decades. For example, since 2010 India has been gauging the impact of fresh water discharge from the Kongsfjorden on the North Atlantic circulation and the global fresh water balance for better model prediction of the Atlantic current and its connection to Indian summer monsoon rainfall. Norway, Italy and Poland are also actively engaged in better understanding ocean circulation and the impacts of melting ice.
- **Terrestrial ecosystems** – With warmer temperatures, thawing permafrost and increased human activity come changes in the Arctic terrestrial ecosystem and research in this area is working toward understanding the impacts. Belgium, Germany, Norway, Switzerland and Spain have created the multidisciplinary, multi-scale project CLIMARCTIC to integrate the knowledge of Arctic terrestrial ecosystems from microbes to landscape scales. Poland is working to harmonise various snow sampling methods to help advance our understanding of the impact of snow changes on Arctic biology. The Czech Republic studies new soils that form after glaciers retreat and their colonisation by microbes and plants. India extends their research on terrestrial biodiversity and the potential human impact on flora and fauna. Norway's Climate-ecological Observatory for Arctic Tundra (COAT) is a large ecosystem-based research and monitoring programme that addresses the impact of climate change on biodiversity and ecosystem services in the arctic tundra; it adopts a food web approach and considers biodiversity and ecosystem services of global concern as well as local human dimension because Arctic people themselves are parts of arctic food webs. Russia has launched a new project looking at plant adaptation strategies in response to climate change. The US and Canadian supported Arctic Boreal Vulnerability Experiment (ABOVE) and Next-Generation Ecosystem Experiment-Arctic (NGEE Arctic) are large, multiyear field campaigns

in Alaska and western Canada to understand processes driving changes to terrestrial ecosystems in the Arctic and boreal region. Portugal, Spain and Canada propose the Terrestrial – Multidisciplinary distributed Observatories for the Study of Arctic Climate (T-MOSAIC) in permafrost environments, which is supported by the International Arctic Science Committee.

- **Freshwater ecosystems** – Changes in freshwater ecosystems, catchments and rivers will have direct influences on societies, tourism, fisheries and peoples of the Arctic. Finland has an interdisciplinary, Pan-Arctic programme to better define processes governing freshwater resources, improving our ability to model and predict basin-scale hydrologic interactions and historical ecohydrology. The Saami Council has a wetland inventory project in Sweden that has the ambition to integrate indigenous knowledge to the work conducted within the Arctic Council; it identifies knowledge gaps regarding wetlands, aims to strengthen the communities depending on wetlands, and to build resilience to changes in wetlands and wetland use. Noting the area of Arctic whitefish production has decreased by 90% in the past 10 years, the RAIPON have begun a project based on indigenous knowledge and modern technologies to contribute to the recovery of this culturally important food source. The US has teams and projects with goals to advance an integrated, landscape-scale understanding of Arctic terrestrial and freshwater ecosystems and the potential for future change.
- **Wildlife** – Wildlife is another area of importance to Arctic peoples and there is an array of research as well as regulatory and political activity driving wildlife management. As an example of research efforts, the Czech Republic have attached geolocators to Arctic terns allowing for the study of the longest migration paths of any bird, some 90,000 km from pole to pole. One of Russia's new research foci is on issues surrounding the protection of Arctic mammals such as elk, brown bear, shrews and walrus. From the cultural and societal perspective, the ICC leads a circumpolar Inuit Wildlife Management Summit which has developed an implementation strategy for circumpolar Inuit wildlife management that moves away from single species management and focuses on a holistic approach. This considers that animals are migrating across international borders and also focusses on the strong connection between components within systems, including how changes impact Inuit, their culture, the biodiversity or wildlife that sustains them culturally, physically, spiritually, and economically.
- **Permafrost and Methane** – The thawing of Arctic permafrost has many impacts from coastal erosion to collapsing infrastructure to the increased release of the powerful greenhouse gas methane into the atmosphere. The EU's Nunataryuk project aims at quantifying organic matter, sediment and contaminant fluxes from thawing coastal and subsea permafrost and at assessing the implications for the indigenous populations, the local coastal communities and environment as well as the global climate; a major goal is also to develop targeted and co-designed adaptation and mitigation strategies. The US has several permafrost projects and has recently created a Permafrost Coastal Erosion Research Coordination Network to further investigate the impacts of coastal erosion and identify solutions to this problem that many Alaskan communities face. Several other groups are looking into the fate of carbon stored in the permafrost to better understand methane release. Singapore's researchers are working on permafrost geochemistry dynamics and predictions of changes in carbon pools and greenhouse gas fluxes from Arctic ecosystems. Italy is leading the EU-funded Arctic Critical Zone and Carbon Dynamics in Permafrost-thawing Environments Project on ecosystem impacts of permafrost thaw and on plant species composition. Italy, Sweden, Russia, US, UK, and the Netherlands are investigating carbon release from sediments in the East Siberian Arctic Ocean, an area with fast rates of climate warming and vast reservoirs of vulnerable carbon. Russia is also working with Germany on studying the fate of permafrost carbon in the Lena River Delta region of West Siberia. Russia also has projects looking at permafrost loss in the Yakutia coastal lowlands and the potential for a mega-pool of sub-sea permafrost carbon. The Republic of Korea's AMAGE field programmes in the East Siberian Sea (2016) and in the Canadian Beaufort Sea (2017) collected data on sub-surface geology, permafrost, and gas hydrates using an autonomous underwater vehicle (AUV) and a remotely operated vehicle (ROV).

- **Ice sheets, glaciers and sea level** – The rate of loss of land ice, such as the Greenland Ice Sheet and coastal Arctic glaciers, is of great importance to global sea level and many groups are working to better understand how these massive ice bodies formed and better predict their melting rates. Denmark is leading several international efforts with China, France, Germany, Japan, Republic of Korea, Sweden, Iceland, Italy, Norway, Switzerland and the US to recover ice cores from various parts of Greenland to understand past climate conditions and ice dynamics. Iceland's researchers are studying causes and impacts of the rapid loss of their glaciers. India and Norway are measuring snow thickness of glaciers and looking at its impact on melting rates. Poland, China, Spain, Japan and the US support several projects to better understand the dynamics between glaciers and oceans and improve our estimation of the contribution of small glacier and ice cap melting to sea level rise. These projects together produce important information for countries like Singapore who plan to assess the vulnerability of the Asian region to sea level change.
- **Economic drivers** – Presently, global economic interests in the Arctic are on the rise and are driving new areas of scientific research. Greenland has established the Arctic Oil & Gas Research Centre to examine the social and economic impacts of oil and gas activities in the Arctic with a focus on Greenland. Singapore, for example, used existing climate change models to investigate the impact of future sea ice changes on commercial transarctic shipping routes. The Republic of Korea is planning a new project for 2020 on Arctic accessibility and the potential for general resource development, based on predictions of changes in the Arctic cryosphere including impacts of diminishing sea ice and thawing permafrost on subsequent business opportunities and potential safety and pollution threats. Several other countries have similar projects in various stages of development.

THEME 3

ASSESSING VULNERABILITY AND BUILDING RESILIENCE OF ARCTIC ENVIRONMENTS AND SOCIETIES

Communities and ecosystems around the Arctic are already experiencing the impacts of global change. Not all changes are perceived to have negative effects, because a warmer Arctic may also present opportunities in terms of resource utilisation, transport routes, tourism and regional growth. It is however increasingly clear that environmental, ecological and social changes are happening faster than ever, affecting ecosystems and the way people live. People's lives are also changing, in particular for indigenous and non-indigenous Arctic residents regarding new livelihoods, new technologies, increasing global connections, and new forms of Arctic governance.

Science will contribute to identifying and minimizing the risks, reducing exposure, improving resilience and adaptation, and form a vital basis for decision-making. Understanding how these changes interact with one another, and what they mean for people and ecosystems alike, requires holistic and trans-disciplinary approaches that look at human and natural dynamics together.

IDENTIFYING RISKS AND MINIMIZING IMPACTS OF CLIMATE AND GLOBAL CHANGES

As the Arctic climate changes, there are many risks to the residents and the ecosystems, as well as risks to the global community. Many countries have projects to help identify these risks and create plans to deal with potential damaging impacts.

- **Pollution** – France proposes a new project studying the distribution and impact of various pollutants (e.g. mercury, per- and polyfluoroalkyl substances [PFASs]) and local and remote sources of black carbon. India and Norway are working together on monitoring organic contaminants in Svalbard and quantifying microplastics in the Kongsfjorden sediments. The Italian-lead iCUPE project plans to improve our knowledge of presence and environmental cycling of persistent organic contaminants, mercury and other elements in the Arctic environment. The EU “Black Carbon in the Arctic” project aims to contribute to the development of collective responses to reduce black carbon emissions in the Arctic and to the reinforcement of international cooperation to protect the Arctic environment. Aiming for a 2021 delivery, AMAP has begun a comprehensive assessment of the state of science on Arctic short-lived

climate forcers (SLCFs) with the aim of improving the understanding of black carbon and methane emissions, emission inventories, Arctic climate and public health effects, and policy options. The trans-disciplinary consortium of EU GRACE includes experts from Europe and Canada and focuses on developing, comparing and evaluating the effectiveness and environmental effects of different oil spill response methods in a cold climate. Singapore aims to analyse ship traffic characteristics and to estimate ship emissions in the Arctic.

- **Food security** – The aim of Norway's BESS is to monitor the status and changes of the Barents Sea Ecosystem and to support scientific research to evaluate the status of and changes in marine commercial stocks, their habitat and environment, and potential for sustaining marine living resources. In addition, the Nordic ReiGN Center of Excellence will establish a Scandinavian interdisciplinary multi-site research centre for holistic understanding of drivers connected to globalisation and climate change that affect reindeer husbandry in Fennoscandia, and how these drivers are linked to ecological, social and political differences between the countries. The Arctic Council's EALLU Project focuses on Indigenous Traditional Knowledge of food as a foundation for diversification of local economies and new approaches to adapt to Arctic change. It focusses on indigenous youth involvement and engagement based on the work of the UArctic's EALÁT Institute. Through their food security project of ICC, Inuit throughout Alaska developed a report that provides an Inuit understanding of food security which describes the Arctic as a puzzle made up of multiple interconnecting pieces including culture, language, sharing, as well as marine mammals, oceanography and other aspects. The indigenous-led climate change work to help restore the Atlantic Salmon populations in Finland and Norway is making great progress with the physical restoration of lost habitats and in 2017 saw the first new trout spawning. The International Council for the Exploration of the Sea (ICES) has groups working on integrated ecosystem assessments including the Norwegian Sea, Barents Sea, and a joint collaboration with the Arctic Council's Protection of the Arctic Marine Environment (PAME) Working Group and the North Pacific Marine Science Organisation (PICES) on the Central Arctic Ocean. In addition, the US, ICES, and

PICES are undertaking a management/sharing pilot study under the remit of the Scientific Experts on Fish Stocks in the Central Arctic Ocean (FiSCAO).

- **Marine traffic** – Increased economic interest in the Arctic also means more ship traffic and projects are underway to help mitigate those risks. The EU “Safe maritime operations under extreme conditions: The Arctic case (SEDNA)” project is developing an innovative and integrated risk-based approach to safe Arctic navigation, ship design and operation, to enable European maritime interests and to harness the Arctic’s significant and growing shipping opportunities, while safeguarding its natural environment. With increased ship traffic comes a need for more safety procedures and the US is helping by working to build and deploy two CubeSats that will detect distress beacons in the polar regions, as well as two ground stations for the Mobile CubeSat Command and Control ground network.
- **Hazards** – Russia is working to minimise risks from a diminishing Cryosphere by developing new methods and technologies to remotely monitor icebergs, glacier movement, areas of potential landslides, explosive methane emissions and other hazards.

DEVELOPING ADAPTATION AND RESILIENCE-BUILDING STRATEGIES

Many Arctic residents, particularly the Indigenous Peoples, are proactively working to build strategies and systems that will help them adapt to the rapidly changing Arctic environment. The health and well-being of Arctic residents is an important area of scientific interest and needs to be considered when looking into adaptation and resilience strategies.

- **Building resilience** – In the most biologically productive region north of the Arctic Circle, the ICC initiated the Pikialasorsuaq Commission to build resilience of Arctic communities in a region where global dynamics have caused immense changes to the marine ecosystem that is integrally linked with culture, health, local economies, infrastructure, and Inuit lives overall. The Saami have projects developing research methods and skills to conserve species, enhance biological diversity and reduce pasture degradation in reindeer herding regions globally, while sustaining resilience of ecosystems and the livelihoods of reindeer herding communities.

This includes the Saami “RIEVDAN: Rapid change – challenges or opportunities for sustainable reindeer husbandry?” project that is investigating the cultural capabilities in Saami reindeer husbandry and the opportunities embedded in indigenous and scientific knowledge with focus on adaptation to change and reconciliation engaging both Russian and Norwegian researchers and students. Another Saami project is assessing the impacts of operational wind farms in Northern Sweden on reindeer, habitat and reindeer husbandry. RAIPON’s project “Arctic Children – Pre-school educational practices” aims to promote the sustainable development of Russian Indigenous Peoples, particularly their integration into modern society while maintaining their traditional way of life. Gwich’in Council International has several initiatives working towards strengthening and preserving their culture, protecting and managing traditional tribal land and resources, and promoting healthy living. The US has a group working to help strengthen coastal community resilience and various other groups working with local communities to provide environmental data and predictions that can be helpful for adaptation planning. Canada will address the topic of coping with a changing environment at local and regional levels by examining case studies of capacity building and partnership development with ‘Big Science’. Sweden has a University-based research centre on building resilience and assessing vulnerabilities of Arctic environments and societies. Norway’s TriArc (The Arctic Governance Triangle: Government, Indigenous Peoples and Industry in change) project is examining how large development projects like mining, aquaculture and production of electric power challenge traditional resource use and management, subsequently to examine the types of governance arrangements established to regulate the relationship between traditional land use and large industrial development.

- **Health and well-being** – The Faroe Islands have long-term monitoring and research into the health risks to children and adults caused by contaminants in animal foods, including whales. The US has several groups addressing responses to societal challenges such as strengthening systems of care to prevent suicide and improve mental health through the promotion of indigenous knowledge, research, evidence-based early intervention, and primary prevention efforts; it includes maximising the health benefits of in-home running



water and sanitation services in rural Alaska. The Czech Republic also has a research focus looking at the life cycle of Arctic parasites and viral pathogens and their impact on human health.

NEW TECHNOLOGIES FOR IMPROVING SUSTAINABILITY OF THE ARCTIC

In many regions of the Arctic, communications and sustainable sources of energy pose technological challenges. Several efforts are underway to help identify issues and gaps as well as develop solutions.

Finland and Denmark are leading the Arctic Council's Task Force on Improving Connectivity in the Arctic which is expected to develop recommendations with regards to a range of specific challenges, such as the identification of geographical areas that would benefit from common, pan-arctic communication-solutions, gaps in the current coverage, how investments and public-private partnerships are sufficiently stimulated and the identification of prospects for future technological solutions. Italy is participating in the Arctic Renewable Energy Atlas project, an activity launched by the Arctic Council's Sustainable Development Working Group (SDWG) by mobilizing national expertise and

experience in renewable energy, identifying trade associations and industries interested in contributing to and discussing the improvement of renewable energy use in the Arctic. The US Remote Alaska Communities Energy Efficiency Competition provides an effective means to empower remote Alaskan communities to develop reliable, affordable solutions using energy efficiency and renewable energy technologies. Norway's Sustainable Arctic Marine and Coastal Technology Centre is developing robust technology necessary for sustainable exploration and exploitation of the valuable and vulnerable Arctic region. The Czech Republic is focusing efforts on low temperature biotechnology by exploring biotechnological potential of polar and other low temperature adapted microalgae in partnership with 5 EU countries.

INCREASING AWARENESS AND BUILDING ADAPTIVE CAPACITY

Interest in learning about the Arctic region is increasing as global economic interests are raising. Many projects ARE AIMED AT SHARING INFORMATION ABOUT THE ARCTIC region, organisations and universities have developed exchange programmes with other countries and science focused conferences, workshops and assessments bring

people together to learn about the Arctic. Arctic policy discussions are of increasing importance and many countries are creating and updating their Arctic plans and inviting international feedback.

- **Raising awareness** – EU's EDU-ARCTIC first offered its innovative online tools aimed at students aged 13-20 in 2017 with almost 900 teachers from 48 countries participating using more than 200 online lessons in 7 languages. Iceland has several programmes dealing with climate education with particular focus on the impacts of the loss of Iceland's glaciers using methods to teach problem solving. Greenland's Climate Research Centre provides opportunities for capacity building and training for young people. Singapore has been actively generating awareness of Arctic issues by holding events that inform and engage students, academics, researchers, government officials, business professionals and the public. In July 2017, Finland sponsored an international expedition through the Northwest Passage where participants discussed the future management of operations in diminishing sea ice conditions, the meaning of Arctic expeditions for Finland and Canada, as well as the means to ensure pluralism and diversity in the process of planning the Arctic futures. The "Narwhal: Revealing an Arctic Legend", a US exhibition running from August 2017-2019, presents Inuit perspectives on their connections to narwhals as well as the latest scientific knowledge about these fascinating animals. The US also leads the annual international peer-reviewed publication of the "Arctic Report Card" describing the state of the Arctic aimed at a wide audience, including scientists, teachers, students, decision-makers, and the general public. To help communicate and illustrate the most critical, connected environmental challenges with Arctic and global relevance, UN Environment and GRID-Arendal are producing a set of maps and graphics, accompanied by short narratives.
- **Exchange programmes** – 220 graduate students have been exchanged through the Japanese-Russian programme for nurturing professionals that play leading roles in creating a sustainable future in the Russian Far East and the Arctic Circle. Canada, Denmark, Sweden and Finland have started a new exchange programme to support early career

scientists, particularly those who are northern-based and/or Indigenous, to conduct research at a partner country research station. Along with collaborative research projects and sharing analytical instruments and methods, the Russian-German Otto Schmidt Laboratory (OSL) provides training for many young scientists in the fields of polar and marine science. The US Fulbright Arctic Initiative brings scholars together to address policy challenges faced by the Arctic Council and Arctic States creating interdisciplinary dialogue and diversifying international perspectives on solutions to pan-Arctic problems. A central research activity of Norway's ARCEX multi-disciplinary research centre is to provide essential knowledge and methodology for eco-safe exploration in the high north, developing and utilizing the best available technology and practices in order to minimise impacts and risks to the Arctic environment. Sweden has several university programmes dedicated to Arctic issues such as Umeå University's focus on understanding of how the lives of Arctic residents are impacted by changing conditions. The University of the Arctic maintains a catalogue listing over 2000 Arctic courses available and has taught over 2000 students in their online "Introduction to the Arctic: Climate" class.

- **Conferences and assessments** – AMAP brought the international science community together to produce the 2017 Snow, Water, Ice and Permafrost in the Arctic Assessment (SWIPA 2017) meant for policy makers to gain an overview of the changes coming to the Arctic and the major consequences for ecosystems and society. Finland and the US are planning an international Arctic STEM Summit to sustain the excitement of and commitments to using Arctic science and local and traditional knowledge to enrich formal and informal education. The 4th International ICES/PICES/IOC/FAO Symposium entitled "The effects of climate change on the world's oceans" held in June in Washington D.C. is another example. APECS regularly organises workshops and panel discussions worldwide bringing international early career researchers together with mentors to discuss research and develop skills. IASSA brings together social scientists and humanities scholars from around the world every 3 years for their International Congress of Arctic Social Sciences.

- **Policy** – China has recently released their 13th 5-year plan for Arctic activities. The Polar Regions have been integrated in the scientific agenda of the Atlantic Interaction Initiative, an intergovernmental framework led by Portugal, acknowledging the importance of the Poles to the Global System and aims to stimulate the exchange of ideas between the scientific and business community. Singapore, Norway, Canada, and the Netherlands are working together to enhance legal debates on the Arctic, particularly dealing with Arctic Shipping Governance issues.

PROTOCOLS FOR EQUITABLE, ETHICAL ENGAGEMENT AND INVOLVEMENT OF INDIGENOUS KNOWLEDGE AND COMMUNITIES IN RESEARCH

Indigenous Peoples have been living in the Arctic Region for thousands of years and their cultures and livelihoods are being impacted by environmental changes. Elders have passed down knowledge from generation to generation and this Indigenous Knowledge is very valuable culturally and scientifically. However, there is still a gap in connecting different ways of knowing and it is critical that researchers working in the Arctic region engage with communities. Many national programmes have adopted ethical codes of conduct to guide their research to respect the lands, peoples and cultures.

- **Indigenous Knowledge** – Many Indigenous Peoples are working to set expectations and practices that researchers should consider when dealing with indigenous knowledge. In March 2018, the Inuit Tapiriit Kanatami (ITK) released the National Inuit Strategy on Research for Canada which promotes a shared understanding of the legacy of Inuit Nunangat research and connects this legacy to current research practices, defines Inuit expectations for the role of research in their regions and communities, and identifies areas for participation and action between Inuit and the research community. Beginning in November 2018, the ICC will bring together Inuit from across Nuunat (homelands), which spans Chukotka, Alaska, Canada, and Greenland, and facilitate discussions to develop Circumpolar Inuit principles/protocols for equitable, ethical engagement and involvement of Indigenous Knowledge and communities which will be used to develop a proposed process and outline for the Arctic Council.

- **Ethical principles** – The EU's INTERACT project has developed information on ethics of research in Indigenous Peoples' communities, coordinated by the International Centre for Reindeer Husbandry. The US is revising its 1990 "Principles for the Conduct of Research in the Arctic" with the goals to strengthen the Principles around a set of core fundamental and mutually beneficial concepts, ensure broad stakeholder participation on the review and revision process, and ensure wide dissemination and practice of the Principles. Denmark is in the process of developing a set of guidelines/ethical recommendations for researchers performing fieldwork in the sphere of arctic research and hope to launch them in Summer 2018.

SUMMARY TABLES FOR CONTRIBUTIONS TO THE 2ND ARCTIC SCIENCE MINISTERIAL

1. Strengthening, Integrating and Sustaining Arctic Observations, Facilitating Access to Arctic Data, and Sharing Arctic Research Infrastructure

1.1 Progress towards an integrated Arctic observing system
1.2 Enhanced cooperation and new activities from Space Agencies
1.3 International access to infrastructure
1.4 Increased data access and cyberinfrastructure
1.5 Increased cooperation on new observation technology and methods

2. Understanding Regional and Global Dynamics of Arctic Changes

2.1 Increase predictive capabilities and skills
2.2 Increased Cooperation on Understanding the Arctic System
2.2.1 Sea ice changes
2.2.2 Marine and Terrestrial Ecosystems
2.2.3 Permafrost and Greenhouse Gases
2.2.4 Ice Sheets and Sea Level Change
2.2.5 Social and economic drivers

3. Assessing Vulnerability and Building Resilience of Arctic Environments and Societies

3.1 Identifying risks and minimizing impacts of climate and global changes
3.2 Developing adaptation and resilience-building strategies
3.3 New technologies for improving sustainability of the Arctic
3.4 Increasing awareness and building adaptive capacity
3.5 Protocols for equitable, ethical engagement and involvement of Indigenous Knowledge and communities in research

← Table 1. International Interest in ASM2 Themes Based on Proposed Initiatives

Shading in this table is based on the total number of individual countries and organisations that contributed at least one initiative to a particular theme/sub-topic for ASM2. Shading key: 1–8 countries/organisations as some interest; 9–17 as medium interest; and more than 18 as high interest. The total number of countries/organisations submitting initiatives was 31. Shading does not reflect the size of project or initiative.

Number of Countries Contributing

High Medium Some

Countries	1. Strengthening, Integrating and Sustaining Arctic Observations, Facilitating Access to Arctic Data, and Sharing Arctic Research Infrastructure	2. Understanding Regional and Global Dynamics of Arctic Changes	3. Assessing Vulnerability and Building Resilience of Arctic Environments and Societies
Canada	Most	Some	Some
China	Most	Some	None to Few
Czech Republic	None to Few	Most	None to Few
Denmark	Most	None to Few	Some
Faroe Islands*	None to Few	Some	Most
Finland	Some	None to Few	Most
France	Some	Some	Most
Germany	Some	Most	None to Few
Greenland*	None to Few	Most	Some
Iceland	Some	Most	None to Few
India	None to Few	Most	None to Few
Italy	Most	Some	None to Few
Japan	Some	Most	Some
the Netherlands	Most	Some	None to Few
Norway	Some	Most	Some
Poland	Some	Most	Some
Portugal	Some	Some	Some
Republic of Korea	Some	Most	None to Few
Russia	Some	Most	Some
Singapore	None to Few	Most	Most
Spain	Some	Most	None to Few
Sweden	Most	None to Few	Some
Switzerland	Most	Most	None to Few
UK	Some	Most	None to Few
US	Some	Most	Some
EU	Most	Some	Some
Arctic Indigenous Peoples			
AIA	Not enough information	Not enough information	Not enough information
AAC	Not enough information	Not enough information	Not enough information
GCI	Not enough information	Not enough information	Not enough information
ICC	Some	None to Few	Most
RAIPON	None to Few	Most	Most
Saami Council	None to Few	Some	Most
International Organisations			
APECS	Not enough information	Not enough information	Not enough information
GEO	Not enough information	Not enough information	Not enough information
IASC	Most	Not enough information	Not enough information
IASSA	Not enough information	Not enough information	Not enough information
ICES	Not enough information	Not enough information	Most
IPS	Not enough information	Not enough information	Not enough information
SAON	Most	Not enough information	Not enough information
UArctic	Not enough information	Not enough information	Most
UNEP	Not enough information	Not enough information	Not enough information
WMO	Not enough information	Not enough information	Not enough information

↑ **Table 2. Initiatives Contributed to ASM2 Themes per Country/Organisation**

Differentiation in this table is based on relative distribution of initiatives contributed per country/organisation categorised into the ASM2 themes based on the main science topic addressed. It is only based on the submitted information and may not represent the full scope of a country/organisations Arctic Science efforts. Differentiation does not reflect the size of project or initiative. On average the 33 participating countries/organisations submitted 8 initiatives, with the range being from 1 to 51.

*For countries that did not submit deliverables, data was gleaned from major initiatives described in their Arctic Research Overview.



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ARCTIC RESEARCH OVERVIEWS



CANADA

Canada aims to support scientific research and the integration of the knowledge gained into policy decisions, including those on the Arctic. Equally important is the need to work in partnership with Northern and Indigenous communities to set the Arctic research agenda, respectfully include Indigenous science and Indigenous knowledge, and use Arctic science and research to address issues of importance to their communities. Canada's approach recognises the importance of international collaboration to address opportunities and challenges in the Arctic, such as climate change and social inequity. The need to support knowledge creation and evidence-based decision-making as essential pillars of sustainable growth and environmental stewardship are particularly relevant in the Arctic.

Permafrost coring.
© Stephanie Coulombe



The territories' Pan-Northern Approach to Science provides their shared vision for a prosperous, healthy and sustainable North that benefits Northerners, Indigenous peoples, and all Canadians. In March 2018, Inuit Tapiriit Kanatami, the national representational organisation for Inuit in Canada, released the National Inuit Strategy on Research (NISR), a pivotal document that identifies the partnerships and actions necessary among Inuit, governments and academic institutions, that can enhance the impact and effectiveness of Inuit Nunangat research.

ARCTIC RESEARCH FUNDERS

Federal Granting Agencies. The Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada promote and support research, training and innovation within Canada.

The Canadian Foundation for Innovation provides funding to universities, colleges, research hospitals, and non-profit research institutions for state-of-the-art facilities and equipment.

Federal Government Departments and Agencies. Various departments and agencies within the Government of Canada deliver Arctic-focused science programmes and/or provide targeted funding for northern and Indigenous research projects and programmes.

Territories. The three territorial governments in Canada (Yukon, Northwest Territories, and Nunavut) play a key role in supporting and delivering applied northern science. Indigenous organisations, Land Claim Organisations and co-management boards also make key contributions to northern science.



MAJOR ARCTIC RESEARCH INITIATIVES

Territorial Colleges and Research Institutes. Territorial colleges and research institutes (Yukon College, Yukon Research Centre, Aurora College, Aurora Research Institute, Nunavut Arctic College and Nunavut Research Institute) play a key role in developing and delivering northern science with academic institutes across Canada and the world.

