



SUPPORTING ARCTIC SCIENCE

A SUMMARY OF THE WHITE HOUSE ARCTIC SCIENCE MINISTERIAL MEETING
SEPTEMBER 28, 2016 – WASHINGTON, DC

MATERIALS DEVELOPED BY THE ARCTIC EXECUTIVE STEERING COMMITTEE AND PARTICIPANTS IN THE ARCTIC SCIENCE MINISTERIAL, HOSTED BY THE WHITE HOUSE OFFICE OF SCIENCE AND TECHNOLOGY POLICY, WERE COMPILED AND EDITED BY THE US ARCTIC RESEARCH COMMISSION





About this Booklet

This document summarizes the first-ever Arctic Science Ministerial, hosted by the White House on September 28, 2016, as an action of the Arctic Executive Steering Committee to advance international research efforts. It includes the meeting agenda, a list of participants, a White House “fact sheet” that describes the outcomes from the meeting, a Joint Statement of Ministers, and a list of media reports on the event. The document also includes a compilation of two-page descriptions of Arctic science support provided by the ministerial delegations (representing 24 governments and the European Union). These self-reported snapshots follow a standardized format that includes (1) points of contact, (2) Arctic research goals, (3) Arctic research policy, (4) major Arctic research initiatives, and (5) Arctic research infrastructure.

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Executive Summary

In recognition of the rapid changes affecting the Arctic—as well as the impacts of these changes on the rest of the world—the Obama Administration, a year after the President’s historic trip to the Alaskan Arctic, convened the first ever meeting for Arctic Science Ministers at the White House to increase international cooperation on Arctic science.

Science ministers from 24 foreign governments gathered in Washington, D.C. on September 26, 2016 to discuss Arctic research themes and to sign a Joint Statement on developing new collaborative Arctic science, including Indigenous Peoples, to understand and respond to Arctic change. The U.S. delegation was led by Dr. John Holdren, the President’s Science Advisor and Director of the Office of Science and Technology Policy, with vice-chairs Dr. France Cordova, Director of the Arctic Research Commission, and Dr. Robert M. Anderson, Director of the National Science Foundation, and The Honorable Frank L. Young, Secretary of the U.S. Arctic Council.

The four themes of the Ministerial were:

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ild Regional Resilience and to
, and Mathematics (STEM)

1. Arctic Science Challenges and Their Impacts
2. Strengthening and Integrating Arctic Science
3. Applying Expanded Scientific Understanding to Arctic Science
4. Empowering Citizens through Science Education Leveraging Arctic Science

of the meeting, the Joint Statement documents a list of support provided by each delegation.

This document is a record of the oral and written statements signed by the Ministers, and a list of media coverage, and a set of two-page documents.


invitation to Arctic indigenous peoples in order to share their concerns and priorities with the U.S. delegation to the Ministerial on September 27, 2016. More than 40 representatives attended.

Given the importance of Arctic research and decision-making to the Arctic region, the U.S. delegation to the Ministerial included senior leaders from the White House, the State Department, and the U.S. Arctic Council.

international collaboration and advance Arctic science. The meeting provided a platform for ongoing dialogue.

The Arctic Science Ministerial research activities on project Arctic Science Ministerial dialogue and for planning.


Dr. Martin Jeffries
Assistant Director for Polar Sciences & Executive Director, International Arctic Research Policy Committee


Ambassador Mark Brzezinski
Executive Director, Arctic Executive Steering Committee

Meeting Agenda

September 28, 2016, Eisenhower Executive Office Building, Indian Treaty Room

- 7:30-8:20 **Delegation Arrival**
Refreshments served at the Indian Treaty Room
- 8:20-9:00 **Ministers' Photos**
- 9:00-9:30 **Opening Session: Welcome, Introductions & Introductory Remarks**
Chair: Dr. John Holdren, Director of the Office of Science and Technology Policy and the Assistant to the President for Science and Technology
Vice-Chair: Dr. France Córdova, Director of the US National Science Foundation (NSF)
Vice-Chair: The Honorable Francis Ulmer, Chair of the US Arctic Research Commission (USARC)
- 9:30-10:45 **Session 1: Identifying Arctic-Science Challenges and Their Regional and Global Implications**
Co-Chairs: Dr. France Córdova & Dr. Alexander Frolov, Head of Roshydromet
Keynote Presentation: Dr. Brendan Kelly, University of Alaska Fairbanks
Rapporteur: Dr. Kelly Falkner, Director of the Division of Polar Programs, NSF
Minister Statements: Germany, Switzerland, Sweden, Netherlands, Spain, Russia
Discussion
- 10:45-11:00 **Morning Coffee Break**
- 11:00-12:15 **Session 2: Strengthening and Integrating Arctic Observations and Data-Sharing**
Co-Chairs: Dr. Kathryn Sullivan, Administrator of the National Oceanic and Atmospheric Administration (NOAA) & Mr. Torbjørn Røe Isaksen, Minister of Education and Research, Norway
Keynote Presentation: Dr. David Grimes, President, World Meteorological Organization
Rapporteur: Dr. Jeremy Mathis, NOAA
Minister Statements: UK, Japan, EU, Italy, Norway, Republic of Korea
Discussion
- 12:15-12:20 **Joint Statement Overview and Signing Process**
Ambassador Mark Brzezinski, Executive Director of the Arctic Executive Steering Committee
- 12:20-1:15 **Lunch & Signing of the Joint Statement**

- 1:15-2:30 **Session 3: Empowering Citizens through Science Technology, Engineering, and Mathematics (STEM) Education Leveraging Arctic Science**
Co-Chairs: Dr. John Holdren & Ms. Sanni Kaisa Grahn-Laasonen, Minister of Education and Culture, Finland
Keynote Presentation: Dr. Erin Freeland Ballantyne, Dechinta Centre for Research and Learning, Canada
Rapporteur: Dr. Mike Kuperberg, US Global Change Research Program
Minister Statements: Finland, Poland, Singapore, Faroe Islands, Greenland, Canada
Discussion
- 2:30-2:45 **Afternoon Coffee Break**
- 2:45-4:00 **Session 4: Applying Expanded Scientific Understanding of the Arctic to Build Regional Resilience and Shape Global Responses**
Co-Chairs: The Honorable Francis Ulmer & Dr. Kirsty Duncan, Minister of Science, Canada
Keynote Presentation: Dr. Johan Rockström, Executive Director, Stockholm Resilience Center, Stockholm University
Rapporteur: Dr. John Farrell, USARC
Minister Statements: Denmark, China, New Zealand, India, Iceland, France
Discussion
- 4:00-5:15 **Plenary Discussion**
Session Summaries by Co-Chairs
- 5:15-5:30 **Summary and Closing Remarks**
Dr. John Holdren

White House Fact Sheet —

About the Ministerial and Its Outcomes

Science Ministers from 25 governments and the European Union gathered at the White House to discuss Arctic research priorities and sign a Joint Statement on increased international collaboration on Arctic science and inclusion of Indigenous peoples in understanding and responding to changes in the Arctic

The Arctic environment is changing at an unprecedented pace, posing threats to livelihoods and ecosystems. One year after President Obama's visit to Alaska, and building on his unwavering commitment to advance understanding of changes occurring in the Arctic and their global consequences, today the White House hosted the first-ever Arctic Science Ministerial (ASM).

Science Ministers, or their representatives, from 25 governments—Canada, the People's Republic of China, the Kingdom of Denmark, the Faroe Islands, Finland, France, Germany, Greenland, Iceland, India, Italy, Japan, the Republic of Korea, the Netherlands, New Zealand, Norway, Poland, the Russian Federation, Singapore, Spain, Sweden, Switzerland, the United Kingdom, and the United States of America—and the European Union and representatives from Arctic Indigenous peoples' organizations gathered to discuss collective efforts to increase the pace of international scientific collaboration in the Arctic.

A capstone of the ASM was the signing and release of a **Joint Statement** by the delegations gathered today. The Joint Statement recognizes that international collaboration and the inclusion of Arctic Indigenous peoples in science and decision-making are essential to advancing research in the Arctic. The Joint Statement and the ASM help chart a new collective approach in Arctic science that will inform national policies concerning climate-change mitigation and resilience, Arctic development, stewardship, and the needs of the region's Indigenous peoples.

The Ministers used the occasion of the ASM to highlight several new initiatives. They include:

- Today, the **United States** released the first ever Arctic-wide digital elevation model (DEM). The result of a collaboration between the National Geospatial Intelligence Agency and the National Science Foundation, this digital representation of the Arctic land surface has an unprecedented high resolution of 8 m. A 2 m resolution Arctic DEM is to be

created during the next 12 months and will be an important baseline for assessing future land surface changes.

- The **European Union** will initiate a new 5-year project (2016-2021) coordinated by Norway to develop an Integrated Arctic Observing System (INTAROS). The project, with a €15.5 million budget, will involve scientists in 14 European countries (Belgium, Denmark, Finland, France, Germany, Greenland, Ireland, Italy, Norway, Poland, Portugal, Spain, Sweden, and the United Kingdom), as well as in a number of countries elsewhere in the world (Canada, the Peoples' Republic of China, the Russian Federation, and the United States, with other countries expected to join).
- The United States is among the countries that will work with the INTAROS scientists. In 2017, the **US Office of Naval Research** will initiate a 5-year project—Arctic Mobile Observing System (AMOS)—that will develop new sensors, platforms, and techniques for mobile-observing systems that drift with the moving sea-ice cover, or operate autonomously in the ocean below the ice.
- The **European Union** will also initiate two new projects to understand the impact of the changing Arctic on the weather and climate of the Northern Hemisphere. The projects APPLICATE (Advanced Prediction in Polar regions and beyond: modelling, observing system design and Linkages associated with a Changing Arctic climate) (2016-2020, €8 million budget) and Blue-Action (2016-2021, €7.5 million budget) will involve scientists in 13 European countries (Belgium, Denmark, the Faroe Islands, Finland, France, Germany, Iceland, Italy, Norway, Poland, Portugal, Spain, and the United Kingdom), as well as in a number of countries elsewhere in the world (Canada, the Peoples' Republic of China, the Republic of Korea, the Russian Federation, and the United States).
- In 2017, the **United Kingdom** will begin fieldwork for the “Changing Arctic Ocean Programme”, a five-year research effort to explore the effects of changes to the physical environment (ice and ocean) on the marine ecosystem and the associated biogeochemical functioning of the Arctic Ocean.
- The United States will support “EyesNorth,” a **US National Science Foundation** research-coordination network of community-based observing initiatives in the Arctic

and beyond. Involving scientists and northern residents in Finland, Greenland, Iceland, Norway, the Russian Federation, Sweden, the United States, and elsewhere, EyesNorth will expand the science of community-based observing, including the use of Indigenous knowledge and local place-based knowledge, and provide a critical connection between observing environmental change and community preparedness and response. “EyesNorth” will contribute to the work of SAON—Sustaining Arctic Observing Networks—a joint effort of the Arctic Council (through its Arctic Monitoring and Assessment Programme) and the International Arctic Science Committee.

- In a further contribution to SAON, the **US National Oceanic and Atmospheric Administration (NOAA)** will open a US SAON Office. It will foster interagency and international collaboration in the development of Arctic observing and data systems, as well as the delivery of higher-level data and information to the scientific community and policymakers.
- The **US Environmental Protection Agency (EPA)** will advance STEM education and empower citizens through Arctic STEM cooperative partnerships with the Local Environmental Observer (LEO) Network—a network of local environmental observers and topic experts who apply traditional knowledge, science and technology to document significant, unusual environmental events in Alaska.

- The **US Department of Energy** will develop a design-support tool for remote off-grid microgrids in the Arctic; and the **Office of Naval Research** will support the Alaska Network of Energy Education and Employment (ANEED).
- In 2017, the **US National Science Foundation** will announce new awards for projects that promote public participation in Arctic research.
- With the assistance of the indigenous community of Pond Inlet, the **Smithsonian Institution** will open a new exhibition, *Narwhal: Revealing an Arctic Legend*, in August 2017 at the National Museum of Natural History in Washington, DC. The exhibition will feature the biology, ecology, and cultural relations of the narwhal and the effects of climate change on its population and range.
- **Finland and the United States** will collaborate to organize an international Arctic STEM Education Summit during the Finnish Chairmanship of the Arctic Council (2017–2019). The summit will bring together senior government officials, students, educators, researchers, technologists, and other experts to share best practices and develop new educational partnerships that enhance STEM education. It will facilitate information and resource sharing, foster new education networks, and promote a legacy of formal and informal STEM education and lifelong learning both inside and outside the Arctic.



Attendees of the White House Arctic Science Ministerial. Photo by US Coast Guard Petty Officer 2nd Class Connie Terrell



John Holdren, Fran Ulmer, and Kirsty Duncan at the Ministerial meeting. Photo by US Coast Guard Petty Officer 2nd Class Connie Terrell

The ASM seeks to deepen international collaborations that enable nations to address large-scale research questions and increase the pace of discovery. Existing national and international observing and research efforts are impressive, but they are not able to meet the demand for comprehensive and integrated information in the Arctic. People in the Arctic are already experiencing significant impacts from climate change. The scale and pace of research must increase to move beyond documenting changes to increasing knowledge and understanding, developing predictive capabilities that inform decision and policy making, and increasing the resilience of Arctic communities and ecosystems.

The White House organized the ASM around four themes that reach across national boundaries and provide opportunities to advance understanding of and ability to respond to rapid environmental change in the Arctic.

The four themes of the Ministerial and the Joint Statement are:

1. Arctic-Science Challenges and Their Regional and Global Implications
2. Strengthening and Integrating Arctic Observations and Data-Sharing
3. Applying Expanded Scientific Understanding of the Arctic to Build Regional Resilience and to Shape Global Responses
4. Empowering Citizens through Science Technology, Engineering, and Mathematics (STEM) Education Leveraging Arctic Science

Today's Arctic Science Ministerial will facilitate progress on each of these themes, described in more detail below. A broad call for deliverables that support the four themes realized more than 150 contributions describing some of the many Arctic science activities of foreign governments and US departments and agencies. Many contributions, described below by theme, are continuing investments that support research efforts

critical to long-term and sustained measurements essential to understanding the Arctic. Other contributions, highlighted today at the ASM and summarized above, are new efforts that build on existing work, and address gaps in information critical to advancing new understanding of the Arctic.

Theme I: Arctic Science Challenges and Their Regional and Global Consequences

The annual average air temperature in the Arctic is rising at more than twice the rate of the annual average global air temperature. This rapid transition in the atmosphere is reflected in rapid transitions on land and in the ocean. The dramatic changes are having a profound impact on Arctic cultures, communities, and ecosystems, and they also have global consequences.

Some of the most dramatic changes are occurring in the cryosphere: sea ice, freshwater ice, snow cover, land ice sheets, glaciers, and permafrost. Permafrost is warming and thawing, changing landscape, drainage patterns, and habitats, and increasing the potential for the release of potent greenhouse gases that will amplify Arctic and global warming. Glaciers, mountain ice caps, and the Greenland ice sheet are shrinking and contributing to worldwide sea-level rise. Sea-ice extent, thickness, and volume are decreasing, resulting in larger ocean surface waves and greater coastal erosion, compounding the challenges of Indigenous communities that hunt ice-dependent marine mammals. There is also growing evidence that the diminishing sea ice is contributing to changing atmospheric circulation patterns that are affecting weather—including some kinds of extremes—in lower-latitude regions.

There is therefore an urgent need for increased monitoring and research to better understand the causes and consequences of the rapidly changing Arctic environmental system. There is also a need for increased effort to incorporate the growing data and knowledge base into improved computer models for enhanced forecasting of weather, water, and ice on hourly to weekly time scales, as well as improved projections of the state of the Arctic System and global climate over yearly to decadal time scales.

In recognition of these needs, the tempo of research sponsored by Arctic and non-Arctic countries has already been increasing for some time, with impetus from the eight-nation Arctic Council, the International Arctic Science Committee, the World Meteorological Organization, and a growing number of national centers for polar research. The existing national research efforts and collaborations among them will be the building blocks for expanded international cooperation going forward, facilitated by the information exchanges and networking at the Ministerial and future such meetings expected to follow. Among the existing efforts highlighted at the Ministerial under the "Arctic Science Challenges" theme were:

- The US National Aeronautics and Space Administration (NASA) is working with scientists in Canada, and with the US Department of Energy (DOE), to carry out a large, multi-year combined fieldwork and remote-sensing campaign to investigate ecosystem vulnerability and greenhouse gas emissions from boreal forests and tundra in the Arctic region.
- Italy and the Netherlands are using advanced synthetic aperture radar remote sensing techniques to measure land-surface elevation changes occurring in response to permafrost degradation.
- Iceland, India, the Netherlands, Norway, Poland, Spain, and Switzerland are each studying different aspects of how Arctic glaciers, ice caps, and the Greenland ice sheet are losing mass to the ocean and contributing to sea-level rise.
- The “Ice sheet Mass Balance Inter-comparison Exercise 2 (IMBIE-2),” a collaboration between scientists supported by the European Space Agency (ESA) and NASA, provides a framework for assessing recent changes in the mass balance of the Greenland ice sheet, and has an explicit aim to widen participation to enable the entire scientific community to become involved.
- The US Office of Naval Research “Stratified Ocean Dynamics of the Arctic” is a 5-year (2016-2021) project that supports scientists in the United States, Republic of Korea, and the United Kingdom to study changes in ocean circulation, stratification, and the flow of heat and their collective impact on sea ice in the Pacific sector of the Arctic Ocean.

Theme II: Strengthening and Integrating Arctic Observations and Data-Sharing

On September 10, Arctic sea-ice reached its annual minimum extent, which tied with 2007 as the second-lowest in the period of satellite observations that began in 1979. All ten of the lowest minimum sea-ice extent values in that period have occurred during the last ten summers (2007–2016) exemplifying the dramatic changes that are occurring throughout the Arctic environmental system.

Observations and observation platforms, systems, and networks confirm that the sea ice and other components of the Arctic environmental system—permafrost; snow cover; glaciers, ice caps, and the Greenland ice sheet; terrestrial and marine ecosystems—are all changing at unprecedented rates. Nonetheless, the Arctic remains under-observed and data-sparse. The current observing capabilities need to be sustained and new capabilities need to be added to deliver a comprehensive view of the Arctic environmental system. To maximize the benefits of enhanced Arctic-observing capabilities there needs to be full and open access to data and the value-added information and products derived from the data. Data sharing is essential.

Observations are vital for the research described in Theme I. They are also needed for improving weather, water, and sea-ice forecasting, and for projecting how changes in the Arctic will affect conditions around the world and how the Arctic will evolve under different global-emissions scenarios. The current inadequacy of Arctic observing is one of the main reasons for the uncertainties in sea-ice and climate predictions and in projections of climate-change impacts on people, communities, and ecosystems.

Since the last International Polar Year began in 2007 there has been a growing awareness of the urgent need to improve Arctic observing capabilities and develop data policies that promote sharing through full and open access. This recognition is reflected in a number of ongoing projects and collaborations that were reviewed at the meeting, including:

- Canada, the Peoples’ Republic of China, the Republic of Korea, Japan, and the United States, working together through the Pacific Arctic Group of the International Arctic Science Committee (IASC), share responsibility for the Distributed Biological Observatory (DBO), a biophysical change detection array in the northernmost Bering Sea and the Chukchi and Beaufort seas.
- Germany is working with multiple countries to carry out the Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC) between October 2019 and October 2020. The centerpiece of MOSAiC is the icebreaker “Polarstern”, operated by the Alfred Wegener Institute in Germany, which will support year-round observations of the physics of the atmosphere, sea ice, and ocean and the biogeochemistry of the ice and ocean as the ship drifts with the moving sea ice.
- The Russian Federation is developing and improving methods, models, and technologies for hydrometeorological prediction.
- The World Meteorological Organization has launched the Year of Polar Prediction (YOPP), which is actually a two-year project running from mid-2017 to mid-2019, aimed at achieving a significant improvement in environmental-prediction capabilities for the polar region and beyond. The Alfred Wegener Institute in Germany hosts the YOPP international coordination office.
- As contributions to YOPP, Canada is developing a high-resolution coupled environmental prediction system that will enhance the accuracy of high-impact weather event predictions in the North, and the European Space Agency Arctic Earth Observation Impact Assessment is addressing the combination of Earth Observation data streams with a numerical model of the Arctic Ocean sea-ice system using advanced data-assimilation techniques to construct a highly flexible system for Arctic Mission Benefit Analysis (ArcMBA).

