KNOWLEDGE FOR A SUSTAINABLE ARCTIC

3RD ARCTIC SCIENCE MINISTERIAL REPORT

3rd ARCTIC SCIENCE MINISTERIAL

08–09 May 2021 | Tokyo, Japan

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EXECUTIVE SUMMARY

To strengthen international cooperation and respond to the severe threat of climate change and biodiversity loss in the Arctic, the Icelandic Ministry of Education, Science and Culture and the Japanese Ministry of Education, Culture, Sports, Science and Technology co-organized the 3rd Arctic Science Ministerial (ASM3) which was held in Tokyo on 08-09 May 2021.

Delegates from 27 different countries and the European Commission, as well as representatives from Arctic Indigenous Peoples' Organizations, gathered in Tokyo and online to discuss developments in international research and commit to future cooperation. This meeting was built on the themes initiated by the first Arctic Science Ministerial hosted by the United States and held in Washington, D.C. in 2016, and the second Arctic Science Ministerial co-hosted by the European Commission, Finland and Germany and held in Berlin in 2018.

Knowledge for a Sustainable Arctic was the overarching theme for ASM3 and included four sub-themes under the titles: **Observe**, **Understand**, **Respond**, **Strengthen**. These reflect elements of the previous ASM themes and reintroduce an emphasis on education which appeared in the first Ministerial.

The Science Advisory Board was brought together under the guiding principles for ASM3: transparency, inclusivity, and implementing a bottom-up approach to science. The ASM3 Science process followed the structure of the previous Ministerials by soliciting theme-based project updates and new projects from participating countries, Indigenous Peoples' organizations, and international organizations engaged in Arctic science and education, while also attempting to create a more formal consultation process with the wider research community through other international fora and through the ASM3 Webinar Series.

This report includes the foundational outcomes of the ASM3 Science Process including the **Science Summary**, **Joint Statement of Ministers**, **Arctic Research Overviews** from countries and organizations, a summary of the **ASM3 Webinar Series**, **Moving Forward** document highlighting opportunities to advance international cooperation, and an **Appendix** documenting the outcomes of the consultation process with the wider Arctic research community. Additionally, some online resources were developed including **recordings of the webinar series**, a list of **International Opportunities and Resources**, and a new **Project Database** mapping all of the ASM3 submitted projects.

The intention of this wide-reaching science process was to have robust and inclusive science outcomes to provide a strong foundation for all the final outcomes of the ASM3. These outcomes create useful tools for cooperation, deepen our understanding of both the achievements and challenges that lay ahead, and provide a strong framework for taking urgent action.

01

SCIENCE
SUMMARY

SCIENCE SUMMARY

KNOWLEDGE FOR A SUSTAINABLE ARCTIC
OBSERVE, UNDERSTAND, RESPOND, AND STRENGTHEN

ABOUT THIS DOCUMENT

This Science Summary presents a synopsis of the contributions provided by the following: Austria, Canada, China, Czech Republic, Denmark, Faroe Islands, Finland, France, Germany, Greenland, Iceland, India, Italy, Japan, the Netherlands, Norway, Poland, Portugal, Republic of Korea, Russia, Singapore, Spain, Sweden, Switzerland, Thailand, United Kingdom (UK), United States of America (USA), European Union (EU), Inuit Circumpolar Council (ICC), Saami Council, Association of Polar Early Career Scientists (APECS), Group on Earth Observations (GEO), International Arctic Science Committee (IASC), International Arctic Social Sciences Association (IASSA), International Council for the Exploration of the Sea (ICES), International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT), North Pacific Marine Science Organization (PICES), Polar Educators International (PEI), Sustaining Arctic Observing Networks (SAON), University of the Arctic (UArctic), UN Environment Programme (UNEP) and the World Meteorological Organization (WMO) and the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP), Conservation of Arctic Flora and Fauna (CAFF), and the Sustainable Development Working Group (SDWG).