Geo-Mapping for Energy and Minerals Programme. Led by Natural Resources Canada, this programme advances geological knowledge and community engagement in the North to support increased exploration of natural resources and land use decision-making that serves conservation needs and creates economic opportunities.

Northern Contaminants Programme. Led by Crown-Indigenous Relations and Northern Affairs Canada, this programme promotes research in human health, community-based monitoring, and environmental monitoring that addresses concerns about human exposure to elevated levels of contaminants from international sources in wildlife species that are important to the traditional diets of northern Indigenous peoples.



← Canadian High Arctic
Research Station campus
© J.Lang DRDC/DND

Sentinel North. Led by the Université Laval, this research programme improves understanding of the environmental changes and their consequences on human health in the North and encourages joint projects focusing on discovery, transdisciplinarity, innovation, collaboration, national and international partnerships, and technology transfer.

ARCTIC RESEARCH INFRASTRUCTURE

Polar Continental Shelf Programme (PCSP)

PCSP provides logistical support to researchers working in Canada's North, including charter air transportation to remote field camps; field equipment for loan; fuel for aircraft, field equipment and camps; meals, accommodations and working space at the PCSP facility in Resolute, Nunavut; coordination for shipping and receiving; advice on science licensing and permitting; and a communications network linking remote field camps to the PCSP facility.

Vessels

- **CCGS Amundsen**, an ice breaker owned by the Government of Canada and operated by the Canadian Coast Guard (CCG), is equipped with laboratory and field equipment to support Arctic research in the natural, health and social sciences fields. Opportunities for Arctic science on board other CCG ice breakers such as **CCGS Louis S St-Laurent** and **CCGS Sir Wilfrid Laurier** are also available during some summer operations.
- **RV Martin Bergmann** is a research vessel operated by the not-for-profit Arctic Research Foundation, available for charter by researchers working in the Canadian Arctic.
- **MV Nuliajuk**. The Government of Nunavut's **MV Nuliajuk** is a state of the art multi-purpose fisheries research vessel supporting science-based conservation and sustainable development of Nunavut fisheries.

Field Stations

- **Canadian Network of Northern Research Operators** provides a variety of research support services to academic, government, private and international scientific researchers. The network consists of over 95 facilities including research vessels, unmanned monitoring installations, field stations, and the Canadian High Arctic Research Station campus in Cambridge Bay, Nunavut. A full list is available at <http://cnro.ca/our-facilities>.

Satellites

- **RADARSAT-2** is a polar-orbiting satellite with a synthetic aperture radar sensor that collects imagery in all light and weather conditions.
- **RADARSAT Constellation Mission** will consist of three satellites, following the same polar orbit in succession, allowing fine-scale temporal change detection and daily full-Arctic coverage.
- **SCISAT** data provides insight on the stratosphere, including the health of the ozone layer. SCISAT's solar-occultation instruments measure a wide range of gases, helping to monitor recovery of the ozone.

These satellites are serviced by the Government of Canada's network of stations, including the Inuvik Satellite Station Facility.

Point of contact:
Polar Knowledge Canada
(www.canada.ca/en/polar-knowledge)

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CZECH REPUBLIC

Arctic Research in the Czech Republic is closely bonded with global and acute requirements of relevant data on climate change. In regard of this, global socioeconomic impact is provided through climate predictions and adaptation and mitigation models. The more direct and visible impact is the open access and background for scientific work in the Polar Regions, provided to the national and international research community.

Research vessel "Clione"
(motorsailer).
© Vaclav Pavel



ARCTIC RESEARCH FUNDERS

Ministry of Education, Youth and Sports. As a main science-funding national body the Ministry administers a number of funding programmes. Funding is available basically on competitive grounds, where long-term infrastructure projects that provide services for diverse kinds of scientific research areas are evaluated once in 3-4 years and the provision of funding is dependent upon past results. Research activities in the Arctic are part of the large infrastructure project Czech Polar Research Infrastructure (acronym CzechPolar2) that overarches both Arctic and Antarctic research.

MAJOR ARCTIC RESEARCH INITIATIVES

The Centre for Polar Ecology (CPE) is in the department of the Faculty of Science, University of South Bohemia in České Budějovice. The main purpose of the CPE is ensuring regular university courses in Polar Ecology and similar science topics. In detail, the Centre is focused on extreme environment biology including microbiology-algology, botany, zoology-parasitology, physiology and molecular biology. The second group of topics covered in collaboration institutions dealing with this topics in the Czech Republic including the Polar-Geo-Lab, Department of Geography, Masaryk University consists of physical geography of Arctic regions including climatology, glaciology, geology, geomorphology and hydrology. In addition to the courses, research is valued equally with education, including both biological sciences and Earth sciences.

Czech Polar Research Infrastructure, its Arctic part respectively, is a member of international research bodies and databases, such as the International Arctic Science Committee (IASC) and the University of the Arctic (UARctic), and is closely connected with the Svalbard



Integrated Arctic Earth Observing System (SIOS), Svalbard Science Forum (SSF) and the EU INTERACT project (International Network for Terrestrial Research and Monitoring in the Arctic).

The Czech Polar Research Infrastructure issues the international journal "Czech Polar Reports", which is listed in the Scopus database. Last but not least the Czech Polar Research Infrastructure team provides the scientific background for the Government of the Czech Republic within the Consultative Party Status to the Antarctic Treaty Consultative Meeting and collaborates also with the industrial application sector on testing advanced materials and equipment in the extreme conditions of the Polar Regions.

ARCTIC RESEARCH INFRASTRUCTURE

Technical equipment consists of instruments and technologies of the life science laboratories of **Centre for Polar Ecology** (CPE in České Budějovice), **The Czech Arctic Josef Svoboda Station** and its research station **JULIUS PAYER HOUSE** (78.22°N, 15.66°E) which is located in Longyearbyen and provides housing for 10 people (up to 20 for short-term accommodation) complete with kitchen and bathroom (including a shower, washer and drier).



← Research station “Julius Payer” house in Longyearbyen.
© Vaclav Pavel

There are two life science laboratories equipped with state-of-the-art optical microscopes, sterile space (laminar flow cabinet, dry heat and infra-red sterilizers), centrifuges, etc.

The Czech Arctic Josef Svoboda Station also consists of the field camp NOSTOC and the research vessel CLIONE. **The Czech Polar Research Infrastructure** is well-equipped (considering the financial framework) for basic field and laboratory life science research (Centre for Polar Ecology in České Budějovice). An integrating part of the programme is equipment to provide scientific multi-degree education of students and services from the wide portfolio, e.g. sample collecting, storage and processing; data collecting (i.e. the services provided by the Open Access Data Unit of the research infrastructure); or life science research basic analyses (microscopy, dissection, physiological measurements, manipulation experiments, etc.).

For general logistical purposes, the czech infrastructure has several means of transport in the field: a research vessel, several rubber boats, an off-road car, all-terrain vehicles, snowmobiles, diving equipment, etc.

Field station(s)

Field camp **NOSTOC FIELD STATION** (78.69°N, 16.46°E, 60 km from Longyearbyen) consists of four modular houses connected by a large tent. It accommodates up to 12 people and includes a kitchen, laboratory, technical facility (energy generators, basic workshop tools), and scuba diving equipment. There are also two additional containers (residential and storage) close to the Pyramiden harbour (78.66°N, 16.39°E, 6 km south of Nostoc) where up to 4 persons may be accommodated.

Vessels

RV CLIONE is a 15-m long motorsailer that can operate around the Svalbard archipelago. It has 3 cabins, a kitchen, upper parlour, and storage space. Up to 12 persons may board the vessel depending on the area of operation (the last three in Svalbard Archipelago, the High Arctic). The infrastructure has a complete array of safety equipment including communication equipment (satellite phones, VHF radios, distress beacons), survival suits, and polar bear defence equipment (rifles and flare guns).

Point of contact:

The Centre for Polar Ecology

(<http://polar.prf.jcu.cz/en/home>)

Ministry of Education, Youth and Sports

(<http://www.msmt.cz/?lang=2>)

Czech Academy of Sciences

(<http://www.avcr.cz/en/>)

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DENMARK

To remain at the global forefront, Denmark's Arctic research policy dictates that research and training support the development of industry and society in the Arctic, and promote cooperation on health and social sustainability. This policy emphasizes research on, and the use of best practices in, areas of shared challenges. Policy also promotes participation of Danish, Greenlandic and Faroese academic and scientific institutions in international research and monitoring activities, including quantification of global and regional impacts of climate change in the Arctic (Kingdom of Denmark: Strategy for the Arctic 2011–2020).

The Zackenberg Research Station, in Northeast Greenland, has nine houses, a powerplant, waterworks, and an airstrip.

© Morten Rasch



ARCTIC RESEARCH FUNDERS

Denmark does not have any specific funding programmes with regards to the Arctic and the applications of Arctic science are subject to competition with application from other scientific disciplines.

The Independent Research Fund Denmark funds specific research activities within all scientific areas that are based on the researchers' own initiatives that improve the quality and internationalization of Danish research. The primary aim of the Fund is to support and promote the most original Danish ideas and initiatives. The Council supports specific, time-limited research activities, and scientific excellence is the most central assessment criterion when awarding funds.

Innovation Fund Denmark invests in cultivating and translating ideas, knowledge and technology to the benefit of Danish Society. The purpose of the Fund is to advance research into science and technology and to facilitate innovative solutions that benefit Danish growth and employment. The Fund supports solutions to specific societal challenges and strengthens private sector research and innovation initiatives in small- and medium-sized enterprises.

The Danish National Research Foundation (DNRF) funds cutting-edge, curiosity-driven research of the highest quality. The Foundation has two funding instruments: (1) Centres of Excellence – a centre grant which is large, flexible and may last up to 10 years; and (2) Niels Bohr Professorships – designed to enrich Danish research communities with top- class researchers from abroad.



MAJOR ARCTIC RESEARCH INITIATIVES

Four of the major universities in Denmark (Copenhagen, Aarhus, Aalborg, and The Technical University of Denmark) have cross-cutting, interdisciplinary Arctic research initiatives. Arctic research is conducted within all fields of science, but the natural sciences account for about 74% of the total. The four other science fields: technology, medicine/health, social sciences and humanities, are similar in size, and each account for between 5% and 8% of the total.

GEM. Established in 1994, Greenland Ecosystem Monitoring (GEM) is an integrated monitoring and long-term research programme on ecosystems and climate change effects and feedbacks. Based on a sophisticated database assembled by Danish and Greenlandic monitoring and research institutions, primarily at two main field stations: Nuuk in low arctic West Greenland, and Zackenberg in high arctic Northeast Greenland, the programme has developed a coherent and integrated understanding of how ecosystems function under highly variable climatic conditions. The stations are, among others, supported by the DANCEA under the Danish Ministries of Environment and Food, and Energy, Utilities and Climate.

Centre for Ice and Climate. Ice core analysis and interpretation of ice-core derived data in a broad, climatic context are the focus of this centre of excellence, which opened in April 2007, with 10 years of funding from the DNRF. The centre, which builds upon a long tradition of ice core research in Copenhagen, coordinates the drilling and recovery of ice cores from deep within the Greenlandic ice sheet, and leads international efforts and develops cutting-edge techniques to reconstruct high resolution paleoclimatic and paleoenvironmental records from the cores over glacial-interglacial timescales.

Center for Permafrost (CENPERM). Located at Copenhagen University this Center of Excellence investigates the biological, geographical and physical effects of permafrost thawing in Greenland – in the short and the long term. Funded in 2012 by DNRF for ten years (a first stage of six years and a second stage of four years).

Greenland Climate Research Centre. This interdisciplinary centre, with expertise in oceanography, and established as a joint venture between Denmark and Greenland, focuses on Arctic marine ecology and its interaction with Greenlandic society. The centre's activities enhance knowledge of the marine ecosystem, and food chain links, in relation to climate change and the exploitation of living resources.

INTERACT Station Managers' Forum. INTERACT is an infrastructure project funded by EU Horizon 2020, a circum-arctic network of currently a little less than 90 terrestrial field bases in northern Europe, Russia, USA, Canada, Greenland, Iceland, the Faroe Islands and Scotland as well as stations in northern alpine areas. INTERACT specifically seeks to build capacity for research and monitoring in the European Arctic and beyond, and it is offering access to numerous research stations through a 'Transnational Access' programme. As one of its major activities, INTERACT runs a Station Managers' Forum being chaired by the University of Copenhagen in cooperation with Aarhus University and with biannual meetings used for exchange of information and knowledge on ecosystem monitoring, station management and administration among research station managers.

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

- **Research Vessel Dana** is a versatile multi-purpose research vessel and the largest in Denmark's fleet. R/V Dana is capable of worldwide operation and can be chartered by other research institutes.
- **The Royal Danish Navy** has two arctic-capable ships at their disposal. When research can be accommodated, based on schedule and berth space, the Navy provides room for scientists and limited ship time for research activities that require such.

Field stations

- **Zackenbergs Research Station** is located in the Young Sund-Tyrolerfjord complex in Northeast Greenland, in the southern part of the National Park of North and East Greenland, the largest national park in the world.
- **Arctic Station** is located on the south coast of Disko Island in central West Greenland. It faces the Disko Bay/Davis Strait and is characterised by a Low Arctic, coastal climate.
- **Villum Research Station, Station Nord** is located on Princess Ingeborgs Peninsula in North Greenland at the military Station Nord that is the northern gateway to the Greenland National Park.
- **Sermilik Station** is located in southeast Greenland, about 20 km north of the small town Tasiilaq (Ammassalik). The station is situated on the shore of the Sermilik Fjord on the west side of Ammassalik Island adjacent to the Mittivakkat Glacier.

Satellites

Denmark participates in Copernicus, a European Earth monitoring system, coordinated and managed by the European Commission. Denmark is also part of the Galileo European programme. Denmark is a member of the European Space Agency, and the first Danish astronaut was on the International Space Station in 2015. The University of Aalborg has created a world-leading company (GomSpace) for nanosatellites.

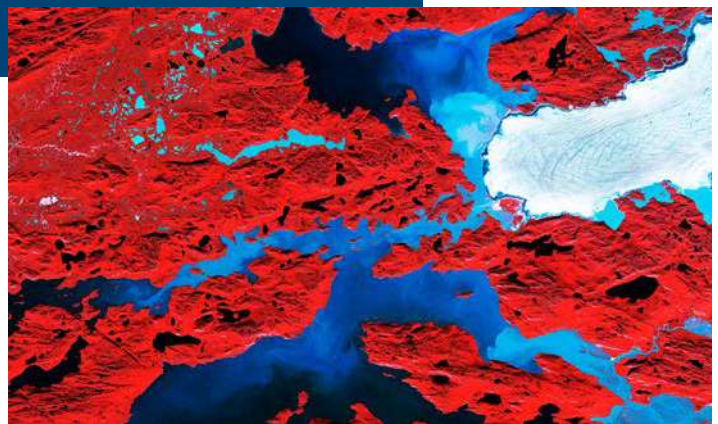
Point of contact:
Ministry of Higher Education and Science
 (<http://ufm.dk>)



EUROPEAN UNION

The EU Arctic research and innovation policy contributes to three priority areas identified in the Joint Communication on integrated EU Arctic policy adopted in April 2016. They are: 1) Climate Change and Safeguarding the Arctic Environment; 2) Sustainable Development in and around the Arctic; and 3) International Cooperation on Arctic Issues. The research and innovation policy is implemented through Horizon 2020, the EU Framework Programme for Research and Innovation 2014–2020, which provides broad funding opportunities to increase our shared knowledge about the Arctic and to promote innovation in and for the Arctic.

Copernicus Sentinel-2A false-colour image of the Nordenskiöld Glacier, Greenland, captured on 8 August 2017.
© modified Copernicus Sentinel data (2017), processed by ESA



ARCTIC RESEARCH POLICY

Rapid Arctic changes are impacting its own fragile ecosystem, and are also, on a broader scale, influencing global changes to the climate system and to sea level. **Arctic research and observation** are both essential to monitor and predict the evolution of these changes.

The EU is a **major** investor and player in Arctic research. The EU also supports development and international access to Arctic **research infrastructure** throughout Europe, and through cooperation activities with non-EU Arctic countries.

International scientific and technological cooperation is essential for the Arctic. Horizon 2020 offers a unique framework for this, considering that five of the eight Arctic countries are either members (Denmark, Finland and Sweden) or associate members (Iceland and Norway). In addition, Horizon 2020 has cooperation agreements with the remaining three Arctic countries (Canada, Russian Federation, and United States of America), and is open to participation of partners from all other countries.

The EU is also proposing to make the Arctic a test location for **sustainable innovation** by developing – for instance – cold-climate technologies and services, and by contributing to the identification of ‘Arctic standards’ to ensure the sustainability of processes and technologies.

MAJOR ARCTIC RESEARCH INITIATIVES

EU-PolarNet (<http://www.eu-polarnet.eu/>), with a budget of ca. 2.3M€, is the world’s largest consortium of expertise and infrastructure for polar research, ensuring coordination of the European scientific and stakeholder polar communities.

INTAROS (<http://www.ice-arc.eu/>), with a budget of ca. 15.5M€, will extend, improve, and unify Arctic observing systems, including community-based ones, contributing to filling critical gaps and creating an integrated data access platform.

APPLICATE (<https://applicate.eu/>), with a budget of ca. 8M€, and **Blue-Action** (www.blue-action.eu), with a budget of ca. 7.5M€, are exploring the predictability of Arctic climate and its impact on climate and weather at lower latitudes, improving models, contributing to the design of appropriate observing systems, and leading to the co-design of better climate services with stakeholders.

NUNATARYUK (<http://www.nuntaryuk.org>), with a budget of ca. 11M€, will determine the impacts of thawing coastal and subsea permafrost on the global climate, and will develop targeted and co-designed adaptation and mitigation strategies for the Arctic coastal population.

ARCTIC RESEARCH INFRASTRUCTURE INITIATIVES

INTERACT (<http://www.eu-interact.org/>), with a budget of ca. 10M€, is a circum-Arctic network of currently 79 terrestrial field bases in northern Europe, Russia, US and Canada, as well as stations in northern alpine areas. It offers access to its network of stations to hundreds of scientists of all nationalities through the Transnational Access Programme.

ARICE (www.arice.eu), with a budget of ca. 6M€, aims at better coordinating the existing polar research fleet, by offering transnational access through a “call for ship-time proposals” to a set of six international High Arctic research icebreakers and by collaborating with the maritime industry in a “programme of ships and platforms of opportunity”.

SPACE INFRASTRUCTURE AND SERVICES

The Copernicus EU Earth observation programme (<http://www.copernicus.eu/>) delivers space-based-products from its space component and dedicated Sentinel satellites as well as information from its environmental thematic operational services using a data policy that ensures full, free, and open access.

The Copernicus space component is managed by the European Commission in collaboration with the **European Space Agency (ESA)** for development and operations and **EUMETSAT** for operations. Six orbiting operational Sentinel missions are foreseen to deliver data on a 24/7 basis. Three of them consisting of two satellites flying in tandem are already in orbit and operational:

- **Sentinel-1:** polar-orbiting, all-weather, day-and-night radar imaging mission. SENTINEL-1 is the primary source of data for information on the Arctic providing information for services related to monitoring of Arctic sea-ice extent or routine sea-ice mapping;
- **Sentinel-2:** polar-orbiting, multispectral high-resolution imaging mission; it contributes to snow coverage measurements and to permafrost monitoring.
- **Sentinel-3:** multi-instrument mission to measure sea-surface topography, sea and land-surface temperature, ocean and land colour. Sentinel-3 mission will for example allow increasing the predictability of characteristics such as sea state, ice formation, ocean circulation and the impact of physical conditions on ocean biogeochemistry which are all relevant for the Arctic Region.

Sentinel-5P was launched in 2017, contributing to Polar/ Arctic observation. The main objective of the Sentinel-5P mission is to perform atmospheric measurements, with high spatial-temporal resolution, relating to air quality, climate forcing, ozone and UV radiation. It contributes to black carbon measurements.

Preliminary activities have started to develop a dedicated mission to address in particular the objectives raised in the EU Arctic Policy. With the top priority concept of mission, the Copernicus Imaging Microwave Radiometer mission, the two poles will be systematically covered on every orbit and the mission will offer a sub-daily coverage (~5-6 hours) of the Arctic area. An initiative on developing an anthropogenic CO₂ emission monitoring and verification support capacity, with its own dedicated space component, will also be implemented.

Copernicus services are delivering Arctic-relevant operational information, such as:

Atmosphere

- Transport of aerosol and other pollutants to polar regions
- Stratospheric composition, ozone and UV radiation

Climate

- Global (ERA-5) and regional (Arctic) re-analyses
- Seasonal forecast products
- Reanalysis and ECMWF/NW and snow cover data assimilation
- Periodic European State of Climate Reporting including dedicated focus region on European Arctic

Marine

- Sea-ice coverage, thickness, drift, edge, type and iceberg density
- Estimates of snow thickness and sea-ice albedo

Land

- energy budget (e.g. albedo, land surface temperature, ...)
- water cycle (e.g. soil water index, water bodies)

ESA has also developed the following missions of Arctic scientific relevance:

- **CRYOSAT** (http://www.esa.int/Our_Activities/Observing_the_Earth/CryoSat): measures fluctuations in the thickness of ice on both land and sea;
- **SMOS** (http://www.esa.int/Our_Activities/Observing_the_Earth/SMOS): provides – together with other products – information to measure thin ice floating in the polar seas.

ESA, in collaboration with the EU, is supporting a large set of scientific activities aimed at developing novel EO methods, products and long-term data records; e.g., Arctic+, CryoTop, IMBIE, CCI sea ice, CCI Ice-sheets Greenland.

Point of contact:

Directorate-General for Research and Innovation

(<https://ec.europa.eu/research/environment/index.cfm?pg=arctic>)

Horizon 2020

(<https://ec.europa.eu/programmes/horizon2020/>)



FAROE ISLANDS

Generally, the Faroe Islands have experience and encourage full partnership in Arctic research cooperation, so the small countries and communities in the Arctic region can participate as full members. The policy is to monitor and research the situation in our area and contribute as an active partner in the scientific projects that build up knowledge about the Arctic region.

On the island of Mykines the density of Atlantic Puffin is estimated based on transect counts
© National Museum of the Faroe Islands



ARCTIC RESEARCH FUNDERS

- Public sector institutions
- Research Council Faroe Islands
- Governmental research funds in Denmark (e.g. Dancea)
- Research funds in the Nordic Council of Ministers (e.g. NORA)
- Research funds in the European Union (e.g. Horizon2020)
- US – National Institutes of Health

MAJOR ARCTIC RESEARCH INITIATIVES

Faroese institutions participate in many different programmes, groups and networks dealing fully or partially with Arctic questions.

Faroese Geological Survey | Jarðfeingi: www.jarðfeingi.fo

- **InterAct II.** Research infrastructure: 82 terrestrial research stations in the circumpolar Arctic focusing on environmental and climate change.
- **EduArctic.** Dissemination of Arctic research to youth in Europe, ages 13-20. The project conducts online lessons about Arctic environments to schools from most European countries. Arctic competitions and arctic expeditions are organised in 2017, 2018 and 2019 for students.
- **NagTec.** Northeast Atlantic Geoscience Tectonostratigraphic Atlas. The NagTec atlas and book detailing the tectonostratigraphic development of the Northeast Atlantic region includes the arctic region.
- **EmodNET Geology.** Maps of European waters, including the Faroese and Arctic waters.
- **IQUAME2500.** International Quaternary Map of Europe in scale 1:2.500.000.
- **Museum geo-exhibition.** On geology in Arctic and Subarctic regions of Greenland, Iceland, Faroe Islands and Norway.



National Museum of the Faroe Islands | Tjóðsavnið:
www.tjodsavn.fo

- **Monitoring and Research.** Monitoring and research of the Faroese terrestrial and marine flora and fauna.
- **CAFF.** Conservation of Arctic Flora and Fauna (CAFF). Working group within the Arctic Council.
- **GLORIA.** Long-term observation network in alpine environments. Vegetation and temperature data document changes in biodiversity and vegetation patterns, caused by climate change.
- **ITEX.** International Tundra EXperiment. The vegetation and phenology of selected plant species are monitored under the influence of experimental warming.

Environment Agency | Umhvørvisstovan:

www.us.fo

- **Monitoring and Research.** Environmental contaminants trends and effects monitoring and research. Including air, water, soil, sediment and biota compartments, and legacy contaminant as well as pollutants of emerging Arctic concern.

**Dept. of Occupational Medicine and Public Health /
Deildin fyri Arbeiðs- og Almannæhilsu:**

www.health.fo

- **Research.** International and local research on health issues of relevance for the people of the Faroe Islands and circumpolar countries.
- **Monitoring and Research.** Long-term monitoring and research of health risks to children and adults caused by methylmercury, PCB and other contaminants in animal foods, including whales.

University of the Faroe Islands | Fróðskaparsetur Føroya:

www.setur.fo

- **West Nordic Studies.** Nordic Arctic joint educational programme.
- **Sustainability.** Sustainable sheep grazing in Nordic countries.
- **Collaborative Learning Initiative Managing and Adapting to the Environment.** Tackling climate change on local and regional levels through increasing public awareness and providing tools for local authorities based on models of best practice to develop Climate Adaptation Plans and a preparedness scale matrix.
- **CBird.** Promotes, facilitates, and coordinates conservation, management and research activities among circumpolar countries and improves communication between seabird scientists and managers inside and outside the Arctic.
- **AMAP – Radioactivity monitoring.** Assessments of radioactivity from anthropogenic sources in the Arctic.
- **Denmark and the new North Atlantic:** Identity Positions, Natural Resources and Cultural Heritage. Renegotiations of identities, climate change and globalisation.
- **Building Shared Knowledge capital** to support natural resource governance in the Northern periphery.

Faroe Marine Research Institute | Havstovan:

www.hav.fo

- **Monitoring and research.** Ocean currents and Essential Ocean Variables (Temperature, Salinity, CO₂, pH, plankton, etc.).
- **Blue-Action.** Arctic Impact on Weather and Climate. EU H2020 project. Objective: To actively improve our ability to describe, model, and predict Arctic climate change and its impact on Northern Hemisphere climate, weather and their extremes, and to deliver valuated climate services of societal benefit.
- **AtlantOS.** Optimising and Enhancing the Integrated Atlantic Ocean Observing Systems. EU H2020 project. Goal: To deliver an advanced framework for the development of an integrated Atlantic Ocean Observing System.
- **FARMON and FARMON II.** Measuring the inflow of Atlantic water north of the Faroes and the outflow of

overflow water through the Faroe Bank Channel. These flows form two of the main branches in the exchanges across the Greenland-Scotland Ridge.

- **Western Valley Overflow.** Study of exchanges of Atlantic water and overflow water in the northwestern part of the Iceland-Faroe Ridge.

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

• **R/V Magnus Heinason 669 BRT**

A new multipurpose research vessel, length 54 m, planned to be operational in 2020. The vessel will improve the contribution of the Faroe Islands to scientific research in the North Atlantic and the Arctic.

- **Other smaller vessels: Biofarið, Nýsan and Andrias Reinert**

Research Park inova iNOVA | Granskarasetrið iNOVA:

www.inova.fo

iNOVA is a facility located in Tórshavn where private enterprise and public institutions can access state-of-the-art laboratories, instruments, offices and an event location.

- **Genetics.** iNOVA houses a genetic sequencing facility used for the Faroese Genome Project FarGen and marine genetic research, among others.
- **Molecular Biology.** iNOVA houses a Mass Spec facility used in the monitoring efforts of the Environment Agency.
- **Human Health and Performance.** The university and the national hospital work together to measure effects on human metabolism.
- **Foodlab and Sensory lab.** Scientific product development in a food-producing region.

Field stations and monitoring

- **Fini-Station, Faroese Geological Survey (Jarðfeingi).**
- **Sornfelli** (Tjóðsavnið)
- **AMAP, OSPAR, Gloria and CAFF Sites** (Fróðskaparsetrið, Tjóðsavnið, Umhvørvisstovan, Deildin fyri Arbeiðs- og Almannæhilsu)
- **Ramsar Sites** (Tjóðsavnið)
- **Havnadal and Tórshavn city centre Air Monitoring Sites** (Umhvørvisstovan)
- **Meteorological and Geohazard Monitoring on roads** (Landsverk)

Point of contact:

Ministry of Education, Research and Culture
(<http://www.mmr.fo>)

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FINLAND

Finland's Strategy for the Arctic Region defines objectives for Finland's Arctic policy. With respect to research, the policy is to invest in expertise and to gain knowledge of northern areas. A diversified array of Arctic research is conducted by higher education institutions and by research institutes. Expertise is also possessed by many companies. Arctic research policy is cooperatively implemented by several ministries.