- With support from Norway, the Sustaining Arctic Observing Networks (SAON) initiative promotes the vision of well-defined, long-lived observing networks that provide users with full and open access to high-quality data that can realize pan-Arctic and global value-added services and societal benefits.
- As a contribution to SAON, Norway is establishing SIOS (Svalbard Integrated Arctic Earth Observing System), a research infrastructure coordination organization of 26 partners from Europe and Asia. SIOS promotes more openness, better access, data sharing and knowledge management for the international research community.
- Canada and the United States continue to collaborate in mapping the seafloor of the Arctic Ocean.
- The US Environmental Protection Agency, Department of the Interior, Department of State, Department of Health and Human Services, Centers for Disease Control and Prevention, and the US Geological Survey are working with Canada and Finland to expand the Local Environmental Observer (LEO) Network into a pan-Arctic network.

Theme III: Applying Expanded Scientific Understanding of the Arctic to Build Regional Resilience and to Shape Global Responses

Arctic peoples and communities face long-standing challenges that are compounded by environmental, social, and economic changes that are occurring in the Arctic, driven above all by global climate change and its accentuation in the Arctic region. These changes are testing the resilience and sustainability of people and communities.

Rapid environmental change, such as degrading permafrost and increasing coastal erosion, is affecting critical infrastructure—buildings; roads, railways and bridges; airports, harbors and ports; and energy-supply chains—and the health and well-being of Arctic residents. It is also exposing the shortcomings of existing capabilities to forecast environmental conditions that affect economic activities and the daily lives of Arctic residents—maritime and air transportation, energy and mines, fisheries, and tourism. In some cases, growing economic activity is challenging the traditional ways of life of Indigenous society. It will be essential to apply the improved scientific understanding and forecasting capabilities sought under Themes 1 and 2 to the development of integrated strategies to meet the basic needs of Arctic people and increase regional resilience and adaptation capacity.

At the same time, improved understanding of how the effects of rapid climate change in the Arctic are affecting both the pace of global climate change and its impacts, including weather patterns and extremes across the Northern Hemisphere, will be important both to motivating increased

ambition around climate-change mitigation and to shaping resilience strategies in countries around the globe.

Efforts reviewed at the Ministerial under Theme 3 include:

- 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”.
- Nordforsk—an intergovernmental organization under the Nordic Council of Ministers—supports a Nordic Centre of Excellence that is investigating climate-change effects on the epidemiology of infectious diseases and impacts on northern societies. NordForsk also supports three additional Nordic Centres of Excellence to collectively focus research on resilience, adaptation, and sustainability as they relate to communities, reindeer husbandry, and resource extraction.
- In 2015, Japan initiated the 5-year “Arctic Challenges for Sustainability (ArCS)” project. The Netherlands and the Russian Federation are also investing in Arctic sustainable development research.
- The US Geological Survey is assessing historical shoreline change and Arctic coastal vulnerability, and mapping coastal flooding to develop a database of historical and future wave and storm-surge conditions across the Arctic Ocean for use in development and mitigation planning of infrastructure, communities, and natural-resource management.
- The Russian Federation is undertaking a comprehensive assessment of the sustainability of its Arctic coastal systems and infrastructure for spatial planning of maritime activities and socio-economic development.
- Norway is studying climate change and its impacts on the Arctic environment and human activities in order to improve the existing integrated management of northern waters.
- The US Department of Transportation is conducting climate-change vulnerability-assessments and developing adaptation options for Alaska transportation infrastructure.
- Japan is investigating the predictability of Arctic weather and sea ice in consultation with forecast users such as shipping companies.
- India is studying the role of the Arctic in modulating the Indian Monsoon over seasonal to millennial time scales.
- The Republic of Korea is investigating the relationship between Arctic warming and sub-Arctic winter weather in order to enhance prediction capability;
- Singapore is interested in identifying sensitivities and feedbacks between Arctic change and vulnerable regions of southeast Asia, and is assessing the viability of trans-Arctic shipping routes and analyzing their impact on maritime transportation.

- Spain is improving process understanding of the large-scale atmospheric response to changing sea ice and assessing the impact of the rapidly changing Arctic on non-Arctic countries, and conducting research into the sustainability of fisheries in the Barents Sea region.
- China is studying Arctic amplification of warming and the global consequences of sea-ice retreat.
- Canada, Denmark, the United States and other countries are collaborating to refine, develop and implement the World Meteorological Organization Arctic Polar Regional Climate Center (PRCC) Network concept. It will develop and deliver improved climate products and services in response to the defined needs of Arctic clients and stakeholders for climate information in support of decision-making.

Theme IV: Empowering Citizens through Science Technology, Engineering, and Mathematics (STEM) Education Leveraging Arctic Science

STEM education is essential for sustainable development in the Arctic and vital for preparing young people in the Arctic to face challenges arising from continuing environmental, social, and economic change. Engagement with Arctic science, combined with Arctic Indigenous and local knowledge, will enhance the delivery of education to students in the region, and inclusion of more Arctic science in STEM education in the region will inspire a new generation of locally educated experts to solve Arctic and global-science challenges and empower the citizens of the Arctic to enjoy full participation in decision-making that improves the quality of their lives.

Arctic science can also be a catalyst for enhancing STEM education outside of the Arctic. The Arctic can serve as a real-world laboratory to train the next generation of scientists and engineers in a variety of Arctic-relevant disciplines. Activities such as virtual participation in field projects, development of high-impact multimedia educational web content, and student engagement in competitions and summer schools in Arctic locations are all known to be effective tools for education and learning.

Activities undertaken as part of the International Polar Year demonstrated that student and public engagement in science can strengthen learning through observations and research about the changing Arctic and how it affects the rest of the world.

Efforts reviewed at the Ministerial under this theme include:

- Norway is supporting the development of a “One Stop Shop for Arctic Knowledge” by the University of the Arctic (UARctic). It unites more than 170 research-focused universities, colleges, and institutes around the circumpolar North of the eight Arctic states, as well as Arctic Council



John Holdren signing the Joint Statement of Ministers. Photo by US Coast Guard Petty Officer 2nd Class Connie Terrell

observer states. UARctic will create four new “mini MOOCs” (Massive Open Online Courses) that will provide a basic introduction to the Arctic for a broad audience, and a catalogue of Arctic courses and study programs, and research infrastructure. UARctic will also use web-based, big-data analytics to create an online directory of Arctic-wide research institutions, researchers and research projects, publications, and research trends and gaps to foster international research and education collaboration.

- The European Union EDU-ARCTIC project supports researchers and educators in the Faroe Islands, France, Iceland, Norway, and Poland to develop an innovative educational program to attract young people to natural sciences and polar research.
- The Arctic Warrior project in Spain uses educational trans-media and game-design elements to promote Arctic environmental protection.
- Singapore is working to increase awareness in the Tropics of the changes in the Arctic by convening seminars and conferences.
- The “Japan-Russia Expert Education Project” will continue to nurture professionals to play leading roles in creating a sustainable future in the Russian Far East and the Arctic.
- The US Department of the Interior will continue its support for the Alaska Native Science and Engineering Program (ANSEP) at the University of Alaska Anchorage, which is effecting systemic change in STEM education and capacity-building among Alaska Native students.

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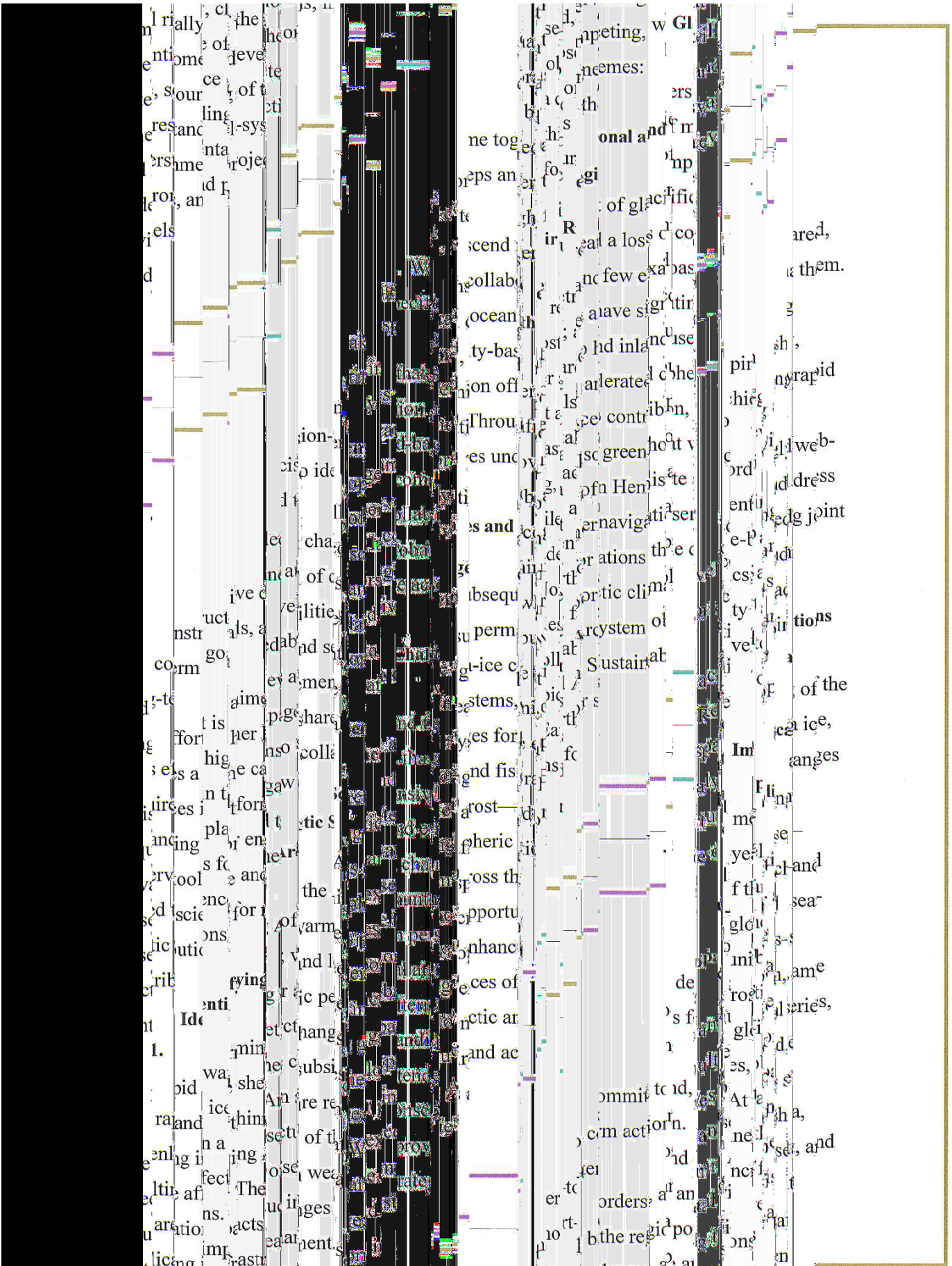
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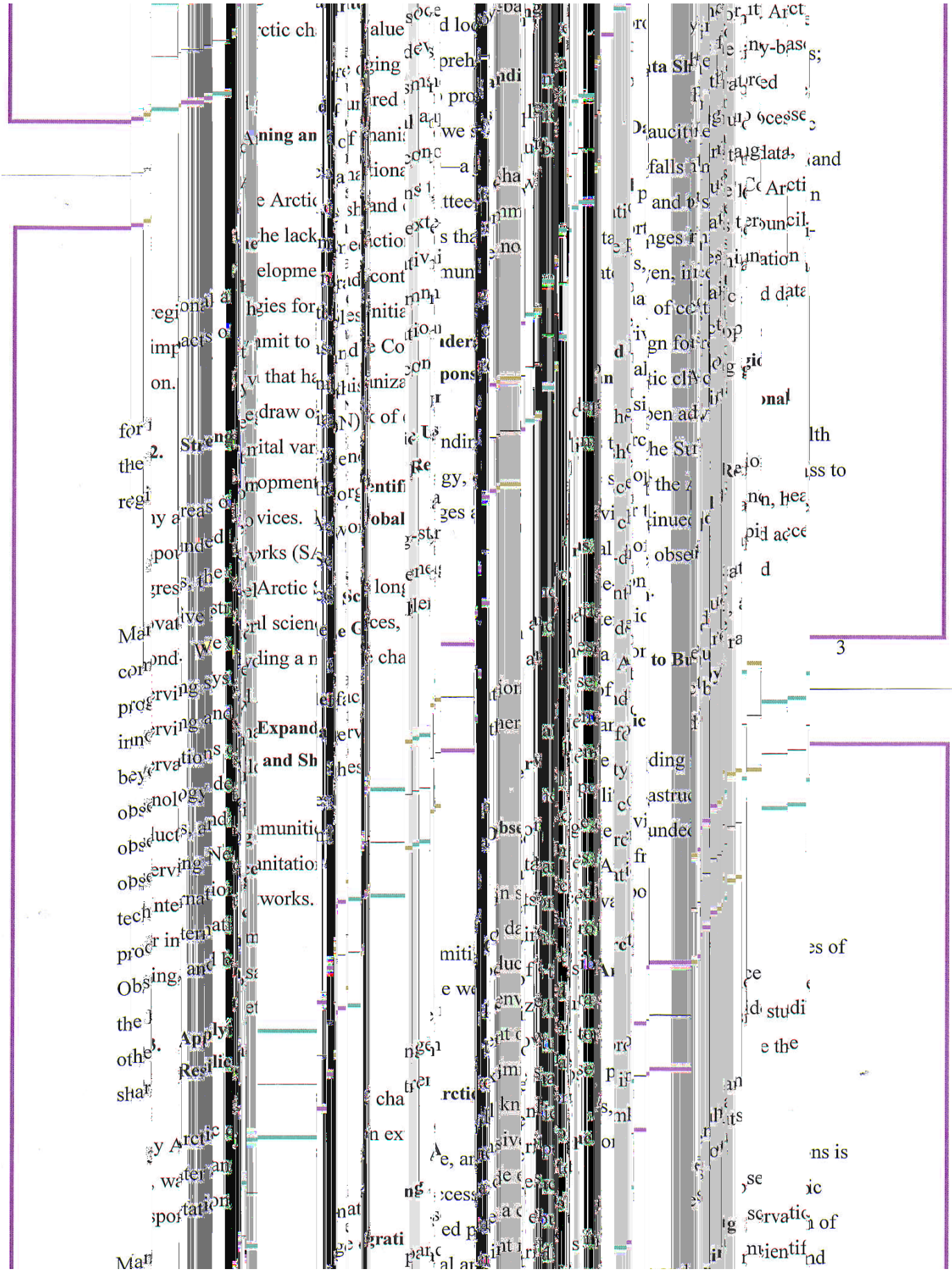
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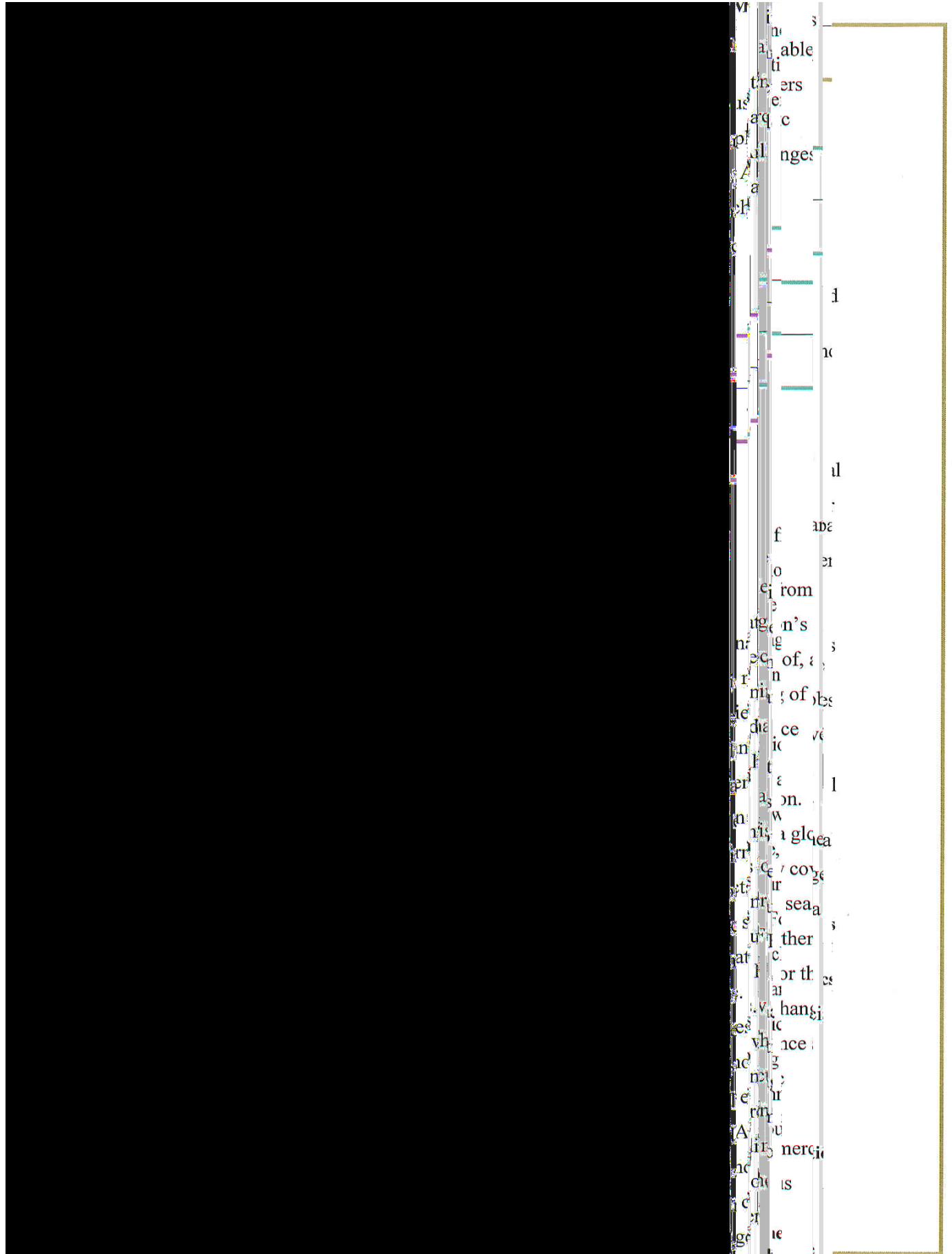
Science Ministerial