As part of the ASM3 Science Process, participating countries and organizations were asked to provide updates to projects submitted in support of the goals of ASM1 and ASM2 as well as new projects that support the themes of ASM3. Standardized forms were used to help in data analysis. In addition, participants were also asked to fill out a survey about international cooperation and provide information about opportunities in their country/organization for international researchers and Indigenous Peoples. The documents received were analyzed and initiatives categorized within the four themes of ASM3 by the Science Advisory Board. Contributions and initiatives proposed ranged from small, localized, and concentrated short-term efforts involving a few researchers to large, multi-national, multi-agency long-term programs involving several hundred professionals. This summary also includes contributions from the larger Arctic research community gathered through several meetings and workshops, including the Arctic Observing Summit (AOS) and the IASC/IASSA/APECS Research Community Workshop, and 6th International Symposium on Arctic Research (ISAR-6). This document, developed by the ASM3 Science Advisory Board, offers a high-level synopsis of these contributions including summary infographics highlighting keywords and locations of research projects. It is not exhaustive, nor a consensus of the ASM3 participants, but rather aims to provide an overview to identify areas of major interests and to help catalyze further cooperation aiding in the advancement of our understanding of the Arctic. ASM3 prioritized transparency in the science process with detailed information available on the ASM3 website.

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- Indigenous Knowledge Holder Representative: **Liza Mack**
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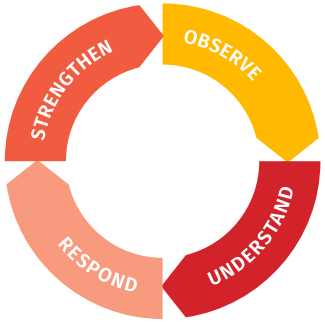


The third Arctic Science Ministerial (ASM3) focused on "Knowledge for a Sustainable Arctic" and built upon the results from projects submitted to the first and second ASM. Particular attention was paid to the research actions needed to address the most urgent challenges facing the Arctic. Many of these grand and pressing challenges are too large for one country alone to solve, making international scientific cooperation essential.

The discussions in the past two Arctic Science Ministerial meetings demonstrated that the following four-step process is indispensable to meet the challenges of a rapidly changing Arctic:

1. **Observe: implementing observing networks; data-sharing**
2. **Understand: enhancing understanding and prediction capability for Arctic environmental and social systems, for the global impact of these changes**
3. **Respond: operationalizing sustainable development, evaluating vulnerability and resilience, and applying Knowledge**
4. **Strengthen: preparing the next generation through capacity building, education, networking; and resilience**

These four steps are not independent, but rather an iterative cycle.

THEME 1: OBSERVE

IMPLEMENTING OBSERVING NETWORKS; DATA-SHARING

The desired actions for this step are to provide support for the implementation of an international observation and data sharing system, and to develop collaboration between scientists and Arctic communities.

Reliable data about changes in the Arctic are more limited than for most other parts of the planet. Vast gaps of *in situ* data in the Arctic remain, and there are limited long-term and space-based observations. In addition, foundational geospatial mapping is a fundamental input to a better understanding of Arctic ocean and coastal ecosystems, but much of the Arctic is not surveyed or is inadequately mapped. Observations of a wide range of variables (such as wildlife, atmosphere, water, land, ice, snow, coastlines, oceans, as well as of social, cultural, and economic impacts) are required from a variety of observation platforms (such as marine, surface, upper air, and space-based). Further, sustaining long-term *in situ* observation systems in the Arctic is demanding and requires considerable human and financial resources. International commitment is required to sustain critical pan-Arctic observation infrastructure, ocean and coastal mapping, a high level of coordinated campaign observations, and a focus on data management and sharing. For some observation systems, empowering Indigenous Peoples and other Arctic residents to engage in research and monitoring programs is important for fostering a localized observing system that includes community-driven observation. The urgency of these actions has become even clearer during the COVID-19 pandemic, apart from satellites and surface networks, which has amplified some of the existing weaknesses in sustaining long-term observational research.

It was noted in ASM1 and ASM2 that the Sustaining Arctic Observing Networks (SAON) initiative can play a key role in resolving these issues. Following the recommendations in the previous meetings, the ASM3 participants also conveyed a strong interest in strengthening the work of SAON and other related efforts. Empowering national focal points and offices in each country as well as focusing on recommendations from international assemblies would be the first step.

PROGRESS TOWARDS AN INTEGRATED ARCTIC OBSERVING SYSTEM

Sustained Arctic Observing - Many large efforts concerned with planning, implementing and sustaining Arctic observing and data systems are collaborating to an unprecedented degree, with considerable new investments launched to further support pan-Arctic strategies for observing and data systems.