Sammaltunturi field station in Lapland
© Tero Pajukallio, Finnish Meteorological Institute



ARCTIC RESEARCH FUNDERS

Ministry of Education and Culture.

Coordinates science policy issues and guides and funds institutions of higher education. The University of Lapland and the University of Oulu strategically prioritize the Arctic research. They also have special tasks related to Sami research, language and cultural conservation. Most Finnish universities and other academic institutions have research programmes focusing on the Arctic, the North, and cold climate regions. The Arctic Centre in Rovaniemi is a national and international hub of information and centre of excellence that conducts multidisciplinary research in changes in the Arctic region.

Ministry of the Environment.

The Ministry's Finnish Environment Institute conducts Arctic research on a range of topics, including global change and environmental issues.

Ministry of Transport and Communications.

The Ministry's Meteorological Institute has Arctic-oriented meteorological, climatic, and geospace research programmes.

Ministry of Agriculture and Forestry.

The Ministry's Natural Resources Institute Finland conducts Arctic research on topics such as Arctic food production and monitoring of natural resources.

Ministry of Economic Affairs and Employment.

This Ministry's entities, VTT Technical Research Centre of Finland, and the Geological Survey of Finland, conduct Arctic research on ice and snow, marine, and geoscientific topics.

Three other Ministries, of Defence, Foreign Affairs, and Social Affairs and Health, also fund Arctic research.

Academy of Finland.

As the umbrella of national Research Councils, it funds high-quality scientific research projects. The Academy of Finland is also a stakeholder in Arctic research priorities, and has the national Arctic research programme ARKTIKO.

Business Finland.

Brings together and markets Finnish Arctic know-how globally. Strengthens Finnish know-how related to Arctic environmental awareness, digitalisation, and autonomy.

MAJOR ARCTIC RESEARCH INITIATIVES

- ***The national research programme ARKTIKO***, run by the Academy of Finland, aims to study and understand the changing factors that affect the development of the Arctic region, the process of transformation, and the dynamics of change.
- ***University of the Arctic***



← R/V Aranda in Helsinki.
She has explored the Arctic
Ocean and the seas around
Antarctica
© MattiPaavola, Wikimedia
Commons

- Finland is co-funding **the NordForsk Arctic research programme of Nordic Centers of Excellence** that is a Joint Nordic Initiative. This programme produces new knowledge about the opportunities and challenges of responsible development of the Arctic region.

ARCTIC RESEARCH INFRASTRUCTURE

Finland actively participates in many European research infrastructure projects (ESFRI) including those with an Arctic focus.

Vessels

- **R/V Aranda**, of the Finnish Environmental Institute, is an ice-reinforced research vessel mostly operating in the Baltic Sea. She is highly capable and has explored the Arctic Ocean and the seas around Antarctica.
- **Ice model basins** owned and operated by Aalto University and companies are large-scale water basins equipped to produce sea ice at model scales. These state-of-the-art “test tanks” are used to conduct experimental research on the design and behaviour of ships and structures at model scales, failure of ice, and other topics dealing with sea ice and Arctic technology.
- **Icebreakers**. Finland has a fleet of icebreakers. Several are multipurpose vessels capable of offshore tasks including serving as research platforms.

Field stations

- **Kevo Subarctic Research Institute** is associated with the University of Turku. It hosts multidisciplinary research on northern natural and social sciences in subarctic Lapland. It is the northernmost research station in the EU.
- **Kilpisjärvi Biological Station** is situated in Finland’s mountain birch forest zone. Long-term follow-up studies are the core of the research activities at this station. The station is associated with University of Helsinki, and specifically, the Faculty of Biological and Environmental sciences.

- **Pallas-Sodankylä Global Atmospheric and Global Cryosphere Watch station** is the main arctic research station of the Finnish Meteorological Institute and is integrated into the WMO GAW and GCW networks. Pallas-Sodankylä is also a WMO GRUAN station.
- **Värriö Subarctic Research Station** belongs to the Institute for Atmospheric Research at the University of Helsinki. The research at the station focuses on the productivity of the subarctic ecosystems, and on Arctic air pollution and atmospheric processes. The station hosts the SMEAR I measurement station.
- **Natural Resources Institute Finland** hosts tens of field stations in Finland, of which several are situated above the Arctic Circle. Arctic research in these stations includes, for example, monitoring of natural resources.

Satellites

- **Finnish National Satellite Data Centre**, located in Sodankylä, is hosted by the Finnish Meteorological Institute. It collaboratively provides Arctic satellite data and products for international research and operational entities. Finland also contributes to satellite product development (snow, ice, land surface, air quality, greenhouse gases, ozone) and data validation in order to ensure high quality of satellite observations in Arctic regions.

Point of contact:

Ministry of Education and Culture

(www.minedu.fi)

Academy of Finland

(www.aka.fi)

The Finnish National Committee of Arctic and Antarctic Research

(<http://www.arcticfinland.fi/EN/Research/polarcommittee>)

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FRANCE

In June 2016, the newly published French National Roadmap defined top French policy priorities in the Arctic. Promotion of international cooperation in the Arctic and strengthening of scientific research for the benefit of Arctic environments and resilience were highlighted as key sectors where France intends to play an active role. France is committed to work within the framework of international law and the Arctic governance forums with Arctic and non-Arctic States, and indigenous communities to promote science-based policies.

PARCS (Pollution in the Arctic System) field campaign in May 2016 making measurements of aerosol and cloud properties in Hammerfest, northern Norway.
© Jean-Christophe Raut (LATMOS/Paris)



ARCTIC RESEARCH FUNDERS

The French National Scientific Research Center (CNRS) and Research Alliance for the Environment (AllEnvi). AllEnvi gathers 12 founding organisations (including CNRS and universities) and 16 partners, all major players in scientific, economic and social aspects of environmental research (>15,000 researchers including ~500 Arctic researchers) and supports Arctic research mostly related to Earth sciences, ecology and environment, technology, and humanities.

The French Polar Institute Paul-Emile Victor (IPEV). IPEV is a governmental agency. Its main missions are to support and implement scientific and technological programmes in the Arctic, Antarctic and Sub-Antarctic, and to maintain polar science infrastructures and equipment.

The National Space Agency (CNES). Arctic challenges are part of the objectives of CNES's Earth Observation programme to improve understanding of the Earth System, to operationally support environment management and to study global climate change.

The National Research Agency (ANR). ANR funds basic and applied research and is a partner of the Belmont Forum.

Ministry of Higher Education, Research and Innovation (MESRI). The ministry is in charge of research, supporting and coordinating research actions led by public scientific bodies and universities, as well as national research infrastructures.

Ministry of Europe and International Affairs (MEAE). The MEAE promotes and supports the participation of French researchers and experts in international Arctic fora.



Ministry of Ecological Transition (MTES). The MTES has built an informal network of French researchers working in the Arctic in order to identify the main scientific issues and challenges in the area.

MAJOR ARCTIC RESEARCH INITIATIVES

French Arctic Initiative (FAI, 2015–2020). CNRS fosters collaboration across the French scientific community on major Arctic themes. FAI currently supports two projects: GREENEDGE (response of Arctic marine ecosystems to receding icepack) and PARCS (Pollution in the Arctic System, understanding of sources, fate and impacts of Arctic pollution).

EQUIPEX. French investment programme currently supporting three instrumentation projects contributing to sustained Arctic observations: IAOOS and NAOS (ice-tethered platforms and ocean drifting floats) and CLIMCOR (new drilling tools in ice, ocean and lakes for paleoclimatology).

ANR funds major Arctic projects on the contamination of Arctic ecosystems, climate science and relationships between human societies and their environment. Within the Belmont Forum, ANR supports Collaborative Research Actions such as “Arctic science for sustainability”.



← Corbel French station.
© JDominique Fleury, IPEV

Horizon 2020. France takes part in most collaborative and research actions of the Arctic Cluster, in ERA-Planet Strand 4 (dedicated to polar areas) and to the educational programme EDU-ARCTIC. Within the EU-Polarnet CSA, CNRS coordinates the drafting of a post-2020 “Integrated European research programme”.

Make Our Planet Great Again. This French initiative selected two Arctic projects led by junior researchers for 5-yr funding on atmosphere-sea ice exchange and on permafrost dynamics in Siberia.

Joint international initiatives. TAKUVIK is a joint international laboratory between CNRS and Université Laval (Canada) focusing on Arctic research. France has other long-term international commitments in various fields of Arctic research: LIA COSIE, YAK-AEROSIB and GDRI CARWETSIB with Siberian universities (Krasnoïarsk, Iakoutsk, Tomsk); OHMI Nunavik with the CEN in Canada. French researchers also take part in major international field campaigns such as EGRIP (ice-coring in northeast Greenland) and contribute to WMO polar research programmes, including the Polar Prediction Project and the Year of Polar Prediction.

ARCTIC RESEARCH INFRASTRUCTURES – CONTRIBUTION TO SAON

France supports Arctic long-term and distributed interdisciplinary observations. It will contribute to the SAON deliverable of the 2nd Arctic Science Ministerial.

Vessels and other Platforms

The French fleet (FOF) is composed of eleven research vessels, four deep-sea vessels and five underwater vehicles. As none of the vessels has ice-breaking capability, France actively participates to trans-national access programmes like the ARICE initiative. Two aircraft from the French national SAFIRE fleet and stratospheric balloons (CNES) are deployed in the Arctic to study, for example, pollutant sources, transport and aerosols/clouds.

CNES coordinates HEMERA, a new research infrastructure, with 12 EU partners, to enlarge the balloon scientific user community in Europe; several balloon flights are planned from Kiruna in Sweden.

Field stations

For 15 years, IPEV and the Alfred Wegener Institute (Germany) have combined efforts in Svalbard to maintain the AWIPEV Arctic research base (including three stations) in Ny-Ålesund which offers operational opportunities in many fields of Arctic research.

Satellites

- **w** infrared atmospheric sounding interferometer CNES/EUMETSAT
- **CALIPSO** Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations, CNES/NASA-USA, 2006
- **Cryosat2** (2010), Sentinel 3A/B (2016/18) ESA/CNES contributing to precise orbitography, altimetric processing
- **SMOS** Soil Moisture and Ocean Salinity, ESA/CNES/CDTI-Spain, 2009
- **AltiKa** CNES/ISRO Indo-French Ka band topographic mission, 2012
- **CFOSAT** French-Chinese mission for seastate observations, CNES/CNSA, 2018
- **MERLIN** Methane Remote Sensing Mission, CNES/DLR-Germany, 2023
- **Pléiades high-resolution** satellites with acquisitions targeted over Glaciers and in Arctic during the MOSAIC campaign

Point of contact:
Ministry of Higher Education and Research- Service Strategy, Research and Innovation
[\(http://www.enseignementsup-recherche.gouv.fr/\)](http://www.enseignementsup-recherche.gouv.fr/)
Ministry of Europe and Foreign Affairs – SG/poles & Legal Affairs
Department /Law of the Sea and polar affairs
<http://diplomatie.gouv.fr>



GERMANY

Germany operates one of the world's largest Arctic research programmes aiming to inform society and policymakers about the consequences of climate change in the Arctic. "Germany's Arctic Policy Guidelines" by Germany's Federal Foreign Office put science and environment at the centre of Germany's approach to engaging with Arctic nations. Germany's Arctic research programme is outlined in the 2015 publication "Rapid Climate Change in the Arctic – Polar Research as a Global Responsibility". Germany is investing substantially into polar research logistics and is building a new icebreaking vessel, Polarstern II.

Alfred Wegener statue
in front of the AWIPEV
Arctic Research Base
© Alfred Wegener
Institute (CC-BY 4.0)



ARCTIC RESEARCH FUNDERS/INSTITUTIONS

The Federal Ministry of Education and Research (BMBF) supports Arctic research through targeted funding programmes, and by sponsoring **the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI)**, as the national polar institute. AWI concentrates on observational and modelling studies of all elements of the Polar Earth System in the Arctic and Antarctic. Main research foci in the Arctic include climate change and its impact on global climate processes. The BMBF framework programme MARE:N (Coastal, Marine and Polar Research for Sustainability) supports interdisciplinary sustainability research, including both natural and social sciences, on polar and marine issues. Funded by BMBF, the GEOMAR Helmholtz Center for Ocean Research is a leading centre of oceanography and has worked for decades in the Arctic Ocean (Laptev Sea). BMBF-funded entities which, in turn, award financial support to individuals, include the German Research Foundation (DFG), and the German Academic Exchange Service (DAAD). DFG runs a Priority Programme titled, "Antarctic Research with Comparable Investigations in Arctic Sea Ice Areas".

The Federal Ministry for Economic Affairs and Energy (BMWi) funds the Federal Institute for Geosciences and Natural Resources (BGR), and the German Aerospace Center (DLR). For five decades, the BGR has improved the understanding of the geological evolution and the resource potential of the circum-Arctic continental margin. DLR conducts extensive research and development work in aeronautics, space, energy, transport and security, and contributes to Arctic research through its satellite missions and remote sensing programmes.



MAJOR ARCTIC RESEARCH INITIATIVES

International research projects coordinated by Germany (AWI)

- **EU-PolarNet** – Connecting Science with Society develops and delivers a strategic framework for European polar science and the use of polar infrastructure.
- **Advanced Prediction in Polar regions and beyond:** Modelling, observing system design and Linkages associated with Arctic ClimATE change (APPLICATE) provides model improvements in climate prediction.
- **Arctic Research Icebreaker Consortium** – A strategy for meeting the needs of marine-based research in the Arctic (ARICE) gives funded access to six research icebreakers including the MOSAiC expedition.
- **European Research Cluster Aerosols and Climate investigates aerosols** and their link to climate change.
- **Permafrost thaw and the changing Arctic coast,** science for socio-economic adaptation (NUNATARYUK) analyses organic matter released from thawing permafrost and risks to local communities.
- **Year of Polar Prediction (YOPP)** is an internationally coordinated period of intensive observing, modelling, prediction and education activities (International Coordination Office hosted by AWI).



← RV Polarstern operating during polar night
© Alfred Wegener Institute/
Stefan Hendricks

- **Multidisciplinary drifting Observatory for the Study of Arctic Climate** (MOSAiC) is the first year-round expedition into the central Arctic exploring the processes in atmosphere, sea ice and Arctic Ocean.

Large national research projects

- **Arctic Amplification** (AC)³ investigates climate relevant processes and feedback mechanisms that cause Arctic amplification. (DFG funded)
- **The Changing Arctic Transpolar System** (CATS) studies environmental changes in the Laptev Sea. (BMBF funded)
- **Quantifying Rapid Climate Change in the Arctic:** Regional Feedbacks and Large-scale Impacts (QUARCCS) models interactions of Arctic atmosphere, ocean, sea ice, and snow. (BMBF funded)
- **Greenland Ice Sheet Ocean Interaction** (GROCE) investigates the complex processes at the boundary between the Greenland Ice Sheet and the adjacent oceans. (BMBF funded)
- **The Circum-Arctic Structural Events** (CASE) project conducts studies on the structural geology, petrography and geochemistry of Arctic volcanic provinces, and aeromagnetism of areas covered by ice and water. (BGR funded)

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

The research icebreaker Polarstern is the most important tool of German Polar Research.

Field stations

- **AWIPEV Arctic Research Base** is operated jointly in Ny-Ålesund by the AWI and the French Polar Institute Paul Emile Victor (IPEV). It offers living quarters and workrooms for researchers focusing on basic research in environmental sciences.
- **The research station “Samoylov Island”**, which is operated by the Siberian Branch of the Russian Academy of Sciences, is used for collaborative permafrost research.

Aircraft

Research aircraft Polar 5 and 6 are Basler BT-67 planes, operated by AWI, have been specially modified to fly under extreme polar conditions. The German High Altitude and Long Range Research Aircraft (HALO) will conduct three missions in the Arctic until 2021.

Satellites

Germany shares satellite missions with many entities. The Earth Observation Center (EOC) at the DLR is Germany's centre of expertise.

- **Sentinel-1:** 2-satellite SAR constellation is used to monitor sea ice, marine winds, waves, currents, land-use change, and land deformation (ESA/EU Copernicus programme)
- **Sentinel-2:** 2-satellite constellation has optical/near-IR radiometers (ESA/EU Copernicus programme)
- **Sentinel-3:** 2-satellite constellation has imaging radiometers and altimeters (ESA/EU Copernicus programme)
- **Cryosat** (interferometric altimeter) measures changes in ice thickness (ESA mission)
- **SMOS** (Soil Moisture and Ocean Salinity) mission (ESA mission)
- **GRACE** (Gravity Recovery and Climate Experiment, Germany with NASA)
- **TerraSAR-X** (phased array synthetic aperture radar (SAR) antenna): DLR and Airbus DS
- **TanDEM-X** (TerraSAR-X add-on for Digital Elevation Measurement)

Point of contact:
Alfred Wegener Institute,
Helmholtz Centre for Polar and Marine Research
(www.awi.de)
German Arctic Office: Volker Rachold
(Volker.Rachold@arctic-office.de)



GREENLAND

Greenland's policy is to promote the development of its society with a strong and sound international research programme based on shared objectives. Greenland's Parliament Act no. 5 of 29 November 2013 addresses research consultancy and the allocation of research funding. The Act emphasizes coordination and prioritisation of research efforts, and enhancing Greenland's participation in international cooperative research initiatives.

Kobberfjord field station.
© Henrik Lund, Greenland
Institute of Natural
Resources.



ARCTIC RESEARCH FUNDERS

The Government of Greenland. The Government is the primary supporter of basic research in Greenland. Funds are distributed to various Greenlandic Research Institutions.

Danish public funding. Several Ministries, such as of science, energy, and environment, provide funding for Arctic research.

Foreign public funding. US (National Science Foundation, National Oceanographic and Atmospheric Administration, Office of Naval Research, NASA), European Union, Nordic Council of Ministers and the Swiss National Science Foundation.

Private foundations. Aage V. Jensen Charity, Oak, Villum, and Carlsberg.

Business. Royal Greenland, Sustainable Greenland Fisheries, and several energy and mining companies. International institutions: Universities and research institutions in the US, Canada, Germany, Iceland, Norway, England, Denmark, Japan and China.

COORDINATING ORGANISATIONS

The Government of Greenland. Ministry of Health and Research. The Office provides coordinating function to the Minister and Research Society in and outside Greenland.

Greenland Research Council (GRC) is an independent National Administrative body for research consultancy, the granting of research funding and the dissemination of research.

MAJOR ARCTIC RESEARCH INITIATIVES

Greenland Climate Research Centre (GCRC) investigates effects of climate changes on local communities, the Greenland society and the marine ecosystem. It is a contact point for a large network of international researchers with interest in effects of Climate Changes in Greenland. GCRC works as a Natural and Social Science HUB for capacity building and knowledge building in Greenland.

Greenland Ecosystem Monitoring (GEM) is an integrated monitoring and long-term research programme on ecosystems and climate change effects and feedbacks in the Arctic.



← R/V Sanna
© Josephine Nyman,
Greenland Institute of
Natural Resources.

Programme for Monitoring of the Greenland Ice Sheet (PROMICE) was initiated as an ongoing effort to assess changes in the mass budget of the Greenland Ice Sheet. Arctic Oil & Gas Research Centre examines the social and economic impacts of oil and gas activities in the Arctic with an emphasis on Greenland.

MARPART – Maritime Preparedness and International Partnership in the High North assesses the risk of the increased maritime activity in the Arctic and the challenges it may represent for emergency prevention, preparedness and response institutions.

The Fulbright Arctic Initiative, Health and Infrastructure Working Group. The Danish Centre for Environmental Assessment and NORDREGIO arranged a workshop with financial support from the Nordic Council of Ministers' Arctic Collaboration Programme.

Arctic Monitoring and Assessment Programme (AMAP) monitors and assesses the status of the Arctic region with respect to pollution and climate change issues.

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

At present Greenland has the research vessel R/V Sanna as well as several smaller vessels. The R/V Paamiut was taken out of service in late 2017. The Government allocated DKK 200 mil for a new oceangoing R/V in coming years.

Field stations

- **Nuuk and the Kobbefjord (NERO)** field station provide access to low Arctic ecosystems in West Greenland with different biotopes such as dwarf-shrub heaths, fens, grasslands and lakes.
- **Zackenberg (ZERO)** is situated in the High Arctic in an area with continuous permafrost. The study area comprises the drainage basin of the river Zackenberg.

- **Daneborg** is located in the outer part of Young Sound, next to the main station of the Sirius Patrol, in Northeast Greenland.
- **Villum Research Station** is situated at the Northeastern corner of Greenland.
- **Niaqornat** conducts long-term studies of beluga and narwhals. Other studies of other game animals and of the environment local to this field station may also be considered.

Drones

The Greenland Institutions are investing in several drones as well as education for drone operators according to local air-traffic and environmental regulations.

Point of contact:
Ministry of Health and Research
Research Coordinator Sten Lund
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Greenland Research Council
Chair Josephine Nyman
(www.nis.gl)

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ICELAND

Iceland places great emphasis on increased international collaboration in science, innovation and education, increased mobility of researchers and effective international cooperation around research infrastructures (Fiscal Policy and Fiscal Strategy Plan 2017-2021). The Parliamentary Resolution on Iceland's Arctic Policy further stresses the principle of a strengthened cooperation with other nations in the Arctic region on research, protection of the biota, observation capabilities and pollution prevention, as well as the preservation of the unique culture and way of life of indigenous peoples (A Parliamentary Resolution on Iceland's Arctic Policy, 2011).

Lake Mývatn
© Una Strand Viðarsdóttir



ARCTIC RESEARCH FUNDERS/INSTITUTIONS

The Icelandic Centre for Research.

The Icelandic Centre for Research (Rannís) administers national competitive funds that support Icelandic research on physical, biological, geological and chemical processes in and around Iceland, as well as research on cultural heritage, society, economy and public health. Rannís also administers the Infrastructure Fund which supports investment in research infrastructures. Rannís cooperates closely with the Icelandic Science and Technology Policy Council and coordinates and promotes international research and innovation collaboration, including the EU Framework Programme for Research and Innovation and research collaboration between the Nordic countries under the auspices of NordForsk. Rannís also hosts the Secretariat of the International Arctic Science Committee (IASC) in Akureyri.

MAJOR ARCTIC RESEARCH INITIATIVES

- ***Glaciers and Climate.*** Extensive collaborative efforts take place involving several Icelandic institutes to understand the ongoing changes of the glaciers in Iceland. The programme involves regular monitoring of annual mass balance and changes of glacier terminus positions as well as mapping of glacier surfaces based on remote sensing from aircraft and satellites. A large group of lay people, including local people, long-term volunteers and school groups, are involved in the regular monitoring of the glaciers. The ice cap Hofsjökull and the neighbouring central Icelandic highland is one of the sites in the international GCW/ CryoNet surface station network for global cryosphere monitoring.
- ***Climate Change Scenarios and Infrastructure.*** An official climate change scenario has been derived for Iceland through a series of national and international research projects and government initiatives. The scenario, which is updated regularly, is used to facilitate long-term planning and design of infrastructure such as harbours, hydro-electric power plants and flood control measures.
- ***Oceanographic Conditions around Iceland.*** The Marine and Freshwater Research Institute collaborates with universities and research institutes nationally and internationally to improve understanding of the marine environment, including physical and chemical parameters and the ecosystem responses to climate change. Long time-series of seasonal observations in the sea are a key element of the collaboration.
- ***Social Impacts of Climate Change.*** The Stefansson Arctic Institute collaborates with the University of Iceland and other research institutes nationally and internationally in order to understand resilience and the social impacts of climate change on human livelihood.



← Monitoring of the Icelandic glaciers
© Anna Hogg

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

Iceland runs three ice-strengthened multi-purpose ocean vessels suitable for a wide range of marine biological and oceanographic research as well as marine geophysical surveying. These vessels are capable of supporting a range of activities in the northern oceans.

- **R/V Árni Friðriksson and Bjarni Sæmundsson** are operated by the Marine Research Institute and used for marine biological, fisheries, oceanographic and marine geology research.
- **Þór** is a multi-purpose vessel of the Icelandic Coast Guard well equipped for a wide range of duties including hydrographic surveying and serves as a platform for a variety of research activities.

Aircraft

Iceland operates two airplanes that are partly used for marine and glacier monitoring.

- **TF-SIF**, a Dash 8 aircraft of the Icelandic Coast Guard equipped with a wide range of surveillance sensors and a SAR radar, used for pack ice mapping, marine monitoring and glacier surface monitoring.
- **TF-FMS**, a Beechcraft 200 aircraft operated by the Icelandic Aviation Services, equipped with surface profiling C-band radar.

Field stations

- **Grímsfjall field station** of the Iceland Glaciological Society is located in the centre of the 7700 km² Vatnajökull glacier. It hosts a variety of geophysical equipment that monitors the active volcanoes beneath the glacier as well as isostatic rebound due to glacier thinning. It also serves as a base for mass balance and other glaciological research on Vatnajökull.
- **The Rif Research Station (RRS)** provides access to a research area in Melrakkaslétta, which includes Iceland's northernmost point. The area allows research and monitoring within the field of natural science, e.g. related to: vegetation and bird life, freshwater biology, coastal ecosystems, geology and geomorphology. RRS is an INTERACT station and is being developed as one of three monitoring stations for the Circumpolar Biodiversity Monitoring Program (CBMP) under the Arctic Council Working Group, Conservation of Arctic Flora and Fauna (CAFF).

Point of contact:

The Ministry of Education, Science and Culture

(<https://www.government.is/ministries/ministry-of-education-science-and-culture/>)

The Icelandic Arctic Cooperation Network

(<https://www.arcticiceland.is/en/>)

The Icelandic Centre for Research

(<http://en.rannis.is>)



INDIA

Scientific studies undertaken by Indian researchers should contribute to the global community's ongoing efforts to understand climate change phenomena and processes, and to develop products that benefit mankind. India's primary focus is to explore the teleconnection between the Arctic and the Tropics. In addition, research efforts should also provide a wealth of data in such diverse but inter-related fields such as glaciology, oceanography, microbiology, marine biology and atmospheric science. Scientific research is implemented by the Ministry of Earth Sciences through the National Centre for Antarctic and Ocean Research (NCAOR), which is a research and development institute under the ministry.

The Indian Arctic Station
Himadri in Ny-Ålesund
© NCAOR



ARCTIC RESEARCH FUNDERS

The Ministry of Earth Sciences funds the Indian Arctic Programme, which provides support for all logistical and scientific research activities associated with India's Arctic research station "Himadri" and Gruevbadet atmospheric laboratory located in Ny-Ålesund, Svalbard.

MAJOR ARCTIC RESEARCH INITIATIVES

The Kongsfjorden-Krossfjorden system in west Spitsbergen is considered as a natural laboratory to understand local variability in the Arctic as well as ecosystem shifts due to climate change. NCAOR has been continuously monitoring the Kongsfjorden since 2010 for understanding response of the fjord to climate variability at different time scales. The fjord is being monitored at close spatio-temporal scales especially in the summer season to decipher the changes in water masses, biota and other chemical parameters. One of the major constraints in such a study has been the difficulty in reaching the location during the harsh Arctic winter and obtaining near-surface data.

A major milestone in India's scientific endeavours in the Arctic region has been achieved on the 23rd July, 2014 when a team of scientists successfully deployed IndARC, the country's first multi-sensor moored observatory in the Kongsfjorden fjord of the Arctic, roughly half way between Norway and the North Pole.

IndARC is programmed to collect sea truth data at close temporal scales even during the harsh Arctic winter. The mooring is serviced and redeployed every year and the data is being analyzed to understand the variability of water masses in the Kongsfjorden. The fjord is also being monitored for presence of emerging pollutants and micro-plastics.