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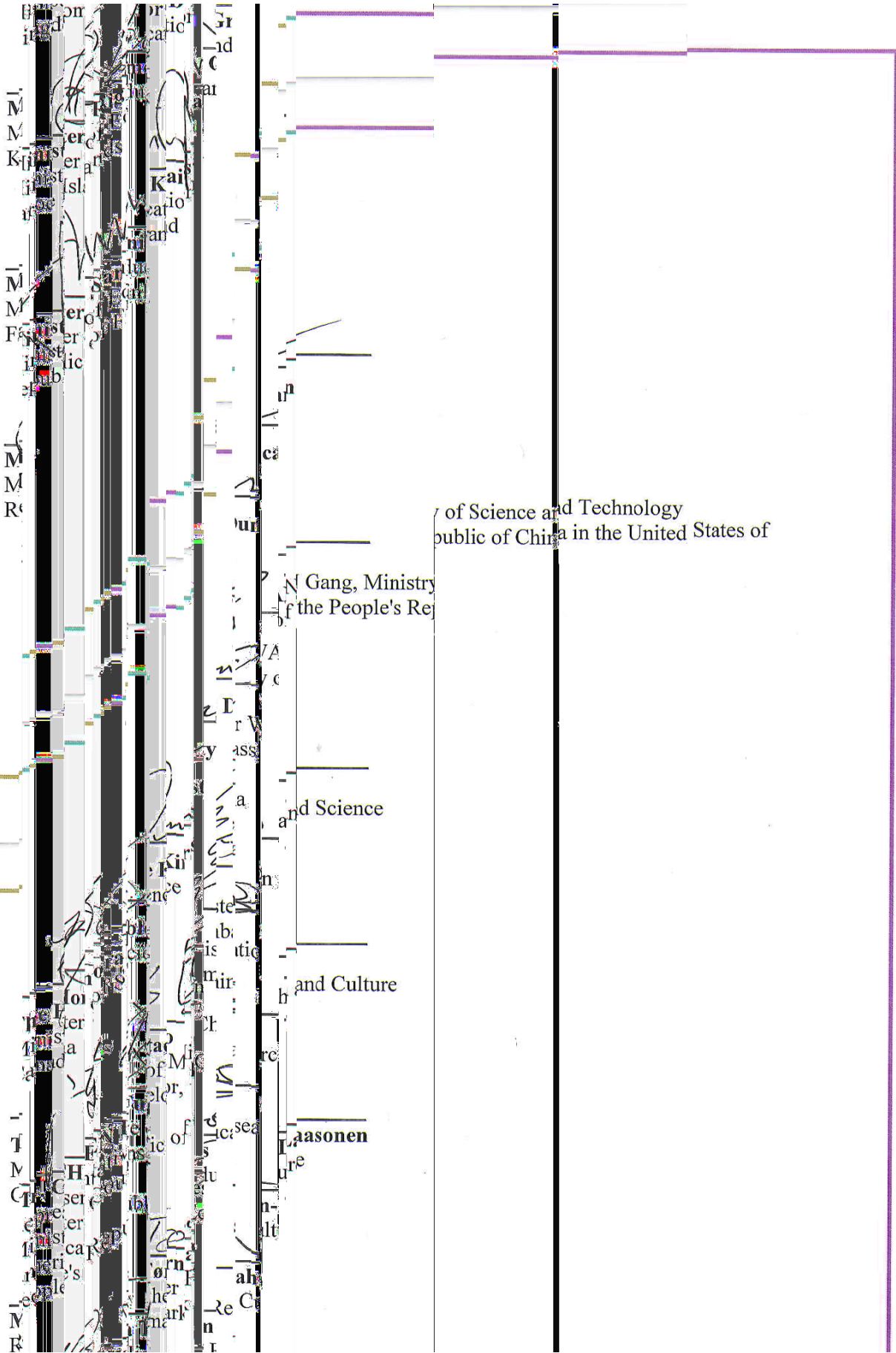
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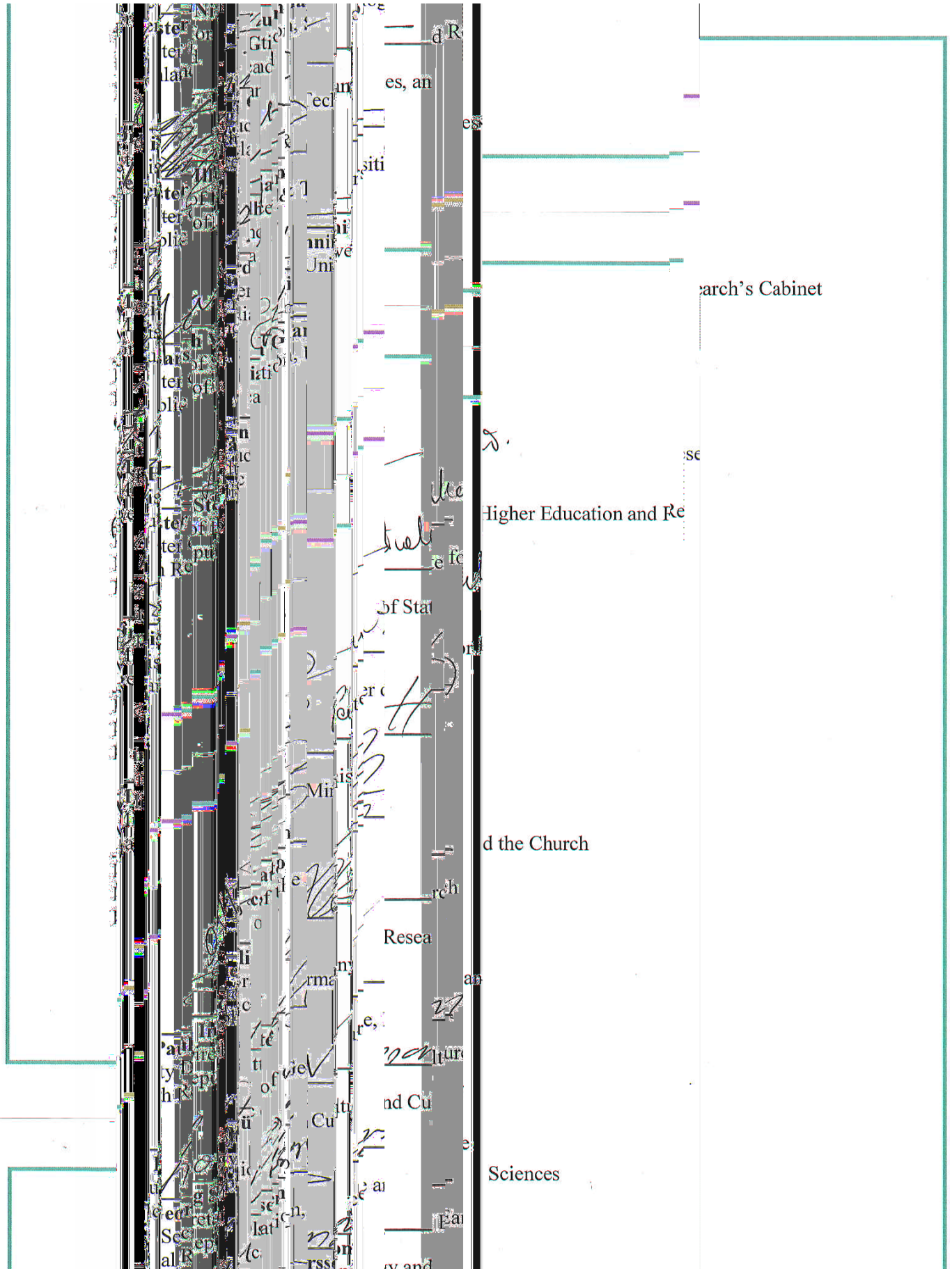


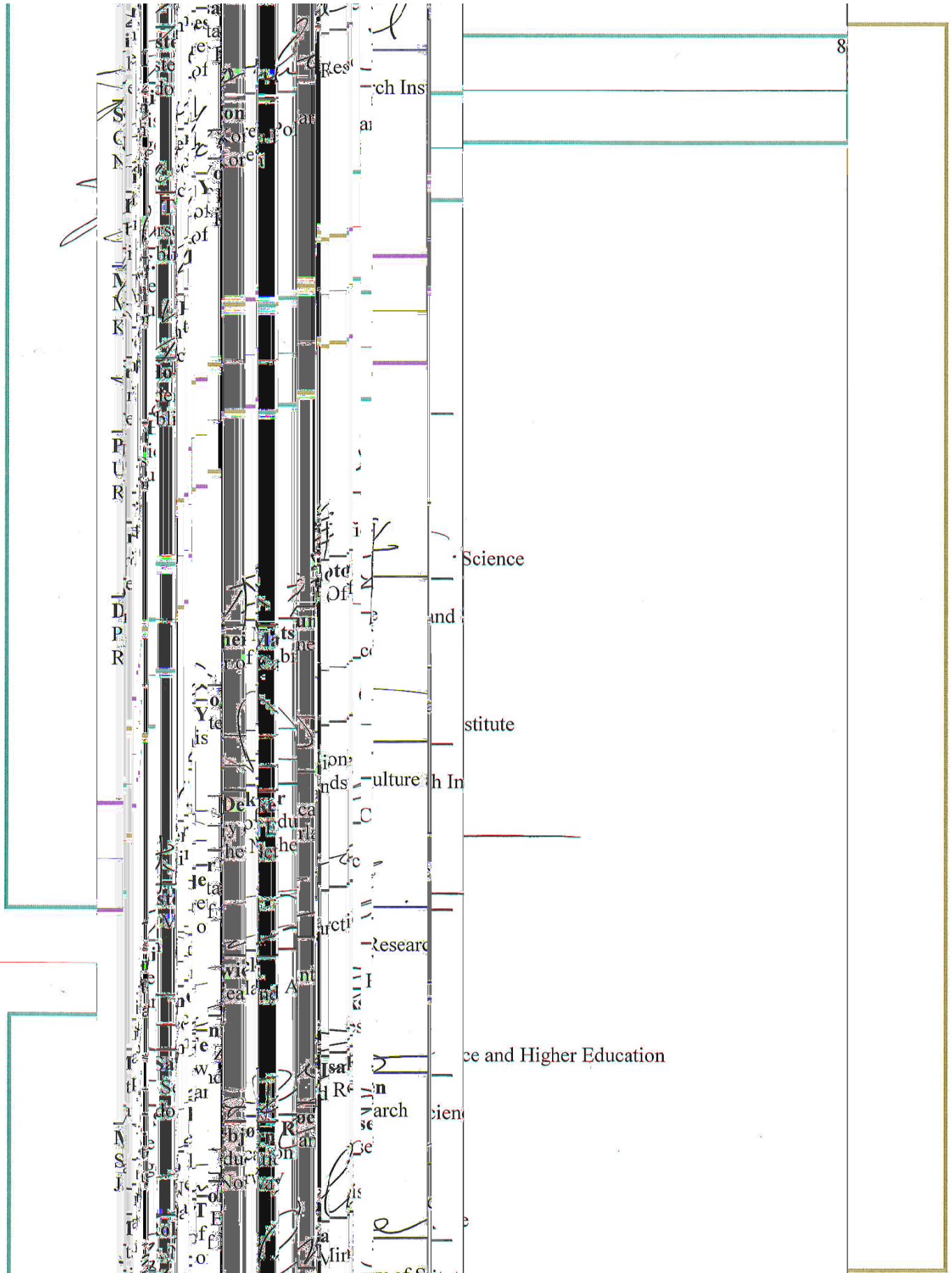
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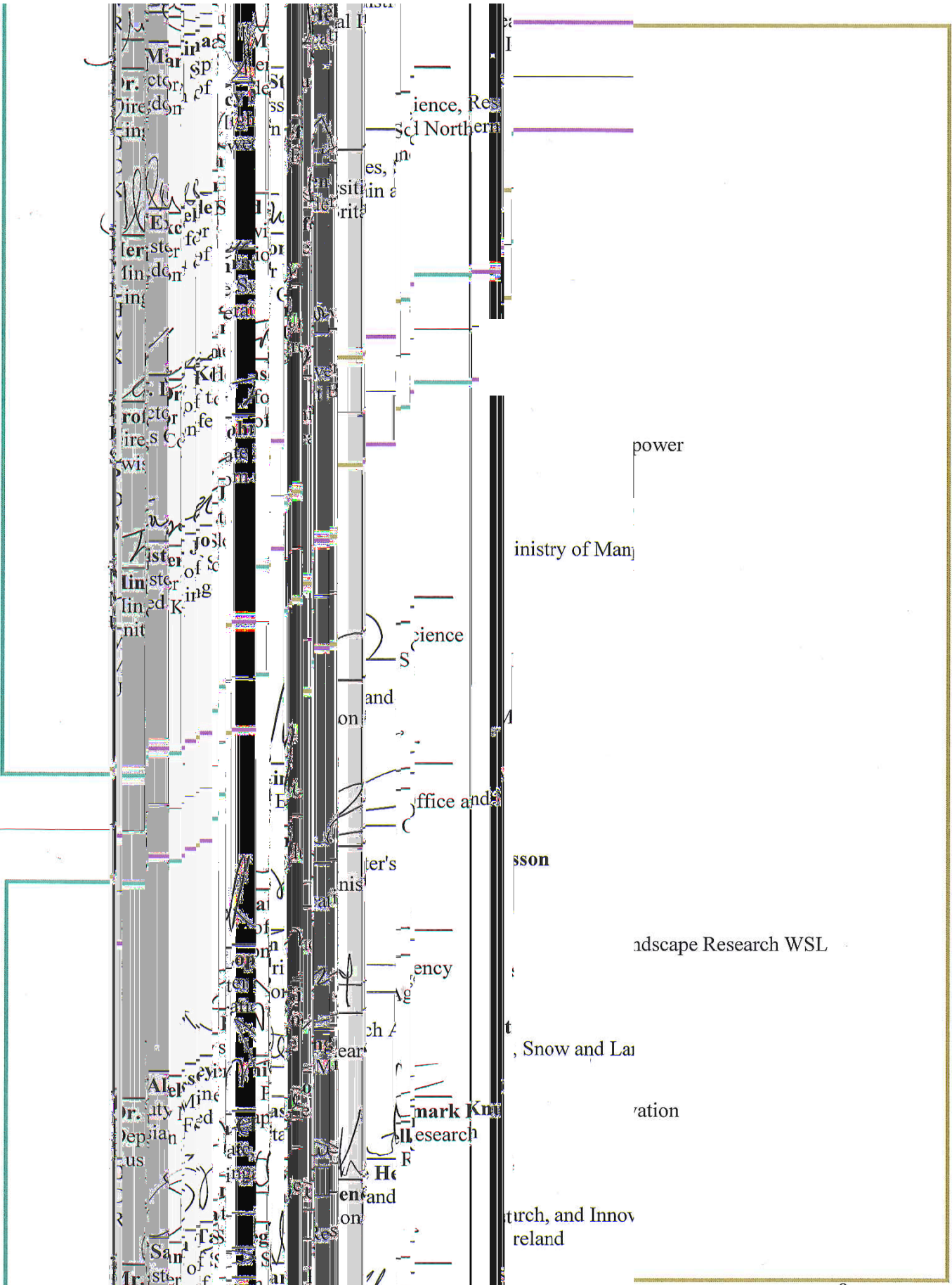
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Dr. Kathryn Sullivan

Administrator
National Oceanic and Atmospheric Administration

Minister Sam Tan

Minister of State, Prime Minister's Office and
Ministry of Manpower
SINGAPORE

Dr. Andrea Tilche

Head of Climate Action and Earth Observation Unit,
DG Research and Innovation
EUROPEAN COMMISSION

Dr. Nikolay Toivonen

Director for International Cooperation,
Ministry of Education and Science
RUSSIA

Minister Ulla Tørnæs

Minister for Higher Education and Science
DENMARK

Ms. Ellen Inga Turi

Head of Delegation, Saami Council
SAAMI COUNCIL

The Honorable Francis Ulmer

Chair
US Arctic Research Commission
USA

Dr. Dick van der Kroef

Acting Director, Netherlands Organization for Scientific
Research, Earth and Life Sciences
NETHERLANDS

Minister Harsh Vardhan

Minister of Science & Technology and Earth Sciences
INDIA

Ms. Carmen Vela

State Secretary for Research, Development, and Innovation
SPAIN

Ms. Elisabeth Verges

Director of Strategy at the Ministry of Research
and Higher Education
FRANCE

Ms. Caroline Vicini

Minister (Deputy Head of EU Delegation to the USA)
EUROPEAN COMMISSION

Ms. Marina Pilat Villegas

Director, State Agency for Research
SPAIN

Dr. Jan-Gunnar Winther

Director, Norwegian Polar Institute
NORWAY

Dr. Ho-Il Yoon

President of Korea Polar Research Institute (KOPRI)
REPUBLIC OF KOREA

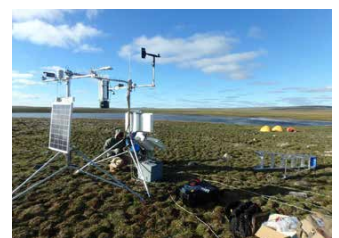
Dr. Jinping Zhao

Professor, Ocean University of China
CHINA

Mr. Ping Zhong

Interpreter
CHINA

Arctic Science Programs Synopses from 24 Governments and the EU



Foreword

Ministerial Delegations:

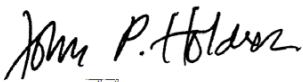
In preparation for the first-ever White House Arctic Science Ministerial, we are pleased to provide this compilation of two-page descriptions of national Arctic-science activities provided by the participants and edited by the US Arctic Research Commission. The background information included in these self-reported descriptions will help frame discussions at the Ministerial and shape ongoing dialog.

Understanding the rapid changes that are affecting the Arctic—as well as the impacts of these changes on the rest of the world—requires a cooperative, global approach based on research partnerships involving participants from Arctic and non-Arctic nations, including, of course, the people who call the Arctic home. That’s why the Obama Administration decided to host this Ministerial, which is taking place on September 28, 2016—just over a year after the GLACIER Conference and President Obama’s visit to the Arctic as the first US President to do so.

The Ministerial brings together ministers of science, chief science advisors, and other high-level officials from countries around the world, as well as representatives from indigenous groups, to expand collaboration focused on Arctic science, research, observations, monitoring, data-sharing, and public education. The goals of the event are to advance promising short-term initiatives to these ends and to create a foundation for increased international scientific collaboration on the Arctic over the longer term.

We welcome you to Washington, DC, and we greatly appreciate your participation in this event.

Sincerely,



John P. Holdren
Assistant to the President for Science and Technology
Ministerial Chair



France A. Córdova
Director, National Science Foundation
Ministerial Vice-Chair



Fran Ulmer
Chair, US Arctic Research Commission
Ministerial Vice-Chair



Canada

Point of Contact

• Polar Knowledge Canada (<http://www.canada.ca/en/polar-knowledge>)

Arctic Research Policy and Goals

Canada's overarching goal is to support scientific research and the integration of the knowledge gained into policy decisions, including those on the Arctic. Canada's approach recognizes 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. Equally important is the need to work in partnership with Northern communities and Indigenous peoples to set the Arctic research agenda, respectfully

include Indigenous science and traditional knowledge, and use Arctic science and research to address issues of importance to their communities.

In April 2016, territorial premiers released *A Pan-Northern Approach to Science*, which includes a shared vision to enable a prosperous, healthy and sustainable North that benefits Northerners and all Canadians, now and in the future. Each territorial government has also identified a science advisor: Aynslie Ogden (Yukon), Andrew Applejohn (Northwest Territories), and Mary Ellen Thomas (Nunavut).

Arctic Research Funders

Federal Granting Agencies. The Canadian Institutes of Health Research (CIHR), the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Social Sciences and Humanities Research Council of Canada (SSHRC) promote and support research, training and innovation within Canada, including the Canadian Arctic.

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 (for example: Environment and Climate Change Canada, Fisheries and Oceans Canada, Health Canada, Indigenous and Northern Affairs Canada, Polar Knowledge Canada, Natural Resources Canada and the National Research Council of Canada) deliver Arctic-focused science programs and/or provide targeted funding for northern research projects and programs.

Territories. Sub-national governments in Canada, in particular the three territorial governments (Yukon, Northwest Territories, and Nunavut) play a key role in supporting and delivering applied northern science. In Canada, Indigenous organizations, Land Claim Organizations and co-management boards also make key contributions to northern science.

Major Arctic Research Initiatives

ArcticNet studies the impacts of climate change and modernization in the coastal Canadian Arctic. It brings together scientists in the natural, human health, and social sciences with partners from Inuit organizations, northern communities, government agencies and the private sector.

Geo-Mapping for Energy and Minerals Program. Led by Natural Resources Canada, this program 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 Program. Led by Indigenous and Northern Affairs Canada, this program 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.

Sentinel North is a major new research program led by the Université Laval that will improve understanding of environmental changes and their consequences on human health in the North. The program will encourage joint projects focusing on discovery, transdisciplinarity, innovation, collaboration, national and international partnerships, and technology transfer.

Territorial Colleges and Research Institutes. Universities and colleges across Canada, including territorial colleges and research institutes (Yukon College, Yukon Research Centre, Aurora College, Aurora Research Institute, Nunavut Arctic College and Nunavut Research Institute) also play a role in developing and delivering northern science.

Arctic Research Infrastructure

POLAR CONTINENTAL SHELF PROGRAM (PCSP)

This program provides logistical support to researchers working in Canada's North. Services provided include 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 Canadian Coast Guard (CCG) ice breakers 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 that supports science-based conservation and sustainable development of Nunavut fisheries.