- ASM2 encouraged SAON with partners to progressively proceed from design to the deployment phase of an integrated Arctic observing system. As a response to this, SAON has developed the Roadmap for Arctic Observing and Data Systems (ROADS) which will stimulate multinational resource mobilization around specific plans with clear societal value propositions. ROADS created the International Arctic Observing Assessment Framework, which will serve as a tool for evaluating the societal value of observing.

- **Other Observing Networks** are also making progress and working towards integrating with SAON. Norway-led Integrated Arctic Observation System (INTAROS), for example, has made great progress since ASM2, including on the development of a roadmap for Arctic systems, of relevance especially to the European Arctic. In the USA, the Research Networking Activity in Support of Sustained Coordinated Observations of Arctic Change was developed, in partnership with SAON and in collaboration with Indigenous Peoples, to follow the ROADS process for observing in the Pacific Arctic sector, through a food security lens. Also, as part of SAON, the Inuit Circumpolar Council (ICC) and partners have created the Atlas of Community-Based Monitoring and Indigenous Knowledge in a Changing Arctic to map community-based monitoring and Indigenous Knowledge initiatives across the circumpolar North. The Svalbard Integrated Arctic Earth Observing System (SIOS) is a collaborative effort to develop and maintain a regional observational system for long-term measurements in and around Svalbard, addressing Earth System Science questions related to Global Change. Since its operation phase in 2018, SIOS has coordinated observations and released three State of Environmental Science in Svalbard reports, launched an access program to optimize the use of research infrastructure and has created a portfolio of training courses and workshops. The newly established Greenland Integrated Observing System (GIOS) is a coordinated network of sustainable long-term research infrastructures in and around Greenland observing the changing air, ice, land, and ocean conditions. Building on the success of the Alaskan Local Environmental Observation (LEO) Network and the expansion to the Circumpolar LEO (CLEO) including the 8 Arctic Nations, a new project was initiated to create a regional hub for CLEO in the area known as Beringia, expanding the use of CLEO in the Russian Far East and connecting them to observers in northwest Alaska and throughout the Arctic.

OBSERVING AND MONITORING OF VARIOUS ENVIRONMENTAL COMPONENTS

- **Atmospheric measurements** are being conducted by a number of nations. The Nordic Observatory brings together an informal association of geophysical ground-based observation facilities in Northern Europe (Finland, Norway, Sweden) and northwest Russia for joint studies of high-latitude phenomena in the atmosphere, ionosphere, and near space. Russia has improved their Kola Arctic Geophysical Infrastructure Network by adding the Polar Geophysical Institute and has plans to upgrade much of its equipment. Italy continues to make progress on harmonizing atmospheric measurements across different methods and platforms, which is contributing to the comparison of measurements across the Arctic. Italy, Denmark and the USA continue to collaborate on efforts at the Thule High Arctic Atmospheric Observatory (THAAO) and plan to add several in situ and remote sensing instruments for measuring precipitation. Researchers from Spain and Germany have been able to collect aerosol measurements year-round, which is a major advancement in technology and will enhance our understanding of the impact of aerosols in winter time.

- Russia is working on improving our understanding of **space weather** and its impacts on the power supply systems in Arctic and subarctic zones. Italy is also active in space weather research and is working to improve its ground-based infrastructure which will in turn improve their modeling capabilities.

- **Terrestrial and freshwater ecosystem monitoring** is an active area for Russian scientists looking at salmon and mussels and is mapping tundra habitats. The USA's Arctic Boreal Vulnerability Experiment (ABoVE) continues to link field-based, process-level studies with geospatial data products derived from airborne and satellite sensors. This provides a foundation for improving analysis and modeling capabilities needed to understand and predict ecosystem responses and societal implications. The Czech Republic also contributes by investigating microclimates around various types of vegetation in the Arctic. In the USA, efforts are underway to track wildlife movement through satellite tags. The CAFF's Circumpolar Biodiversity Monitoring Programme (CBMP) continues to play an important role in coordinating and harmonizing ecosystem data across the Arctic and has now begun a project on monitoring Arctic bird migration.