Ever since the first expedition to Arctic, measurements on atmospheric aerosols and black carbon are being done. The infrastructure at Gruevbadet atmospheric laboratory is dedicated to understanding various atmospheric parameters like monitoring clouds, precipitation, humidity profiles, etc. The facility houses instruments like the micro rain radar, ceilometer, radiometer profiler, etc. which are being operated continuously streaming in data to NCAOR for the last several years.

Precipitation in Polar Regions has been forecast to increase with potential increases in global temperature. Our confidence in measurements of polar precipitation is low due to the lack of data and the difficulty in separating real precipitation from drifting snow. In order to achieve this goal, a micro rain radar was installed at Gruevbadet observatory which collects precipitation characteristics at every one-minute interval and will help to understand the high latitude precipitation characteristics. The Gruevbadet observatory also serves as an excellent platform for instruments like quartz crystal microbalance, photo acoustic soot spectrometer, transmissometer, micro aethalometer, high volume sampler, optical particle counter etc. used for the detailed characterisation of aerosols.



← Indian scientists approaching a major glacier meltwater channel in Ny-Ålesund to collect samples for scientific research
© NCAOR

India's Arctic glaciological programme fosters close ties with Himalayan glaciological research. Major activities in the Arctic include conducting measurements on the accumulation/ablation and mass balance of Feringgreen and Vestre Broggergreen glaciers in Ny-Ålesund, Svalbard during summer and winter seasons. Indian researchers have also conducted DGPS and GPR surveys on the glacier to delineate the snout and thickness and volume of ice. Mass balance is also being estimated through preparation of a digital elevation model. Measurements on glacier velocity and ice thickness also enable Indian scientists to compute ice flux rates. Snout position is also being monitored by using differential GPS. Indian researchers have also embarked on a mission to target larger glaciers in the Arctic for comparative studies with the Himalayan region.

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

India is in the process of acquiring a state-of-the-art polar research vessel. The vessel will be well equipped to negotiate the Arctic waters and will prove to be a significant platform for ocean and atmospheric research in the near future.

Field stations

Himadri station: Situated in Ny-Ålesund, on the west coast of Svalbard, the 'Himadri' station is manned for nearly 180-200 days per year. To date, Himadri has provided base support to over 250 scientists. The Gruebadet atmospheric laboratory, attached to the Himadri station, houses several instruments that measure a variety of atmospheric parameters.

Satellites

India operates several polar orbiting satellites and shares satellite missions with other countries. The following three satellite systems are being used to study the Arctic region, and have additional potential for collaborative, international research of the Arctic region:

1. Cartosat-2 series
2. Megha-Tropiques
3. SARAL

Point of contact:

Ministry of Earth Sciences

(MoES: secretary@moes.gov.in)

National Centre for Centre for Antarctic and Ocean Research

(NCAOR: director@ncaor.gov.in)

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ITALY

Italy's Arctic policy aims to increase knowledge of change in the Arctic, its impacts and feedbacks, through scientific monitoring, multidisciplinary research, and by enhancing international scientific cooperation. This policy was stated in the Italian Arctic Strategic agenda and is implemented by the National Research Council of Italy (CNR), in collaboration with universities and research organisations, including the Italian Space Agency (ASI), National Institute for Oceanography and Experimental Geophysics (OGS), National Institute for Geophysics and Volcanology (INGV) and the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA).

The CNR Arctic Station Dirigibile Italia – Ny-Ålesund, Svalbard.
© Mauro Mazzola



MAIN ARCTIC RESEARCH FUNDERS

Ministry of Education, Universities and Research (MIUR, www.miur.gov.it) supports research and innovation in the polar regions. MIUR has a dedicated Programme for the Arctic (PRA), managed by the CNR.

CNR (www.cnr.it/en) supports research activities in the Arctic, such as atmospheric and climate change, geology and geophysics, marine and terrestrial ecosystems, and paleoclimate studies.

ASI (www.asi.it/en) uses various satellite constellations, including the COSMO-SkyMed, to support observational research (sea-ice, permafrost and environmental monitoring as well as surveillance applications).

INGV (www.ingv.it/en/) supports space weather research as well as marine, paleomagnetic and paleoclimate studies.

OGS (www.ogs.trieste.it/en) supports oceanographic research, particularly along the Fram Strait and Spitzbergen.

ENEA (www.enea.it/en) sustains the activities of the Thule Observatory, contributing to atmospheric physics research.

Ministry of Foreign Affairs and International Cooperation (www.esteri.it/mae/en) supports international collaborative research projects in the Arctic.



MAJOR ARCTIC RESEARCH INITIATIVES

CCT-IP. The Climate Change Tower Integrated Project investigates atmospheric boundary layer dynamics, surface energy budget and fluxes, and the roles played by complex coupling processes involving air, aerosols, clouds, snow, ice and land.

ReCAP and EastGRIP. These projects aim at collecting ice cores from the eastern and north-east sectors of Greenland to reconstruct past atmospheric conditions, investigate ocean related processes (sea ice extent, primary production), and understand the changes in ice flow velocity that may be induced by the warming of the Greenland ice sheet.

MELT. Monitoring and Investigating Arctic change along a Longitudinal Transect aims to strengthen and integrate observations to understand the interconnected processes involved in climate change.

DEFROST. This project investigates the temporal and spatial variability of the deep flow in the southwestern region of Svalbard, an area where water masses with different properties interact with each other. The side project SOA aims to correlate oceanographic and meteorological data.



← The Amundsen-Nobile Climate Change Tower during maintenance.
© Fabio Giardi

DRAFT (Damping Role of Arctic Fjords in climate change) and **SNOW** (Sensor Network for Oceanography in Shallow Water) aim to collect time series oceanographic data in Kongsfjord using permanent mooring arrays to understand how climate change is affecting fjord systems, and how the effects may be mitigated.

Metrology For The Arctic. Metrology and environmental science communities cooperate to develop improved and dedicated calibration procedures, assess the response of instruments and sensors to polar conditions, evaluate uncertainty of field measurements. They are also implementing a metrology laboratory in Ny-Ålesund.

ACZ-Dynamics. This initiative intends to investigate changes in the Arctic Critical Zone, and their related impacts on ecosystem function and associated biogeochemical fluxes, focusing on the contribution of land ecosystems to the carbon budget.

C3 is an international, multi-disciplinary and multi-year programme whose overarching goal is to constrain the linkages between Climate, Cryosphere (sea ice and coastal permafrost) and Carbon release from sediments to the atmosphere in the East Siberian Arctic Ocean.

ARCTIC RESEARCH INFRASTRUCTURES

Field Stations

- **CNR Arctic Station 'Dirigibile Italia'.** The Arctic station (<http://arcticnode.dta.cnr.it/welcome>), located at Ny-Ålesund, Svalbard, is a multidisciplinary research station operated by the CNR that can host up to seven scientists in its laboratories and offices. Active since 1997, it is named after Umberto Nobile's airship Italia, used in the expedition of 1928.
- **The Amundsen-Nobile Climate Change Tower.** This facility is connected to the Italian Arctic Station in Ny-Ålesund. The tower is 33 m high and is equipped with instruments to investigate surface radiation and energy budgets and PBL dynamics.

- **Gruvebadet Atmospheric Laboratory.** It is a modern laboratory equipped with atmospheric and aerosol instrumentation.
- **Thule Observatory.** Inside the THAAO Observatory, ENEA and INGV operate an aerosol/temperature lidar, a water vapor emission spectrometer, and carry out surface radiation and aerosol measurements.
- **ISACCO network.** INGV manages a specially modified GNSS network at Svalbard to monitor and model the upper atmosphere and ionospheric scintillation.
- **Satellite Observations**
- **COSMO-SkyMed** is an ASI satellite constellation consisting of four medium-size satellites equipped with a microwave high-resolution synthetic aperture radar operating in the X-band.

Vessels

OGS is in the process of acquiring a polar research vessel for geophysical and oceanographic research activities in polar regions.

Other infrastructures

- **SIOS** (Svalbard Integrated Arctic Earth Observing System). Italy is member of SIOS, with the aim of coordinating and developing existing and new research infrastructure in Svalbard, as a support to the pan-Arctic observing system. SIOS also coordinates open data, transnational access, logistics and training.
- **Italian Arctic Data Center.** This interoperable data center manages Arctic data and observations. The center is operated by the CNR in cooperation with all the other Italian scientific institutions involved in Arctic research, and is strongly connected with the SIOS Data Management System.

Point of contact:
**National Research Council of Italy (CNR),
Department of Earth System Science and Environmental Technologies**
(<http://dta.cnr.it>)



JAPAN

In 2015, the Government of Japan adopted its first, comprehensive, and strategic Arctic policy, “Japan’s Arctic Policy.” The policy clearly states that Japan will: (1) make use of its strength in science and technology, (2) give full consideration to the Arctic environment and ecosystem, as well as (3) ensure the rule of law and promote international cooperation. It is important for Japan to play a leading role for sustainable development in the Arctic with foresight and policy based on science and technology. Japan focused on the Arctic policy as one of the main topics of the 3rd Basic Plan on Ocean Policy, approved by the Cabinet in May 2018, in order to accelerate to address Arctic issues.

Ny-Ålseund
Research Station
© NIPR



ARCTIC RESEARCH FUNDERS

MEXT initiated the 5-year national flagship research project of Arctic Challenge for Sustainability (ArCS) in fiscal year 2015, and the following three organisations have leading roles:

- National Institute of Polar Research (NIPR)
- Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
- Hokkaido University

MAJOR ARCTIC RESEARCH INITIATIVES

ArCS aims to: (1) promote Arctic research to elucidate the changes in the climate and environment in the Arctic, and clarify their impacts on human society, (2) provide robust scientific information to Arctic and global stakeholders to help them to make decisions and address Arctic issues. The project promotes international collaborative research in eight themes associated with social and economic challenges caused by recent environmental changes in the Arctic, as described below:

1. Predictability study on weather and sea-ice forecasts linked with user engagement
2. Variation in the ice sheet, glaciers, ocean, climate and environment in Greenland region
3. Atmospheric climate forcers in the Arctic
4. Observational research on Arctic Ocean environmental changes
5. Study on Arctic climate predictability
6. Response and biodiversity status of Arctic ecosystems under environmental change
7. People and community in the Arctic: possibility for sustainable development
8. Arctic Data Archive System (ADS)



In some themes, research is aiming at sustainable development with information on the impact on living acquired from indigenous peoples of the Arctic region and for analyzing the relationship between environmental change and social culture.

The project is also working on establishing of research and observation stations, dispatching young researchers to institutions abroad, and experts to the Working Groups and Task Forces of the Arctic Council and other international committees.

One of the achievements of this project is the development of a high-precision black carbon (BC) measuring instrument “COSMOS” which was recognised as the standard of BC observation technology in Expert Group on Black Carbon and Methane (EGBCM) of the Arctic Council. The result of continuous observation of BC in the atmosphere at Barrow and Ny-Ålseund using COSMOS proved conventional measurements overestimated black carbon density. ADS accumulates observed and simulated data in various research fields, and obtained around 2 million accesses in 2017, of which 70% were from abroad, with connection to the Global Earth Observation System of Systems (GEOSS) Portal.



← Arctic expedition
with R/V MIRAI
© JAMSTEC

ArCS is also working on the construction of Arctic Ocean route search system utilizing ADS.

JAMSTEC embarks on development of technologies related to an autonomous underwater vehicle (AUV) for Arctic Ocean observations. During an Arctic expedition with R/V MIRAI in 2017, JAMSTEC's development team carried out a field test of a compact prototype of such AUV. Team members are planning to promote development of underlying technologies for position monitoring of the AUV beneath sea ice and also for its highly-accurate navigation system, with the aim of the practical operation in the Arctic Ocean.

Principal investigators from Hokkaido University are currently leading two Belmont Forum Collaborative Research Actions. RACArctic focuses on resilience and adaptive capacity of Arctic Marine systems under a changing climate. COPERA examines carbon budgets of ecosystems, cities and villages on permafrost in the eastern Russian Arctic.

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

Using R/V MIRAI, JAMSTEC's ice-strengthened research vessel that is equivalent to Polar Class 7, Japan primarily conducts oceanographic research and mooring-based observations during the summer, in the Pacific sector of the Arctic Ocean. Studies of the Arctic Ocean marine ecosystem and fisheries are occasionally carried out by T/S Oshoro-maru owned by Hokkaido University. In addition, Japan determines to pursue considerations on a new Icebreaker for the Arctic research.

Field stations

Field observations are conducted by Japanese researchers at research stations in the Arctic with the cooperation of respective countries including Ny-Ålseund Research Station in Svalbard, Norway, Poker Flat Research Range

in Alaska, USA, Ice Base Cape Baranova in Severnaya Zemlya and Spasskaya Pad Scientific Forest Station in Yakutsk, Russia. At these stations, scientists conduct environmental research across a variety of disciplines in cooperation with research institutes from other countries.

Satellites

The Japanese Aerospace Exploration Agency (JAXA) uses the "GCOM-W(SHIZUKU)" satellite to make one-full-day observation images of the Earth. As SHIZUKU flies over polar regions every 100 minutes, and thus the entire area of the Arctic Ocean can be observed daily with high resolution, one-day images created and the data shared publicly. The "ALOS-2(DAICHI 2)" satellite detects changes of permafrost, ground, boreal forest and sea ice in the Arctic. The new satellite "GCOM-C(SHIKISAI)", was launched to observe aerosols, clouds and ocean color at Arctic region in Dec. 2017.

Point of contact:

Ministry of Education, Culture, Sports, Science and Technology
(MEXT; <http://www.mext.go.jp/english/>)

National Institute of Polar Research
(NIPR; <http://www.nipr.ac.jp/aerc/e/index.html>)

Japan Agency for Marine-Earth Science and Technology
(JAMSTEC; <http://www.jamstec.go.jp/e/>)

Hokkaido University
(<http://www.arc.hokudai.ac.jp/en/>)

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NETHERLANDS

The poles are very sensitive to changes in climate: they form the heartbeat of our climatic system. Changes in the polar regions have significant physical, ecological, social and economic consequences far beyond those regions, including the Netherlands. To advance the development of policy, the Netherlands Polar Programme provides scientific support to generate knowledge about the polar regions. Dutch polar research policy is developed along four main scientific themes as outlined in the report Pole Position – NL 2.0 (available on NWO website): (1) Ice, climate and rising sea levels, (2) Polar Ecosystems, (3) Sustainable exploitation, (4) Social, legal and economic landscape.

Collecting water samples
at Kongsfjorden,
Spitsbergen.
© Gemma Kulk



ARCTIC RESEARCH FUNDERS

The Netherlands Polar Programme, under a contract until 2020, is funded by five ministries, including Education, Culture and Science (OCW), Foreign Affairs (BZ), Infrastructure and the Environment (I&E), and Economic Affairs and Climate (EZK), and by the Netherlands Organisation for Scientific Research (NWO), which also serves as the operator of the Programme. Additional funding is provided by several Dutch Universities and institutes. The Netherlands Polar Programme has an annual budget of approx. 4.2 million euro. A recent report (published March 2018, available on NWO website) of the Committee on Polar Infrastructure (CPI) for the Netherlands Organisation for Scientific Research (NWO) gives seven recommendations to strengthen the Netherlands commitment to polar research. Amongst it is the recommendation to significantly increase the overall funding level of the Netherlands Polar Programme and to establish a Dutch Polar Research Institute. All these recommendations will be under consideration in 2018.

MAJOR ARCTIC RESEARCH INITIATIVES

- ***During 2018, a call for proposals for policy-related polar research projects will open to accommodate research projects*** linking to 'The Netherlands Polar Strategy 2016-2020'. Funded projects will support excellent scientific research that will provide knowledge for an evidence-based policy regarding the polar regions. This call for proposals aims to advance the exchange of knowledge between government ministries and researchers and use this knowledge for Dutch policy to support negotiations on polar issues. The total funding will amount to approximately 5 M€.



- ***The Netherlands will extend their offer to host the European Polar Board*** for another five years (<http://www.europeanpolarboard.org/secretariat>) at the Netherlands Organisation for Scientific Research (NWO) in The Hague until 2025. The first hosting period runs for a period of five years from 1 January 2015 until 1 January 2020.
- ***The Netherlands has committed to take part in the Svalbard Integrated Arctic Observation System*** (SIOS), 'an international observing system for long-term measurements in and around the Norwegian archipelago of Svalbard addressing Earth System Science questions' <https://sios-svalbard.org/>. Further commitments in Ny-Ålesund are under consideration as part of the abovementioned CPI report.



← Dutch scientists collecting a lake sediment core from a glacial lake during the Scientific Expedition Edgeøya Svalbard (SEES).
© Dick van der Kroef

- **The Netherlands will take part in the German-led Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAIC) project** (<http://mosaicobservatory.org/>), which will be 'the first year-round expedition into the central Arctic exploring the Arctic climate system'. The Netherlands Polar Programme will contribute 1 M€ to MOSAiC and will participate on-board the Polarstern icebreaker with two Dutch scientists during several legs of the expedition.
- **The Netherlands Polar Programme supports the development of the Multifunctional Arctic Research Vessel (MARVEL) project** to study the mating habits of the bowhead whale (*Balaena mysticetus*) for the Ice Whale Project, the only whale species to spend its entire life in the arctic region. Little is yet known about the reproduction of this arctic whale species which is presumed to take place during the polar night in the Arctic Ocean. The MARVEL project will be further developed using crowd-funding and private investments. Outreach activities are planned, e.g. exhibits at National Museum.
- **The Netherlands will contribute 400 k€ in the Arctic call of the Belmont Forum** (<http://www.belmontforum.org/>) as Collaborative Research Action 'Understanding sustainability and resilience in rapidly changing Arctic climate-socio-ecological systems (CRA Arctic II).

ARCTIC RESEARCH INFRASTRUCTURE

The Netherlands Polar Programme has supported the development of autonomous automatic weather stations for collaboration in international arctic research projects in e.g. Greenland and Svalbard.

The Netherlands has developed the Mobile Laboratory concept that has been successfully implemented at the Dutch Dirck Gerritsz Laboratory at Rothera Station in Antarctica, in close collaboration with the British Antarctic Survey (BAS). The Netherlands Polar

Programme has the ambition to extend the mobile laboratory concept to their research activities in the Arctic, e.g. at Ny-Ålesund, Spitsbergen.

Vessels

None

Field stations

The Netherlands Arctic Station, Ny-Ålesund, Spitsbergen (<http://www.arcticstation.nl/>)

Satellites

None

Point of contact:

The Netherlands Organisation for Scientific Research (NWO),
main contact person: Dick van der Kroef,
director Netherlands Polar Programme
(alwnpp@nwo.nl, www.nwo.nl/en/research-and-results/programmes/Netherlands+Polar+Programme)

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↑ The Netherlands Arctic Station, Ny-Ålesund, Spitsbergen
© Netherlands Organisation for Scientific Research (NWO)



NORWAY

The objective of Norway's Arctic research is to support quality research to acquire the knowledge needed to implement policy, manage economic activity, and support knowledge-based environmental and resource management. International cooperation is of high priority. Guidelines for Norwegian Arctic research and higher education can be found in Norway's Arctic Strategy, the Long-term plan for research and higher education 2015–2024 and Strategy for research and higher education in Svalbard. Goals and thematic research priorities are also given in the Policy for Norwegian Polar Research (2014–2023).

Ny-Ålesund
© Helge Markussen/
Norwegian Polar Institute



ARCTIC RESEARCH FUNDERS/INSTITUTIONS

The total Norwegian funding of polar (Arctic and Antarctic) research is almost 200 MEUR, where about 90 percent is Arctic research. Most of the funding comes from the ministries and is partly channelled directly to universities and institutes and partly through the Research Council of Norway.

MAJOR ARCTIC RESEARCH INITIATIVES

Norwegian Arctic research is geographically extensive, international, and covers a broad range of research disciplines. A selection of ongoing initiatives includes (not in prioritized order):

The Nansen Legacy project (2018 – 2023) is a large dedicated research effort to explore and establish a holistic understanding of a changing Arctic ocean and ecosystem. The project includes extensive field investigations using the new ice going vessel Kronprins Haakon. Project leader is The University of Tromsø – The Arctic University of Norway (UiT).

The Institute of Marine Research's **The Barents Sea and Arctic Ocean Ecosystem Programme** is a partnership with the Russian institute PINRO. It is one of the world's most comprehensive monitoring surveys of a marine ecosystem that on an annual basis gathers long-term data on ocean environment, commercial stocks, and biodiversity.

The High North Research Centre for Climate and the Environment (The Fram Centre) in Tromsø consists of approximately 500 scientists from 20 institutions involved in interdisciplinary research in the fields of natural science, technology and social sciences.



The Norwegian Polar Institute's Centre for Ice, Climate and Ecosystems (ICE) focuses on climate-related research, such as on ice, sea ice, alpine glaciers and the effects of climate change on ecosystems.

Research Centre for Arctic Petroleum Exploration (ARCEX) at UiT contributes to an understanding of the geological resources in the Arctic, development of exploration techniques and improved knowledge of environmental risks and impact from petroleum activities in the northern areas.

Polar Climate is one of four research themes at The Bjerknes Centre for Climate Research in Bergen. Polar Climate is dedicated to understanding changes and providing predictability in the Arctic earth system – combining fieldwork and modelling to quantify past, present and future Arctic climate change.

Centres of Excellence

- **The Centre for Arctic Gas Hydrate, Environment and Climate (CAGE)** at UiT investigates the role of gas hydrates in Arctic areas, and the future effects they may have on oceans and global climate.



← The new Norwegian polar research vessel Kronprins Haakon
© Øystein Mikelborg/
Norwegian Polar Institute

- **The Birkeland Centre for Space Science (BCSS)** at the University of Bergen is dedicated to the coupling of Earth with space through the Arctic. Main research topics include aurora and the predictability of “space weather”.

Centres for research-based Innovation

- **Sustainable Arctic Marine and Coastal Technology (SAMCoT)** at the Norwegian University of Science and Technology is targeted toward developing robust technology for sustainable exploration and exploitation of the Arctic region.
- **The Centre for Integrated Remote Sensing and Forecasting for Arctic Operations (CirFA)** at UiT focuses on methods and technologies to reliably detect, monitor, integrate, and interpret multi-sensor data that characterise the physical environment of the Arctic.

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

Norway has several research vessels supporting Arctic research, including two with the ability to operate in ice-infested polar waters; R/V Kronprins Haakon and F/F Helmer Hansen.

Field stations and other selected infrastructures

- **Ny-Ålesund** in Svalbard is a permanent Norwegian research facility for climate and environmental research that hosts national and international research projects and programmes. Ny-Ålesund serves as an observatory, laboratory, and field base for Arctic research.
- **Kjell Henriksen Observatory** in Svalbard is an optical observatory that studies the middle- and upper atmosphere.
- **EISCAT**, the European Incoherent Scatter Scientific Association, conducts research on the lower, middle, and upper atmosphere and ionosphere. Two of the world’s ten incoherent scatter radars are located in Norway, one in Longyearbyen and the other in Tromsø.

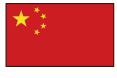
- **COAT**, the Climate-ecological Observatory for Arctic Tundra in Northern Norway and in Svalbard, is a system for long-term adaptive terrestrial ecosystem monitoring that is based on food-web theory.
- **SIOS**, Svalbard Integrated Arctic Earth Observing System, is a regional research infrastructure consortium hosted by Norway. The goal is to establish an observing system that will improve knowledge of environmental and climatic changes in the Arctic.
- **NORMAP**, the Norwegian Satellite Earth Observation Database for Marine and Polar Research, provides scientists with access to remote sensing products based on data collected north of 55°N.
- **INES**, Infrastructure of Norwegian Earth System Modelling, develops and sustains the Norwegian earth system modelling capability including routinely providing simulations for the IPCC assessments.
- The **Norwegian Mapping Authority’s geodetic observatory** in Ny-Ålesund plays a key role in providing reference frames and global earth observations.

Satellites

Kongsberg Satellite Services runs and owns the **Svalbard Satellite Station** (SvalSat) in Longyearbyen, which is the world’s largest commercial ground station for polar-orbiting satellites.

Norway participates in Copernicus and is an active partner in the European Space Agency (ESA) satellite initiative, Earth Explorers. The Norwegian satellites **NorSat-1** and **NorSat-2** are carrying state of the art vessel detection instruments and are also equipped with space weather and future marine communication instrumentation.

Point of contact:
Research Council of Norway
(<http://www.rcn.no>)
Norwegian Polar Institute
(<http://www.npolar.no/en>)



PEOPLE'S REPUBLIC OF CHINA

China's policy goals on the Arctic are: to understand, protect, develop and participate in the governance of the Arctic, so as to safeguard the common interests of all countries and the international community in the Arctic, and promote sustainable development of the Arctic; which includes: improving capacity in scientific research; protecting its unique natural environment and ecological system; and contributing to the economic and social development of the Arctic. "Sustainability" is the fundamental goal of China's participation in Arctic affairs.

China's Yellow River
Research Field Station in
Svalbard, Norway.
© Polar Research
Institute of China



ARCTIC RESEARCH FUNDERS

Ministry of Science and Technology (MOST).

Dedicated to Chinese scientific and technological development, MOST provides ongoing support for Arctic research, particularly in these areas: (a) satellite remote sensing observations along the Arctic northern passages; (b) ocean-sea ice-atmospheric circulation coupling mechanisms; (c) the impact of Arctic environmental change on global and Chinese climate; (d) establishing a polar environment data sharing platform; and (e) technological development of polar engineering equipment.

Ministry of Natural Resources (MNR) and its subordinate **State Oceanic Administration (SOA)**. These entities fund polar research and logistical support for Chinese researchers studying Arctic terrestrial environments, geology and mineralogy, ice sheet and sea ice prediction, surveying and mapping technology, the Arctic marine ecosystem and other topics.

National Natural Science Foundation of China (NSF).

Following the geoscience development plan, NSF establishes priority research topics, such as in ocean and atmospheric science, ice sheet/ice shelf interaction, subglacial remote sensing, and information management. NSF funds about 40 Arctic research projects per year, at a level of up to 18 million RMB (~\$2.7M US) in 2015.

Ministry of Education (MOE). Paying close attention to global climate change, MOE funds universities and colleges to conduct Arctic research in the following areas: (a) ecology; (b) oceanography; (c) geology; (d) glaciology; (e) climatology; (f) engineering technology; and (g) the social sciences of law, economics, and political science.



China Meteorological Administration (CMA).

CMA focuses on Arctic meteorological observations, modelling, and analysis. It funded the development of the FengYun meteorological satellite constellation and it supports weather / ice condition forecasting, which is vital for vessel navigation and other field work.

MAJOR ARCTIC RESEARCH INITIATIVES

Arctic Environment Comprehensive Assessment.

Initiated in 2012, it's by far the largest and most comprehensive investigation of the Arctic environment. Focusing on marine physics, abyssal oceanic circulation, basin geology/tectonics, and sea ice response to climate change, this project integrates several disciplines and dozens of Chinese polar experts.

Northern Hemispheric Cryosphere Change, Its Effects and Adaptive Strategy Project.

This project developed an accurate algorithm to invert Arctic Sea Ice Concentration (SIC) from satellite observations and found an anomaly of extremely low SIC in the central Arctic Ocean. Deeper insights are being gleaned from the links between the state of the cryosphere and lower-latitude atmospheric weather and climate patterns, the resulting hazards, and adaptation strategies that are being developed to respond to such threats.



← China's icebreaker
MV Xuelong in the
Arctic Ocean.
© Polar Research
Institute of China

Arctic Amplification Processes and Global Effects Caused by Arctic Sea Ice Retreat. Supported by MOST, this project is the first Arctic-related initiative in the larger “National Programme on Key Basic Research Projects of China.”

This project brings together expertise from six universities and research authorities to tackle key problems. Focusing on Arctic amplification phenomenon and ocean forcing effects, they analyse the critical physical processes and interaction mechanisms among sea ice, ocean, and atmosphere that result in Arctic amplification.

ARCTIC RESEARCH INFRASTRUCTURE

China has taken great effort to participate in Arctic research activities and has made substantial investments in research infrastructure.

Vessels

Built in the Ukraine in 1993, the MV Xuelong is currently China's only operational icebreaker for scientific research. In 2007, it was ice-strengthened to CCS Ice Class B1 (capable of proceeding at 1.5 knots in 1.1 m ice with 0.2 m snow depth) and can carry two helicopters. The vessel has laboratories for marine physics, chemistry, biology, and meteorology, as well as a data processing centre. Operated by the Polar Research Institute of China, MV Xuelong has conducted all eight of China's Arctic expeditions. China is currently building a new icebreaker, with a significantly higher ice class, which is designed by both foreign and domestic experts.