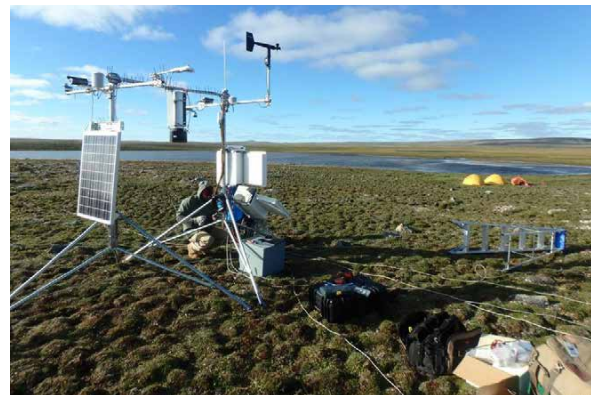
FIELD STATIONS AND INSTRUMENTATION

Canadian Network of Northern Research Operators (CNNRO) is a network of research support facilities (including research vessels, unmanned monitoring installations and field stations) that provides a variety of services to academic, government, private and international scientific researchers. The network includes 95+ facilities across Manitoba, Newfoundland and Labrador, Ontario, Quebec, Northwest Territories, Yukon and Nunavut. A full list of facilities is available at <http://cnnro.ca/our-facilities>.

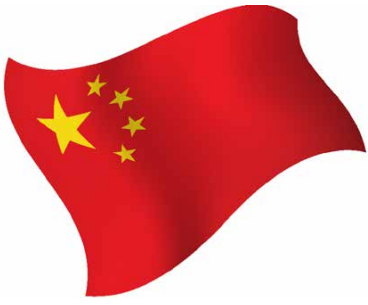
SATELLITES

- **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 (RCM)**, to be launched in 2018, will complement its predecessor. It 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 Canadian satellites are all serviced by the Government of Canada's network of stations, including the Inuvik Satellite Station Facility.



(LEFT) Construction of the Canadian High Arctic Research Station (CHARS) in Cambridge Bay, Nunavut. *Photo by Canada Centre for Mapping and Earth Observations*
(ABOVE) Installation of a weather station at Greiner Lake, Nunavut. *Photo by Polar Knowledge Canada*



People's Republic of China

Point of Contact

• Chinese Arctic and Antarctic Administration (CAA; <http://www.chinare.gov.cn/caa>)

Arctic Research Policy and Goals

The Arctic research policy of China includes: playing an active role as an observer in the Arctic Council; enhancing scientific observation and modeling prediction capabilities; promoting international data sharing and research collaborations; protecting the Arctic ecosystem and environment; and encouraging cooperation between Arctic

countries and non-Arctic countries. The research policy, which is implemented by Chinese Arctic and Antarctic Administration (CAA), is to understand, protect, use, and manage the Arctic based on decision-making that is informed by rigorous scientific research results.

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 Land and Resources (MLR) 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, 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, modeling, 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 fieldwork.

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.

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 Program 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 analyze 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 invests in research infrastructure.

VESSELS

Built in 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 center. Operated by the Polar Research Institute of China, MV *Xuelong* conducted all seven of China's Arctic expeditions. China is currently building a new icebreaker, with a significantly higher ice class, that was designed by both foreign and domestic experts.

FIELD STATIONS

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, a dormitory, and storage, and can support a crew of 20-25 people. The four labs support research in the fields

of meteorology and space-earth measurements, glaciology, marine ecosystems, and environmental and weather patterns. A rooftop 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 organizations to conduct experiments at the Yellow River Field Station. Support projects include, ice core drilling and analysis, upper ionosphere physics, fish and phytoplankton community analysis, and snow/ice radiometric investigations, among others.

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 (arose from 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.



(ABOVE) China's Yellow River Research Field Station in Svalbard, Norway. Credit: <http://space.iggcas.ac.cn/YellowRiverScenery>

(LEFT) China's icebreaker MV *Xuelong* in the Arctic Ocean. Credit: Sinoshipsnews.com



Denmark

Point of Contact

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

Arctic Research Policy and Goals

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, Greenland 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).

Arctic Research Funders

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

Innovation Fund Denmark invests in cultivating and translating ideas, knowledge and technology to benefit 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) Centers of Excellence – a center grant 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.

Danish Environmental Protection Agency (Danish EPA, Ministry of Environment and Food) supports environmental monitoring and assessment of biodiversity and global pollution in the Arctic (Greenland and the Faroe Islands). The support

is given via the Danish Environmental Support Programme, DANCEA. The work contributes to the Arctic monitoring and assessment programme (AMAP), the Conservation of Arctic Flora and Fauna (CAFF), and the Circumpolar Biodiversity programme (CBMP) under the Arctic Council.

Major Arctic Research Initiatives

Four of the major universities in Denmark (Copenhagen, Aarhus, Aalborg, and The Danish Technical University of Denmark) have cross-cutting, interdisciplinary Arctic research initiatives. Polar research is conducted within all fields of science, but 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 accounts 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.

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. This biannual forum is used to exchange information and knowledge on ecosystem monitoring, station management and administration among research station managers and with other partners and stakeholders.

Global Atmosphere Watch (GAW) Programme. Denmark contributes to the Global Ozone Observing System (GO3OS) with three stations in Greenland (Kangerlussuaq, Pituffik and Illoqqortoormiut) and one in Denmark (Copenhagen). The stations are operated by the Danish Meteorological Institute (DMI). The stations in Greenland are primary and secondary stations in the Network for the Detection of Stratospheric Change (NDSC) that is supported by the International Ozone Commission. The Greenlandic ozone stations are supported by (DANCEA) under the Danish Ministry of Environment and Food.



(ABOVE) Lake monitoring, part of the GEM program, involves training the next generation of polar scientists. *Photo credit: Morten Rasch*

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

- **Zackenber 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 member of 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 nano-satellites.

(BELOW) The Zackenberg Research Station, in Northeast Greenland, has nine houses, a powerplant, waterworks, and an airstrip. *Photo credit: Morten Rasch*





Greenland

Points of Contact

- Ministry of Education, Culture, Research and Church (<http://www.nanoq.gl>)
- Greenland Research Council (<http://www.forskningsraadet.gl>)

Arctic Research Policy and Goals

Greenland's policy is to promote the development of its society with a strong and sound international research program 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 prioritization of research efforts, and enhancing Greenland's participation in international cooperative research initiatives.

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

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.

Major Arctic Research Initiatives

Greenland Climate Research Centre manages research funds, which, through completion of research projects, contribute to increasing knowledge of climate, nature, technology and society.

Greenland Ecosystem Monitoring (GEM) is an integrated monitoring and long-term research Programme on Ecosystems and Climate Change effects and feedbacks in the Arctic.

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.

Greenland Perspective is an interdisciplinary collaborative effort to investigate what Greenland has to offer – in terms of natural and human resources.

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.



R/V Sanna. Photo courtesy natur.gl

Arctic Research Infrastructure

VESSELS

Greenland has two research vessels, the R/V *Paamiut* and the R/V *Sanna*, as well as several smaller vessels.



R/V Paamiut. Photo courtesy Josephine Nymand natur.gl

FIELD STATIONS

- **Nuuk and the Kobbefjord Field Station** provide access to low Arctic ecosystems in West Greenland with different biotopes such as dwarf-shrub heaths, fens, grasslands, and lakes.
- **Zackenberg** is situated in the High Arctic in an area with continuous permafrost.
- **Daneborg** is located in the outer part of Young Sund, next to the main station of the Sirius Patrol, in Northeast Greenland.
- **Villum Research Station** is situated at Station Nord. A substantial upgrade of its existing air pollution monitoring station is planned.
- **Niaqornat** conducts long-term studies of beluga and narwhals. Studies of other game animals and of the environment local to this field station may also be considered.



Zackenberg Research Station. Photo by Kristian Hassel, NTNU Vitenskapsmuseet

DRONES

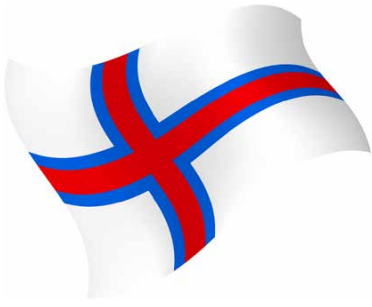
- **ASIAQ.** The Greenland Survey entity, ASIAQ, has invested in two small drones for use in several field studies.



Villum Research Station.



Niaqornat Research Station.



The Faroe Islands

Points of Contact

- Ministry of Education, Research and Culture (<http://www.mmr.fo>)
- Faroese Geological Survey (<http://www.jardfeingi.fo>)
- National Faroese Heritage (<http://www.savn.fo>)
- Faroe Marine Research Institute (<http://www.hav.fo>)
- University of the Faroe Islands (<http://www.setur.fo>)
- Environmental Agency (<http://www.us.fo>)
- Public Health Institute (<http://www.health.fo>)

Arctic Research Policy and Goals

The Faroe Islands do not yet have an explicitly formulated Arctic research policy. 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 research 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.

Arctic Research Funders

- Public sector expenses
- The Faroese Research Council
- Governmental research funds in Denmark (for example Dancea)
- Research funds in the Nordic Cooperation (for example, Nora)
- Research funds in the European Union (for example, Horizon2020)

Major Arctic Research Initiatives

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

FAROESE GEOLOGICAL SURVEY

(Jardfeingi: <http://www.jardfeingi.fo>, Contact: Lis Mortensen)

- **InterAct.** Research infrastructure: 33 terrestrial research stations in the circumpolar Arctic focusing on environment and climate change. The infrastructure program involves over 60 research station in the circumpolar region and includes cooperate with University of the Arctic. Partners: entire circumpolar region. Project manager: Sweden. (<http://www.eu-interact.org>)
- **EduArctic.** Dissemination of Arctic research to youth in Europe, ages 13-20. Partners: Poland, Faroe Islands, Iceland, Norway and France. (<http://edu-arctic.eu>)

- **NagTec.** Northeast Atlantic Geoscience Tectonostratigraphic Atlas. A new atlas detailing the tectonostratigraphic development of the Northeast Atlantic region with an emphasis on conjugate margin comparison. Partners: UK, The Netherlands, Norway, Faroe Islands, Germany, Iceland, Denmark and Greenland. (<http://nagtec.org>)
- **EmodNET Geology.** Primary geological survey information to generate geological maps of European waters, including the Arctic waters. Partners: Faroe Islands, Iceland, Norway and all coastal states of EU. (<http://emodent.eu.geology>)
- **EmodNET Bathymetry.** Topography of the seabed in European waters, including Arctic waters. Partners: Faroe Islands, Iceland, Norway and all coastal states of EU. (<http://emodent.eu/bathymetry>)
- **IQUAME2500.** International Quaternary Map of Europe in scale 1:2500. Contact: Dr. Kristine Asch. (http://www.bgr.bund.de/EN/Themen/Sammlungen-Grundlagen/GG_geol_Info/Karten/International/Europa/Quartaergeologie/Iquame_Review.html)
- **Sustainable Land Use, Geohazards and Erosion.** Projects and cooperation in the Faroe Islands with local stakeholders.

THE NATURAL MUSEUM, NATIONAL FAROESE HERITAGE

(<http://www.savn.fo>, Contact: Anna Maria Fosaa)

- **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.

FAROE MARINE RESEARCH INSTITUTE

(<http://www.hav.fo>, Contact: Eilif Gaard)

- **Monitoring and Research.** Monitoring and research of the marine environment of the Faroese territory.
- **WOW.** Western Valley OverfloW. Dancea project. Partners: Havstovan and Danish Meteorological Institute.
- **Blue-Action.** Arctic Impact on Weather and Climate. EU Horizon 2020 project (BG-10-2016). 41 participants from 17 countries. 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 valued climate services of societal benefit (Project starts: Dec. 2016)
- **AtlantOS.** Optimizing and Enhancing the Integrating Atlantic Ocean Observing System. EU Horizon 2020 project. 62 partners from 18 countries.
- **NACLIM.** North Atlantic Climate. EU-FP7. 18 partners from 10 European countries. Selected objectives: Monitoring of volume, heat and fresh water transports across key sections in the North Atlantic; Quantifying the impact of predicted North Atlantic upper ocean state changes on the oceanic ecosystem (<http://naclim.zmaw.de>)

UNIVERSITY OF THE FAROE ISLANDS

(<http://www.setur.fo>, Contact: Sigurð í Jákupstovu, rector)

- **West Nordic Studies.** Nordic joint educational program.
- **Research.** Research on social and political implications of climate change and sustainable development in the Arctic and Nordic region.
- **Sustainability.** Sustainable sheep grazing in Nordic countries.



Researchers establishing the monitoring site on Sornfelli mountain. Photo by: L. Mortensen

ENVIRONMENTAL AGENCY

(<http://www.us.fo>, Contact: Maria Dam)

- **Monitoring and Research.** Chemical, air pollution and biological pollution monitoring and research.
- **Sustainability.** Sustainable green energy for the Faroese society

PUBLIC HEALTH INSTITUTE

(<http://www.health.fo>, Contact: Pál Weihe, professor)

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

Arctic Research Infrastructure

VESSELS

- **R/V Magnus Heinason 669 BRT** (<http://ewww.hav.fo>). A new multipurpose research vessel is planned to be operational in 2019 for use in The North Atlantic and the Arctic.
- **Biofarið 34' boat.** Havlívfrøðiliga kanningarstovan Biofar (<http://ewww.biofar.fo>)
- **Nýsan 25' Boat.** Landsverk (<http://www.lv.fo>)

FIELD STATIONS AND MONITORING SITES

- **Fini-Station, Faroese Geological Survey (Jardfeingji).** Monitoring sites include: Sornfelli and Slættaratindur. (<http://www.jf.fo>)
- **Sornfelli, The Natural Museum, National Faroese Heritage** (<http://www.savn.fo>)
- **AMAP Monitoring Sites** (<http://ewww.savn.fo>)
- **Gloria Monitoring Sites** (<http://ewww.savn.fo>)
- **CAFF Monitoring Sites** (<http://ewww.savn.fo>)
- **Ramsar Sites** (<http://ewww.savn.fo>)
- **Meteorological Monitoring Sites at Landsverk** (<http://ewww.lv.fo>)
- **Geohazard on Roads Monitoring Programme** (<http://ewww.lv.fo>)



A view of the Faroe Islands. The high relief islands are surrounded by the Gulf current in the eastern North Atlantic Ocean with oceanic temperate climate at sea level and Arctic climate in the mountains. Photo by L. Mortensen.



Finland

Points of Contact

- Ministry of Education and Culture (<http://www.minedu.fi>)
- Academy of Finland (<http://www.aka.fi>)
- The Finnish National Committee of Arctic and Antarctic Research (<http://www.academies.fi>)

Arctic Research Policy and Goals

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.

Arctic Research Funders

Academy of Finland. As a national funding agency, the Academy of Finland (the Finnish research councils) funds high-quality scientific research projects. The Academy of Finland is also a stakeholder in Arctic research priorities, and it funds the national Arctic research programme ARKTIKO.

Tekes – the Finnish Funding Agency for Innovation. Tekes offers funding for research and development conducted by Finnish companies, research organisations, and public sector service providers. Tekes funds the national Arctic Seas programme.

Ministry of Education and Culture. This Ministry coordinates science policy issues and guides and funds institutions of higher education. Universities in Lapland and Oulu strategically prioritize the Arctic region. Most Finnish universities and other academic institutions have research programs focusing on the Arctic, the North, and cold climate regions.

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 programs.

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.

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

European Union. EU Horizon 2020 program provides funds for collaborative Arctic research.



A winter image of Finland's Pallas research station operated by the Finnish Meteorological Institute. *Photo by Ahti Ovaskainen*

Major Arctic Research Initiatives

ARKTIKO. The national research programme ARKTIKO (2014–2018), 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.

Arctic Seas Programme. The primary goal of this programme, run by Tekes, is to strengthen Finland’s reputation as an internationally attractive centre of Arctic “know-how.”

Arctic Centre. The Arctic Centre conducts internationally recognized and highly regarded multidisciplinary research on the Arctic region. Its emphasis on science communication and on public exhibitions improves the visibility of Finland’s Arctic expertise, and increases international access to Arctic information.

Joint Nordic Initiative on Arctic Research. Finland is co-funding the NordForsk Arctic research programme of Nordic Centers of Excellence. 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.

ICE MODEL BASINS

Ice model basins, owned and operated both by Aalto University and private enterprise, 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.

VESSELS

- **R/V Aranda.** 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.
- **Icebreakers.** Finland has a fleet of icebreakers. Several are multipurpose vessels capable of offshore tasks including serving as research platforms. Current plans include equipping a vessel for an international Arctic research expedition in the summer of 2017.



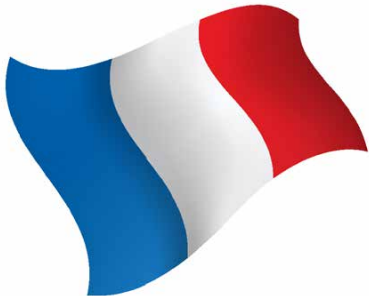
Indigenous Nenets nomads on the Yamal Peninsula, West Siberia where Arctic Centre scientists, from the University of Lapland, conduct field research. *Photo by Bruce Forbes*

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.



France

Points of Contact

- Ministry of Foreign Affairs and International Development SG/poles & DJ/sea (<http://diplomatie.gouv.fr>)
- Ministry of Education, Higher Education and Research – Service Strategy, Research and Innovation (<http://enseignementsup-recherche.gouv.fr>)

Arctic Research Policy and Goals

In June 2016, France published a National Roadmap for the Arctic titled, “The Great Challenge of the Arctic,” based on inter-ministerial consultation among four Ministries (Defense, Ecology, Sustainable Development & Energy, Higher Education & Research, and Finance) and on input from several government agencies under the aegis of the French Ministry of Foreign Affairs and International Development. Four focus areas were

selected: (1) Identifying France's interests (e.g., economic, defense, scientific, and influence) in the Arctic; (2) Enhancing the legitimacy of France in Arctic affairs and forums; (3) Working to balance national interest and broader, international interest in governance of the Arctic Ocean; (4) Promoting a high level of protection for this unique and fragile marine environment.

Arctic Research Funders

The Centre National de la Recherche Scientifique (CNRS). The French National Center for Scientific Research supports research in all major fields. Three domains support Arctic research: Earth and Universe Sciences, Ecology and Environment, and Social Sciences. The International Research Unit Takuvik is a joint laboratory effort focusing on Arctic research between University Laval (Canada) and the CNRS.

Institut Polaire Français Paul-Emile Victor (IPEV). The French Polar Institute is the governmental support agency that provides a legal framework and resources to French researchers in polar regions. The main missions of IPEV are to: (1) implement scientific and technological programs in the Arctic, Antarctic and Sub-Antarctic, (2) organize scientific expeditions, (3) maintain infrastructure and equipment in support of research, and 4) organize oceanographic campaigns (R/V *Marion-Dufresne* and *Astrolabe*).

Centre national d'études spatiales (CNES). The National Centre for Space Studies defines and executes France's space policy. The scientific objectives of the Earth Observation program of CNES (including in the Arctic region) are to: (1) improve our understanding of the Earth System, and to operationally support environment management and sustainable development, (2) study global climate change, and (3) study the feasibility of geostationary or high-temporal revisit capability observational systems.

Agence Nationale de la Recherche (ANR). The French national research agency funds research to better understand the mechanisms underlying global environmental change and its impacts on local and regional resources, and human societies and activities, particularly those that depend on ecosystem services, across scales ranging from local landscapes to global.

Ministry of Education, Higher Education and Research (MENESR). The Ministry in charge of research supports and coordinates the research actions led by public scientific bodies and universities. A specific committee has been established to coordinate national efforts in Arctic research.

Ministry of Foreign Affairs and International Development (MAEDI). This Ministry has long considered science to be a major diplomatic tool in polar affairs. “Reinforcing scientific research and cooperation” in the Arctic has become a national priority, as per the aforementioned Roadmap. The MAEDI promotes and supports the participation of French researchers in international Arctic fora.

Ministry of Environment, Energy and the Sea (MEEM). The Directorate for Sea Fisheries and Aquaculture follows international negotiations on a convention to oppose illegal fishing in the Arctic Ocean, in which France participates on behalf of the European Union. A scientific committee has been established, and in Sept. 2016, a joint research program will be set up to provide a framework for future scientific studies of fisheries.