- **Ocean observing** efforts carried out by Canada, Germany, India, Italy, Japan, Korea, Norway, and the USA contribute to better understanding of freshwater inputs into the Arctic Ocean, gyre systems, Arctic fjords, deep ocean currents and marine productivity. The Distributed Biological Observatory (DBO), an important international effort originating in the

Bering to Beaufort Seas, has continued to collect data throughout the COVID-19 pandemic and plans to expand its work into the Baffin Bay and Labrador Sea region. The Synoptic Arctic Survey (SAS) is a new effort, led by Norway and involving researchers from 12 countries, that aims at collecting empirical data from multiple research cruises to generate an unmatched dataset for a complete characterization of Arctic Ocean hydrography and circulation, organismal and ecosystem functioning and productivity, carbon uptake and ocean acidification.

- **Sea ice observations** are carried out in many nations benefitting from new technologies on the ground and through remote sensing. China's Multi-Parameters Arctic Environmental Observations and Information Services (MARIS) is a major effort to advance modelling and forecasting of sea ice based on better data, designed to increase safety of shipping in the Arctic Ocean. New technologies are also being developed to observe sea ice thickness, sea ice / wave interactions and the connection between spring rainfall and earlier snow melt. Under-ice drones are being developed by Japan and Norway and could lead to a major advancement in understanding sea ice formation and melt as well as sea ice / ecosystem relationships.

- The number of projects observing the dynamics of **glaciers and ice sheets** with various remote sensing methods is increasing, advancing understanding of melt and its connection to **sea-level rise**. However, limited work seems to be going on in the area of impacts of melt on Arctic communities. Iceland is working on this aspect in regards to rock glaciers and avalanche hazards.

- **Permafrost monitoring** is increasing due to a number of stations being added to Korea's CAPEC project, which aims to improve our understanding of the atmosphere-permafrost-ecosystem interactions. Korea is also looking at the release of gas hydrates from sub-sea permafrost. Japan is investigating the release of greenhouse gases from thawing permafrost and Italy is also working in this area, specifically on carbon dioxide and methane release. The EU-funded Nunataryuk effort includes promising collaborations with local and Indigenous communities on the broad issues related to permafrost thaw, including impacts on the mercury cycle. Long-term monitoring of permafrost change is essential to assess risks for local populations and impacts on global climate.

- **Pollution monitoring** is increasingly important in the Arctic. Black carbon is a major pollutant, studied through Japan's Continuous Soot Monitoring System (COSMOS). Shipping emissions are also of great concern, with the UK leading projects in this area. Oil pollution, spill detection and its modelling are growing areas of concern and Singapore is looking into contributing to related research efforts in the future. Russia is working through the Arctic Council's Arctic Contaminants Action Program (ACAP) to inventory and monitor persistent organic pollutants and mercury in the Murmansk region. Plastic debris in the Arctic environment is also an emerging area of concern. AMAP continues to play an important role in internationally coordinating assessments on pollution in the Arctic.

- **Mapping** of the Arctic Ocean seafloor continues to improve, particularly through the General Bathymetric Chart of the Oceans Seabed 2030 effort, which is a global initiative to map the world's oceans to better understand its depths and seabed morphology. Through this framework, as well as the Arctic Regional Hydrographic Commission, Arctic States will assess their gaps in seafloor knowledge and work together to fill them.

OBSERVING SATELLITES AND NEW TECHNOLOGIES

The advancement and development of new technology both in space and on Earth continues to grow in importance in Arctic research observations.

- Copernicus, the EU Earth Observation program, has scaled up its emergency and security services and has started operating in the Arctic. Two new satellites have been launched, while several others are in production. Additionally, there are five digital hubs for Data and Information Access Services, which merge all Copernicus information products and Sentinel data into centralized complete data sets, free and open worldwide with cloud-computing for data exploitation.

- Researchers in the UK worked with ESA to implement a small adjustment to their CryoSat-2 mission that will allow for comparisons between different types of measurement procedures looking at sea ice, land ice and ocean surface elevation for the first time, paving the way for more effective and efficient future satellite design.