Field station

The first Chinese Arctic scientific research field station, “Yellow River,” was established in July 2004 at 11°56'E, 78°55'N in Ny-Ålesund, Spitsbergen, Norway. The Station, a two-story building of about 500 m², includes labs, an office, a lobby, dormitory and storage, and can support a 20-25-person crew. The four labs support research in the fields of meteorology and space-earth measurements, glaciology, marine ecosystems and environmental and weather patterns. A roof-top observational platform enables the study of upper atmospheric physics.

China encourages field research, and thus annually selects scientists from a variety of universities and research organisations to conduct experiments at the Yellow River Field Station. Supported projects include ice core drilling and analysis, upper ionosphere physics, fish and phytoplankton community analysis and snow/ice radiometric investigations.

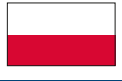
Satellites

China has launched several polar-orbiting satellites in cooperation with other countries or independently. These satellites have sensors for visible/near infrared spectrometer, thermal infrared radiometer, microwave radiometer and synthetic aperture radar, which significantly improve remote sensing capabilities.

- **CBERS-01/02/02B/02C/04** (arising from a partnership between Brazil and China) investigates Earth resources with multi-spectral, moderate resolution and large swath imaging.
- **HJ-1A/1B/1C** (HuanJing, funded by the Ministry of Environmental Protection) is a constellation that investigates environmental conditions and forecasts hazard information.
- **FY-1A/1B/1C/1D/2C/2D/2E/2F/3A/3B/3C** (FengYun, funded by CMA) is a polar-orbiting and geostationary constellation that provides measurements of atmospheric conditions.
- **BNU-1** (funded by Beijing Normal University) is specifically designed to study polar climate and environment in rapidly changing polar regions by providing high-quality, high-frequency multispectral remote sensing data.

Point of contact:
Ministry of Science and Technology
(MOST; www.most.gov.cn)

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POLAND

Poland's Arctic research policy is guided by the "Strategy for Polish Polar Research – a concept for the years 2017–2027". The main goals of the research are: (1) to increase the knowledge of the abiotic components of the environment and understanding the specificity of the interactions between natural processes; (2) to advance analyses of the state and changes in the biotic components of the environment; (3) to better understand the human and social dimensions of developments in the region; (4) to develop applied research focused on the use of technology in extreme conditions; and (5) using Polish polar platforms for space research and astronomical observations.

Glaciological field work
in winter.
© Photo by Dariusz
Ignatiuk



ARCTIC RESEARCH FUNDERS

Ministry of Science and Higher Education, National Science Centre (NCN), The National Centre for Research and Development (NCBiR)

MAJOR ARCTIC RESEARCH INITIATIVES

Development of Arctic research platforms for Svalbard area and database. This initiative is focused on significant development of platforms collecting key sets of data on climate and various components of the terrestrial and marine environment. The observation system is based on a long-term monitoring programme covering meteorology, geodetic surveys, glaciological observations, and other observations. Additionally, the R/V Oceania conducts regular observations of atmosphere, hydrology, marine biology and chemistry both in the water column and sea bed.

Shrinking ice in Arctic – the Svalbard case. Processes and environmental consequences. This interdisciplinary programme comprises of long-term monitoring programmes and several projects focused on assessment of the causes, mechanisms and consequences of de-icing of the Arctic, taking Svalbard as an example. It is focused on the recession of tidewater glaciers in southern Svalbard and the decrease of fast sea ice extent. It will deliver: (1) a model of the opening of a new "Hornsund strait" between a warmer Greenland Sea and a colder Barents Sea with associated landscape and seascape changes, and (2) estimation of freshwater supply to Svalbard fjords and near shore waters.



Understanding the role of snow cover in the High Arctic environment. The initiative is based on the assumption that information on spatial distribution and temporal changes of snow properties combined with datasets on chemistry, microbiology, plants and animal ecology, hydrology, and permafrost can provide a better insight into functioning of the High Arctic ecosystem. It aims to: (1) test and unify field methods and sampling strategies for assessment of the snowpack properties; (2) to assess available datasets and identify knowledge gaps in snow-oriented environmental studies; (3) to create a platform for interdisciplinary research of environmental processes dependent on snow cover.

EduArctic. This initiative is an innovative programme that attracts young people to natural sciences and polar research. It includes: (1) online broadcasts of lessons from polar stations on natural sciences and polar research related to key societal challenges; (2) "Polarpedia" – a web-based encyclopedia in at least five languages; and (3) Arctic competitions for pupils in which prize winners participate in polar expeditions.



← Polish Polar Station
Hornsund in summer.
© Piotr Dolnicki

ARCTIC RESEARCH INFRASTRUCTURE

Polish Arctic research activities – initiated during the 2nd International Polar Year 1932/33 – are concentrated in, though not limited to, the Svalbard archipelago in the Norwegian Arctic and in the Nordic Seas.

Vessels

Research vessel *R/V Oceania*, operated by the Institute of Oceanology, PAS, provides facilities for research in hydrography, optics, aerosols, acoustics, chemistry, and marine biology. The *M/S Horyzont II*, operated by the Maritime Academy of Gdynia, is used for training of navigation, to transport researchers and their equipment, and intermittent research activities.

Research stations

Polish Polar Station, Hornsund (est. in 1957). Since 1978, this station has been operated as a year-round research facility by the Institute of Geophysics PAS. It is a modern research platform with well-equipped laboratories and satellite communication offering accommodation for 20 scientists in addition to the staff. Permanent observations include: meteorology, air pollution, glaciology, geophysics (e.g., seismology, geomagnetism, atmospheric electricity), permafrost, geomorphology, and the physical oceanography of the fjord system. The Hornsund station is involved in an international cooperation as a member of the INTERACT network and is offering opportunities for local logistical support, field instrumentation, and lab facilities.

Universities Field Stations in Svalbard

- **Stanisław Baranowski Spitsbergen Polar Station** (est. in 1971; nickname Baranówka) is located near the Werenskiöld Glacier in southern Spitsbergen and is operated by the University of Wrocław.
- **Nicolaus Copernicus University (in Toruń) Polar Station** (est. in 1975, nickname Hahut) is located in the northern part of Kaffiøyra, northwest Spitsbergen.

- **Adam Mickiewicz University (in Poznań) Polar Station (AMUPS)** – the station consists of two modern cabins that are located on the eastern coast of Petuniabukta, Billefjorden, in central Spitsbergen.
- **Maria Curie-Skłodowska University (in Lublin) Polar Stations** buildings of an abandoned mining settlement Calypsobyen, Bellsund in southern Spitsbergen.

Usually, the stations host summer expeditions. Winter field studies are also quite frequent. Their research profile includes meteorology, glaciology, hydrology, geology, geomorphology, permafrost, periglacial and coastal processes, as well as botanical studies, soil science, environmental protection and studies related to past human activities. Regular student participation in expeditions plays an important role in academic education and polar field training of early-career scientists.

Point of contact:

Committee on Polar Research, Polish Academy of Sciences (CPR-PAS)
(<http://kbp.pan.pl>)

Polish Polar Consortium (PKPol)
(<http://www.pkpolar.pl>)

Centre for Polar Studies (CPS)
(<http://www.polarknow.us.edu.pl/csp-2/>)

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PORTUGAL

The Portuguese Republic's commitment to Arctic science is in line with the EU Arctic Policy and acknowledges the global importance of Arctic processes with impacts also for Portugal in what concerns to sea-level rise and coastal processes, climate, fisheries and sea transportation among others. Mainland Portugal, the Azores and the Madeira archipelagos with its position in the north Atlantic are exposed to Arctic changes and the Portuguese Republic shares the international responsibility for contributing for improving the understanding of the Arctic and of its Global impacts.

Sampling water from permafrost thaw lakes for chemical analysis near Kuujuarapik (Nunavik, Quebec, Canada).
© João Canário, Gonçalo Vieira



Portugal aims at being an international reference as a non-Arctic nation with an Atlantic dimension investing in research, technology and innovation in the Arctic and ensuring that knowledge generated by scientific research underpins social and economic development.

ARCTIC RESEARCH FUNDERS

- Fundação para a Ciência e a Tecnologia, I. P. (Ministério da Ciência, Tecnologia e Ensino Superior)
- European Commission, mainly under H2020
- Universities and Research Institutions

MAJOR ARCTIC RESEARCH INITIATIVES

Portugal has a long history of navigation in the Arctic and with the 4th International Polar Year 2007-08 started the implementation of a national programme for promoting Polar research – the Portuguese Polar Programme (PROPOLAR) – created within the Portuguese Foundation for Science and Technology (FCT, I. P.). PROPOLAR opens annual calls for Polar research projects and has funded 18 projects on the Arctic since 2014, focusing on themes such as atmospheric aerosols, terrestrial and marine biogeochemistry, permafrost and ecosystem dynamics, bird ecology and marine zooplankton.

Portugal has been a member of the European Polar Board since 2006, of the Forum of Arctic Research Operators since 2014 and of the International Arctic Science Committee since 2015. FCT, I. P. is also committed with the IASC cross-cutting programme T-MOSAIC (Terrestrial Multidisciplinary distributed Observatories for the Study of Arctic Connections – www.t-mosaic.com) with the international secretariat being hosted at the University of Lisbon and with two Portuguese in the Steering Committee (the Chair and a member).



Portugal is also represented in Polar scientific organisations such as the International Permafrost Association and the International Association for Cryospheric Sciences, and in international programmes such as the Global Terrestrial Network for Permafrost (GTN-P/IPA/GCOS), with a Portuguese scientist in the Steering Committee. Portuguese research institutions participate in the EU Arctic cluster projects EU-POLARNET and NUNATARYUK. Portuguese research in the Arctic has been essentially conducted through research partnerships with Canada, Germany, Iceland and Norway. The main regions of research are the Eastern Hudson Bay, the Beaufort Sea Coast and Svalbard, with projects also taking place in Iceland and sporadically in other Arctic regions. Recently, Portuguese researchers have also been involved in scientific cruises in the European sector of the Arctic Ocean in collaboration with Norwegian institutions.

An MoU with Spain on Polar research was signed in 2009 and has been implemented mainly in the Antarctic, with a new cooperation strategy for the Arctic fostered within the present Arctic Science Ministerial.



← UAV remote sensing for lake colour analysis and vegetation mapping near Kuujjuarapik (Nunavik, Quebec, Canada)
© Ana Padeiro

Nunataryuk – Permafrost thaw and the changing Arctic coast, science for socioeconomic adaptation, is currently the largest project with Portuguese participation in the Arctic. Scientists from the University of Lisbon in collaboration with various international partners (Alfred Wegener Institute and Geological Survey of Canada) are monitoring coastal erosion using remote sensing technologies and field surveys across the Arctic, with a focus on the Beaufort Sea coast in the Yukon and the Northwest Territories of Canada. In the Sub-Arctic region of the Eastern Hudson Bay, a long-term collaboration with the Centre of Northern Studies at the University of Laval, is underway on permafrost thaw lake chemistry, also by the University of Lisbon Polar research group.

In 2017, FCT, I. P. initiated the process of developing a Research & Innovation Agenda in Polar Sciences and Technologies, a strategic document that is to be completed by the end of 2018 and that has mobilised experts from R&D institutions and companies in the identification of challenges and opportunities in the national scientific and technological system, especially in medium and long-term perspectives.

Portugal is leading the Atlantic Interactions Initiative, a new intergovernmental initiative to unleash the potential of the Atlantic for Society to be implemented through the Atlantic International Research Centre (AIR Centre). It fosters knowledge-driven solutions for Atlantic and Global societal challenges that require interdisciplinary research and innovation of complex earth systems through cooperation targeting the Atlantic.

Within this strategy the Polar Regions play a key role, since they are deeply inter-related with Atlantic Ocean processes and dynamics and influence the whole circum-Atlantic region. Portugal's contribution to Arctic science will hence be associated with the AIR Centre and fostered within its activities.

The national framework for supporting Polar science implemented during the last decade has enabled a steady growth of the Portuguese scientific community conducting Arctic research and promoted international cooperation with Arctic and non-Arctic nations.

To strengthen the Portuguese commitment to Arctic research, FCT, I.P. proposed to the International Arctic Science Committee (IASC) the organisation of the Arctic Science Summit Week in 2021. The proposal under the theme “The Arctic: Regional Change, Global Impacts” was accepted at the IASC Council Meeting in Davos in June 2018 and the event will take place in Lisbon, from 19 to 26 March 2021.

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

Not applicable.

Field stations

Not applicable.

Satellites

Not applicable.

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REPUBLIC OF SINGAPORE

The Arctic research policy of Singapore, which was admitted as an Arctic Council observer state in 2013, is to: (i) increase knowledge of the Arctic; (ii) develop applied research solutions to tackle challenges faced by companies and local communities; and (iii) create awareness of Arctic issues in Southeast Asia through public education and information. Singapore's research interests are to understand the effects of climate change in the Arctic, and to contribute to the evolving state of Arctic marine transportation by helping to create new sea routes, and by balancing sustainable economic development with environmental concerns and the needs of local communities.

Minister of State Sam Tan at the Arctic Frontiers Abroad Forum in Singapore.
© Ministry of Foreign Affairs



ARCTIC RESEARCH FUNDERS

National University of Singapore (NUS). NUS' research institutions, including the Centre for Offshore Research and Engineering (CORE); Centre for International Law (CIL); Centre for Maritime Studies (CMS); Keppel-NUS Corporate Laboratory; Energy Studies Institute (ESI); Tropical Marine Science Institute (TMSI) and the Department of Geography, focus on a variety of topics, including Arctic international law, shipping governance, remote energy systems in the Arctic, climate change, and Arctic social sciences.

Nanyang Technological University (NTU). The Climate and Ecology Groups at NTU's Asian School for the Environment are researching the sensitivity of Arctic land ice to past climate variability and its future impact to Singapore.

Singapore Maritime Institute (SMI). SMI works with universities and research institutions to promote a sustainable research and development ecosystem in Singapore, and to develop solutions for the maritime and offshore industry. SMI's key focus areas include ports, shipping, maritime services, and offshore and marine engineering.

Maritime and Port Authority (MPA). As Singapore's port regulator, authority, and planner, MPA partners with industry and other agencies to enhance safety, security and environmental protection in port waters, facilitate port operations, and conduct maritime research and development.



Meteorological Service Singapore (MSS). MSS is Singapore's national authority on weather and climate. MSS' research centre, the Centre for Climate Research Singapore (CCRS), conducts research on tropical climate change, variability, and associated weather systems that affect Singapore and Southeast Asia.

Ministry of Foreign Affairs (MFA). MFA coordinates Singapore's Arctic engagement, supports research activities that enhance Singapore's knowledge of Arctic issues, and increases awareness of Arctic issues throughout Southeast Asia.

MAJOR ARCTIC RESEARCH INITIATIVES

Arctic Offshore Technology. The Arctic is a focus of international attention because of its rich petroleum and mineral resources, as well as its importance as a strategic shipping route. The Keppel-NUS Corporate Laboratory is developing a robust, efficient, and safe drilling system for



← Artist's impression of the Technology Centre for Offshore and Marine Singapore (TCOMS) facility.
© National University of Singapore

shallow-water regions in the Arctic Ocean. This research seeks to understand ice-structure interaction, a critical factor in designing an Arctic drilling system.

MPA-CIL Oceans Governance Research Programme. The goal of this joint research programme, between MPA and CIL, is to develop institutional expertise in ocean governance and to spearhead thought leadership in order to bolster Singapore's position as a global maritime knowledge hub. Research activities focus on Arctic shipping governance, transit passage regimes under the UN Convention on Law of the Sea (UNCLOS), and marine environmental governance.

ARCTIC RESEARCH INFRASTRUCTURE

Technology Centre for Offshore and Marine, Singapore (TCOMS). The Agency for Science, Technology and Research (A*STAR) and NUS are currently spearheading the construction of TCOMS. When completed in 2019, TCOMS will house a state-of-the-art deep-water ocean basin capable of integrating numerical simulations with physical testing to develop innovative and more cost-effective solutions to operate in harsh environments such as those in the Arctic.

Point of contact:

National University of Singapore

(www.nus.edu.sg)

Nanyang Technological University

(www.ntu.edu.sg)

Singapore Maritime Institute

(www.maritimeinstitute.sg)

Maritime and Port Authority

(www.mpa.gov.sg)

Meteorological Service Singapore

(www.ccrs.weather.gov.sg)

Ministry of Foreign Affairs

(www.mfa.gov.sg)



RUSSIAN FEDERATION

At present, the development and use of the economic potential of the Russian Arctic has become one of the main directions of the country's development.

In this regard, the Russian research policy has two directions; one ensures the economic activities in the Arctic and near-Arctic areas, and the other is the creation of new theoretical and experimental methods and technologies that minimise the anthropogenic impact in the unique Arctic nature.

The Russian Arctic
© Arctic and Antarctic
Research Institute. High-
Latitude Arctic Expedition



GOALS OF THE NATIONAL RESEARCH INITIATIVES

- conservation of the Arctic ecosystem
- effective nature management
- sustainable development of Arctic territories
- preservation of the cultural and historical heritage of the Arctic peoples
- creation of new functional materials and equipment
- improving the quality of life of the Arctic population
- adaptation to changes in natural and climatic factors

ARCTIC RESEARCH FUNDERS

Ministry of Science and Higher Education of the Russian Federation. Supports civil research and development target projects, awards grants to support young Russian scientists and lead scientific universities.

Russian Academy of Sciences. Supports and conducts basic fundamental scientific research as per the annual programmes.

Federal Service for Hydrometeorology and Environmental Monitoring. Conducts applied research, projects, and services in hydrometeorology, provides scientific support in the area of navigation, hydrography, hydrometeorological support for navigation of vessels in the Northern Sea Route.

Science Foundations. The Russian Science Foundation and the Russian Foundation for Basic Research support fundamental, exploratory, and bottom-up Arctic research projects.

Ministry of Natural Resources and the Environment of the Russian Federation. Supports research projects to ensure the rational and safe use of natural resources in the Arctic.



Ministry of Economic Development of the Russian Federation. Performs applied economic research where results are used to apply new knowledge to achieve practical goals in key areas of economic development of the Russian Arctic.

MAJOR ARCTIC RESEARCH INITIATIVES

- development and approval of the State programmes and projects directed towards the advanced development of the Arctic zone territories of the Russian Federation and the sustainable development of small indigenous minorities of the North
- entering into force the agreement on strengthening of Arctic scientific cooperation in May 2018 developed in accordance with the Arctic Council decisions
- assuring high living standards in Arctic regions via an initiative to modernise civil infrastructure and housing facilities, provide accessible and high-quality healthcare to all citizens, advance professional training relevant to Arctic conditions and develop conventional industrial management practices to ensure employment of indigenous minorities



← The Ice Base of Baranov Cape.
© Arctic and Antarctic Research Institute. High-Latitude Arctic Expedition

- development of the Northern Sea Route ensuring sustainable operation of the Northern Sea Route as a unified national transport line, conducting projects to further develop and expand the Russian icebreaking fleet using modern technologies
- constructing a new railroad in the Yamalo-Nenets Autonomous District, the new “Northern Latitudinal Railway”, which will be 707 km long and located along the Arctic Circle
- establishing the federal nature reserve “Novosibirsky Islands”
- publishing the “National Atlas of the Arctic” containing a number of mutually agreed spatio-temporal information on the geographic, ecological, economic, historical, ethnographic, cultural and social features of the Arctic zone of the Russian Federation
- launching the floating observatory “North Pole” to provide research and monitoring of the natural environment in the latitudes of the Arctic Ocean
- launching the “Arctic-M” space system to obtain high-resolution hydrometeorological data for the Polar Regions of Earth in 2019

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

Annually the Russia Federation conducts about 50 marine scientific and exploratory expeditions in the Arctic. The Russian icebreaker fleet includes 40 ships, 5 of which are nuclear-powered. It is planned to put into operation a few more modern nuclear icebreakers.

Field Stations

Currently a stationary terrestrial network, consisting of 52 operating polar stations providing hydrometeorological information. The stationary terrestrial network is located in the coastal regions and on the islands of the Arctic Ocean in the Russian Arctic sector. Russian drift stations, which operate nearly year-round, conduct a comprehensive research programme on oceanography,

glaciology, meteorology, aerology, geophysics, hydrochemistry, hydrophysics and marine biology. The modern coastal scientific infrastructure in the Arctic regions of the Russian Federation includes the Russian Research Center located on the Svalbard archipelago, the research stations on Samoylovsky Island, the “Ice Base of Baranov Cape”, the hydrometeorological observatory in Tiksi, the network of scientific research stations on the Yamal peninsula and other objects.

Satellites

Currently the Russian Arctic remote sensing system consists of 7 satellites in polar orbit, including:

- The “Resurs-P” satellite that was launched in 2013 to study natural resources.
- The “Canopus-B-IK” satellite, launched in 2017, is used for operative monitoring of man-made and natural emergency situation.
- The “Meteor-M” satellite was launched in 2014 and is used to monitor the Earth in sun-synchronous orbits.
- The geostationary hydro-meteorological “Electro-L” satellite was launched in year 2015.
- The “Canopus-B № 3” and “Canopus-B № 4” were launched in year 2018. These satellites are for operative monitoring of man-made and natural emergency situation.

Point of contact:

The Ministry of Science and Higher Education of the Russian Federation

(<http://minobrnauki.gov.ru>)

The Federal Service for Hydrometeorology and Environmental Monitoring

(<http://www.meteorf.ru/>)

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SPAIN

Spain promotes polar scientific research that respects regional legislation and fosters international cooperation out of the conviction that these extreme regions of the Earth, the Arctic and the Antarctic, must be used for peaceful means and in a sustainable manner.

Spain considers scientific research findings to be vitally important sources of knowledge of the environmental processes and risks that climate change can bring to our planet; for our ability to predict the impact of these variations on Arctic populations; and to foresee the possible effects on people at lower latitudes.

Oceanographic activity
on the Arctic sea ice from
R/V Hesperides.
© Antonio Quesada



THE SPANISH ARCTIC STRATEGY

1. Fosters peacekeeping, environmental protection and security in the polar regions, and develops scientific and technical polar research in the framework of international cooperation.
2. Considers Spain's presence in the polar regions as an affair of State, and as the basis for its participation in all polar activities, both civilian and military.
3. Considers the impact of climate change on the polar regions and vice versa, protecting the polar environment on the basis of the precautionary principle, making use of the best available scientific knowledge, and adopting measures to reduce greenhouse gas emissions.
4. Supports Spain's involvement in all major polar organisations to ensure participation in activities associated with scientific research, environmental protection, nature reserves, energy, industry, resources, polar technologies, bioprospecting, tourism, transport, fisheries and support for the lifestyles and cultures of the indigenous Arctic populations.
5. Considers the importance of action in the social and human spheres, pursuant to resolutions adopted by the Arctic coastal states. The views and opinions of indigenous communities must be taken into account.
6. Aligns with the Arctic strategies developed by the EU and encourages active participation in the design and development of corresponding policies.
7. Considers the option of becoming a full member of the Barents Euro-Arctic Council (BEAC), taking into account, among other factors, the EU's involvement in BEAC, and the major energy resources existing in the Barents region. Spain is currently an observer at the CBSS (Council of the Baltic Shore States).
8. Fosters the creation, within the framework of the EU Council, of a specialized commission devoted to polar issues (CPOLAR) as part of the EU's Common Foreign and Security Policy (CFSP).
9. Promotes the necessary measures for free, safe, and environmentally-friendly trans-Arctic maritime transit, in strict compliance with the 1982 UNCLOS and the IMO's International Code for Ships Operating in Polar Waters (Polar Code), the natural multilateral framework for managing navigation issues, including polar navigation.



ARCTIC RESEARCH FUNDERS

The recently created **Spanish Agency for Research** funds research projects in all disciplines. The Agency does not prioritize topics for support, and thus, potentially any discipline of scientific or humanities research may be funded, depending on the intellectual merit and broader impacts of the proposed work. Moreover, Spanish researchers frequently apply and lead European projects, on Arctic-related themes, through Horizon 2020.

MAJOR ARCTIC RESEARCH INITIATIVES

Ongoing research initiatives span several disciplines, including terrestrial and freshwater research, glaciology, oceanography, and sustainable fishing. Initiatives on



← Glacier in Svalbard.
© Antonio Quesada

glaciology, oceanography, aerosols and atmospheric science are being evaluated for future consideration.

- **Biodiversity of Arctic Terrestrial and Freshwater Ecosystems.** CLIMARCTIC. The initiative is aimed at studying the effects of climate change on the diversity and genetic functional attributes (nutrient and carbon cycling) of a High Arctic terrestrial microbiome in soils, wetlands and lakes.
- **Ice Thickness of Svalbard and Greenland Glaciers.** The goal is to follow and forecast the ice dynamics and mass balance changes of small glaciers in the Arctic, as a consequence of climate change.
- **Arctic glaciers and their contribution to sea-level-rise.** The goal is to estimate the iceberg calving and submarine melting in Arctic tidewater glaciers combining oceanographic, glaciological and remote sensing observations with modelling of glacier thermo-mechanics and fiord water circulation.
- **GLACKMA.** Monitoring of the glacial melting in both polar zones, considering the catchment hydrology and variations in the liquid water balance.
- **Coupling Physical Oceanography to Marine Biology through Climate Change.** To reconstruct the mechanisms of marine sediment transport and dispersal during the last deglaciation stage of the Svalbard/Barents Sea Ice Sheet, and to evaluate the effect of sediment laden melt-water plumes on ocean circulation, benthic habitats and sediment accumulation.
- **Interactions atmosphere-ice-ocean.** To identify atmospheric aerosols emitted in the Arctic, their biological origin and their impact on the indirect radiative effect.

- **AERONET.** This is a long-term international project monitoring aerosol optical depth in the Arctic.
- **Polar Fisheries.** Monitoring the effects of global change on the Arctic fisheries, in the context of sustainable and ecologically responsible fisheries.
- **Climatology.** Modelling refinements of Arctic sea-ice predictability and prediction, and reconstructions or re-analyses of the Arctic sea ice conditions over the past 50 years.

ARCTIC RESEARCH INFRASTRUCTURE

Spain does not have terrestrially based infrastructure in the Arctic, but our strategy has been to pursue the sharing of such, with other nations, through agreements. By virtue of these, our scientists have been conducting research in many Arctic locations, including the US, Greenland, Scandinavia, Canada, Svalbard and Siberia. New polar vehicles, such as a wind sledge, are being developed by Spain, as are the means for ultrapure sampling, which has been successfully deployed in Arctic and Antarctic expeditions.

Research Vessels

BIO Hespérides (Polar Ship Lloyd Ice Class 1C), and BO Sarmiento de Gamboa have been operating in both polar regions.

Point of contact:
Spanish Polar Committee
 (www.ciencia.gob.es/portal/site/MICINN/CPE)
Spanish Polar Research Programme
 (www.ciencia.gob.es)

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SWEDEN

The overarching goal of Swedish research policy, including that for polar research, is that Sweden should be a prominent research nation, where research and innovation are performed with high quality and contribute to the development of society and the competitiveness of industry. Sweden's policy is to play a leading role in international polar research.

Oden during the Petermann Expedition 2015.
© Swedish Polar Research Secretariat



ARCTIC RESEARCH FUNDERS

Two funding agencies, Swedish Research Council and The Swedish Research Council Formas, are the primary funders of polar research. Research infrastructure for polar research is funded and provided by the Swedish Polar Research Secretariat.

The Swedish Research Council. The council funds fundamental research in all areas. Regarding polar research it has in addition to research funding also a mission to support long-term planning of research in polar areas in cooperation with the Research Council Formas and the Swedish Polar Research Secretariat and to create opportunities for Swedish scientists to participate in polar expeditions and to cooperate and collaborate internationally in polar research.

The Research Council Formas. The council funds fundamental and mission-oriented research in environment, agriculture and spatial planning. A focus of Formas is climate-related research.

The Swedish Polar Research Secretariat. The Secretariat's primary mission is to organise and provide infrastructure for polar research expeditions. The Secretariat runs the research-equipped icebreaker Oden, the field station Abisko, and two research stations on Antarctica, Svea and Wasa.