Major Arctic Research Initiatives

- The French Arctic Initiative (FAI, 2015–2020, CNRS) fosters collaboration across the French scientific community on major Arctic research themes. FAI supports: (1) GREENEDGE (cofounded with ANR, CNES, CNRS and Arctic-Net; dynamics of the phytoplankton spring bloom and its role in the Arctic Ocean), and (2) PARCS (understanding of the sources and fate of Arctic pollution and its impacts).
- EQUIPEX program (Investments for the Future supported by the French Prime Minister up to 2020): IAOOS and NAOS develop and implement autonomous instrumentation (ice platforms and floats) to contribute to a long term observing system in the Arctic Ocean.
- The “Belmont Forum – Arctic Observing and Research for Sustainability” cofounded by ANR: Pan-ARCTIC OPTIONS (holistic Integration for Arctic Coastal-Marine Sustainability) and TAMANI (long-term monitoring sites for Arctic vertebrates) and the Arctic-ERA (Arctic climate change and its impact).
- The “Mobility and Sustainable Urban Systems” (ANR, launched in 2015): PUR (Polar Urban centers; understanding the Arctic settlement and urbanization process).
- Horizon 2020 Blue Growth initiative of the European Commission: INTAROS (BG9) and BLUE-ACTION (BG10) with the participation of CNRS.



Snow sampling, Svalbard.
Photo by IPEV

Base Jean Corbel, AWIPEV
Station, Svalbard. Photo by
Christelle Marlin



Arctic Research Infrastructure

VESSELS AND AIRCRAFT

While France has a fleet (CNRS/IFREMER/IPEV/IRD) of 10 research vessels, none have icebreaking capability. To gain physical access to ice-infested or -covered regions of the Arctic Ocean, France encourages research institutes and teams to develop international or European collaborations, such as the ongoing European ARICE initiative. Additionally, France measures the transport of pollutants, aerosols, atmospheric chemical species and air masses over the Arctic with two planes in its national SAFIRE fleet (CNES/CNRS/METEO-FRANCE), and with stratospheric balloons (CNES).

FIELD STATIONS

For 13 years, IPEV and the Alfred Wegener Institute (Germany), have combined efforts in Svalbard, and have made full use of logistic and scientific assets, to advance scientific understanding of the Arctic. The joint AWIPEV French-German Arctic Research Base, that is situated in the Norwegian settlement of Ny-Ålesund, on Spitsbergen (78°55.4'N; 11°55.25'E), offers operational opportunities in atmospheric research, geophysics, geochemistry, oceanography, biology, ecology and glaciology.

SATELLITES

France is a partner in the following Earth observation satellite systems that are heavily used by the international community to study sea ice and ice-covered surfaces, clouds, atmosphere, ocean circulation, marine primary production, and (soon) land surfaces, including those in the Arctic region.

- SMOS (Soil Moisture and Ocean Salinity; ESA/CNES/CDTI-Spain)
- IASI (Infrared Atmospheric Sounding Interferometer; CNES in partnership with Eumetsat).
- CALIPSO (Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations, CNES/NASA-USA).
- PLEIADES. Launched in 2011 and 2012, Pleiades is a constellation of two very-high-resolution satellites capable of providing images of any point on the globe.
- MERLIN (Methane Remote Sensing Mission, French-German minisatellite climate mission scheduled for launch in 2020, CNES/DLR-Germany).



Germany

Point of Contact

• Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research Program
(<http://www.awi.de>; Speaker: Prof. Jung (thomas.jung@awi.de))

Arctic Research Policy and Goals

Though not an Arctic nation, Germany operates one of the world's largest Arctic research programs. Germany has been an active and committed member of the International Arctic Science Committee (IASC) for more than three decades, and since 2011, has hosted IASC's secretariat in Potsdam. The 2013 publication "*Guidelines of German Arctic Policy*," by Germany's Federal Foreign Office, puts science and environment at the center of Germany's approach to engaging with Arctic nations. Germany's Arctic research program informs society and policymakers about the consequences of climate change in the Arctic as expressed by declining sea ice, thawing permafrost, melting glaciers and ice sheets, sea

level rise, and changing ecosystems (strategic approach of Arctic science government published in 2015: "*Rapid Climate Change in the Arctic - Polar Research as a Global Responsibility*"). Germany also supports basic research in other Earth System Sciences in support of political decision making. Arctic research results inform Germany's policies on sustainability and resilience at the national and international level. To this end, Germany is investing heavily in polar research logistics, with an Arctic research station in Ny-Ålesund, Spitsbergen, two aircraft equipped for polar research and a new icebreaking vessel, *Polarstern II*, due to begin operating in 2020.

Arctic Research Funders

Germany's federal ministries fund the Arctic activities of a number of federal research and development institutions and research centers.

The Federal Ministry of Education and Research (BMBF) supports Arctic research through targeted funding programs, and by sponsoring the **Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI)**, the national polar institute. The BMBF framework program **FONA** (Research for Sustainable Development) supports sustainability research. This program's subsection **MARE:N – Coastal, Marine and Polar Research for Sustainability**, focuses on polar and marine sustainability research.

To define the role of the polar regions in a changing planet, AWI's research concentrates on observational and modeling studies of all elements of the Polar Earth System. Paleoclimatic and paleoceanographic research, based on proxy records constructed from ice and sediment cores recovered from the polar regions, are also a focus of AWI's research, as they reveal past states of the Earth's climate, including extreme conditions. Funded by BMBF, the **GEOMAR Helmholtz Center**

for Ocean Research is a leading center of oceanography and has worked for decades, together with AWI, in Arctic permafrost regions.

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 Program for universities titled, "**Antarctic Research with Comparable Investigations in Arctic Sea Ice Areas**".

The Federal Ministry for Economic Affairs and Energy (BMWi) funds the national geoscientific authority **Federal Institute for Geosciences and Natural Resources (BGR)**, and the **National Aeronautics and Space Centre (DLR)**. BGR provides advice to the German Federal Government on all Earth science-relevant questions and is a partner in the government's Arctic research activities. DLR, which conducts extensive research and development work in aeronautics, space, energy, transport and security, is integrated into national and international cooperative ventures, and contributes to Arctic research through its satellite missions and remote sensing programs.

Major Arctic Research Initiatives

Germany leads a large number of bilateral and multilateral Arctic projects, for example:

- **EU-PolarNet – Connecting Science with Society.** AWI coordinates EU-PolarNet, the world's largest consortium of expertise and infrastructure for polar research. It consists of 17 countries represented by 22 of Europe's internationally respected multi-disciplinary research institutions. EU-PolarNet develops and delivers a strategic framework and mechanisms to prioritize science, to optimize the use of polar infrastructure, and to broker new partnerships that lead to the co-design of polar research projects that deliver tangible benefits for society.

EU-funded research projects coordinated by Germany (AWI):

- **European Research Cluster Aerosols and Climate.** The goal of this project is to better understand the distribution of aerosols in Earth's atmosphere, and how they are linked to climate change.
- **Changing Permafrost in the Arctic and its Global Effects in the 21st Century (PAGE21)** aims to understand and quantify the vulnerability of permafrost environments to a changing global climate, and to investigate the feedback mechanisms associated with increasing greenhouse gas emissions from permafrost zones.

Large national research projects:

- **(AC)3 – Arctic Amplification,** funded by DFG, investigates climate relevant processes and feedback mechanisms that cause Arctic amplification.
- **System Laptev Sea,** funded by BMBF, conducts process studies to understand the dynamics of permafrost in the Laptev Sea.
- **CASE.** For five decades, the BGR has improved understanding of the geological evolution and the resource potential of the circum-Arctic continental margin by supporting terrestrial and marine research. Through the CASE – projects under the Circum-Arctic Structural Events program, BGR conducts studies of the structural geology, the petrography and geochemistry of Arctic volcanic provinces, and aeromagnetism of areas covered by ice and water.



The German research vessel *Polarstern* during an expedition into the central Arctic Ocean. © Alfred-Wegener-Institut / Mario Hoppmann (CC-BY 4.0)

International projects currently being planned for coordination by AWI:

- **Year of Polar Prediction (YOPP)**
- **MOSAIC** – Multidisciplinary drifting Observatory for the Study of Arctic Climate.

Arctic Research Infrastructure

VESSELS

- The research icebreaker *Polarstern* is the most important tool of German Polar Research. Her successor vessel, *Polarstern II*, will be operational in 2020.

FIELD STATIONS

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

AIRCRAFTS

- Research aircraft **Polar 5** and **Polar 6** are Basler BT-67 planes, operated by AWI, have been specially modified to fly under extreme polar conditions.

SATELLITES

Germany shares satellite missions with many entities including ESA Member States, the European Union, the USA, and in public-private partnerships. The Earth Observation Center (EOC) at the DLR is Germany's center of expertise for earth observations.

- **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 antenna (DLR and Airbus Defence) and **SpaceTanDEM-X** (TerraSAR-X add-on for Digital Elevation Measurement)



Iceland

Points of Contact

- The Ministry of Education, Science and Culture (<http://eng.menntamalaraduneyti.is>)
- The Icelandic Centre for Research (<http://en.rannis.is>)

Arctic Research Policy and Goals

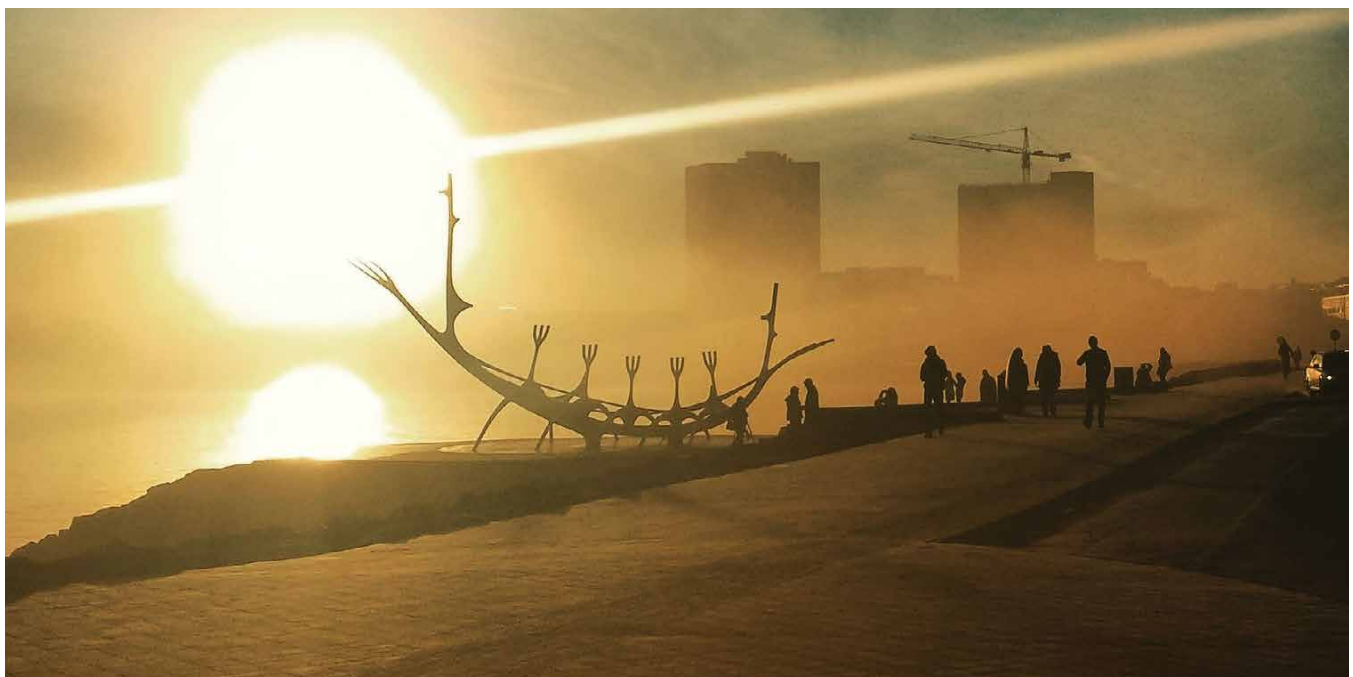
Iceland places great emphasis on increased international collaboration in science, innovation and education, greater mobility of researchers, and effective international cooperation associated with research infrastructures (“Fiscal Policy and Fiscal Strategy Plan 2017-2021”). The Parliamentary Resolution on Iceland’s Arctic Policy further stresses the principle of

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).

Arctic Research Funders

The Icelandic Centre for Research (Rannís). Rannís administers national competitive funds to support research on physical, biological, geological, and chemical processes in and around Iceland, as well as research on cultural heritage, society, economics, 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 Program for Research and Innovation and research collaboration among the Nordic countries under the auspices of NordForsk.



Sun Voyager by artist Jón Gunnar Árnason, Reykjavik.
Photo credit: Magnús L. Magnússon



Scientists and volunteers gather data on Vatnajökull ice cap.
Photo credit: Ásdís Jónsdóttir

Major Arctic Research Initiatives

Glaciers and Climate. Extensive collaboration, involving several institutes, is focused on understanding the evolution of Iceland's glaciers. The program involves regular monitoring of annual mass balance, changes in the position of glacier termini, and mapping of glacier surfaces based on remote sensing from aircraft and satellites. Many people from the general public, including locals, long-term volunteers, and school groups, regularly monitor the glaciers. The ice cap Hofsjökull, in the 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 harbors, hydro-electric power plants, and flood control measures.

Oceanographic Conditions around Iceland. The Marine and Freshwater Research Institute collaborates with universities and research institutes, both domestic and abroad, to improve understanding of the marine environment, including physical and chemical parameters and the ecosystem response 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, both domestic and abroad, to understand resilience and the social impacts of climate change on human livelihood.

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 for marine geophysical surveying. These vessels are capable of supporting a range of activities in the northern oceans.

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

AIRCRAFT

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

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

FIELD STATIONS

Grímsfjall field station of the Iceland Glaciological Society is located in the center 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.



India

Points of Contact

- Ministry of Earth Sciences (MoES; secretary@moes.gov.in)
- National Centre for Antarctic and Ocean Research (NCAOR; director@ncaor.gov.in)

Arctic Research Policy and Goals

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.

Arctic Research Funders

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



The Indian Arctic research station Himadri in Ny-Ålesund.
Photo courtesy: NCAOR

Major Arctic Research Initiatives

Marine Research. India has established a multisensor moored observatory (IndARC) in the Kongsfjorden fjord, Svalbard. Scientists affiliated with the Ministry's Earth System Science Organization (ESSO) and the NCAOR have been continuously monitoring Arctic fjords since 2010. A major milestone in India's scientific endeavors was achieved on July 23, 2014, when IndARC was deployed. IndARC is programmed to collect seawater temperature, salinity, currents, and certain chemical and biological parameters at high temporal scales throughout the spring-summer-fall seasons.

Biological Research. Arctic biodiversity, especially at the microbial level, has been a subject of immense interest. Research has led to the discovery of several novel species, molecules, and processes. Results are being incorporated into 'micro models' to better understand biological responses to climate change.



Indian scientists collecting snow from the glacier (left) and water from Kongsfjorden (right). *Photo courtesy: NCAOR*



Atmospheric Research. To learn more about the evolving Arctic climate, within the context of a changing global climate, India is focusing its efforts on key variables, such as Arctic precipitation processes and quantification of changes in precipitation rates. An additional research objective has been to better understand the transport of atmospheric aerosols from low latitude regions to the Arctic atmosphere, and the subsequent deposition of these aerosols in Arctic snow/glaciers and ice sheets.

Glaciological Research. India's Arctic glaciological program fosters close ties with Himalayan glaciological research. Major activities in the Arctic include conducting measurements on the accumulation/ablation and mass balance of selected glaciers in Svalbard during summer and winter seasons. Measurements on glacier velocity and ice thickness also enable Indian scientists to compute ice flux rates.

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 200 scientists. The Gruvebadet 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:

- Cartosat-2 series
- Megha-Tropiques
- SARAL



Italy

Point of Contact

Consiglio Nazionale delle Ricerche (CNR), Department of Earth System Science and Environmental Technologies (<http://dta.cnr.it>)

Arctic Research Policy and Goals

Italy's Arctic policy is to increase knowledge of Arctic change, and its impacts and feedbacks, through scientific observations and monitoring, multidisciplinary research, and by enhancing international scientific cooperation. This policy is stated in the Italian Arctic Strategic and is implemented by Consiglio Nazionale delle Ricerche (Italian National Research Council, CNR), in collaboration with universities and research organizations, including the Italian Space Agency (ASI), Istituto Nazionale di

Oceanografia e Geofisica Sperimentale (OGS), Istituto Nazionale di Geofisica e Vulcanologia (INGV) and the National Agency for New technologies, Energy and Sustainable Economic Development (ENEA). Italy's overarching Arctic research goal is to obtain the necessary knowledge and understanding of climate change in order to mitigate its impacts, to increase resilience, and to enable sustainable, ecosystem-based management of resource development in the region.

Arctic Research Funders

Italian Ministry of Education, Universities and Research (MIUR, <http://www.istruzione.it>) supports research and innovation in the polar regions. This involves scientific research in the Arctic and Antarctica, such as observing and monitoring the atmosphere, sea ice, snow, and glaciers, and modeling of climate change and its impacts on terrestrial and marine ecosystems.

Consiglio Nazionale delle Ricerche (CNR) – The Italian National Research Council (<https://www.cnr.it/en>) supports research activities carried out at the CNR Arctic Station Dirigibile Italia. These include atmospheric and climate change studies, geology and geophysics, marine and terrestrial ecosystems, and paleoclimate and marine environment studies in the Kongsfjord, in the Svalbard Islands (Norway).

Agenzia Spaziale Italiana (ASI) – ASI (<http://www.asi.it>) uses various satellite constellations, including the COSMO-SkyMed, to support observational research that focuses on environmental monitoring and on surveillance applications to manage and respond to natural and anthropogenic hazards.

Ministero degli Affari Esteri e della Cooperazione Internazionale (<http://www.esteri.it/mae/it>) supports international collaborative research projects in the Arctic.

Istituto Nazionale di Oceanografia e Geofisica Sperimentale (OGS) supports Arctic oceanographic research and operates the R/V OGS Explora.

Major Arctic Research Initiatives

CCT-IP. The Climate Change Tower Integrated Project investigates Arctic 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 (permafrost and vegetation).

MELT. Using an internationally cooperative approach, and as an element of a pan-Arctic observing network, the scientific objectives of the project Monitoring and Investigating Arctic Change along a Longitudinal Transect are to strengthen and integrate Arctic observations, and to enhance understanding of complex processes involved in climate change.

PERMASAR conducts remote sensing of ice, snow and permafrost using DInSAR techniques. The objective of this research is to increase knowledge about the effects of global warming on permafrost, and to monitor small ground displacements and their effects on infrastructures in support of risk management.

ARCA. The project ARctic present Climate change and pAst extreme events is funded by MIUR and aims to develop a conceptual model of the mechanisms responsible for the release of large volumes of fresh, cold water from melting ice caps. The processes in this complex system are investigated by using both paleoclimatic and modern observations.

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

UVASS. The objectives of the CNR project Unmanned Vehicles for Autonomous Sensing and Sampling are to develop and use unmanned marine vehicles and drones to perform in situ measurements in areas that are difficult or dangerous to access, such as glacier fronts.

GULP. The main goal of the Gruvebadet Atmospheric Laboratory Project is to assess Arctic aerosols, to understand local sources and long distance transport, and to increase knowledge of the complex processes that characterize the snow-air interface.

MOSSCO. The project Morphological and chemical evolution of the Svalbard snow cover, led by CNR and University of Venice, studies Svalbard snow cover and documents snow-pack changes in glacial and periglacial areas.

Arctic Research Infrastructure

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 CNR. It can host up to seven scientists working in laboratories and offices. Active since 1997, it is named after the Umberto Nobile's airship Italia expedition of 1928.

Amundsen-Nobile Climate Change Tower is a CNR-operated facility connected to the Italian Arctic Station in Ny-Ålesund. The tower is 32 m high and is equipped with

instruments to investigate surface radiation and energy budgets, planetary boundary layer dynamics, spectral surface reflectance, and greenhouse gas fluxes.

SIOS (Svalbard Integrated Arctic Earth Observing System). Italy participates in SIOS, within the European Strategy Forum on Research Infrastructures (ESFRI) in support of a pan-Arctic observing system. SIOS coordinates and develops existing and new research infrastructure in Svalbard. The SIOS objective is to increase knowledge about climate change and develop climate scenarios. SIOS also coordinates open data, transnational access, logistics and training.