- The US and Indian joint NISAR Mission, planned for launch in 2022, will provide an unprecedented level of detail in its Earth observations by measuring some of the planet's most complex processes including ecosystem disturbances, ice-sheet collapse, permafrost and glacier dynamics, and natural hazards such as earthquakes, volcanoes, land subsidence and landslides.

- The USA's GRACE-FO mission continues to track Earth's water movement providing far reaching societal benefits, helping to determine that melting glaciers and ice sheets contribute about one-third of current sea-level increase.

- Canada's new generation of earth observation satellites, the RADARSAT Constellation Mission, provides solutions to key challenges in the areas of maritime surveillance, disaster management and ecosystem monitoring, among others.

- China launched its first polar observation remote sensing satellite, the Ice Road Satellite. After completing its Antarctic observation mission in 2019, it has begun its Arctic mission. In collaboration with Germany it will advance space-based remote sensing for sea ice research.

- New technologies for ground-based observations are also progressing. Norway's GLIDER project has demonstrated an innovative, flexible and cost-efficient offshore monitoring and data management system using three autonomous and mobile marine platforms including a sea glider, sailbuoy and wave glider, which has no environmental footprint or CO2 emissions. The UK aims to develop autonomous underwater vehicles, associated sensors and supporting infrastructure to explore extreme environments with emphasis on under-ice operations. The USA has several uncrewed aircraft systems, sail drones, gliders, autonomous floats, and innovative sensor technologies that are used to investigate ice edges, ice breakup, heat transfer, ocean dynamics, and to carry out marine mammal surveys. Further, the USA is using satellite-based tagging, eDNA, and uncrewed data collection systems in Alaska to support fisheries and ecosystem management, while cloud-based data processing tools are being developed to accommodate the increased data volumes the high throughput collection systems.

DATA MANAGEMENT

- Data collection and sharing continues to be an issue for Arctic research. Efforts are ongoing to improve this area. The IASC and SAON Arctic Data Committee promotes and facilitates international collaboration towards the goal of free, ethically open, sustained and timely access to Arctic data through useful, usable, and interoperable systems and is making progress particularly through their Polar Data Forums. Japan and Italy continue to improve their data repositories to enhance user experience and accessibility. As part of the ASM3, Japan will be adding a layer to the Arctic Data Archive System that includes all projects submitted to the ASM3. This will provide a historical archive of the meeting and a way for researchers worldwide to find potential collaborators. Participants in the Year of Polar Prediction (YOPP) are collaborating to combine data from multiple sensors operating from a single location, with files to be compliant with metadata standards set by the international data management community including formal attribution for multiple data contributors. The CBMP has launched the Arctic Biodiversity Data Service (ABDS) to facilitate access, integration, analysis and display of biodiversity information for scientists, practitioners, managers, policy makers and others working to understand, conserve and manage the Arctic's wildlife and ecosystems.

MULTIDISCIPLINARY DRIFTING OBSERVATORY FOR THE STUDY OF ARCTIC CLIMATE (MOSAIC)

MOSAiC was an ambitious year-around multidisciplinary expedition with a focus on investigating the coupled Arctic climate system. The aim was to collect data for a better understanding of key climate process and finally to improve sea ice, weather and climate forecast. The expedition was based on the German research icebreaker Polarstern, which drifted with the sea ice from the Siberian sector of the Arctic across the polar ice cap towards the Atlantic. MOSAiC focused on carrying out in-situ observations of climate processes that couple the atmosphere, ocean, sea ice, bio-geochemistry and ecosystem. The 389-day expedition involved hundreds of researchers from 20 countries and persisted despite the COVID-19 pandemic. This massive undertaking required efficient and effective international collaboration and all participants should be proud of their accomplishments. Now that the expedition is over and the data collected, resources are still needed to support the analysis and dissemination of the results. The Science Advisory Board encourages participating countries to continue to support these important last steps.

THEME 2: UNDERSTAND

ENHANCING UNDERSTANDING AND PREDICTION CAPABILITY FOR ARCTIC ENVIRONMENTAL AND SOCIAL SYSTEMS, FOR THE GLOBAL IMPACT OF THESE CHANGES

The desired actions for this step are to recognize the complexity of the system connecting all environmental and socio-economic components and to encourage further interdisciplinary research.