The Swedish Research Council and the Research Council Formas evaluate and fund polar research projects. The Swedish Polar Research Secretariat provides the logistics and infrastructure necessary to perform the research. The three agencies work together to plan scientific expeditions.



MAJOR ARCTIC RESEARCH INITIATIVES

Swedish polar research, which primarily focuses on the Arctic Ocean and the surrounding coastal areas, uses the icebreaker Oden as a platform for scientific experiments, observations, and other means of data collection. Expeditions are often collaborative efforts with other countries, and foreign scientists are welcome to participate in Swedish expeditions.

In 2018, a collaborative expedition with the United States (National Science Foundation) using icebreaker Oden focused on enhanced understanding of bio-geo-chemical processes contributing to cloud formation in the Arctic. These are of crucial importance to improve the knowledge of the weather system and will enhance weather and climate predictions. The expected enhanced process understanding will support the interpretations of the data collected during the MOSAiC-programme. The cruise will also contribute to the data collection of the WMO campaign Year of Polar Prediction (YOPP). Another strong Swedish focus in field-based science has involved a multi-year pan-Arctic field campaign



← The Abisko Research Station
in Abisko National Park.
© Swedish Polar Research
Secretariat

investigating the effects of past, present and future climate change on Arctic ecology with specific focus on Arctic islands as ecological refuges.

Research topics are generally determined through the evaluation of proposals from university researchers. There are on-going polar research initiatives at most universities and colleges. Climate research centres exist at universities in Stockholm and Lund. Marine research centres are established at universities in Stockholm, Umeå, and Gothenburg. A centre for interdisciplinary arctic research is located at Umeå University with studies in medicine, natural sciences, social sciences and humanities.

ARCTIC RESEARCH INFRASTRUCTURE

The Swedish Polar Research Secretariat is responsible for the main Swedish polar research infrastructures, the icebreaker Oden, the Abisko scientific station, Tarfala Research Station, and SITES Research Locations.

Vessels

- **Research-equipped icebreaker Oden, and aided by other Swedish icebreakers as required**
Swedish icebreaker Oden is 108 meters long and displaces 13 kilotons.

Field stations

- **Abisko Scientific Station, The Tarfala Research Station, SITES.** The Abisko Scientific Station is run by the Swedish Polar Research Secretariat. The station is in the Abisko national park, 200 km north of the Polar Circle. The Abisko Scientific Station began operating in 1910 following temporary operations since 1903. Continuous meteorological and scientific measurements have been recorded there since 1913. The station now holds a unique environmental record that extends over 100 years, and serves the basis for some 3,000 scientific publications. Abisko hosts about 200 individual scientists per year.

- **The Tarfala Research Station**, run by Stockholm University, in the Tarfala Valley, has been systematically monitoring certain glaciers since 1910, and annually monitoring the largest glacier since 1946. Starting in 1980, all glaciers in the valley have been monitored.
- **Swedish Infrastructure for Ecosystem Science (SITES)**, funded by the Swedish Research Council, is nationally coordinated infrastructure for terrestrial and limnological field research. The research locations are situated along a gradient from arctic, to sub-arctic, to temperate climate zones.

Upper atmosphere studies

- **European Incoherent Scatter Scientific Association, (EISCAT)** operates three incoherent scatter radar systems in Northern Scandinavia to study the interaction between the Sun and the Earth as revealed by perturbations in the ionosphere and the magnetosphere. The system is currently being upgraded to EISCAT_3D, which is a multistatic radar with five antenna systems to measure the geospatial environment and its coupling to the Earth's atmosphere from its location in the auroral zone at the southern edge of the northern polar vortex.

Point of contact:

Ministry of Education and Research
(www.regeringen.se)

The Swedish Research Council
(www.vr.se)

The Swedish Research Council Formas
(www.formas.se)

The Swedish Polar Research Secretariat
(www.polar.se)

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SWITZERLAND

Scientific exploration of the cryosphere is of great importance to Switzerland, a country whose territory is largely composed of mountain ranges containing numerous glaciers. Swiss scientists collaborate with others around the world to study the climate conditions and ecosystems of mountainous and polar regions. The impacts of human-induced changes and their consequences on ecosystems and the global climate are at the forefront of their research.

Swiss Camp on the
Greenland ice sheet
© Konrad Steffen – WSL



Switzerland's research is multidisciplinary and improves the understanding of the world's climate system. It reveals the past behaviour of this system and makes future predictions about it. Swiss scientists participate in many Arctic research projects, often with partners from the Arctic Council member states. Since 2017, Switzerland is an Observer State to the Arctic Council. The Observer status will foster Switzerland's long-lasting and reliable commitment to research excellence and to peaceful international cooperation. As one of the global leaders in research, innovation and technology, Switzerland actively advances scientific knowledge to limit the environmental and socio-economic impacts of Arctic change.

ARCTIC RESEARCH FUNDING

Research funding is awarded on a competitive basis, according to qualitative assessment criteria. The Federal government provides funding through the federal agency **Swiss National Science Foundation (SNSF)**. The government also provides funding to research institutes within the Domain of the Federal Institutes of Technology as well as to 30 other research institutes. There is no special funding window for polar research.

Switzerland is fully associated to **Horizon 2020** and is involved in many projects linked to the climate and polar topics currently underway. In 2018, the Swiss Polar Institute (SPI) launched the **Polar Access Fund** (field trips for young researchers in polar regions) and the SPI Exploratory Grants (seed funding for Polar-related projects).

MAJOR SWISS ARCTIC RESEARCH INITIATIVES

The Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) performs world-class research on snow, the atmosphere, natural hazards, permafrost



and mountain ecological systems. Other centres of excellence include the **High Altitude Research Station on Jungfrauoch**, the two Federal Institutes of Technology in Zurich and Lausanne, and various Swiss universities.

For more than a century, the **World Glacier Monitoring Service (WGMS)** and its predecessor organisations have compiled and disseminated standardised data on glacier fluctuations. Thereto, the WGMS annually collects glacier data through its **scientific collaboration network** that is active in more than 30 countries.

The University of Bern hosts the division for Climate and Environmental Physics (CEP) with its well-earned reputation of excellence in polar ice core research, the Oeschger Centre for Climate Change Research (OCCR) and also **the Future Earth core project** Past Global Changes (PAGES).

In 2016, **the Swiss Polar Institute** was founded by the Swiss Federal Institute of Technology in Lausanne (EPFL), acting as Leading House, WSL, the Swiss Federal Institute of Technology in Zurich (ETHZ), the University of Bern and Editions Paulsen. Its aim is to support the Swiss Polar community with dedicated funding, create



← Sphinx Observatory
© Jungfraubahnen 2017

new opportunities through their own expeditions or international collaborations and to spark the polar research interests of a new generation of young scientists and explorers.

The Swiss Committee on Polar and High Altitude Research (SCPHAR) of the Swiss Academies of Arts and Sciences, acts as the platform of exchange and coordination for Swiss scientists at various international research institutions, and coordinates participation in the scientific work of Arctic Council, the International Arctic Science Committee (IASC), the Scientific Committee on Antarctic Research (SCAR), and the Climate and Cryosphere project of the World Climate Research Programme (WCRP).

The profound knowledge of Swiss scientists in glaciology finds its hallmark in many international research projects such as the long-lasting project by WSL, ETHZ and the University of Colorado at Boulder, which is investigating the impact of climate change on the Greenland ice sheet. The test site, at “Swiss Camp” (see the first page) is used to calibrate the ice sheet’s 20 automatic weather stations that deliver data for **the Greenland Climate Network** (GC-Net).

Swiss researchers will also contribute actively to the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAIC) initiative, leading two projects (one on snow and the other on atmospheric measurements) which will be implemented in 2019–2020.

Switzerland has recently organised and contributed to the international conference **POLAR2018**, a joint activity of SCAR and IASC that took place in Davos, Switzerland from 15–26 June 2018. At this occasion, the SCAR meetings, the Arctic Science Summit Week (ASSW), the Arctic Observing Summit and the Open Science Conference have been hosted by WSL under the patronage of SCPHAR.

ARCTIC RESEARCH INFRASTRUCTURE

Field stations on Greenland

Swiss Camp (69°N, 49°W), established in 1990, is situated at about 1,100 m elevation, 70 km northeast of Ilulissat. Summit Station, run by the US National Science Foundation, is located on the highest point (3216 m) of the Greenland ice sheet at (72°N, 38°W). At both locations, Swiss researchers have maintained a number of long-term climate monitoring instruments over the past 20 years. The University of Bern has been a partner of deep ice core drilling projects on the Greenland ice sheet for decades, with changing drill and campsite locations. A deep drilling is currently carried out at EGRIP (75°N, 38°W).

Field stations in Switzerland

Research Station and Sphinx Observatory at Jungfraujoch, together with the two astronomical observatories, Gornergrat South and Gornergrat North, provide the infrastructure and support for international scientific research to be carried out at an altitude of 3,000–3,500 meters above sea level in a high alpine climate and environment, accessible by the Jungfrau railway.

Satellites

While Switzerland does not operate its own satellite network, Swiss researchers use data from NASA and/or ESA and EUMETSAT satellite systems.

Point of contact:

Prof. Hubertus Fischer

(President, Swiss Committee on Polar and High Altitude Research – SCPHAR)

Dr. Christoph Kull

(Secretary SCPHAR)

Prof. Konrad Steffen

(Director, Swiss Federal Institute for Forest, Snow and Landscape Research – WSL)

Ms. Danièle Rod

(Executive Director, Swiss Polar Institute – SPI)



THE REPUBLIC OF KOREA

Korea's primary Arctic research and policy goals have been: (1) to contribute knowledge, expertise, and understanding of the Arctic region to the global community; (2) to enhance international cooperation in the region; and (3) to better connect the results of scientific research with policy making and sustainable business development. The aforementioned goals were reflected in the Master Plan for Arctic Policy released in December 2013. The new five-year Arctic Master Plan has reached its final stage of completion, and it will become soon available.

Overview of the Arctic Dasan Station and Ny-Alesund research village.
© KOPRI



Developing sincere and effective partnership with Arctic states, Arctic Council, Indigenous communities and other partners, strengthening scientific research to address the common challenges faced by the Arctic and global communities, and enhancing mutually beneficial economic cooperation/connectivity will remain among others as key elements that shape Korea's Arctic policy for the coming years.

The most important motivation for Korea to pursue Arctic Science is to understand the nature of rapid Arctic changes and its impact to the regional and global climate systems. Furthermore, in recognition of the geographical proximity of Korea to the Arctic, it is also critical to determine how changes in the Arctic affect the Korean Peninsula and prepare responses to its derivative aspects such as prediction of weather patterns, sustainable utilization of marine living resources, and shipping opportunities. This will form the basis for Korea to better prepare for the future that Arctic changes may bring forth. Korean Arctic research dates back to 1999, when Korean scientists for the first time sailed to the Arctic Ocean on a scientific expedition. Currently, Arctic scientific research is conducted by or managed through the Korea Polar Research Institute (KOPRI), the lead agency of the national polar programme.

ARCTIC RESEARCH FUNDERS

Ministry of Oceans and Fisheries. The Ministry of Oceans and Fisheries (MOF) supports KOPRI's major in-house and ministry-commissioned projects such as the 'Korea-Arctic Ocean Observation System', 'Investigation of submarine resource environment and seabed methane release in the Arctic' and 'Development and Application of the Korea Polar Prediction System for Climate Change and Weather Disaster'.



Ministry of Science and ICT. The Ministry of Science and ICT (MSIT) supports research projects such as the 'Circum-Arctic Permafrost Environment Change Monitoring, Future Prediction' and 'Changes in environment and coastal geomorphology of Svalbard fjord'.

MAJOR ARCTIC RESEARCH INITIATIVES

Korean Arctic science currently includes marine and terrestrial observations, prediction, and paleo environmental reconstruction. A few key examples are:

1) Korea-Arctic Ocean Observing System (K-AOOS)

The objectives of K-AOOS are to identify key environmental parameters (physical/biogeo chemical) in rapid transition due to the decrease of sea ice in the western Arctic Ocean (Chukchi/ East Siberian Seas), and to predict environmental change patterns.



← IBRV Araon, Conducting research over Arctic sea ice.
© KOPRI

2) Circum-Arctic Permafrost Environment Change Monitoring, Future Prediction (CAPEC)

The objectives of CAPEC are to detect and understand circum-Arctic permafrost environmental change, to develop a prediction model for future change, and to develop practical technologies based on permafrost observation nodes.

3) Development and Application of the Korea Polar Prediction System (KPOPS) for Climate Change and Weather Disaster

The objectives of KPOPS are to understand and predict links between Arctic and mid-latitude weather and climate change by developing state-of-the-art modelling tools, and to study the Arctic polar vortex, which is thought to be responsible for global weather extremes (cold surges, heat waves).

4) Investigation of submarine resource environment and seabed methane release in the Arctic

This project is designed to acquire basic data and information on Arctic submarine geological environments to study the release of subsea methane, a potent greenhouse gas.

5) Early animal evolution and the primitive Earth system of North Greenland

This project aims to elucidate the evolution of early animals of the Cambrian and the development of the primitive Earth system, by examining the geological data of North Greenland.

6) Research on analytical technique for satellite observation of Arctic Sea Ice (2018–2022)

This project aims to develop prototype satellite data archiving and management system and advance remote sensing data processing and analysis techniques for Arctic sea-ice monitoring.

In summary, the major foci of Korean Arctic science are:

- Research on environmental change, greenhouse gas dynamics, and associated responses of marine and terrestrial ecosystems across a range of physical and geographical settings
- Research on the marine geological and biological history and evolution of the Arctic
- Observation, simulation and prediction modelling of the Arctic

ARCTIC RESEARCH INFRASTRUCTURE

Vessel

The icebreaker research vessel Araon supports multidisciplinary scientific research encompassing geophysics, biology and oceanography and provides logistics to the stations in the Polar regions. A planning and preliminary feasibility study is underway for a second research icebreaker.

Field Station

The Arctic Dasan Station is located in Ny-Ålesund, on the island of Spitsbergen in Norway. The station supports a wide range of atmospheric and biological science.

Observation nodes

- Cambridge Bay, Canada
- Council, Alaska, USA
- Svalbard, Norway
- Nord station, Greenland
- Stórhöfði, Iceland
- Baranovo, Russia

Point of contact:
Korea Polar Research Institute
(KOPRI: eng.kopri.re.kr)

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UNITED KINGDOM

To support independent and rigorous research of the highest quality to address the most important questions, to help understand this key part of the global system and to develop practical responses in the face of unprecedented change. The UK's approach recognises that increasing international collaboration is vital for tackling the most pressing research questions.

RRS Sir David Attenborough, entering service in 2019.
© Rolls-Royce



ARCTIC RESEARCH FUNDERS

Natural Environment Research Council (NERC) supports most of the UK's natural science research in the Arctic. This is via national capability funding to research centres such as the British Antarctic Survey (BAS), British Geological Survey, the National Centre for Atmospheric Science, the National Oceanography Centre (NOC) and research grants to universities and research centres, including major Arctic-themed programmes.

Research Councils, such as those for Engineering and Physical Sciences, Arts and Humanities and Economic and Social research support a range of research activity in the Arctic. Now brought together with NERC & Innovate UK under the leadership of United Kingdom Research and Innovation (UKRI), there will be increasing opportunities for collaborative funding and research.

Government Departments, such as the Department for Business, Energy and Industrial Strategy (BEIS), the Foreign and Commonwealth Office, the Ministry of Defence and the Department for Transport as well as their delivery agencies, provide support to facilitate research, often in coordination with other national partners. For example, the **Meteorological Office** supports and delivers significant Arctic research, often in partnership with research institutions. BEIS are directly supporting a UK-Canada Arctic Bursary Programme and participation in MOSAiC.

Other types of organisations also support projects and research in connection with the Arctic, inter alia: The **Royal Society**, which is the independent scientific academy of the UK; The **British Council**, which is the UK's international organisation for cultural relations and educational opportunities; and, the **Leverhulme Trust**, which is a large national grant-making foundation.



MAJOR ARCTIC RESEARCH INITIATIVES

NERC Changing Arctic Ocean: Implications for Marine Biology and Biogeochemistry. This £16m programme (2017–2022) explores the effects of changes to the physical environment (ice and ocean) on the marine ecosystem and the associated biogeochemical functioning of the Arctic Ocean. Its four initial projects involve 17 UK research institutions and 70 scientists as well as international partners from Norway, Canada, Germany, Switzerland, the USA, Poland, Denmark and many more. In the latest phase, 10 three-year joint UK-Germany projects were announced.

The EU Arctic Cluster. Funded by Horizon2020, this has broad participation of UK universities and research centres (specifically in EU-PolarNet, Blue-Action, APPLICATE, ARICE and INTERACT programmes). The UK is committed to working with partners in the EU and beyond to maximise international cooperation across these programmes and delivering quality research and advice for decision makers.

MOSAIC. In March 2017, the UK became the first formal partner to MOSAiC, outside the expedition organisers of Germany, Russia and the USA. With over £2m financial investment from BEIS and NERC, UK researchers will be supported to conduct research as part of this unique expedition to the Arctic Ocean in 2019–20.



← NERC Arctic Research Station, Ny-Ålesund, Svalbard, Norway.
© British Antarctic Survey

Centre for Polar Observation and Modelling (CPOM).

Operates as a multi-site centre studying polar latitudes. It uses theoretical and laboratory-derived understanding to form models of interactions between the ice, ocean and atmosphere, and uses ground and satellite observations to test these and other climate models. In the Arctic, CPOM quantifies sea ice volume and transport, ocean circulation, and Greenland ice sheet mass balance, including its contribution to global sea level rise.

ARCTIC RESEARCH INFRASTRUCTURE

Vessels & autonomous vehicles

NERC maintains research vessels and vehicles capable of supporting Arctic research activities.

- The ice-strengthened vessel ***RRS Sir David Attenborough*** will be launched in autumn 2018 and fully enter service in 2019. She will provide a step-change in the ability to carry out complex and multi-task research in the polar regions. As part of the EU ARICE icebreaker consortium, trans-national research access will be provided to the vessel in the Arctic.
- ***RRS James Clark Ross*** and ***RRS Ernest Shackleton*** are ice-strengthened vessels and the ***RRS James Cook*** and ***RRS Discovery*** are 'blue water' vessels – all are capable of Arctic work.
- Research centres such as NOC, BAS, and the Scottish Association for Marine Sciences, operate a fleet of autonomous vehicles, including AUTOSUB3, with new investment in AUTOSUB 6000 and ALR-1500 to deliver new and distinct capabilities for Arctic science.

Aircraft

NERC owns six specially-equipped aircraft capable of carrying out scientific measurements and logistical support to science projects in the Arctic.

- Four Twin Otters (DHC-6) and a Dash-7 (DHC-7) operated by BAS; and a BAe-146 large atmosphere research aircraft, managed by the Facility for Airborne Atmospheric Measurements.

Field stations

- ***Ny-Ålesund***. The UK Arctic Research Station in Ny-Ålesund, Svalbard (Norway) is funded by NERC and operated by BAS. It provides facilities and accommodation for researchers to carry out environmental science research. Access by international researchers is welcome through the EU's ***INTERACT*** programme.

Satellites

The UK is a key partner in satellite systems including, through CPOM, CryoSat2 operated by the European Space Agency (ESA) which measures the thickness of sea ice and monitors changes to the Greenland ice sheet. Data used from other satellites includes:

- ***Sentinel-1*** and ***Sentinel-3 (ESA)*** monitoring sea ice, glaciers and ice sheets.
- ***ENVISAT*** and ***ERS 1+2 (ESA)*** in determining recent changes to the Arctic.
- ***Terrasar-X*** (DLR)
- ***ICESat-1*** (NASA)
- ***ALOS*** (JAXA)
- ***AltiKa*** (CNES-ISRO)

Point of contact:

Natural Environment Research Council Arctic Office

(<http://www.arctic.ac.uk>)

UK Arctic and Antarctic Partnership

(<https://ukaapartnership.org>)

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UNITED STATES OF AMERICA

U.S. policy includes enhancing scientific monitoring and research into local, regional, and global environmental issues, involving the Arctic's indigenous communities, and promoting international scientific collaboration (National Security Presidential Directive 66: Arctic Region Policy). The policy, implemented by the Interagency Arctic Research Policy Committee (IARPC) and the U.S. Arctic Research Commission (USARC), is designed to increase understanding of the Arctic through scientific research and indigenous knowledge in support of science-informed decision-making.

A Saildrone and the NOAA fisheries and oceanographic research vessel Oscar Dyson in the Bering Sea in summer 2016.
© NOAA/LT. Mark Frydrych



ARCTIC RESEARCH FUNDERS

- **National Aeronautics and Space Administration (NASA).** The Earth Science Programme is a comprehensive, global approach to Earth System Science. Observations, research, and modelling of Arctic oceans, atmosphere, ice, permafrost, carbon, and ecosystems strive to understand Arctic systems and the Arctic's role in the global system. Through this approach, NASA contributes to a better understanding of Arctic change, impacts, and resilience.
- **National Science Foundation (NSF).** NSF supports basic research that advances understanding of engineering, physical, biological, geological, chemical, education, social and cultural processes in the Arctic, and the interactions and connections of oceanic, terrestrial, atmospheric, biological, and human systems within the Arctic and between the Arctic and global systems.
- **National Oceanic and Atmospheric Administration (NOAA).** Supports research to: (1) forecast sea ice; (2) strengthen foundational science to understand and detect climate and ecosystem changes; (3) improve weather and water forecasts and warnings; (4) enhance national and international partnerships; (5) improve stewardship and management of ocean and coastal resources; and (6) advance resilient and healthy communities and economies.
- **Department of the Interior (DOI).** Protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honours its trust responsibilities or special commitments to Alaska Natives and other indigenous peoples.
- **Department of Energy (DOE).** Research advances predictability of the Earth system for advanced solutions to the Nation's energy challenges. In



the Arctic, DOE supports Atmospheric Radiation Measurement (ARM) facilities on Alaska's North Slope; the Next Generation Ecosystem Experiment-Arctic (NGEE-A); and integration of these within the Energy Exascale Earth System Model and the Regional Arctic System Model.

- **Department of Defense (DOD).** The U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory provides scientific and engineering support. The Office of Naval Research supports research to better understand and predict the physical environment of the Arctic Ocean at a variety of time and space scales via new technologies and integrated models.
- **Department of Health and Human Services (DHHS).** The National Institutes of Health and the Centers for Disease Control and Prevention conduct and support research to improve human health in the Arctic.

MAJOR ARCTIC RESEARCH INITIATIVES

- The NSF "**Navigating the New Arctic**" initiative will transform understanding of rapid changes in the biological, physical, chemical and human systems by establishing an observing network of mobile and fixed platforms across the Arctic, and enhanced tools for data assimilation, modelling and synthesis.



← Installation of soil temperature data logger for NSF sponsored Arctic field programme.
© University of Alaska Fairbanks/Santosh K. Panda

- The DOE **NGEE-A** project is improving climate model predictions by advancing understanding of coupled processes in Arctic terrestrial ecosystems.
- The NASA **ICESat-2** mission will measure ice sheet elevation, sea ice freeboard, land topography and vegetation characteristics to quantify changes in ice sheet mass balance, sea ice thickness, and large-scale biomass changes.
- The ONR **Stratified Ocean Dynamics of the Arctic** (SODA) research initiative investigates ocean heat, momentum, and buoyancy in the Beaufort Sea/Canada Basin to better understand upper ocean stratification and circulation and their role in sea ice behaviour and acoustic propagation.
- **NOAA** supports sustained and integrated networks of Arctic observations through the U.S. interagency Arctic Observing Network, and, in partnership with NSF and others, the Distributed Biological Observatory, a multidisciplinary Arctic Ocean sampling programme.
- The DOI-initiated **Marine Arctic Ecosystem Study** (MARES) is a public-private initiative of U.S. and Canadian partners addressing the structure and function of the Beaufort and Chukchi seas ecosystems via field campaigns using physical, chemical and biological sensors.

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

The U.S. has three vessels capable of supporting a wide range of Arctic research activities. NSF's **R/V Sikuliaq** is a global class, ice-capable research vessel. The U.S. Coast Guard operates the **USCG Healy**, a medium icebreaker, and the **USCG Polar Star**, a heavy icebreaker. Plans for a new heavy icebreaker are in progress.

Field Stations

- **Toolik Field Station, Beaufort Lagoon Ecosystem, Bonanza Creek and Northern Gulf of Alaska** are NSF-supported Long-Term Ecological Research (LTER) sites in Alaska that host biological and physical sciences.

- **Utqiavik, Alaska** hosts a DOE Atmospheric Radiation Measurement facility, and a NOAA atmospheric monitoring observatory.
- **Summit Station**, atop the Greenland Ice Sheet, is managed by NSF in cooperation with the Government of Greenland. The station supports meteorology, atmospheric chemistry, glaciology and astrophysics research, and long-term atmospheric monitoring by NOAA.

Satellites

The U.S. operates many polar-orbiting satellites, and shares satellite missions with other countries, to observe the Arctic environment and for other research purposes. Chief among the current instruments and missions are:

- **MODIS** (Moderate Resolution Imaging spectroradiometer on the NASA Terra and Aqua satellites)
- **ICESat-2** (Ice, Cloud, and Land Elevation Satellite-2; NASA, scheduled for launch in 2018)
- **CERES** (Clouds and the Earth's Radiant Energy System on NASA's Terra and Aqua satellites, on NASA-NOAA's Suomi-NPP satellite, and on the NOAA-20 satellite)
- **AIRS** (Atmospheric Infrared Sounder on the NASA Aqua satellite)
- **VIIRS** (Visible Infrared Imaging Radiometer Suite on the Suomi NPP satellite; NASA, NOAA & DOD)
- **SSMIS** (Special Sensor Microwave Imager/Sounder on the DMSP satellite; DOD & NOAA)
- **NOAA-20** (Formerly JPSS-1, environmental observations; NOAA)
- **Landsat-8** (USGS, NASA)

Point of contact:
Interagency Arctic Research Policy Committee
(IARPC: <http://iarpccollaborations.org>)
U.S. Arctic Research Commission
(USARC: <http://arctic.gov>)

ARCTIC COUNCIL INDIGENOUS PEOPLES'S SECRETARIAT

The IPS is a support secretariat for the six indigenous organisations that have Permanent Participant status in the Arctic Council: Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International, Inuit Circumpolar Council, Russian Association of Indigenous Peoples of the North, and the Saami Council. According to the founding document of the Arctic Council – called the Ottawa Declaration – Permanent Participants have the right to “active participation and full consultation” at all levels of the Arctic Council.

Inuit people welcome the Arctic Ministers with a drum dance ceremony. 2015, Iqaluit, Nunavut, Canada
© Linnea Nordstrom



The IPS does not speak for the Permanent Participants. Instead, the IPS (1) creates opportunities for Permanent Participants to speak for themselves and (2) provides Permanent Participants with necessary information and support to participate in the work of the Arctic Council.