Gruvebadet Atmospheric Laboratory, also connected to the Italian Arctic Station, and operated by CNR and the University of Florence, is a modern laboratory with atmospheric and aerosol instruments.

COSMO-SkyMed is an ASI satellite constellation consisting of four medium-size satellites equipped with a microwave high-resolution synthetic aperture radar (SAR) operating in X-band.

R/V OGS Explora is a polar capable, research vessel equipped for geophysical and oceanographic research.

Italian All-Sky Cameras For Auroral Observations. In a cooperative effort, cusp auroras are studied with two cameras, operated by INAF (Italian National Institute for Astrophysics), and located in Ny-Ålesund and in Daneborg, on the northeastern coast of Greenland.

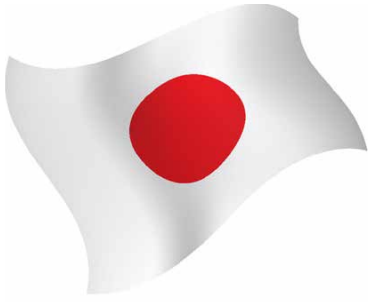
Italian Arctic Data Center. This digital center manages Arctic data and observations. The center is operated by CNR in cooperation with all other Italian research Institutions.



The Amundsen-Nobile Climate Change Tower during maintenance. Photo: Fabio Giardi, University of Firenze



The CNR Arctic Station Dirigibile Italia – Ny-Ålesund, Svalbard. Photo: Giuseppe Pellegrino, Ca'Foscari University, Venezia



Japan

Points of Contact

- The Secretariat of the Headquarters for Ocean Policy (<http://www.kantei.go.jp/jp/singi/kaiyou/arcticpolicy>)
- 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>)
- Japan Agency for Marine-Earth Science and Technology (JAMSTEC; <http://www.jamstec.go.jp/e>)
- Hokkaido University (<http://www.arc.hokudai.ac.jp/en>)

Arctic Research Policy and Goals

In October 2015, the Government of Japan (the Headquarters for Ocean Policy chaired by Prime Minister Mr. Abe) adopted its first, comprehensive, and strategic Arctic policy, “Japan’s Arctic Policy.” The policy clearly states that Japan should make the best

use of its strength in science and technology, engage in active international cooperation, and enhance collaboration between stakeholders in comprehensive and cross-disciplinary research.

Arctic Research Funders

Ministry of Education, Culture, Sports, Science and Technology (MEXT) initiated the Arctic Challenge for Sustainability (ArCS) in fiscal year 2015, and the following three organizations have leading roles:

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



R/V MIRAI. Photo by JAMSTEC

Major Arctic Research Initiatives

- Since 1957, Japan has actively participated in international efforts in Arctic research stations, Arctic oceanographic expeditions, and in other collaborative and cooperative research initiatives to advance knowledge of the Arctic region.
- During fiscal years 2011-2015, the MEXT Higher Education Bureau supported a “GREen Network of Excellence (GRENE)” initiative on “Arctic Climate Change Research” to promote high quality scientific research and the training and development of scientists. NIPR, as a core institute, led the GRENE Arctic Program that involved 39 other Japanese institutions. Many excellent scientific publications were produced on the following subjects: elucidating the factors that contribute to Arctic warming; the relationship between the amplification of Arctic warming and the extreme cold spells experienced by Japan and other mid-latitude countries; prediction of the distribution of sea ice along Arctic sea routes; and other topics.

The achievements of GRENE resulted in a new multi-year (fiscal 2015-2019) program of Arctic research in Japan, supported by MEXT, and named “Arctic Challenge for Sustainability (ArCS).” This program will further strengthen international collaborative research, in part, by expanding the scope of nations with whom Japan will cooperate. NIPR implements this project, in cooperation with JAMSTEC and

Hokkaido University. These three entities, critically important to Japan's Arctic research enterprise, have established their own respective Arctic research centers, and they will work together on ArCS. The three main aims of the ArCS program are to: (1) provide robust scientific information to Arctic and global stakeholders to help them to make decisions and address Arctic issues; (2) build research stations in the Arctic region through international collaboration; and (3) train and dispatch young researchers to overseas research organizations and universities to reinforce international cooperation. The project promotes international collaborative research in eight research themes that are 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
 - improve the accuracy of regional forecasts.
 - conduct R&D on navigation support systems.
 - create a wave-ice interaction model for the Northern Sea Route.
2. Variation in the ice sheet, glaciers, ocean, climate and environment in Greenland region
 - observe ice sheet variations and climate.
 - investigate the interactions between ice sheets/ glaciers and the ocean, and their impacts on local communities.
3. Atmospheric climate forcers in the Arctic
 - observe the behavior of short-lived climate forcers (such as black carbon and methane) and other greenhouse gases in the Arctic atmosphere.
4. Observational research on Arctic Ocean environmental changes
 - observe and model ongoing environmental change and its impacts.
5. Study on Arctic climate predictability
 - predict and project medium- and long-term climate variations.
6. Response and biodiversity status of the Arctic ecosystems under environmental change
 - study the impacts of human activities on ecosystem and the nutrient supply mechanisms that maintain biological productivity.
7. People and community in the Arctic: possibility for sustainable development
 - study the concepts of Arctic economic development, environmental conservation, and sustainable development through scenarios and recommendations from international organizations.
 - work cooperatively with scientists from the natural sciences.
8. Arctic Data Archive System (ADS)
 - further develop an Arctic Data Archive System (ADS).
 - promote sharing and visualization of Arctic research data.



Ny-Ålesund Research Station. Photo by NIPR

- JAMSTEC is initiating additional research and development on a new Autonomous Underwater Vehicle for observations under sea ice which will be used as a platform for international cooperation on Arctic Ocean observations.
- 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*, an ice-protected, NK-IC class vessel, owned by Hokkaido University.

FIELD STATIONS

Field observations are conducted by Japanese researchers at the Ny-Ålesund Research Station in Svalbard, Norway, and Poker Flat Research Range in Alaska, USA. 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 "SHIZUKU" (water) 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, high resolution, one-day images can be created, and the data are shared publicly. Japan also measures greenhouse gases, such as carbon dioxide and methane, using the "GOSAT Ibuki" satellite system. The "DAICHI 2" satellite is detecting changes of permafrost, ground, boreal forest and sea ice in the Arctic.



Republic of Korea

Point of Contact

- Korea Polar Research Institute (KOPRI; <http://eng.kopri.re.kr>)
- Ministry of Oceans and Fisheries (<http://www.mof.go.kr/eng>)

Arctic Research Policy and Goals

Korea's primary Arctic research and policy goals are: (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 results of scientific research with policy making and sustainable business development.

Korea has two primary reasons for pursuing Arctic science. The first is a desire to understand and address the globally important issues of the Arctic. Second, in recognition of the geographical proximity of Korea to the Arctic, Koreans understand that what occurs in the Arctic

also impacts the Korean peninsula, whether through climate change, weather patterns, migration of fish stocks, shipping or economic factors. Korean Arctic research dates back to 1999, when Korean scientists first 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 program. While Korean resources dedicated to Antarctic research are still greater, the share being allocated to Arctic research continues to grow significantly.

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 including "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, ICT and Future Planning. The Ministry of Science, ICT and Future Planning (MSIF) supports research projects such as "Circum-Arctic Permafrost Environment Change Monitoring, Future Prediction" and "Changes in Environment and Coastal Geomorphology of Svalbard Fjord."



IBRV Araon conducting research over Arctic sea ice. Credit: KOPRI

Major Arctic Research Initiatives

Korean Arctic science currently includes marine and terrestrial observation, prediction, and paleoenvironmental 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/biogeochemical) 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.

2. Circum-Arctic Permafrost Environment Change Monitoring, and 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. Develop and Apply 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 modeling 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 Resources 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. Arctic Dasan Station Environmental Change Studies of Geology, Atmospheric Science, and Ecology.

Research at Dasan Station aims to understand changes in the atmosphere, pedosphere, and biosphere along a glacial chronosequence and microtopography in the forefield of Midtre Lovénbreen, Svalbard to make paleo-environmental interpretations, as well as to conduct geological, mineralogical, geochemical research in Spitsbergen.

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 modeling of the Arctic



Overview of the Arctic Dasan Station. Credit: KOPRI

Arctic Research Infrastructure

VESSEL

The icebreaker research vessel R/V *Araon* supports multidisciplinary scientific research encompassing geophysics, biology and oceanography and provides logistics to the stations in Polar region.

FIELD STATION

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

OBSERVATION NODES

- Cambridge Bay, Canada
- Council, Alaska, USA
- Svalbard, Norway
- Nord Station, Greenland



The Netherlands

Point of Contact

• The Netherlands Polar Committee (alwnpp@nwo.nl)

Arctic Research Policy and Goals

To advance the development of policy, The Netherlands Polar Programme provides scientific support to generate knowledge about the polar regions.

Arctic Research Funders

The Netherlands Polar Programme is funded by five ministries, including Education, Culture and Science, Foreign Affairs, Infrastructure and the Environment, and Economic Affairs, and by The Netherlands Organisation for Scientific Research, which also serves as the operator of the Programme. Additional funding is provided by several Dutch universities and institutes.



Installing an Automatic Weather Station in Greenland.
Photo: Paul Smeets

Major Arctic Research Initiatives

Dutch polar research links closely with the objectives of the White House Arctic Science Ministerial (WHASM) in Theme I: Arctic Science Challenges and their Regional and Global Implications; Theme II: Strengthening and Integrating Arctic Observations and Data Sharing; and Theme III: Applying Expanded Scientific Understanding of the Arctic to Build Regional Resilience and Shape Global Responses. Research within The Netherlands Polar Programme is aligned along the following four lines:

- **Line 1: Ice, Climate and Rising Sea Levels.** Research within this line focuses on observations and modeling of polar climate, the dynamics of ice caps and glaciers, and their impact on global and regional sea levels. This line also includes paleoclimatic studies of the natural causes and consequences of the initiation and termination of polar glacial periods over geological timescales. These data contribute to large-scale climate models. This line links closely with Themes I and II of the WHASM.
- **Line 2: Polar Ecosystems.** Terrestrial and marine polar ecosystems are subject to rapid climate changes and to increasingly large impacts from human activities. We still know little about the impact of these factors on the functioning of the polar ecosystem, let alone impacts associated with natural variability—to say nothing of the combined impacts. There is great need for knowledge about the resilience and capacity of these systems, including any tipping points and possible warning signals prior to reaching these tipping points. The scientific underpinning of these issues is essential for the conservation, management, and sustainable use of polar ecosystems. This links closely with WHASM Themes I and II.

- **Line 3: Sustainable Exploitation.** Due to the current and predicted decrease in Arctic sea ice, and the increasing global demand for natural resources, interest in mining activities and fisheries is on the rise. New transportation routes are opening up, as are new opportunities for polar tourism. The Dutch, among others, consider it important to develop clear preconditions for sustainable use, and for conservation of biodiversity and environmental quality. This line is concerned with the impact of human activity and its limitations, and with determining whether sustainable and safe maritime operations can be conducted in the polar regions. This links closely with WHASM Theme III.
- **Line 4: Social, Legal and Economic Landscape.** What are the consequences of changes to the polar regions for the existing governance structures, for the exploitation of natural resources, and for local communities? Research into these questions can provide insight into the resilience of Arctic societies. The increasing human activities in the polar regions will require further international consultation, governance, and regulation. Knowledge of the changes that the various local communities in the Arctic region have experienced, and are currently undergoing, as well as knowledge of the local political, social, and legal framework is also particularly important for Dutch organisations and companies that plan to operate in the Arctic. This links closely with WHASM Theme III.

DELIVERABLES

Relevant running or starting projects:

1. “Quantifying shallow and deep permafrost changes using radar remote sensing,” Free University Amsterdam
2. “Methane permafrost feedbacks in the Arctic,” The Netherlands Earth System Science Centre (NESSC)
3. “Impact of refreezing on the mass balance of the Greenland ice sheet (GrIS) in a changing climate,” Utrecht University
4. “Climate monitoring instruments for collaborative research in the Polar Regions,” Utrecht University
5. “Extreme Greenland melt events: extending the record back to 1900,” Utrecht University.
6. “Validating recently-developed twenty-first century regional sea level projections using satellite observations,” Royal Netherlands Meteorological Institute
7. “An interactive narrowband albedo model for the Greenland Ice Sheet,” Utrecht University
8. “Chemicals in Arctic food chains: accumulation and potential population effects,” Radboud University Nijmegen
9. “Remote sensing based characterisation of functional diversity for polar ecosystems,” Leiden University
10. “Unravelling the annual cycle of an Arctic migrant in search of the cause of its decline,” The Netherlands Institute of Ecology



Archaeological fieldwork on the island of Edgøya (Spitsbergen).
Photo: Liesbeth Noor

11. “Developing benefit-sharing standards in the Arctic: Toward coexistence of oil and gas companies and traditional indigenous communities,” Wageningen University and Research Centre
12. “Participation, Allocation and the Ecosystem Approach in Polar Fisheries,” Utrecht University

HIGHLIGHTS

- The Netherlands Polar Programme has an open call (deadline for applications is the 13th of October 2016) for scientific proposals amounting 6 million Euro (appr. \$6.7 million USD) for polar projects (Antarctica and the Arctic). Roughly 50% of the budget will be granted to Arctic projects.
- In 2017, another call for proposals with a similar budget will be launched for policy-related polar research projects. Within this call, research projects that fit in The Netherlands Policy Framework for the polar regions will be funded. These projects support excellent scientific work that is immediately useful to policy makers.
- The Netherlands committed itself to supporting the European Polar Board (<http://www.europeanpolarboard.org/organisation/secretariat>) by hosting its secretariat in The Hague, since 1 January 2015.
- The Netherlands is an active partner in the EU-financed programme EU-Polarnet (<http://www.eu-polarnet.eu/about-eu-polarnet>) that aims to develop and deliver a strategic framework and mechanisms to prioritise science, optimise the use of polar infrastructure, and to broker new partnerships that will lead to the co-design of polar research projects that deliver tangible benefits for society.

Arctic Research Infrastructure

FIELD STATION

- **The Netherlands Polar Station** (<http://www.arcticstation.nl/index.php>) in Ny Alesund, Spitsbergen



New Zealand

Points of Contact

- Ministry of Foreign Affairs and Trade (<http://www.mfat.govt.nz/en/environment/antarctica>)
- Antarctica New Zealand (<http://www.antarcticanz.govt.nz>)

Nota Bene. *New Zealand has been involved in research activities on/in the Arctic, but its primary polar research interest and activities focus on Antarctica. Comparative data sharing and analysis between the two polar regions is of interest to New Zealand. New Zealand's contribution to the Ministerial meeting will be through this perspective, and this paper outlines our position regarding Antarctica.*

Antarctic Research Policy and Goals

New Zealand's strategy for Antarctic and Southern Ocean science parallels research efforts in the Arctic. The research supported generates knowledge that helps preserve Antarctica for future generations and provides greater understanding on how changes may impact New Zealand. Under the unifying theme of "Global Change," New Zealand's priority is for research that progresses understanding of the effects of global change on the polar ecosystems and Antarctic ecosystem protection. Three key research domains include:

- Climate, cryosphere, atmosphere – improving understanding of the significance and implications of the role of Antarctica in global change, and implications of global change for Antarctica
- Inland and coastal ecosystems – improving understanding of inland and coastal ecosystems of the Ross Sea Region leading to enhanced knowledge, conservation and protection priorities in Antarctica
- Open marine systems – improving conservation and resource management of the Antarctic marine environment

Antarctic Research Funders

The New Zealand government provides a range of funding mechanisms to support Antarctic science. These include:

- **Antarctica New Zealand** provides logistical support to scientific research activities in Antarctica.
- **The Ministry of Business, Innovation & Employment (MBIE) Endeavour Fund** provides contestable funds for excellent, high-impact science, including for Antarctic research.
- **Marsden Fund (administered by the Royal Society of New Zealand)**. The Marsden Fund provides grants for investigator-initiated research, and continues to support a range of Antarctic research efforts.
- **The Deep South National Science Challenge**, funded by MBIE, supports research and observations of climate processes in the Southern Ocean and Antarctica, and the

development of an earth systems model to achieve climate prediction and enhanced knowledge of the future environment in New Zealand.

- **The Catalyst Fund**, administered by MBIE, supports New Zealand's participation in global science partnerships, including for science cooperation in Antarctica.
- **Crown Research Institutes**. Government-supported entities such as the National Institute of Water and Atmospheric Research (NIWA) and GNS Science study Antarctic marine ecosystems, observe the processes and interactions in the Antarctic atmosphere, and support paleoclimate research.
- **Ministry for Primary Industries** contributes to marine systems research, including improving our understanding of the effects of human influences in the Ross Sea region on the ecosystem, in support of the Convention for the Conservation of Antarctic Marine Living Resources.

- **Universities.** Various New Zealand Universities support Antarctic research including: remote sensing of atmosphere-climate-cryosphere interactions to investigate the causes, effects, and responses of the Antarctic system to global change; examining Antarctic ecosystems and their interaction with the environment and environmental change; study of the paleoclimate, the history of the Antarctic ice sheet and its role in global sea level change.

Non-New Zealand government funders include:

- **New Zealand Antarctic Research Institute (NZARI)** supports research into the impacts of global change on Antarctica (its climate, oceans, icesheets and ecosystems) and Antarctica's impacts on global change.

Major Antarctic Research Initiatives

Past Antarctic Climate Project examines the effect of climate warming on Antarctica's ice-sheets by studying modern processes at the ice sheet margin and pre-historic/geological data. These observations will be used to develop climate and ice sheet models that will improve our capacity to project future global sea level rise.

Ross Ice Shelf Programme investigates the rate-determining processes associated with deglaciation in the Ross Sea region of West Antarctica, to improve understanding

of interactions in the ice-ocean-atmosphere system so that uncertainty in projections of future climate change can be reduced.

McMurdo Dry Valley Ecosystem is an evidence-based risk assessment of the biodiversity, productivity and sensitivities of ecosystems in the McMurdo Dry Valley region, to deliver objective-based and sustainable environmental management tools and policies.

Arrival Heights. Atmospheric observations and modelling to improve understanding of how Antarctic atmospheric chemistry drives and responds to global climate change.

KOPRI Collaboration for Marine and Terrestrial Monitoring Programme is a scientific collaboration between key New Zealand research agencies and the Korean Polar Research Institute to investigate the impacts of a warming global climate on Antarctica, including eco-system monitoring, ice-ocean interactions beneath ice shelves, understanding ice and ocean responses to past global warming events.

Antarctic Research Infrastructure

VESSEL

R/V *Tangaroa* is an ice-strengthened, deep water research vessel, equipped for a wide range of environmental survey and ocean science work, operated by NIWA.

FIELD STATION

Scott Base is New Zealand's permanent research support station in Antarctica. It was established in 1957 and is located on the south end of Ross Island. Scott Base provides the logistics hub for research teams throughout the year and to support a number of remote huts operated by New Zealand.



(LEFT) New Zealand's deep-water research vessel *Tangaroa* in Antarctica. Photo courtesy of NIWA

(BELOW) Scott Base. Photo courtesy of Jenny Ryan





Norway

Points of Contact

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

Arctic Research Policy and Goals

International cooperation is at the core of Norway's Arctic Policy. The Government's priorities for the North include: (a) broad-based knowledge development; (b) a knowledge-based business sector; (c), further improving infrastructure reliability; and (d) better preparedness and response mechanisms for environmental protection.

Norway's Arctic research objective 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 a high priority. Guidelines for Norwegian Arctic research are in the High North strategy and the Long-term plan for research and higher education 2015–2024. Goals and thematic research priorities are given in the *Research Strategy for the Arctic and Northern Areas (2011-2016)* and the *Policy for Norwegian Polar Research (2014-2023)*.

Arctic Research Funders

Much of the funding for Norwegian Arctic Research comes from Norwegian Ministries, particularly the Ministry of Climate and Environment, the Ministry of Education and Research, the Ministry of Foreign Affairs, the Ministry of Petroleum and Energy, and the Ministry of Trade, Industry and Fisheries.

The Research Council of Norway supports research in all subjects and disciplines, all thematic areas, and all aspects of society, from basic research to research-based innovation and commercialisation. The Polar Research Programme is dedicated to supporting Arctic research.

Norwegian Arctic research is also funded by the private sector and by the European Commission.