Changes in the Arctic are not only affecting the people who call the Arctic home and are inextricably linked to the Arctic environment and its resources, but actions outside the region continue to impact the Arctic environment and the changes occurring have cascading effects on the rest of the world. Globally, changes in the Arctic significantly contribute to sea level rise, trigger extreme events and further accelerate global warming among other things. To understand the structure and dynamics of these complex systems we need focused and cross-cutting research, including Indigenous-led research, as well as long-term and multi-scale observations that fully represent the Arctic.

Past climate archives, reliable predictions, and enhanced modelling capabilities for the Arctic are essential for developing effective mitigation and adaptation strategies. To progress from *Observing* to *Understanding* we must understand not only how the patterns are changing, but also how the biological and ecological mechanisms that determine the patterns are changing. The ASM3 process worked to strengthen international collaboration for Arctic science and research to enhance the assessment of ongoing change and to improve prediction for future change.

ENHANCING CLIMATE AND WEATHER PREDICTION

- The Arctic is warming at two to three times greater than the global average. **Predicting** how warming will impact the Arctic as well as its influence on global climate and weather patterns represents a major area of research. Denmark and Norway have coordinated national research efforts aimed at better predicting Northern Hemisphere climate. Developing enhanced predictive capacity for weather and climate in the Arctic and beyond and determining the influence of Arctic climate change on Northern Hemisphere mid-latitudes, for the benefit of policy makers, businesses and society, is the overarching goal of the EU-funded APPLICATE project. The UK and Russia are looking at the consequences of accelerating Arctic warming for European climate and extreme weather. Working to coordinate these efforts, the WMO Earth System approach to the Arctic aims at promoting cooperative international research enabling development of improved weather, climate and environmental prediction services for the polar regions, on time scales ranging from hours to decades. In addition, the WMO is in year three of the Arctic Regional Climate Centre Network (ArcRCC-N) demonstration phase to provide climate scale (seasonal) information for temperature, precipitation and sea-ice for the circumpolar Arctic. 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.

- Japan, China, Korea, and India are working to better understand the **teleconnections** between Arctic climate and lower latitudes. Singapore aims to better understand the sensitivities and feedback between Arctic change and the vulnerable region of Southeast Asia.

- Looking to the past, through **paleoclimate** records can help to improve climate models and our understanding of change. Italy is looking at the depositional record from the Barents Sea and Fram Strait to reconstruct past climate. India is working to improve the quantitative estimates of the Mid-Pliocene warmth in the Arctic Ocean through proxy-based reconstruction and explore its past teleconnections with Asian/Australian monsoon system.

YEAR OF POLAR PREDICTION (YOPP)

YOPP is a major international activity initiated by WMO's World Weather Research Programme (WWRP) as a key component of the Polar Prediction Project (PPP). YOPP is an internationally coordinated period of intensive observing, modelling, prediction, verification, user-engagement and education activities, which involves various stakeholders. As a response to rapid Arctic climate change and related transformation of societal and economic activities, YOPP contributes to the knowledge base needed to manage the opportunities and risks that come with Arctic environmental transitions.

Since the YOPP Core Phase (mid-2017 to mid-2019), scientists and operational forecasting centers from different countries continue to work together to significantly advance our environmental prediction capabilities for the polar regions and beyond. By observing and modelling of the Arctic and Antarctic weather and climate systems, this international effort will lead to better forecasts of weather and sea-ice conditions to improve future environmental safety at both poles. More reliable forecasts in polar regions are also expected to result in better weather prediction at lower latitudes, where most people live.

The activity is currently in its consolidation phrase, working on data analysis and a YOPP super-site model inter-comparison project. They plan for a final summit presenting results in May 2022.