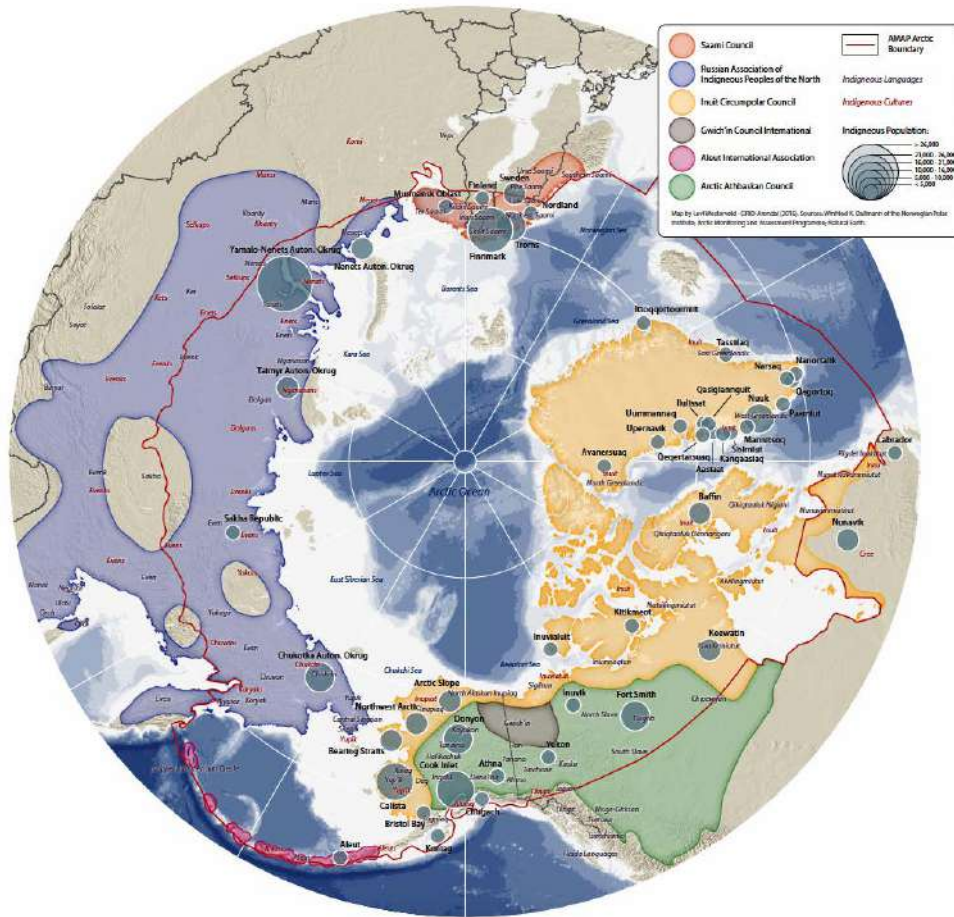
ARCTIC RESEARCH FUNDERS

The IPS is managed by a Board comprised of 9 members, of whom 6 represent the Permanent Participants and 3 represent the Arctic States. The IPS has its Work Plan and a designated budget. Norway and the Kingdom of Denmark contribute equally to the IPS basic budget, while other Arctic States contribute to the IPS funding for implementation of the Arctic Council's research and outreach projects. The IPS seeks contributions from elsewhere to assist and support the Permanent Participants in the work of the Arctic Council.

MAJOR ARCTIC RESEARCH INITIATIVES

The IPS endeavours to:

- **Facilitate** participation of indigenous peoples' organisations in the work of the Arctic Council; assist and provide secretarial support to the Permanent Participants primarily in Arctic Council activities; facilitate and assist the Permanent Participants to prepare and submit proposals relevant to the work of the Arctic Council; facilitate the presentation of the perspectives of indigenous peoples in the Council's Working Groups and in meetings of Senior Arctic Officials and Ministers.
- **Enhance** the capacity of the Permanent Participants to pursue the objectives of the Arctic Council; assist the Permanent Participants in developing their internal capacity to participate and intervene in the work of the Arctic Council; and assist the Permanent Participants in relation to their active participation and full consultation within the Arctic Council.
- **Facilitate** dialogue and communications among the Permanent Participants and Arctic Council subsidiary bodies; provide opportunities for cooperative and coordinated activities among the Permanent Participants and IPS; and facilitate meetings and communication between the Permanent Participants.
- **Support** the Permanent Participants in carrying out actions to maintain and promote sustainable development of indigenous peoples' cultures in the Arctic.
- **Gather** and disseminate information on, as well as provide and list sources of different forms of knowledge.
- **Contribute** to raising public awareness of Arctic Council issues through a regularly updated website and other publications.



← Permanent Participants of the Arctic Council.
© Produced by GRID-Arendal for the Indigenous Peoples' Secretariat. 2017

The map demonstrates the approximate scale of each Permanent Participant's boundaries, but not the exact area each organisation represents.

PERMANENT PARTICIPANTS

The Arctic Council Indigenous Peoples' Secretariat is located in the Fram Centre in Tromsø, Norway. However, the IPS facilitates the representation of Indigenous peoples across the Circumpolar North. Over 500,000 indigenous people live in the Arctic spanning across three continents, eight countries, and 30 million square kilometres. Six Permanent Participant organisations represent them in the Arctic Council.

Aleut International Association

AIA represents 19,000 Aleuts in the United States and Russian Federation living on a chain of islands in the North Pacific and Bering Sea.

Arctic Athabaskan Council

AAC represents approximately 45,000 people and 76 communities in Alaska (US), the Northwest Territories and Yukon (Canada).

Gwich'in Council International

GCI represents 9,000 Gwich'in across Alaska (USA), the Northwest Territories and Yukon (Canada).

Inuit Circumpolar Council

ICC represents 160,000 Inuit in Greenland, Canada, Alaska (USA), and Chukotka (Russian Federation).

Russian Association of Indigenous Peoples of the North

RAIPON represents 270,000 people and 41 various indigenous peoples of the North, Siberia and the Far East of the Russian Federation.

Saami Council

The Saami Council represents 100,000 Saami in Norway, Sweden, Finland, and the Kola Peninsula (Russian Federation).

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Arctic Council
Indigenous Peoples' Secretariat

INUIT CIRCUMPOLAR COUNCIL

Founded in 1977, the Inuit Circumpolar Council (ICC) is a major international, Indigenous non-governmental organisation representing approximately 165,000 Inuit of Alaska, Canada, Greenland, and Chukotka (Russia). The organisation holds Consultative Status II at the United Nations Economic and Social Council and is a Permanent Participant at the Arctic Council.

ICC 2018 General Assembly.
© Jacqueline Cleveland



To thrive in their circumpolar homeland, Inuit had the vision that they must speak with a unified voice on issues of common concern and combine their energies and talents towards protecting and promoting their way of life. The principal goals of the ICC are, therefore, to:

- Strengthen unity among Inuit of the circumpolar region;
- Promote Inuit rights and interests on an international level;
- Develop and encourage long-term policies that safeguard the Arctic environment; and
- Seek full and active partnership in the political, economic, and social development of circumpolar regions.

ICC holds General Assemblies every four years at which Inuit delegates from across the circumpolar region elect a new Chair and an Executive Council, develop policies, adopt resolutions and approve a declaration that will guide the activities of the organisation for the coming term. The General Assembly is the heart of the organisation, providing an opportunity for sharing information, discussing common concerns, debating issues, and strengthening the bonds between all Inuit.

ICC works collectively to address issues of concern to Inuit and is guided by Indigenous Knowledge¹ (IK). Recognizing that both IK and science are necessary for building evidence-based information for use in decision-making and policy, much of our work aims to bring together science and IK.



Current ICC activities and programmes related to science and IK focus on food security, wildlife management, economic development, education, climate change, contaminants, biodiversity, shipping, use of Arctic waterways, Inuit health and well-being, information sovereignty, and monitoring.

ICC has placed national and global focus on addressing food security. The Alaskan Inuit Food Security Conceptual Framework: How to Assess the Arctic From an Inuit Perspective aids in educating and directing research to apply a holistic (ecosystem based) approach to understanding the Arctic, while emphasizing the connections between the health of people, animals, and plants, the different states of land, sea, and air, and the cultural fabric held together by language, cultural expression, and social integrity.

¹ Indigenous knowledge is a systematic way of thinking applied to phenomena across biological, physical, cultural and spiritual systems. It includes insights based on evidence acquired through direct and long-term experiences and extensive and multigenerational observations, lessons and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation. IK goes beyond observations and ecological knowledge, offering a unique 'way of knowing' to identify and apply to research needs which will ultimately inform decision makers.



← ICC 2018 General Assembly.
© Jacqueline Cleveland

ICC works at many levels to advocate for environmental stewardship and has brought the vision of Inuit led management and monitoring to the international community through the Pikialasorsuaq Commission. ICC maintains a strong voice bringing attention to the human dimensions of climate change on an international level, providing contributions to research and policy. For example, in 2008, ICC produced the report 'The Sea Ice is our Highway: An Inuit Perspective on Transportation in the Arctic' for the Arctic Marine Shipping Assessment.

More recently, ICC is working to define and implement international regulations and has negotiated an international treaty to take a precautionary approach to commercial fisheries in the Central Arctic Ocean.

ICC is engaged with monitoring initiatives through national programmes, Arctic Council initiatives, and the Sustaining Arctic Observing Networks (SAON). Under SAON, ICC and partners created the online Atlas of Community-Based Monitoring (CBM) & Indigenous Knowledge in a Changing Arctic. The atlas is a searchable inventory that maps CBM projects across the circumpolar Arctic. The atlas was expanded to include Inuit mental health and wellness programmes.

Contaminants and pollutants have accumulated in the Arctic environment and have magnified up the food chain, a concern amongst Inuit community for decades. Our concerns are further amplified with the increasing amount of long-range transport of contaminants and pollutants into the Arctic from across the globe, including (micro-)plastics, thawing permafrost, and the continued threat of persistent organic pollutants (POPs) and mercury. Therefore, ICC has been actively engaged in the negotiations and implementation of United Nation conventions addressing some of these contaminants, such as the Stockholm Convention on POPs and the Minamata Convention on Mercury.

Much of the research findings ICC brings forward in this context are generated in Arctic contaminant monitoring programmes, such as Canada's Northern Contaminants Programme and the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP). ICC is involved in these monitoring activities, and co-authors and reviews associated assessment reports. Examples include the AMAP Assessment 2015: Human Health in the Arctic and the 2011 AMAP assessment on Mercury in the Arctic.

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SAAMI COUNCIL

The Saami Council is an Indigenous Peoples Organisation founded in 1956. It has nine member organisations based in Finland, Norway, Sweden and the Russian Federation. The Saami Council has since its foundation been a spearhead in Saami political and cultural development.

© Saami Council



The primary aim of the Saami Council is the promotion of Saami rights and interests in the four countries where the Saami people are living. The Saami Council vision is to consolidate the feeling of affinity among the Saami people, to attain recognition for the Saami as a nation and to maintain the cultural, political, economic and social rights of the Saami in the legislation of the four states (Norway, Sweden, Russia and Finland) and in agreements between states and Saami representative organisations. The Saami Council participates in international processes on topics such as indigenous peoples, human rights and arctic and environment.

The Saami Council's activities are based on the decisions, statements, declarations and political programmes of the Saami Conference that takes place every fourth year, the last one in Trondheim, Norway, in February 2017.

The Saami Conference appoints the 15-member council that gathers approximately twice a year to discuss current issues regarding the rights and culture of the Saami and other indigenous peoples. Among the 15 members, four are elected to the Executive Board, one from each country. Ms Åsa Larsson-Blind from Sweden is elected as the president of the Saami Council.

The Saami Council organisation operates through thematic units, at present those are: Human Rights Unit, Arctic- and Environmental Unit, Cultural Unit and recently also an EU Unit. The Saami Council has a Cultural Committee that manages a cultural fund received from the Nordic Council of Ministers. The tasks of the committee are to increase and reach out with knowledge about the Saami culture, to improve the cooperation between cultural institutions and the Saami Council and to distribute cultural funds.



The Saami Council has decades of experience with promoting indigenous peoples' rights internationally, mainly through UN fora. It has played a major role in essentially all significant developments with regard to indigenous peoples' rights internationally. In recent years, the Saami Council has also gained significant expertise in promoting Saami rights domestically, particularly in relation to the extractive industry.

The Saami Council is one of six Permanent Participants of the Arctic Council. The Arctic and Environment Unit participates in the activities of the Arctic Council and its working groups to promote the Saami perspective and interests. The Saami Council also participates in the work of the UN Convention on Biological Diversity (CBD), United Nations Framework Convention on Climate Change (UNFCCC) and the Sustainable Development Goals.



← © Carl Johan Utsi

Healthy and productive ecosystems, both terrestrial and marine, are still the foundation for the Saami culture and identity. The protection of the natural resources and the environment, as well as sustainable development is therefore a high priority for the Saami Council. The Saami people hold unique knowledge about living and thriving in our part of the Arctic region – we call it the indigenous knowledge. In a rapidly changing Arctic, we do also need science and research to help us understand all the implications of change.

The Saami Council promotes the use of indigenous knowledge as a knowledge system that should be equally valued with science and should be an equal valued part of the knowledge basis for decision-making and policy development. In all processes the Saami Council participates in, we call for the best available knowledge, both science and indigenous knowledge to be the basis for decision-making and recommendations. Through our broad constitution with our member organisations, and the position as a representative of the Saami civil society being active on the international arena, we nominate Saami academics and knowledge holders to contribute their expertise in scientific assessments and research projects.

Within fields the Saami community might hold less expertise, we try to initiate pilot projects to increase the capacity. One such field is broad utilization of systematic community based monitoring.

The Saami Council has also over the years contributed with our perspectives and understanding of the Arctic environment in science cooperation organisations such as UArctic, IASC, SAON, IASSA, Arctic Science Summit Week and Arctic Observing Summit.

Point of contact:
Saami Council
 (www.saamicouncil.net)



SÁMIRÁÐÐI
 SAAMELAISNEUVOSTO
 SAMERÅDET
 COIŌ3 CAAMOB
 SAAMI COUNCIL

GWICH'IN COUNCIL INTERNATIONAL

Gwich'in Council International participates in research which supports effective decision-making on issues affecting our communities. GCI's research initiatives currently focus on renewable energy and economic decision-making.

Gwich'in Council International (GCI) represents 9,000 Gwich'in in the Northwest Territories (NWT), Yukon, and Alaska as a Permanent Participant in the Arctic Council. GCI supports Gwich'in by amplifying our voice on sustainable development and the environment at the international level to support resilient and healthy communities.

Inuvik, NWT.
© Sara French, GCI



GCI's membership consists of two representative bodies in Canada: Gwich'in Tribal Council (GTC), who represents the beneficiaries of the Gwich'in Land Claims Settlement Act in NWT and the Vuntut Gwitchin First Nation (VGFN), which is a self-governing First Nation in Old Crow, Yukon. The Council of Athabaskan Tribal Governments participates in GCI on behalf of Gwich'in in Alaska. Each member has their own particular research policies and goals for their region.

ARCTIC RESEARCH FUNDERS

Gwich'in Council International receives research funding from the Government of Canada. Gwich'in organisations partner with government, non-governmental organisations, and academic institutions on research initiatives.

MAJOR ARCTIC RESEARCH INITIATIVES

Council of Athabaskan Tribal Governments. The mission of CATG is to advocate and provide technical assistance to enhance the regional economy by protecting and supporting local employment and private enterprise; to protect and manage traditional tribal land and resources for future generations; to empower tribal governments; and to promote healthy living. It undertakes research to support this mission¹.

Heritage Resources Branch, Vuntut Gwitchin First Nation.

Undertakes research to preserve, protect, document and promote the culture and language of the Vuntut Gwitchin. See: <https://www.vgfn.ca/nrher.php>.

Gwich'in Renewable Resources Board: GRRB conducts or participate in wildlife research studies in the Gwich'in Settlement Area².

Gwich'in Social and Cultural Heritage Institute (now Gwich'in Department of Heritage). The objective of the Institute is to conduct research in the areas of culture, language and traditional knowledge so that this body of knowledge is recorded and available for future generations and the development of programmes appropriate for Gwich'in needs³.

Point of contact:
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¹ <https://www.catg.org/natural-resources/reports/>

² <http://www.grrb.nt.ca/research.htm>

³ <https://www.gwichin.ca>

ASSOCIATION OF POLAR EARLY CAREER SCIENTISTS

The Association of Polar Early Career Scientists (APECS) is an international and interdisciplinary network for early career students, researchers, professionals, educators, and others interested in polar, alpine regions, and the wider cryosphere. The role of APECS in the polar research community during the last decade has been fundamental towards developing a diverse future leadership in polar matters. APECS has grown from a small group established during the 2007/08 International Polar Year (IPY) to a global community of thousands of actively-engaged early career researchers (ECRs) representing all continents.

The APECS leadership: representatives of the Council, National Committees and the Executive Committee met in Davos, Switzerland at the APECS World Summit 2018.

© Stephen Curtain



APECS aims to create a network of polar researchers across disciplines and national boundaries, to provide career development opportunities for both academic and non-academic career paths, and to promote education and outreach as integral components of polar research.

A key goal of APECS is to develop international career development opportunities for ECRs, and part of that is achieved by integrating ECRs into polar research and coordination projects from the outset. APECS works with many organisations in the polar research community, including the International Arctic Science Committee (IASC), the Scientific Committee on Antarctic Research (SCAR), the Arctic Council Working Groups 'Arctic Monitoring and Assessment Programme' (AMAP) and 'Conservation of Arctic Flora and Fauna' (CAFF), and the European Polar Board (EPB). These fundamental partnerships provide opportunities to include ECRs in a range of committees, conference convening groups, and review panels (including the current review of the upcoming IPCC report on Ocean and Cryosphere in a Changing Climate) and thereby contribute to the scientific activities of these organisations and projects.

APECS additionally provides opportunities for ECRs through its engagement in large project consortia like the EU Horizon-2020 funded projects APPLICATE¹, ARICE², INTERACT³ and Nunataryuk. As part of these projects,



APECS organises for example training schools, such as the recent Polar Prediction School 2018 in Abisko, Sweden in April 2018, in cooperation with the APPLICATE project, the WMO's Polar Prediction Project (PPP), the Year of Polar Prediction (YOPP) and other partners.

APECS regularly organises workshops and panel discussions worldwide – well over 200 in more than 30 countries since its creation. In the past year, these included events at the Arctic Frontiers Conferences in Norway, the AMAP International Conference on Arctic Science in the United States (April 2017), the Arctic Science Summit Week 2017 in Czech Republic (April 2017), the Arctic Change Conference in Canada (December 2017) and POLAR2018 in Switzerland (June 2018). APECS also provides resources, career and skills development training for ECRs online. In cooperation with our partner organisations APECS has held over 130 webinars.

¹ APPLICATE – Advanced Prediction in Polar regions and beyond: modelling, observing system design and Linkages associated with a Changing Arctic Climate

² ARICE – Arctic Research Icebreaker Consortium

³ INTERACT – International Network for Terrestrial Research and Monitoring in the Arctic



← Participants of the Polar Prediction School 2018 setting up the micrometeorology mast on the surface of frozen Lake Torneträsk near Abisko Scientific Research Station, Sweden in April 2018.
© Fiona Tummon

All webinars are recorded and are available as a free resource on the APECS website. To foster multi-disciplinary research exchange amongst its international membership, APECS organises an annual online conference. The conference is now in its third year and the theme for 2018 was “Butterfly Effect: Small Changes: Big Impact!”.

Another central focus area of APECS is helping to stimulate polar literacy through innovative science communication and public engagement. Highlights include the International Polar Weeks organised by APECS twice a year in March and September, and Antarctica Day organised annually on 1 December. During these initiatives, APECS members and committees worldwide organise education and outreach events related to the polar regions both as in-person events (e.g. workshops or presentations in schools) and as online events in the form of webinars and social media activities. APECS regularly partners with organisations such as Polar Educators International (PEI) to coordinate these events. In 2011, APECS, in cooperation with IASC and SCAR and funded through the International Council for Science (ICSU), assessed the education and outreach activities during the IPY 2007/2008.

APECS aims to continue to grow and provide opportunities for polar ECRs around the globe through capacity building and education and outreach. In this way we will foster the future leadership in polar science.

For more information about APECS please visit our website at www.apecs.is.

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GROUP ON EARTH OBSERVATIONS

The Group on Earth Observations (GEO) is a global partnership of 105 governments and more than 100 Participating Organizations, including the Sustaining Arctic Observing Networks (SAON). GEO is working to connect the demand for sound and timely environmental information with the supply of data and knowledge about the Earth so that decisions and actions, for the benefit of humankind, are informed by coordinated, comprehensive, and sustained Earth observations.

Ittoqqortoormiit,
Scoresbysund, Greenland
© Annie Spratt on Unsplash



At its 13th meeting (Saint Petersburg, Russian Federation, 2016), the GEO Plenary requested that GEO focus its efforts on providing Earth observations in support of global monitoring frameworks for major policy initiatives, in particular the United Nations 2030 Agenda for Sustainable Development and the associated Sustainable Development Goals (SDGs), the UN Framework Convention on Climate Change (UNFCCC) 21st Conference of the Parties (CoP) Paris Climate Agreement, and the Sendai Framework for Disaster Risk Reduction 2015–2030. With respect to the SDGs, GEO is working with several UN custodian agencies and/or conventions, such as UN Environment (UNEP), the World Health Organization (WHO), and the UN Convention to Combat Desertification (UNCCD), to identify those specific targets and indicators where Earth observations could provide supplemental data in their assessment.

The work GEO is doing in the Arctic is directly related to each one of these global policy agendas. The GEO Cold Regions Initiative (GEOCRI) contributes to national, regional and international decision-making processes and science strategies. Via its contributors, GEOCRI provides reliable, science-based Earth observation data and information for researchers and policy makers, enabling better, well-informed and more effective decisions in cold regions and beyond. GEO has participated in the 2015, 2016 and 2017 Arctic Circle Assemblies, as well as the 2016 and 2018 Arctic Observing Summits, both in recognition of, and to advance, its contributions to monitoring of the Arctic.



ARCTIC RESEARCH FUNDERS

Entities contributing dedicated financial and/or in-kind resources towards GEO projects in the Arctic include: SAON; Svalbard Integrated Arctic Earth Observing System (SIOS); Finland Thule Institute; European Commission (EC); European Space Agency (ESA); United States National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA) and National Snow and Ice Data Center (NSIDC); Chinese Academy of Sciences (CAS); Japan Agency for Marine-Earth Science and Technology (JAMSTEC); Italian Arctic Data Centre (IADC); and the Belmont Forum.

MAJOR ARCTIC RESEARCH INITIATIVES

GEOCRI's vision is to provide coordinated Earth observations and information services to a range of stakeholders in order to facilitate well-informed decisions and support the sustainable development of cold regions globally, including for the Arctic. GEOCRI's mission is to develop a user-driven approach for cold regions information services to complement the mainly current science-driven efforts, which will



← GEO in Numbers, 2018
© Group on Earth Observations (GEO).

strengthen synergies among the environmental, climate, and cryosphere research efforts as well as foster collaboration for improved Earth observations and information on a global scale.

The activities conducted in GEOCRI are prioritized by a Science Advisory Group and are grouped into six overarching thematic tasks:

1. Infrastructures;
2. Monitoring Networks and Data;
3. In-situ and Remote Sensing Integration;
4. User Engagement and Communication;
5. Capacity Building and Knowledge Transfer; and,
6. Management and Monitoring.

These tasks and related activities are the fundamental elements for liaison, coordination, implementation and reporting.

ARCTIC RESEARCH INFRASTRUCTURE

The Seventh Ministerial Meeting of the Arctic Council (AC), via the Nuuk Declaration, recognised the importance of the SAON process as a major legacy of the international Polar Year (IPY) for enhancing scientific observations and data sharing. SAON's vision centres on a connected, collaborative, and comprehensive long-term pan-Arctic Observing System that serves many societal needs. SAON's mission is to facilitate, coordinate, and advocate for coordinated international pan-Arctic observations and mobilise the support needed to sustain them. To that end, SAON is proposing the establishment of an Arctic component of the Global Earth Observation System of Systems (GEOSS) as a GEO Initiative, titled Arctic GEOSS, which will engage and facilitate connections among the producers and end-users of Arctic observations. This regional initiative, downscaling what is done globally in

GEO, would further leverage and advance the policies and processes established by GEO's Member Governments and Participating Organizations.

A roadmap is being developed to realise SAON's major objectives for Arctic GEOSS, which include identifying resources necessary for supporting infrastructure required to sustain and/or add new observational capabilities and technological innovations to improve observation capacity, promote free and open access to Arctic observational data and ensure the sustainability of Arctic observations.

Satellites

The Committee on Earth Observation Satellites (CEOS) and the Coordination Group of Meteorological Satellites (CGMS) are two of GEO's Participating Organizations, with the former serving as GEO's space arm for coordination of Earth observations from satellites.

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GEO GROUP ON
EARTH OBSERVATIONS

INTERNATIONAL ARCTIC SCIENCE COMMITTEE

The International Arctic Science Committee (IASC) is a non-governmental, international scientific organisation which encourages and facilitates cooperation in all aspects of Arctic research, in all countries engaged in Arctic research, and in all areas of the Arctic region. Through its work, IASC promotes and supports multi-disciplinary research to foster greater scientific understanding of the Arctic region and its role in the Earth system.

The IASC Secretariat is located in Akureyri, Iceland and is supported by Rannís, the Icelandic Centre for Research.
© Kári Fannar Lárusson



ARCTIC RESEARCH POLICY AND GOALS

The IASC Founding Articles from 1990 call upon IASC to periodically host international research planning conferences to “review the status of Arctic science, provide scientific and technical advice, and promote cooperation and links with other national and international organisations.” Following the International Conferences on Arctic Research Planning in 1995 and 2005 (ICARP I and II), IASC-led ICARP III, which was a two-year long bottom-up process that resulted in the report, “Integrating Arctic Research – a Roadmap for the Future” published in 2015.

ICARP III Key Science Priorities

1. The Role of the Arctic in the Global System: The Arctic’s accelerated changes are not fully understood, yet they cascade throughout the entire global climate system. In order to address current gaps and global connections, we need an approach that spans disciplines, scales and diverse knowledge systems in future research activities.
2. Observing and Predicting Future Climate Dynamics and Ecosystem Responses: It is critical to anticipate Arctic changes and develop adaptation actions rather than just responses. To do so, increased monitoring and sustained observations must be made and integrated with new and innovative modelling approaches to provide more timely information to Arctic residents and policy-makers alike.
3. Understanding the Vulnerability and Resilience of Arctic Environments and Societies and Supporting Sustainable Development: Sustainable infrastructure development and innovation to strengthen the resilience of Arctic communities and ecosystems requires a collaborative approach involving scientists from all disciplines, as well as representatives from communities, governments and industry.



ICARP III suggested steps to make these scientific priorities more accessible and meaningful to a broader audience through capacity building, incorporating traditional and local knowledge, and communication.

IASC SUPPORT AND FUNDING

Funding for IASC activities (meetings, workshops, early career support, outreach activities, etc.) comes from contributions from IASC’s 23 member countries: Austria, Canada, China*, Czech Republic, Denmark/Greenland, Finland, France, Germany, Iceland*, **, India, Italy, Japan, The Netherlands, Norway, Poland*, Portugal, Russia*, Republic of Korea, Spain*, Sweden*, Switzerland, United Kingdom, United States

MAJOR ARCTIC RESEARCH INITIATIVES

IASC’s scientific Working Groups drive forward IASC science. Each Working Group has published scientific foci for the coming 5 years; these are meant to help Arctic scientists get involved in IASC activities, and it is expected that they will evolve in the coming years as the Working Groups continue with their work.

*Supports the IASC Dispersed Secretariat | **Supports the IASC Secretariat, including budget and two FTEs



← Fieldwork in West Greenland – IASC facilitates cooperation in cutting edge international and interdisciplinary Arctic research.
© Jason Briner

Atmosphere

- Clouds, Water Vapor, Aerosols, Fluxes
- Arctic Air Pollution
- Coupled Arctic climate system
- Arctic Weather extremes
- The Arctic in the global climate system

These topics have been put under the three pillars of the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC), Air Pollution in the Arctic: Climate, Environment and Societies, and the Year of Polar Prediction / Polar Prediction Project (YOPP).

Cryosphere

- Atmosphere-glacier-ocean interactions: implications on the pan-Arctic glacier mass budget
- Extreme Cryospheric Events
- Cutting Barriers in Snow Science

Marine

- The Arctic in Rapid Transition Network
- MOSAiC
- Proglacial Marine Ecosystems
- Distributed Biological Observatory

Social & Human

- Arctic residents and change
- Histories, perceptions and representations of the Arctic
- Securities, governance and law
- Natural resource(s)/use/exploitation and development: past, present, future
- Human health and well-being

Terrestrial

- Biodiversity, land and freshwater ecosystem services
- Natural resources & sustainable use
- Biotechnologies
- Atmospheric pollutants and terrestrial & freshwater contaminants
- Permafrost landscapes & infrastructure

Actions Groups are also established by IASC to provide strategic advice concerning both long-term activities and urgent needs. IASC is currently convening and considering actions groups addressing Communicating Arctic Science to Policymakers, Indigenous Inclusion in IASC, and Arctic Science and Business/Industry Cooperation.