Major Arctic Research Initiatives

Norwegian Arctic research is geographically extensive, and covers a broad range of research disciplines. A selection of ongoing initiatives include:

The High North Research Centre for Climate and the Environment (The Fram Centre) in Tromsø, which 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. A new programme has recently been initiated—Norwegian Young Sea Ice (N-ICE)—which seeks to understand the effects of the Arctic's new, thin, first-year sea ice regime on energy flux, ice dynamics, the ice-associated ecosystem, and the local and global climate.

The Barents Sea Ecosystem Programme is a partnership between the Institute of Marine Research and the Russian institute PINRO. On an annual basis, this program gathers long-term data on ocean environment, commercial stocks, and biodiversity that are essential for sound management of the Barents Sea.



Ny-Ålesund. Photo: Max König / The Norwegian Polar Institute

The Centre for Arctic Gas Hydrate, Environment and Climate is a Norwegian Centre of Excellence at the University of Tromsø that investigates the role of gas hydrates in Arctic areas, and the future effects they may have on oceans and global climate.

The Centre for Integrated Remote Sensing and Forecasting for Arctic Operations is a research-based innovation centre at the University of Tromsø that focuses on methods and technologies to reliably detect, monitor, integrate, and interpret multi-sensor data that characterize the physical environment of the Arctic. The centre also assimilates this information into models that predict sea ice state and meteorological and oceanographic conditions over a variety of timescales.

The University Centre in Svalbard (UNIS) is the world's northernmost higher education institution, located in Longyearbyen, at 78° N. It provides research-based education for the next generation of Arctic experts in the fields of biology, geology, geophysics and technology.

Arctic Research Infrastructure

VESSELS

Norway has several vessels, including two with the ability to operate in ice-infested polar waters, that support Arctic research and that are owned and operated by universities and research institutes.

- **Kronprins Haakon** is a new polar research vessel scheduled for delivery in 2017.
- **Lance** is an ice-strengthened vessel operated by the Norwegian Polar Institute.

FIELD STATIONS

Ny-Ålesund, in Svalbard, is a permanent Norwegian research facility for climate and environmental research which hosts national and international research projects and programmes. Ny-Ålesund serves as an observatory, a laboratory, and field base for Arctic research.

Other selected infrastructure and facilities:

- **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 is in Svalbard, and the other is in Tromsø.



Model of the new Norwegian polar research vessel *Kronprins Haakon*. Illustration: Rolls Royce Marine (RRM)

- **COAT**, the Climate-ecological Observatory for Arctic Tundra, is coordinated by the University of Tromsø. It is a system for long-term adaptive terrestrial ecosystem monitoring that is based on food-web theory.
- **SIOS**, the Svalbard Integrated Earth Observing System, is a new coordinating research infrastructure collaboration hosted by the University Centre in Svalbard. SIOS will establish an integrated observing system in the Earth System Science domain, building on the extensive and advanced research infrastructure and observing capacities that already exist. With respect to data for the international research community, SIOS will establish greater openness, access, sharing opportunities, and knowledge management systems.
- **NORMAP**, the Norwegian Satellite Earth Observation Database for Marine and Polar Research, is coordinated by the Nansen Environmental and Remote Sensing Centre, and provides scientists with access to remote sensing products based on data collected north of 55°N.

SATELLITES

Norway hosts the **Svalbard Satellite Station (SvalSat)** in Longyearbyen, which is the world's largest commercial ground station for polar-orbiting satellites, with more than 31 state-of-the-art multi-mission and customer dedicated antenna systems. SvalSat is run and owned by Kongsberg Satellite Services.

Norway participates in **Copernicus**, a European Earth monitoring system, coordinated and managed by the European Commission. Norway is also an active partner in the European Space Agency (ESA) satellite initiative, **Earth Explorers**. Norwegian satellites AISSat-1 and AISSat-2 are used for vessel identification. There are planned launches of AISSat-3, Norsat-1 and Norsat-2.



Poland

Points of Contact

- Committee on Polar Research, Polish Academy of Sciences (<http://kbp.pan.pl/en>)
- Polish Polar Consortium (<http://www.pkpolar.pl/eng/home-eng>)
- Centre for Polar Studies (<http://www.polarknow.us.edu.pl/csp-2>)

Arctic Research Policy and Goals

Poland's Arctic research policy is driven by the:

- need to monitor and predict trends of Arctic climate change, which also affects lower latitudes, thereby generating global environmental challenges, such as sea level rise, and extreme weather events;
- desire to better understand processes that shaped Poland's landscape in the geological past, and remain active today in the High North;

- requirement to advise policymakers to make knowledge-informed decisions in regard to Arctic issues and global environmental change.

Poland's policy is implemented by several academic institutions, many of which are members of the Polish Polar Consortium, which operates under the guidance of the Committee on Polar Research, Polish Academy of Sciences.

Arctic Research Funders

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

Major Arctic Research Initiatives

Interactions among the main components of the climate system in the Svalbard area: ocean, atmosphere, sea ice, and glaciers. This program identifies mechanisms of climate variability operating on interannual and longer timescales. Research considers the inflow of warmer Atlantic waters, ocean-fjords exchange, and rapid deglaciation.

Increasing knowledge of interrelations among the sea, the atmosphere, and the cryosphere is highly important given their responses to accelerated climate warming in the Arctic. Results will improve our understanding of processes, and models of future environmental change at high latitudes.

Changes in the Arctic fjord system. As a link between land and ocean, Svalbard's fjords are vulnerable to climate change, and are expected to exhibit the earliest environmental consequences of a warming Arctic. This initiative aims to: (1) strengthen and develop technologically systematic, long-term, and precise in situ observations of the Hornsund fjord system and combine them with remote sensing results; (2) use common methodologies, tools, and technologies to obtain comparable data sets, and establish a pan-Arctic network of fjord research/monitoring sites; and (3) develop comprehensive data bases that integrate Arctic observations and facilitates data sharing.

Towards a better understanding of the role of snow on changes in the Pan-Arctic environment aims to: (1) define the importance of snow in the polar environment by identifying its feedbacks to forcing functions, and to reveal the response of snow cover properties to environmental change (e.g., alterations in climate, state of the permafrost, etc.); and (2) find similarities and differences in the snowpack characteristics, across a broad range of Svalbard's environments, to search for spatial patterns and to understand their



The Polish Polar Station, Hornsund, Svalbard in April 2016.

Photo by Malgorzata Blaszczyk.

environmental significance (by cooperation between the Polish field stations and international partners).

Evolution of Arctic glaciers terminating into the sea and its local and global consequences aims to: (1) assess the importance of ice loss, due to calving, for an overall mass budget, and to understand the evolution of glaciers under different Arctic climatic conditions; (2) provide a more precise estimate of the contribution of Arctic glaciers and the Greenland Ice Sheet to global sea level rise (by both melting and calving); (3) collect data sets to better understand calving mechanisms; and (4) determine the local and regional consequences on marine and terrestrial ecosystems.

Edu-Arctic – Innovative educational program attracting young people to natural sciences and polar research includes: (1) online broadcasts of lessons from polar stations on natural sciences and polar research related to important societal challenges; (2) “Polarpedia” – a web-based encyclopedia with scientific information, educational resources, and dictionaries in at least five national European languages; and (3) Arctic competitions for European pupils in which prize winners participate in polar expeditions.

Arctic Research Infrastructure

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

VESSELS

- **Research vessel *s/y Oceania***, operated by the Institute of Oceanology, PAS, has been used since 1986 for research expeditions in the Baltic Sea and the European Arctic region. It provides facilities for research in hydrography, optics, aerosols, acoustics, chemistry, and marine biology.
- **Research vessel *m/s Horyzont II***, operated by the Maritime Academy of Gdynia, is primarily used for training, to transport researchers and their equipment, and for onboard conferences during the research cruises around Svalbard.

FIELD STATIONS

Polish Polar Station, Hornsund [77°00'N,15°33'E] – est. in 1957. Since 1978, this station has been operated as a year-long research facility by the Institute of Geophysics at the Polish Academy of Sciences. The station is a modern research platform with well-equipped laboratories and satellite communication offering accommodation for about 20 scientists (in addition to staff). Permanent observations include



Glaciological survey on Hansbreen, southern Spitsbergen during polar night. Photo by Piotr Lepkowski.

those associated with meteorology, air pollution, glaciology, geophysics (e.g., seismology, geomagnetism, atmospheric electricity), permafrost, geomorphology, and the physical oceanography of the fjord system. The primary study objectives is the evolution of the Arctic environment in response to climate warming. Changes in marine and terrestrial ecosystems, including a strong ornithological component, are systematically studied. The Hornsund station is a member of the INTERACT network and offers a broad array of opportunities for international cooperation.

Universities Field Stations in Svalbard

- **Stanisław Baranowski Spitsbergen Polar Station** (est. in 1971; nicknamed 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 (Hahut)** is located in the northern part of Kaffiøyra, north-west Spitsbergen.
- **Adam Mickiewicz University (in Poznań) Polar Station (AMPUS)** – Until 2011, this station was located in Skottehytta. Currently, 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 Station** occupies buildings of an abandoned mining settlement Calypsobyen, Bellsund in southern Spitsbergen.

Typically, the stations host summer expeditions. 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 participation of students in expeditions plays an important role in academic education and polar field training of young scientists.



Russian Federation

Points of Contact

- Ministry of Education and Science (MON; <http://minobrnauki.rf>)
- Russian Academy of Sciences (PRAS; <http://www.ras.ru>)
- Federal Service for Hydrometeorology and Environmental Monitoring (Rosgidromet; <http://www.meteorf.ru>)

Arctic Research Policy and Goals

Russia's fundamental strategic document is the "Strategy for the Development of the Arctic Zone of the Russian Federation and National Security Efforts for the period up to 2020." It was developed in response to the document, "Fundamentals of the State Policy of the Russian Federation in the Arctic for the Period up to 2020 and Beyond," adopted by the President of the Russian Federation. The strategy implements the sovereignty

and national interests of the Russian Federation, and it addresses the main tasks of state policy in the Arctic that are defined in the Fundamentals. Part of the strategy is to consolidate the resources and efforts of all stakeholders, including federal and state entities (whose territories includes all or part of the Arctic zone of the Russian Federation, local authorities and organizations) to address key issues and national security in the Arctic.

Arctic Research Funders

Ministry of Education and Science. Supports civil research and development projects in the federal program, "Research and Development in Priority Areas of Development of the Russian Science and Technology Complex 2014-2020." This Ministry also awards grants to support young Russian scientists and leading scientific universities to conduct research.

Ministry of Economic Development. Performs applied economic research, and conducts research and development activities. The results are used to apply new knowledge to achieve practical goals and to address specific objectives in key areas of economic development of the Russian Arctic.

Ministry of Natural Resources and the Environment. Supports research projects to: (a) ensure the rational and safe use of natural resources in the Arctic; (b) avoid depleting natural resources; and (c) prevent irreversible deterioration of the environment such that the benefits of nature are maintained for future generations.

Federal Service for Hydrometeorology and Environmental Monitoring. Conducts research, projects, and services in hydrometeorology and related topics, and monitors Arctic environmental pollution.

Russian Science Foundation. Funds fundamental, exploratory, and bottom-up Arctic research projects.

Russian Foundation for Basic Research. Supports the best scientific projects focused on Arctic basic research through a competitive selection process.

Russian Academy of Sciences. Supports and conducts research as per the annual program of the Presidium of the Russian Academy of Sciences, "Basic research for the development of the Russian Arctic zone."



Pilotage on the Northern Sea Route.



Natives of the Russian Arctic.



Sabetta Port Complex, the Yamal Peninsula.

Major Arctic Research Initiatives

The Working Group on “Education and Science Development,” established by the Ministry of Education and Science, addresses the challenges of Arctic sustainable development through the following efforts.

Assuring high living standards in Arctic regions. This initiative: (a) modernizes civil infrastructure and housing facilities by deploying energy saving methodologies; (b) provides affordable access to information and telecommunication services; and (c) provides accessible and high-quality healthcare to all citizens. Other projects advance education through: (a) refresher courses; (b) advanced professional training relevant to Arctic conditions; (c) the socioeconomics of labor force evaluation and forecasting; and (d) developing conventional industrial management practices to ensure employment of indigenous minorities.

Mitigating climate change and reducing ecological risk. This initiative develops and implements an integrated system to ensure the safety and security of Arctic ecosystems and other environmental elements of critical importance in case of natural disasters, or human-caused emergencies that may possibly arise during the development and operation of industrial or resource development projects on Arctic lands, in the near short, or on the continental shelf. Special efforts are in place to preserve biological species and ecosystems sensitive to economic activity and global climate change, including establishing and enlarging networks of areas that are specially protected and monitored.

Improving information infrastructure. This initiative develops and implements modern information and telecommunication technologies and communication systems, broadcasting, traffic management and aviation, remote sensing, surveys of ice-covered areas, meteorological and hydrographic support, and assistance to scientific expeditionary research. Technological capabilities in this area, that are regularly being upgraded and improved, include the space-based global satellite navigation system GLONASS, the multipurpose space system “Arctic”, and the long-range radio navigation system RSDN-20 (Marshrut).

Modernizing transportation and logistics infrastructure. This initiative, which ensures sustainable operation of the Northern Sea Route as a unified national transport line, conducts projects to further develop and expand the Russian icebreaking fleet using modern technologies. These include advanced nuclear power systems, modernized Arctic ports, new industrial complexes, modern vehicles ideally suited for Arctic conditions, and hydrographic and hydrometeorological support systems.

Arctic Research Infrastructure

VESSELS

Each year, Russia conducts about 50 marine scientific and exploratory expeditions in the Arctic. The Russian icebreaking fleet, the largest and most powerful in the world, includes 38 ships, 7 of which are nuclear powered. A subset of these vessels is used to protect Russia’s Arctic coast and islands.

FIELD STATIONS

Russia has conducted field research in the Arctic for over a century. Its first land-based polar stations were established in 1910, and its first Arctic Ocean drift station, North-Pole 1, was established on May 21, 1937. Currently, 16 polar stations are operating along the Northern Sea Route. Russian drift stations, which operate nearly year-round, conduct a comprehensive research program in oceanography, glaciology, meteorology, aerology, geophysics, hydrochemistry, hydrophysics, and in marine biology.

SATELLITES

Russia’s Arctic remote sensing system currently consists of 7 satellites in polar orbit, including:

- Resurs-P
- Canopus-B-IK
- Meteor-M

Satellite data are available upon request.



Republic of Singapore

Points of Contact

- National University of Singapore (<http://www.nus.edu.sg>)
- Singapore Maritime Institute (<http://www.maritimeinstitute.sg>)
- Maritime and Port Authority (<http://www.mpa.gov.sg>)
- Meteorological Service Singapore (<http://www.ccrs.weather.gov.sg>)
- Ministry of Foreign Affairs (<http://www.mfa.gov.sg>)

Arctic Research Policy and Goals

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.

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.

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 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

MARINE AND OFFSHORE 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 deepwater 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.



Deputy Prime Minister Teo Chee Hean at the Arctic Circle Singapore Forum.



Conceptual drawing of the TCOMS facility.



Spain

Points of Contact

- Spanish Agency for Research (<http://www.idi.mineco.gob.es>)
- Spanish Polar Committee (<http://www.idi.mineco.gob.es>)
- Spanish Polar Research Program (<http://www.idi.mineco.gob.es>)

Arctic Research Policy and Goals

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.

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 organizations 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. Their environments and lifestyles are to be respected, and they are entitled to benefit from the activities conducted in their regions.
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). This commission would serve as a forum for discussion, cooperation, and consensus building among the EU Member States and for financing a variety of activities related to the polar regions.
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.
10. Considers Spain's geopolitical interest in having an Arctic presence and in maintaining its status as observer country in the Arctic Council. To maintain this status, the necessary measures must be taken to facilitate and promote the involvement of Spanish researchers in the Council's various working groups and task forces.

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. The Spanish funding system includes two programs, the excellence program and the societal challenges program, which are inspired by the Horizon 2020 (European funding system). Moreover, Spanish researchers frequently apply and lead European projects, on Arctic-related themes, through Horizon 2020. In recent years, this European Program has held specific calls for polar, and specifically Arctic topics, in which Spain has participated.

Major Arctic Research Initiatives

Ongoing research initiatives span several disciplines, including terrestrial and freshwater research, glaciology, oceanography, and sustainable fishing. Initiatives on glaciology, oceanography, aerosols and atmospheric science are being evaluated for future consideration.

Biodiversity of Arctic Terrestrial and Freshwater Ecosystems. The goal is to understand the diversity, vulnerability and resilience of terrestrial and freshwater ecosystems in relation to climate change.

Ice Thickness of Svalbard 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.

GLACKMA. Monitors glacial melting in both polar regions and considers the catchment hydrology and variations in the liquid water balance.



AERONET. This is a long-term international project monitoring aerosol optical depth in the Arctic.

Polar Fisheries. Monitors the effects of global change on the Arctic fisheries, in the context of sustainable and ecologically responsible fisheries.

Climatology. Refines models 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.

VESSELS

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



(ABOVE) Spanish Navy Oceanographic Research Vessel *Hespérides* (A33) working in polar waters. The R/V *Hespérides* is a multipurpose polar class vessel (Lloyd Ice class 1C) equipped for physical, geological and marine biology all waters oceanographic research. *Photo credit: UTM/CSIC archives*

(LEFT) Spanish multipurpose oceanographic vessel *Sarmiento de Gamboa* (UTM/CSIC). The vessel has a dynamic positioning system and multipurpose oceanographic equipment that allow it to operate ROVs (remotely operated vehicles) and AUVs (autonomous underwater vehicles). *Photo credit: UTM/CSIC archives*



Sweden

Points of Contact

- Ministry of Education and Research (<http://www.regeringen.se>)
- The Swedish Research Council (<http://www.vr.se>)
- The Swedish Research Council Formas (<http://www.formas.se>)
- The Swedish Polar Research Secretariat (<http://www.polar.se>)

Arctic Research Policy and Goals

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.

Arctic Research Funders

Two funding agencies, Swedish Research Council and The Swedish Research Council Formas, are the primary funders of polar research.

The Swedish Research Council. The council funds fundamental research in all areas, including 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, in order 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 particular focus of Formas is climate-related research, with an emphasis on polar regions.

The Swedish Polar Research Secretariat. The Secretariat's primary mission is to organize and support polar research expeditions. It also has responsibility for research infrastructure associated with polar research. The Secretariat runs the research-equipped icebreaker *Oden*, the field station Abisko, and two research stations on Antarctica.

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. The Polar secretariat also engaged in discussion with scientists and funding agencies in other countries to coordinate research logistics and to plan joint expeditions.



Sweden has a long history in polar research. Nils Adolf Erik Nordenskiöld was the first to sail the Northeast Passage in the Vega expeditions in 1878–1879.



Swedish icebreaker *Oden*, commissioned in 1989, is a highly capable vessel that has reached the North Pole many times during scientific expeditions. A study for a future replacement was initiated in March 2016.

Major Arctic Research Initiatives

Swedish polar research, which primarily focuses on the Arctic Ocean and the surrounding coastal areas, uses the icebreaker *Oden* as 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 2014, a collaborative expedition with Russia focused on oceanography, seafloor characteristics, and sea ice conditions between Siberia and Barrow, Alaska.
- In 2015, a collaborative expedition with the United States (National Science Foundation) explored the paleoceanographic history of the Petermann Glacier, off Greenland.
- In 2016, a collaborative expedition with Canada examined seafloor morphology and structure in the Canadian sector of the Arctic.
- In 2018, another expedition with the US (NSF) will be conducted.
- Terrestrial polar research is also performed at mountain research stations in the far north of Sweden.

Research topics are generally determined through proposals from university researchers, and there are on-going polar research initiatives at most universities and colleges. Specific programs exist in climate modeling and marine research. Climate research centers exist at universities in Stockholm and Lund. Marine research centers are established at universities in Stockholm, Umeå, and Gothenburg. MISTRA, a Swedish foundation for strategic environmental research, is providing significant financial support for a center of interdisciplinary Arctic research, hosted at Umeå University with studies in medicine, natural sciences, social sciences and humanities.

Arctic Research Infrastructure

The Swedish Polar Research Secretariat is responsible for polar research infrastructure, such as icebreaker *Oden* and the Abisko scientific station. Scientific expeditions are planned through cooperation and coordination among the Secretariat, the Swedish Research Council, and the Research Council Formas.