INFRASTRUCTURE:

ARCTIC SCIENCE SUMMIT WEEK (ASSW)

ASSW was initiated by IASC in 1999 to provide opportunities for coordination, cooperation and collaboration. Over the years the summit evolved into an important annual gathering of Arctic research organisations. In odd-numbered years, the ASSW includes a 3-day Science Symposium. These symposia create a platform for exchanging knowledge, cross fertilization and collaboration and attract scientists, students, policy makers and other professionals. In even-numbered years, the ASSW includes the Arctic Observing Summit (AOS), a high-level, biennial summit that aims to provide community-driven, science-based guidance for the design, implementation, coordination and long-term operation of Arctic observing systems.

2018: Davos, Switzerland | 2019: Arkhangelsk, Russia | 2020: Akureyri, Iceland | 2021: Lisbon, Portugal

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www.iasc.info



INTERNATIONAL ARCTIC SOCIAL SCIENCES ASSOCIATION

IASSA, established in 1990, is the professional association of Arctic social sciences and humanities scholars that includes more than 700 members encompassing disciplines relating to behavioural, psychological, cultural, anthropological, archaeological, linguistic, historical, social, legal, economic, environmental, and political subjects, as well as health, education, the arts and humanities, and related subjects.

IASSA is an observer to the Arctic Council and contributes to its work through the involvement of its representatives and members in the wide scope of the Arctic Council activities.

© Peter Skold, Umea University



The IASSA objectives and research and policy goals are:

- **to promote** and stimulate international cooperation and to increase the participation of social scientists in national and international Arctic research
- **to expand** the role of social sciences and humanities in Arctic research and policy, including the Arctic Council
- **to promote** the active collection, exchange, dissemination, and archiving of scientific information in the Arctic social sciences
- **to support** Indigenous scholars, organisations and residents, facilitate Indigenous knowledge (IK) and knowledge co-production
- **to facilitate** culturally, developmentally, and linguistically appropriate education in the North
- **to follow** the IASSA statement of ethical principles for the conduct of research in the Arctic
- **to support** the implementation of the Agreement on Enhancing International Arctic Scientific Cooperation signed by the Arctic Council members in 2017

IASSA has been involved in the Integrating Arctic Research – A Roadmap for the Future what significantly strengthened the social dimension of the Arctic research envisioned in the ICARP III Final Report. The ICARP III final report formulated three main research priority areas, one of which directly speaks to the social sciences: understand the “vulnerability and resilience of Arctic environments and societies and support sustainable development” (ICARP III, p. 5).

IASSA intends to play an important role in the implementation of the Agreement on Enhancing International Arctic Scientific Cooperation and advocates for the development of the action plan for its immediate enactment.

ARCTIC RESEARCH FUNDERS

IASSA does not fund projects itself, but it works with various public and private funders to facilitate funding opportunities for IASSA members. Most important funders that contribute significantly to the social sciences and humanities research in the Arctic are:

- **The National Science Foundation (NSF)** Arctic Social Sciences Programme. This programme is the flagship under of the IASSA international activities and research projects by IASSA members in the Arctic.
- **National funding** agencies and bodies play a significant role in supporting Arctic social sciences and humanities internationally: Polar Knowledge Canada, Social and Humanities Research Council of Canada, RANNIS, Nordic Council of Ministers, Russian Foundation for Basic Research, Nordforsk, EU-PolarNet, etc.
- **Private funders**, such as Canadian Weston Foundation, Gordon Foundation, and the Northern Scientific Training Programme (NSTP).

MAJOR ARCTIC RESEARCH INITIATIVES

- ***The International Congress of Arctic Social Sciences***, a major triennial meeting of Arctic social scientists and humanities scholars took place in June of 2017. Nearly 800 participants and 1,000 papers were presented. Twenty-two key themes were identified. A special emphasis was given to the role of the Indigenous knowledge and Indigenous knowledge holders.
- ***The Arctic Horizons*** project brought together members of the Arctic social science research and Indigenous communities to reassess the goals, potentials, and needs of these diverse communities and NSF Arctic Social Science Programme within the context of a rapidly changing circumpolar North. Report will be released by NSF in 2018. www.arctichorizons.com
- ***Arctic-FROST*** builds an international interdisciplinary collaborative network that teams together environmental and social scientists, local educators and community members from all circumpolar countries to enable and mobilise research on sustainable Arctic development aimed at improving health, human development and well-being of Arctic communities while conserving ecosystem structures, functions and resources. Arctic-FROST and IASSA published a first synthesis of sustainability science research in the Arctic. <https://arctic-frost.uni.edu/>
- ***Belmont projects***: IASSA members actively participate in Belmont interdisciplinary international projects improving current understanding, best practices, and metrics for achieving sustainability in the Arctic.
- ***Indigenous knowledge and knowledge co-production*** initiatives involving IASSA as a AC observer: IASSA is deeply engaged in supporting activities associated with promoting Indigenous knowledge and Indigenous knowledge holders and developing methodologies for knowledge co-production in the Arctic.
- ***Participation in Arctic Council activities***: IASSA regularly contributes to the Arctic Council activities, most directly through the Sustainable Development Working Group (SDWG). IASSA is a member of the Social, Economic and Cultural Working Group. Other recent Arctic Council initiatives and projects with a substantial participation by IASSA members include Arctic Resilience Report, Adaptation Actions for a Changing Arctic, One Health, ECONOR, and EALLU.

- ***Arctic Youth and Sustainable Futures***: Following up on a key recommendation in AHDR-II (2015), this project (2016–18) on “Arctic Youth and Sustainable Futures” convenes an international working group of Arctic scholars, alongside Arctic youth representatives, to investigate the needs, opportunities and aspirations of Arctic youth, to fill an identified gap in knowledge on the lives, ambitions, needs and challenges of youth – indigenous and non-indigenous – across the circumpolar Arctic.

ARCTIC RESEARCH INFRASTRUCTURE

Vessels

Not applicable

Field stations

IASSA members work on various field sites located in all Arctic counties. Most frequently, IASSA members are deeply embedded within Arctic communities and maintain continuous and mutually beneficial contacts with Arctic residents.

Satellites

Not applicable

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SUSTAINING ARCTIC OBSERVING NETWORKS

The Arctic is one of the fastest changing regions on the Earth where impacts of major changes are felt both early and more strongly than elsewhere on the globe. The Arctic is shaped by global processes, and in turn, influences living conditions not only of the people living there and depending on it, but also of hundreds of millions of people at lower latitudes.

© Matthew Sturm



One of the main themes at the 2016 Arctic Science Ministerial¹ was Strengthening and Integrating Arctic Observations and Data Sharing. The ministers committed to the “shared development of a science-driven, integrated Arctic-observing system” and saw “a critical role for the Sustaining Arctic Observing Networks (SAON) initiative”. In the 2017 Fairbanks Declaration², Arctic Council governments “recognise the need to increase cooperation in meteorological, oceanographic and terrestrial observations, research and services, and the need for well-maintained and sustained observation networks and continuous monitoring in the Arctic”.

THE ROLE OF SAON IN BUILDING AND SUSTAINING A PAN-ARCTIC OBSERVING SYSTEM

SAON’s vision is a connected, collaborative, and comprehensive long-term pan-Arctic Observing System that serves societal needs. SAON facilitates, coordinates, and advocates for coordinated international pan-Arctic observations and mobilises the support needed to sustain them.

SAON has the mandate to mobilise new/additional resources to meet observing needs as well as promote cooperation and coordination among existing initiatives. To that end, collaborating nations must ensure long term support and engagement for Arctic Observations based upon consideration of the main societal benefits of long-term monitoring.

SAON is a joint initiative of the Arctic Council and the International Arctic Science Committee (IASC) that aims to strengthen multinational engagement in pan-Arctic observing. The SAON process was established in 2011 at the Seventh Ministerial Meeting of the Arctic Council (AC) via the Nuuk Declaration.



SAON CAPACITY

A new strategy for SAON was approved in May 2018. It describes SAON’s vision, mission, guiding principle and goals, and outlines in concrete steps the manner in which the goals will be achieved³.

SAON has adopted the following three goals and SAON’s guiding principles support its work across these:

- Create a holistic roadmap to a well-integrated Arctic Observing System;
- Promote free and ethically open access to all Arctic observational data; and
- Ensure sustainability of Arctic observing.



← © Henning Thing

Addressing SAON goals requires a wide range expertise, knowledge and cooperation of rights- and stakeholders. SAON collaborates with policy-makers at all levels, Arctic Indigenous Peoples organisations, academicians, civil society and the private sector. SAON currently has 18 member nations, two AC Permanent Participants (Arctic Indigenous Peoples organisations) and partnerships with numerous regional and international organisations including the European Union/European Commission (EU/EC), European Space Agency (ESA), the Group on Earth Observations (GEO), International Study of Arctic Change (ISAC), the World Meteorological Organisation (WMO) and many more. Our strong connections to the research policy priorities of our member nations and our partner organisations enable SAON to play the central coordinating role in integrating observing systems and networks throughout the circumpolar Arctic. SAON is currently in the process of applying for status as a regional initiative within GEO as the ArcticGEOSS.

Sustainability of Arctic observing, requires improved coordination of national programmes and improved sharing of data by all relevant entities. SAON will play the liaison/advocate role between the research communities and policy makers. This approach must include a balance of national priorities vs circumpolar coordination priorities, and assessment of the benefits of Arctic coordination for the respective national observation priorities.

RECOMMENDATION

Following the recommendation from ASM1 and the Arctic Observing Summit in 2016 and 2018 (see also the ASM2 Deliverable on Arctic Observing Summit 2018), it is recommended that SAON is supported and resourced at levels sufficient to enable international coordination for building of an Arctic Observing System.

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THE INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA

ICES is an intergovernmental organisation whose main objective is to increase the scientific knowledge of the marine environment and its living resources and to use this knowledge to provide unbiased, non-political advice. ICES supports its Member Countries and international governmental institutions like the EU Commission, NEAFC, NASCO, NAFO, NAMMCO, OSPAR and HELCOM by providing scientific information and knowledge and advice on ecosystem, fisheries, and aquaculture issues.

Deploying the CTD in the East Greenland Coastal Current.

© Penny Holliday, National Oceanography Centre Southampton, UK.



ARCTIC RESEARCH POLICY AND GOALS

The Arctic marine environment is currently undergoing major changes due to climate change and human activities. ICES has prioritized arctic research to help improve understanding of ecological processes and human impact.

A number of ICES expert groups focus on subarctic fish stocks in the Barents Sea, Iceland and East Greenland, as well as widely distributed and straddling stocks. ICES has a network of Integrated Ecosystem Assessment (IEA) Groups, providing opportunity to share methods and guidance between ecoregions.

Of specific Arctic relevance are three IEA groups:

- Working Group on the Integrated Assessments of the Norwegian Sea (WGINOR)
- Working Group on the Integrated Assessments of the Barents Sea (WGIBAR)

Both of these groups can provide knowledge about the state of ecosystems, overviews of available data, monitoring strategies, and adaptive management. In addition

- the Working Group on Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA; joint group with the North Pacific Marine Science Organization (PICES) and the Arctic Council Working Group Protection of the Arctic Marine Environment (PAME)) works on IEA for the Central Arctic Ocean, with a specific focus on prospects for future fisheries and sensitivity and vulnerability in relation to shipping activities

A joint ICES and PAME workshop Ecosystem Approach guidelines and Integrated Ecosystem Assessment in the Arctic dealt with the inclusion of indigenous knowledge



in IEAs in the changing Arctic region. This is crucial not only to avoid risks to human life and to secure resources important for indigenous peoples and their cultures, but also to support the scientific basis for management in rapidly changing Arctic ecosystems.

Our IEA Groups have compiled Ecosystem overviews for the Barents Sea, Icelandic waters, and Norwegian Sea, providing a description of the ecosystems, identifying the main human pressures, and explaining how these affect key ecosystem components.

We provide the evidence base for marine assessments in the ICES area; for example, the Contaminants and Biological Effects dataset is related to the work of AMAP. This includes potential further cooperation on a hazardous substances assessment tool, generating an on-demand dataset product from the ICES databases.

For more than a decade ICES has produced an annual report of the North Atlantic and Nordic seas describing the state and trends in ocean climate. The report is available as an operational data tool; <http://www.ices.dk/news-and-events/newsarchive/news/Pages/Climate-report-enters-the-digital-age.aspx>



← On board RV "Oceania".
© Agnieszka Beszczynska-Möller, Institute of Oceanology, Polish Academy of Sciences, Poland.

Biannually, ICES publishes Zooplankton, Phytoplankton, and Microbial Plankton Reports covering subarctic waters.

ICES works collaboratively with several international groups active in Arctic science, such as working groups of the Arctic Council, International Arctic Science Committee (IASC), Third International Conference on Arctic Research Planning ICARP (III), and Association of Polar Early Career Scientists (APECS).

Meetings of Scientific Experts on Fish Stocks in the Central Arctic Ocean (FiSCAO), supporting the December 2017 concluded Agreement to prevent unregulated high seas fisheries in the central Arctic Ocean

The FiSCAO meetings have focused on potential fisheries resources in the Central Arctic Ocean, including the design of a 1–3 yearlong mapping programme for fisheries resources and a potential monitoring programme, as well as the identification of resources needed for mapping and monitoring, and the development of data collection, sharing, and hosting protocols.

The recent meeting of FiSCAO concluded that the development of a data sharing protocol will require negotiation and legal review among the parties and recommended that a data management/sharing pilot study be undertaken. USA, ICES, and PICES in cooperation offered to undertake the pilot study.

Examples of events, scientific symposia, and themes sessions with Arctic focus

- 2016 Workshop on impacts and consequences of ocean acidification for commercial species and end-users
- 2017 ICES Scientific advice on distributional changes in fish stocks linked to environmental conditions (mostly through sea temperature) and fishing
- Joint ICES/PICES working group on climate change and biologically driven ocean carbon sequestration

- 2017 Symposium: Ecosystem Studies of Subarctic and Arctic Seas Programme International Open Science Meeting
- 2017 Workshop on global ecological and economic connections in Arctic and sub-Arctic crab fisheries
- 2017 Joint ICES/PICES strategic initiative on climate change impacts on marine ecosystem, covering among other issues vulnerability assessments on fish and shellfish and on the human communities depending on them
- 2018 joint ICES/PICES Workshop on Political, Economic, Social, Technological, Legal and Environmental scenarios to be used in climate projection
- 2018 symposium: Fourth International ICES/PICES/ IOC/FAO Symposium, The effects of climate change on the world's oceans, Washington D.C., USA – addressing both consequences and impacts of climate change in the world oceans, gaps and insufficiencies in the evidence-base as the basis for proposals for priorities for future research, as well as to derive appropriate climate-ready policies that can help society adapt and protect the marine environment and living resources in the future – ICES Annual Science Conference, 24–27 September 2018, Theme Session: The Nordic seas and the Arctic – climatic variability and its impact on marine ecosystems, fisheries and policymaking

Point of contact:
General Secretary Anne Christine Brusendorff



ICES
CIEM

International Council for
the Exploration of the Sea
Conseil International pour
l'Exploration de la Mer

THE UNIVERSITY OF THE ARCTIC

UArctic facilitates collaboration, resource sharing and capacity building in both research and education among higher education institutions interested in the Arctic. The core tool for cooperation in UArctic is the 50 Thematic Networks and Institutes each cooperating on concrete northern-relevant issue-based themes of research and/or education on all academic levels. The network cooperation is supplemented with the north2north mobility programme that enable exchange and cooperation.

UArctic Permafrost
Summer School
Participants.
© Kenji Yoshikawa



UArctic supports the use of Participatory Research Methods, including local and traditional knowledge into research. Much of this research is increasingly producing innovative solutions with global applications, particularly for a sustainable use of natural resources and sustainable economic growth. In addition, research-informed practices at both the policy-making and practical level enhance the empowerment of northern people and provide possibilities for livelihoods, social inclusion and sustainable development in the Arctic.

ARCTIC RESEARCH FUNDERS

Research activities conducted in the UArctic Thematic Networks and Institutes are supported by the Research Liaison Offices in Finland and in Russia that help to identify funding opportunities and to foster interregional cooperation. Since UArctic is a network of almost 200 organisations from 20 countries various funding sources both nationally and internationally are used.

MAJOR ARCTIC RESEARCH INITIATIVES

UArctic takes a proactive role in promoting a holistic understanding in Arctic research, including the value of traditional knowledge. Actors in the Arctic region have taken the global lead in promoting the understanding of and respect for northern peoples and their knowledge in Arctic science over the last decade, including the unique position of permanent participants in the Arctic Council, the establishment of UArctic, and progressive research leadership (in particular within IASSA and IASC). UArctic, with its strong commitment to the North and northern perspectives, will continue to be a driver in this for years to come.



UArctic Chairs are highly qualified academics who serve as academic drivers in a broad problem area of relevance to the Arctic. They implement and drive collaborative actions among UArctic members and Thematic Networks; develop research cooperation, including undergraduate, graduate, PhD and postdoctoral scientist training; and build partnerships with the broader Arctic community. First UArctic Chair was appointed in 2017.

Half of the global Arctic research output measured as publications is produced at UArctic member Institutions while the majority of the remaining research comes from national research agencies including Polar Institutes¹. Arctic Science output is dominated by natural sciences (environment and earth sciences), reflecting the importance of the Arctic Region in understanding climate and earth systems. The broad set of Thematic Networks and Institutes of UArctic provide a unique infrastructure to also address other Arctic Concerns, in particular those with local relevance and importance.

¹ Aksnes et al. UArctic Science Analytics task force.



← Weather Monitoring
Store Torungen Coastal
Archipelago Park Sorla.
© Peter Prokosch

UArctic works actively with the circumpolar scientific community to raise awareness of Arctic issues and increase knowledge that is based on strong northern research with in-depth understanding of local and traditional knowledges. Thematic Networks and member institutions work with local communities to develop outreach products and programmes that reflect the latest scientific research and also respond to articulated needs of the people living in the circumpolar region. UArctic works closely with the Arctic Council, its Working Groups and Permanent Participants. UArctic also partners with the International Arctic Science Committee (IASC), the International Arctic Social Science Association (IASSA), and the Association for Polar Early Career Scientists (APECS) to achieve this goal.

ARCTIC RESEARCH INFRASTRUCTURE

UArctic's online research infrastructure catalogue presents currently 129 entries of the research infrastructures hosted by UArctic member organisations: <https://research.uarctic.org/resources/research-infrastructure-catalogue/>

UArctic provides the infrastructure for international education cooperation, citizen empowerment, and capacity building relevant to the Arctic and the world.

UArctic Thematic Networks and Institutes provide a strong basis for shared curriculum and science-based education initiatives.

UArctic Thematic Networks and Institutes provide a strong basis for shared northern relevant issues based research collaboration prepared to act on present and emerging needs in and about the Arctic.

UArctic represents an operationally unique multilateral infrastructure to enable student and faculty mobility, and internships both within and to the Arctic that can be readily further expanded to meet present and emerging needs. UArctic ensures the best use of present-day and future investments in higher education and research institutions through international collaboration that benefits the Arctic and the world.

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UN ENVIRONMENT

UN Environment and its collaborating centre, GRID-Arendal, have been engaged in the Arctic for many years – starting prior to the establishment of the Arctic Council – on climate change, pollution, biodiversity and governance. This engagement aligns with the focus of this summit “on specific themes which reach across national boundaries and provide opportunities to advance understanding of, and ability to respond to major societal challenges in the Arctic.”

Iceberg in the
Davis Strait
© John Crump



Science cooperation and science-policy interaction is fundamental to the policy goals of UN Environment which uses its global reach to link the latest Arctic research on emerging environmental issues with decision-makers and policy processes where concrete actions can be developed. To do this, UN Environment combines its mandate to keep the global environment under review with its convening power and experience in normative work (negotiating international conventions and other instruments, policy guidance) with GRID-Arendal's knowledge and ability to communicate complex topics in clear and understandable formats to raise the profile of Arctic issues on the global stage.

Improving global understanding of the implications of Arctic change for the rest of the planet in order to build resilience is a major UN Environment policy goal. At the same time, UN Environment aims to transmit the knowledge of global environmental processes, changes and issues and their specific impacts on the Arctic to the attention of the policy- and decision-makers at global and regional levels. UN Environment's integrated and transboundary approaches, such as steering of most of the regional seas programmes, help ensure a better understanding of how changes interact and what they mean for people and the planet at various scales. This approach will support the integration of the three themes of this year's summit and ensure the integration of Arctic science into the implementation of the Sustainable Development Goals.



MAJOR ARCTIC RESEARCH INITIATIVES

Three relevant initiatives with concrete deliverables are underway at GRID-Arendal to support the focus and themes of this summit.

Promoting global science cooperation – Following the signing of the Arctic Science Agreement, UN Environment and GRID-Arendal will assist the Arctic Council and its members to bring the message about Arctic changes and the link between science cooperation and the themes of the 2nd Arctic Ministerial Science meeting to the next United Nations Environment Assembly, to be held in March 2019. The presentation and a discussion will be organised in partnership with the Arctic Council members and the Permanent Participants. The 2019 Environment Assembly will also feature the launch of the Sixth Global Environmental Outlook, the flagship science-policy report produced by UN Environment. This will be a good opportunity to highlight the need to further integrate Arctic science, and Indigenous knowledge, in global processes. In addition, effort will be made to inform global stakeholders about the specific impacts



← Uummannaq, Greenland
© John Crump

for the Arctic region of draft resolutions negotiated in the Environment Assembly. The messages of the Berlin summit which connect Arctic and non-Arctic stakeholders will be reinforced at the global Environment Assembly.

Expanding knowledge on permafrost change – UN Environment and GRID-Arendal are working with the Government of Canada on a Rapid Response Assessment on Emerging Issues Related to Permafrost in a Changing Arctic. The rapid assessment is an effort by leading experts and institutions to assess critical research gaps related to Arctic permafrost and to consider how these gaps can be addressed through international cooperation. We are working with agencies that have conducted expert reviews such as the International Permafrost Association and the Arctic Monitoring and Assessment Programme. Within the context of permafrost responding to a warming Arctic, the goal is to consolidate societal research priorities affecting the well-being of those living in the north and to determine the global-scale drivers that are influencing change.

Explaining Arctic Science – UN Environment and GRID-Arendal are producing a set of maps and graphics, accompanied by short narratives to synthesize and illustrate the most critical environmental challenges with the Arctic and their global relevance. These graphics and supporting information focus on issues which call for common solutions. The graphics will build on Arctic and global environmental assessments and reflect the dynamic connection between the Arctic and the rest of

the planet. It will present state and trends and provide important information for policy development. The issues covered by this product will reflect the themes of the Finnish Chairmanship of the Arctic Environment Ministers' meeting in October 2018 – climate change, biodiversity conservation and pollution prevention. Once finalised, the product in the various formats will serve as a reference material for decision-makers in the Arctic and globally, as well as the wider public, to demonstrate Arctic / global connections.

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United Nations
Environment Programme



WORLD METEOROLOGICAL ORGANIZATION

The World Meteorological Organization (WMO) is a specialized agency of the United Nations and includes 191 Member States and Territories. It is the UN system'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.

The WMO Polar and High Mountain regions priority activity promotes and coordinates relevant observations, research and services that are carried out in the Arctic, Antarctic and high mountain regions by nations and by groups of nations.

WMO is an Observer to the Arctic Council.

Project N-ICE2015
(Norway)
© Frede Lamo, UNIS
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ARCTIC RESEARCH FUNDERS

WMO provides funds for the coordination of polar research through its various research activities, including the World Climate and World Weather Research Programmes. The World Climate Research Programme is also co-sponsored by the International Council for Science and IOC-UNESCO and also receives voluntary national contributions from various countries. WMO also works in partnership with others to maximise the benefit of resources, e.g. with the Prince Albert II Foundation for the Polar Challenge.

MAJOR ARCTIC RESEARCH INITIATIVES

WMO fosters the development of key research activities which constitute the bedrock of Arctic Science and contribute to the sustainable development of the Planet:

Year of Polar Prediction. The Polar Prediction Project (PPP) of the World Weather Research Programme (WWRP) aims to advance the science in numerical models, data acquisition and assimilation, ensemble forecast methods, verification, and the production of prediction products – all with a polar emphasis. Observations are a key element in this endeavour and the PPP is launching a modelling and field campaign (mid-2017 to mid-2019) to assist planning an Arctic observational network for improving predictive capabilities.



The World Climate Research Programme (WCRP)¹.

WCRP coordinates a number of research activities in the Arctic Region, often in partnership with its sister programme WWRP.

Co-sponsored with the International Arctic Science Committee and the Scientific Committee on Antarctic Research, the **Ice Sheet Mass Balance and Sea Level project²** aims to promote research on the estimation of the mass balance of ice sheets and its contribution to sea level.

The CLIVAR/CliC **Northern Oceans Panel³** serves as an international forum for coordinating and strategizing activities on the role of the Arctic Ocean in the context of the global climate system from a coupled perspective. Related to this WCRP coordinates various groups focused on sea ice such as the CliC **Sea Ice Working Group⁴** and the CliC **Sea Ice and Modelling Forum⁵**.

¹ <https://www.wcrp-climate.org>

² <http://www.climate-cryosphere.org/activities/groups/ismass>

³ <http://www.clivar.org/clivar-panels/northern>

⁴ <http://www.climate-cryosphere.org/activities/groups/arctic-sea-ice-working-group>

⁵ <http://www.climate-cryosphere.org/activities/groups/seaicemodeling>

WCRP has a Grand Challenge on **Melting Ice and Global Consequences**⁶, which has the overall aim to consolidate historical observations from a range of sources and focus effort on better representing the shrinking cryosphere in climate models used to make quantitative projections that underpin the IPCC Assessment Reports.

WCRP carries out a range of Antarctic-related activities focussed on permafrost, for example the CliC/IPA⁷ **Permafrost Research Priorities: A Roadmap for the Future**⁸.

Polar-CORDEX⁹ (Coordinated Regional Downscaling Experiment – Arctic and Antarctic Domains) aims to produce an improved generation of regional climate change projections for input into impact and adaptation studies.

The **Polar Climate Predictability Initiative¹⁰ (PCPI)** aims to improve the understanding of the predictability of polar climate. The PCPI has a focus on the polar regions and their role in the global climate system and aims to improve predictability of the climate system on all time scales by improving our understanding of the underlying physical mechanisms and their representation in climate models.

Global Cryosphere Watch. The Global Cryosphere Watch (GCW) is an international mechanism for supporting all key cryospheric in-situ and remote sensing observations. To meet the needs of WMO Members and partners in delivering services to users, the media, public, decision and policy makers, GCW provides authoritative, clear, and useable data, information, and analyses on the past, current and future state of the cryosphere.

Polar Challenge. The cryosphere is a major indicator of global climate change and plays a fundamental role in the climate system. Despite advances in numerical modelling, the reliability of long-term climate change predictions in the Arctic and Antarctic are severely limited by the lack of systematic in situ observations of and beneath the sea ice. For this reason, the WCRP and the Prince Albert II of Monaco Foundation are sponsoring a Polar Challenge that will reward the first team to complete a 2 000 km mission with an Autonomous Underwater Vehicle under the Arctic or Antarctic sea ice.

Maritime safety. Reliable marine weather forecasts and knowledge of state of the sea and sea-ice are crucial for safe navigation and planning voyages in Arctic waters. In cooperation with the International Maritime Organization, WMO supports the UN International Convention for Safety of Life At Sea (SOLAS) through the provision of maritime safety information, including in the Arctic. In order to improve such services WMO is promoting the collection under the Polar Code of cryosphere and weather observations from ships sailing in polar regions.

Pan-Arctic Regional Climate Outlook Forum.

Acknowledging the growing need for reliable and timely information on the status of, and threats of the Arctic environment, in support of decisions of governments on mitigating the impact of climate change and sustaining the economic development, in particular in the remote area of the Arctic, the WMO Executive Council has endorsed the development and implementation of an Arctic Polar Regional Climate Centre Network (Arctic PRCC-Network) and the organization of Polar Arctic Regional Climate Outlook Forums (PARCOFs).

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WORLD
METEOROLOGICAL
ORGANIZATION

⁶ <http://www.wcrp-climate.org/index.php/gc-cryosphere>

⁷ International Permafrost Association (<http://ipa.arcticportal.org>)

⁸ <http://www.climate-cryosphere.org/activities/targeted/permafrost-research-priorities>

⁹ <http://www.climate-cryosphere.org/activities/targeted/polar-cordex>

¹⁰ <http://www.climate-cryosphere.org/wcrp/pcpi>

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