VESSELS

- **Oden.** Research-equipped Swedish icebreaker *Oden* is 108 meters long and displaces 13 kilotons.
- **Other.** Other Swedish icebreakers as required.

FIELD STATIONS

- **Abisko Scientific Station.** The Abisko Scientific Station is run by the Swedish Polar Research Secretariat. The station is located in the Abisko national park, 200 km north of the Polar Circle. Operations began in 1903 at a temporary research station at Katterjokk, 35 km west of Abisko. The Abisko Scientific Station began operating in 1910. 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.
- **Tarfala Research Station.** The Tarfala Research Station, run by Stockholm University, in the Tarfala Valley, has been systematically monitoring certain glaciers since 1910, and annually monitoring the large glacier since 1946. Starting in 1980, all glaciers in the valley have been monitored. Other, smaller research stations, with Arctic and sub-Arctic conditions, occur along the mountains bordering Norway.
- **SITES.** The 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

- **EISCAT.** The 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 geospacial 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.



Switzerland

Points 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)

Arctic Research Policy and Goals

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. At the forefront of their research are the impacts of human-induced changes and their consequences on ecosystems and the global climate. Switzerland's research improves our understanding of the world's climate system. It reveals the past behavior of

this system, and make future predictions of it. Scientific progress depends on communication among diverse scientific domains, and polar studies are no exception. Switzerland's research is thus truly multidisciplinary. Swiss scientists participate in about 10 Arctic research projects per year, often with partners from the Arctic Council member states. 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 Funders

Research funding is awarded on a competitive basis, according to qualitative assessment criteria. The Federal government provides funding through two federal agencies: the Swiss National Science Foundation (SNSF) and the Commission for Innovation and Technology (CTI). The government also provides funding to affiliated research institutes within the Domain of the Federal Institutes of Technology as well as to 30 non-university research institutes. For their part, the Cantons are in charge of managing and co-funding cantonal universities and universities of applied sciences. There is no special funding window for polar research. Switzerland is fully associated to Pillar I of Horizon 2020 and successful proposals receive EU funding. In Pillars II & III Switzerland is being considered as an industrialized Third Country and is eligible to participate.

Major 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.

Particularly noteworthy are the World Glacier Monitoring Service (WGMS) at Zurich University and the Oeschger Centre for Climate Change Research at Bern University, which has a well-earned reputation of excellence in polar ice core research, and which hosts the Future Earth core project Past Global Changes (PAGES). Those institutions have been engaged in polar and alpine research for decades.

In 2016, the Swiss Polar Institute was founded by École Polytechnique Fédérale de Lausanne (EPFL), WSL, the Swiss Federal Institute of Technology in Zurich (ETHZ), the University of Bern, and Editions Paulsen. It enhances international relations and collaboration among countries, and sparks 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 work of the International Arctic Science Committee (IASC) the Scientific Committee on Antarctic Research (SCAR), the International Partnerships in Ice Core Sciences (IPICS) and the Climate and Cryosphere project of the World Climate Research Programme (WCRP).

For more than a century, the World Glacier Monitoring Service (WGMS) and its predecessor organizations have been compiling and disseminating standardized data on glacier fluctuations. Thereto, the WGMS annually collects glacier data through its scientific collaboration network that is active in more than 30 countries. In close collaboration with the US National Snow and Ice Data Center (NSIDC) and the Global Land Ice Measurements from Space (GLIMS) initiative, the WGMS runs the Global Terrestrial Network for Glaciers (GTN-G) in support of the UNFCCC, UNEP, WMO, UNESCO and ICSU.

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,” is used to calibrate the ice sheet’s 20 automatic weather stations that deliver data for the Greenland Climate Network (GC-Net).

Switzerland is also at the forefront of polar research in snow science, which is crucial for determining the Earth’s radiation balance. Bern University is a pioneer and world leader in ice core research in Greenland and Antarctica, providing paleoclimate data over past glacial cycles.



Switzerland is also contributing to the international knowledge exchange POLAR2018, a joint activity of SCAR and IASC that will take place Davos, Switzerland from 15–27 June 2018. There, the SCAR meetings, the Arctic Science Summit Week (ASSW), and the Open Science Conference will be hosted by WSL under the patronage of SCPHAR.

Arctic Research Infrastructure

FIELD STATIONS ON GREENLAND

Swiss Camp, established in 1990, is situated at 69°N, 49°W, 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 of the Greenland ice sheet at 72°N, 38°W, at 3216 m. It was built in 1989 and has been occupied year-round since 1997. At both locations, Swiss researchers have maintained a number of long-term climate monitoring instruments over the past 20 years.

FIELD STATIONS IN SWITZERLAND

Research Station and Sphinx Observatory at Jungfrauoch, together with the two astronomical observatories, Gornergrat South and Gornergrat North, provide the infrastructure and support for international scientific research that must 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.



(LEFT) Sphinx Observatory. (ABOVE) Konrad Steffen WSL. Swiss Camp on the Greenland ice sheet is located 80 km inland from Ilulissat has served to study the climate and ice interaction since 1990. Photos courtesy Jungfraubahnen



United Kingdom

Points of Contact

- Natural Environment Research Council Arctic Office (<http://www.arctic.ac.uk>)
- United Kingdom Arctic and Antarctic Partnership (<https://ukaapartnership.org>)

Arctic Research Policy and Goals

The United Kingdom's approach to Arctic science is 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 United Kingdom's approach recognizes that increasing international collaboration is vital to tackle the most pressing research questions.

Arctic Research Funders

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

Research Councils. In addition to NERC, other Government-funded Research Councils, such as those for Engineering and Physical Sciences, Arts and Humanities and Economic and Social research can support a range of research activity in the Arctic.

Royal Society. As the independent scientific academy of the United Kingdom, the Royal Society supports a range of grants and fellowships which can be applicable to research in connection with the Arctic.

British Council. The British Council is the United Kingdom's international organisation for cultural relations and educational opportunities and can provide support to programmes with Arctic research elements.

Leverhulme Trust. Non-governmental and charitable organisations such as the Leverhulme Trust and many others can provide support to a range of projects with direct Arctic relevance, or which have applicability to the Arctic.

Government Departments. Government Departments, such as the Department for Business, Energy and Industrial Strategy, the Foreign and Commonwealth Office, the Ministry of Defence and the Department for Transport and their delivery agencies can provide support to facilitate research, often in coordination with other national partners.

Meteorological Office. Specific organisations such as the Meteorological Office support and deliver significant research with Arctic elements, often in partnership with other research centres and universities.



Visualisation of RRS *Sir David Attenborough*. Image: Cammell Laird/British Antarctic Survey



UK Arctic research station, Ny-Ålesund (Svalbard).
Photo: British Antarctic Survey

Major Arctic Research Initiatives

NERC Arctic Research Programme. This NERC-funded Arctic Research Programme addresses specific topics of scientific uncertainty in the Arctic. The programme is co-ordinated and managed by British Antarctic Survey through the NERC Arctic Office. Research is focused on the underlying causes of observed environmental changes in the Arctic and the potential impact on levels of greenhouse gases and future extreme weather events.

ICE-ARC. This four-year programme, led by the UK, is an example of significant EU-funded research which brings together physicists, chemists, biologists, economists, and sociologists from 21 institutes in 11 countries across Europe, to understand and quantify the multiple stresses involved in the change in the Arctic marine environment. ICE-ARC directly assesses the social and economic cost of sea-ice loss.

The Changing Arctic Ocean: Implications for Marine Biology and Biogeochemistry. NERC is investing in a new five-year research programme to explore the effects of changes to the physical environment (ice and ocean) on the marine ecosystem and the associated biogeochemical functioning of the Arctic Ocean.

Centre for Polar Observation and Modelling. Part of the National Centre for Earth Observation, CPOM operates as a multi-site centre studying polar latitudes. It uses theoretical and laboratory-derived understanding to form new 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

NERC maintains two ice-strengthened research vessels capable of supporting a wide range of Arctic research activities, including a comprehensive range of marine, atmospheric, ecological and geophysical research. UK research centres such as NOC, and the Scottish Association for Marine Sciences, operate a sophisticated fleet of autonomous vehicles, including AUTOSUB3, with new investment in AUTOSUB 6000 and ALR-1500 to deliver new and distinct capabilities for Arctic science. The UK also deploys SMRU seal tags.

- **RRS James Clark Ross** and **RRS Ernest Shackleton** are ice-strengthened vessels which can work successfully in the Arctic. Both ships are operated by the British Antarctic Survey.
- A new, larger and more scientifically-capable NERC vessel, the **RRS Sir David Attenborough**, will enter service in 2018.

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 the British Antarctic Survey; 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 the British Antarctic Survey. It provides facilities and accommodation for researchers to carry out environmental science research. The station supports a range of long-term monitoring, glaciology, marine and terrestrial studies, including via access to local boating facilities.

SATELLITES

The United Kingdom is a key partner in satellite systems including, through CPOM, CryoSat2 operated by the European Space Agency (ESA) which measures the thickness of polar 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)



United States of America

Points of Contact

- Arctic Executive Steering Committee (AESC: <http://arctic.gov/aesc>)
- Interagency Arctic Research Policy Committee (IARPC: <http://iarpccollaborations.org>)
- US Arctic Research Commission (USARC: <http://arctic.gov>)

Arctic Research Policy and Goals

US policy is to “enhance scientific monitoring and research into local, regional, and global environmental issues”, “involve the Arctic’s indigenous communities”, and promote “international scientific collaboration” (National Security Presidential Directive 66: Arctic Region Policy). This policy is implemented by the inter-agency Arctic Executive Steering Committee (AESC), the

Interagency Arctic Research Policy Committee (IARPC), and the US Arctic Research Commission (USARC). US Arctic research policy is designed to increase understanding of the Arctic through scientific research and indigenous knowledge in support of science-informed decision-making.

Arctic Research Funders

National Aeronautics and Space Administration. NASA’s Earth Science Program is a comprehensive, global approach to Earth System Science. For the Arctic, NASA’s research, observations, and modeling focus on understanding Arctic systems as well as the Arctic’s role in the global system, and include the study of Arctic oceans, atmosphere, ice, permafrost, carbon, and ecosystems. Through this Earth System Science approach, NASA’s work contributes to a better understanding of Arctic change, impacts, and resilience.

National Science Foundation. The National Science Foundation (NSF) Arctic Sciences Section supports research to better understand physical, biological, geological, chemical, social and cultural processes in the Arctic, and the interactions and connections of oceanic, terrestrial, atmospheric, biological, social, cultural, and economic systems.

National Oceanic and Atmospheric Administration. The 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, through its many Bureaus, conducts scientific research to inform the Nation’s resource management policies and improve the stewardship of the Arctic region through focused work on marine, wetlands, terrestrial, and freshwater ecosystems, ground and surface water resources, and mineral and energy resources.

Department of Energy. The Department of Energy (DOE) Office of Science advances climate change research to provide knowledge of effects of greenhouse gas emissions on Earth’s climate and biosphere. In the Arctic, DOE supports modeling and prediction, including the Regional Arctic System Model; atmospheric system research, including Atmospheric Radiation Measurement facilities on the North Slope of Alaska; and the Next Generation Ecosystem Experiment-Arctic (NGEE – see below).

Department of Defense. In the Department of Defense, 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 is supported by the Office of Naval Research. The US Army Corps of Engineers Cold Regions Research and Engineering Laboratory also provides scientific and engineering support.

Department of Health and Human Services. In the Department of Health and Human Services, the National Institutes of Health and the Centers for Disease Control and Prevention support research to improve human health in the Arctic.

Major Arctic Research Initiatives

SEARCH. The Study of Environmental Arctic Change (SEARCH) improves understanding, prediction and consequences of the changing cryosphere.

Operation IceBridge. NASA's Operation IceBridge uses detailed airborne remote sensing measurements to produce yearly, multi-instrument, 3D views of Arctic (and Antarctic) ice sheets, ice shelves and sea ice, until lidar satellite measurements resume.

OMG. NASA's Oceans Melting Greenland experiment observes changing water temperatures, elevation, gravity and bathymetry on Greenland's continental shelf to understand how warm ocean waters are melting Greenland ice.

ABOVE. NASA's Arctic Boreal Vulnerability Experiment will improve ecosystem models using surface-, aircraft-, and satellite-based observations to increase understanding of the vulnerability and resilience of Arctic and boreal ecosystems and society to environmental change.

NGEE. The goal of the DOE NGEE project is to improve climate model predictions through advanced understanding of coupled processes in Arctic terrestrial ecosystems.

RUSALCA. The Russian-American Long-term Census of the Arctic (RUSALCA)—a partnership among NOAA, the Russian Academy of Sciences and Roshydromet—focuses on gathering long-term observations for understanding the causes and consequences of the reduction in sea ice cover in the northern Bering Sea and the Chukchi Sea in the Arctic Ocean.



(ABOVE) R/V *Sikuliaq*, operated by the University of Alaska Fairbanks, during ice trials in April 2015 in the Bering Sea. Photo by Roger Topp

(RIGHT) Aurora borealis above Toolik Field Station, Alaska. Photo by Justin Johnson

Arctic Research Infrastructure

VESSELS

The USA has three vessels capable of supporting a wide range of Arctic research activities: marine geology and geophysics; physical and biological oceanography; marine ecology and ecosystems; sea ice geophysics; atmospheric science. Plans for a new heavy icebreaker are in progress.

- R/V *Sikuliaq* is a new global class, ice-capable research vessel operated by the University of Alaska Fairbanks with support from NSF.
- The US Coast Guard operates the **USCGC Healy**, a medium icebreaker, and the **USCGC Polar Star**, a heavy icebreaker.

FIELD STATIONS

- **Toolik Field Station** (TFS) on the North Slope of Alaska is operated by the University of Alaska Fairbanks with support from NSF. TFS hosts a wide range of biological and physical sciences research, and is also the location of the NSF Arctic Long-term Ecological Research (LTER) site.
- **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 observations. NOAA operates Arctic atmosphere monitoring observatories at Summit Station and Barrow, Alaska.

SATELLITES

The USA operates many polar-orbiting satellites, and shares satellite missions with other countries, to remotely sense the Arctic environment and for other research purposes. Chief among the 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)
- **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)
- **Landsat-8** (USGS, NASA)
- **GRACE** (Gravity Recovery and Climate Experiment, NASA with Germany)
- **NISAR** (NASA-ISRO Synthetic Aperture Radar; NASA with India, scheduled for launch in 2021)





European Union

Points of Contact

EUROPEAN COMMISSION

- Directorate-General for Research and Innovation
(<https://ec.europa.eu/research/environment/index.cfm?pg=arctic>)
- Horizon 2020 (<https://ec.europa.eu/programmes/horizon2020>)

Arctic Research Goals

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.

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 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 also 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>) is the world’s largest consortium of expertise and infrastructure for polar research, ensuring coordination of the European scientific and stakeholder polar communities.

ICE-ARC (<http://www.ice-arc.eu>) examines current and predicted future changes in Arctic sea ice and their physical and socioeconomic impacts.

NACLIM (<http://www.naclim.eu>) investigates the predictability of the climate on seasonal-to-decadal time scales. NACLIM has shown that the extent of the Arctic sea-ice cover in October can help to predict average winter temperatures in eastern North America and Europe.

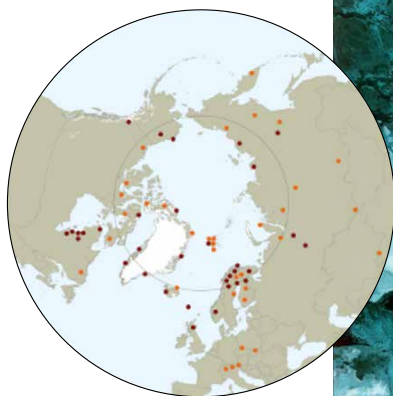
Transatlantic Ocean Research Alliance. The Arctic, through its interplay with the Atlantic, is part of the EU-US-Canada Transatlantic Ocean Research Alliance launched by the trilateral Galway declaration in May 2013. The Alliance triggered the decision to invest in a broad package of Arctic research activities in Work Programme 2016-17 of Horizon 2020. Three large research projects have already been selected and will begin in late 2016. The **INTAROS** project, with a budget of ca. 15.5M€, will extend, improve, and unify Arctic observation systems, including community-based ones, contributing to filling critical gaps and creating an integrated data access platform. **APPLICATE**, with a budget of ca. 8M€, and **Blue-Action**, with a budget of ca. 7.5M€, will explore, through complementary approaches, 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. All projects are based on large transnational consortia, extending beyond the Transatlantic Ocean Research partnership. Details on the three projects will be available once grant agreements are signed, expected by October 2016.

Arctic Research Infrastructure

INITIATIVES

- **SIOS** (<http://www.sios-svalbard.org>) is an international infrastructure (Earth observing system) with partners from Europe and Asia. Its objective is to establish better services for the international research community with respect to access, data and knowledge management, logistics, and training at this Svalbard “supersite”.
- **INTERACT** (<http://www.eu-interact.org>) currently is a circum-Arctic network of more than 70 terrestrial field bases in northern Europe, Russia, US, Canada, as well as stations in northern alpine areas. The main objective of INTERACT is to build the capacity to identify, understand, predict, and respond to Arctic environmental changes throughout the Arctic. It offers access to its network of stations to hundreds of scientists of all nationalities through the Transnational Access Programme. A new project, under review by the EC, could expand further INTERACT activities starting in late 2016.



(ABOVE) Field sites map of the INTERACT infrastructure network. Courtesy of INTERACT project



SPACE INFRASTRUCTURE AND SERVICES

Copernicus. The Copernicus EU Earth observation programme (<http://www.copernicus.eu>) delivers space-based data and geo-information products and services using a data policy that ensures full, free, and open access.

The Copernicus space component is directed by the European Commission in partnership with the European Space Agency (ESA) and EUMETSAT. Four orbiting operational Sentinel satellites deliver data on a 24/7 basis:

- **Sentinel-1:** polar-orbiting, all-weather, day-and-night radar imaging mission. Sentinel-1A was launched in 2014 and Sentinel-1B in 2016;
- **Sentinel-2:** polar-orbiting, multispectral high-resolution imaging mission. Sentinel-2A was launched in mid-2015 and Sentinel-2B will follow in 2017;
- **Sentinel-3:** multi-instrument mission to measure sea-surface topography, sea and land-surface temperature, ocean and land colour. Sentinel-3A was launched in early 2016. Sentinel-3B is scheduled for launch in 2017.

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;
- **Marine:** sea-ice coverage, thickness, drift, edge, type and iceberg density; estimates of snow thickness and sea-ice albedo.

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

- **CRYOSAT** (http://www.esa.int/Our_Activities/Observing_the_Earth/CryoSat) carries an innovative SAR/interferometric radar altimeter and measures fluctuations in the thickness of ice on both land and sea;
- **SMOS** (http://www.esa.int/Our_Activities/Observing_the_Earth/SMOS) is exploiting an innovative two-dimensional interferometer to acquire brightness temperature observations at L-band (1.4 GHz) and provides—together with other products—information to measure thin ice floating in the polar seas.

(LEFT) Sentinel-1B's first data strip stretches 600 km from 80°N degrees through the Barents Sea. The image, which shows the Norwegian Svalbard archipelago on the left, was captured on 28 April 2016 at 05:37 GMT (07:37 CEST). Courtesy of ESA.

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About the US Arctic Research Commission

The US Arctic Research Commission (USARC) is an independent federal agency in the US Government that was created by the Arctic Research and Policy Act of 1984, as amended. It is a presidentially appointed advisory body supported by staff in Washington, DC, and in Anchorage, AK. By law, the USARC publishes a biennial statement of goals and objectives for Arctic research to guide the development of the 5-year Arctic Research Plan by the Interagency Arctic Research Policy Committee (IARPC). The Commission also: (1) reviews Federal Arctic research programs and recommends improvements in coordination; (2) develops and recommends US Arctic research policy; (3) recommends methods to improve Arctic research logistical planning and support, and efficient sharing and dissemination of data and information; and (4) builds cooperative links in Arctic research within the federal government, with the State of Alaska, and with international partners. The law also requires the Commission to review and report to Congress on the adherence of the President's integrated Arctic research budget request to the 5-year Arctic Research Plan.



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