UNDERSTANDING ICE

- **Sea ice** is changing rapidly in the Arctic and many projects are working to improve prediction as well as produce more user-friendly products. Norway's Dynamics of Floating Ice project combines theory, field measurements, and laboratory experiments, to improve the current state of knowledge of ocean-ice dynamics with the goal of better risk management for human activities in the Arctic. The US-led Sea Ice Drift Forecast Experiment (SIDFEx) is a community effort to collect and analyze Arctic sea ice drift forecasts at lead times from days to a year and now provides a consensus forecast by automatically combining short-term and longer-term forecasts to obtain best-guess forecasts, including uncertainties, in near-real-time. The USA is also developing a Unified Forecast System, including a coupled ocean-atmosphere-sea ice model showing major improvements in ice coverage prediction in sub-seasonal and seasonal applications. The international, Norway-led ID Arctic project, which examined Arctic sea ice changes and their impacts on society, contributed synthesis products to various assessments and IPCC special reports. China has been working in Utqiagvik, Alaska and have revealed the triggering mechanism of sea ice ablation, clarifying a key process that affects the rapid melting of Arctic sea ice. The EU-funded ICE-ARC is looking into the current and future changes in Arctic sea ice and investigating the consequences of these changes both on the economics of the Arctic and globally.

- Studies of **ice sheet** dynamics and their interactions with the ocean, which can reveal past climate dynamics, represent a major area of international research collaboration. Active since 2011, the Ice Sheet Mass Balance Inter-comparison Exercise (IMBIE) is an international community effort, funded by ESA and NASA (USA), to reconcile satellite measurements of ice sheet mass balance. IMBIE is now entering a new phase where researchers from 14 countries will work together to update annual assessments (split between surface and glacier dynamics) and perform regional assessments. The Dutch Polar Climate and Cryosphere Consortium cooperates with other projects to study primarily the Antarctic and Greenlandic cryosphere, ice-ocean-atmosphere interactions and sea level rise using remote sensing, field observations and modelling.

- Nowhere is ice sheet behavior more uncertain than where it meets the ocean. To fill in these gaps in understanding, the UK is proposing a new project looking at marine terminating glaciers and their impact on sea-level. The EU-funded PROTECT project will significantly advance our understanding of **sea-level rise** by examining changes in the land-based cryosphere and creating regional and local projections on a range of timescales. Singapore, China and Japan also have projects looking at the impact of the melting of the Greenland Ice Sheet on sea-level rise.

- The RECAP and EastGRIP are international efforts looking at **ice cores** from eastern Greenland to understand past climate as well as past sea ice extent. The projects' goals are to obtain a Northeast Greenland Ice Stream core and improve our understanding of how ice streams will contribute to future sea-level change.

- Poland is investigating the spatial distribution and temporal changes of **snow** properties combined with datasets on chemistry, microbiology, plants and animal ecology and hydrology to provide insight into the functioning of pristine and vulnerable High Arctic ecosystem in the age of Global Change.

- Understanding the impacts of ice on **Arctic geology** can give us a better look into past environments. Singapore is looking at the history of Arctic deglaciation and creating a three-dimensional Earth structure of the subterranean Arctic. Since ASM2, it has already revealed the lithosphere structure and three-dimensional mantle viscosity structure beneath the Russian Arctic. Korea, together with Norway, is carrying out research to understand changes in environments and the coastal morphology of Arctic Svalbard fjords, which provide an excellent setting for mapping and investigating geologic and environmental consequences of the past, present and future climate changes. Italy is leading a new initiative, Past for Future, which will develop essential basic knowledge for building climatic models that help project future scenarios. The initiative brings together scientific efforts focused on the reconstruction of the quaternary palaeoceanographic history of the Arctic margins and their inter-connection with paleoclimatic changes.

UNDERSTANDING ECOSYSTEMS

The Changing Terrestrial Ecosystems and Environment

Climate change and loss of biodiversity threaten terrestrial ecosystems globally. This is of particular concern in the circumpolar tundra where we are witnessing widespread responses to these threats, with clear consequences for many Arctic societies. However, our understanding of the functioning of tundra ecosystems is far from complete.

- In addition, the US NGEE Arctic project is improving the representation of **tundra ecosystems** in Earth System Models by adding components to observations, experiments, and modeling that address the vulnerability and resilience of Arctic ecosystems to disturbance, and how those disturbances alter the physical and ecological structure and function of these ecosystems. Iceland is leading the herbivory network of UArctic, to increase our understanding of how herbivores influence tundra ecosystem functioning which will guide informed adaptive strategies to preserve tundra's natural values and ecosystem services. Researchers from Canada, Denmark, Sweden and Greenland are collaborating on a project aimed at increasing our understanding of the ecological interactions among pollinators and flowering plants in tundra ecosystems, and the ways these interactions may be altered due to climate change.

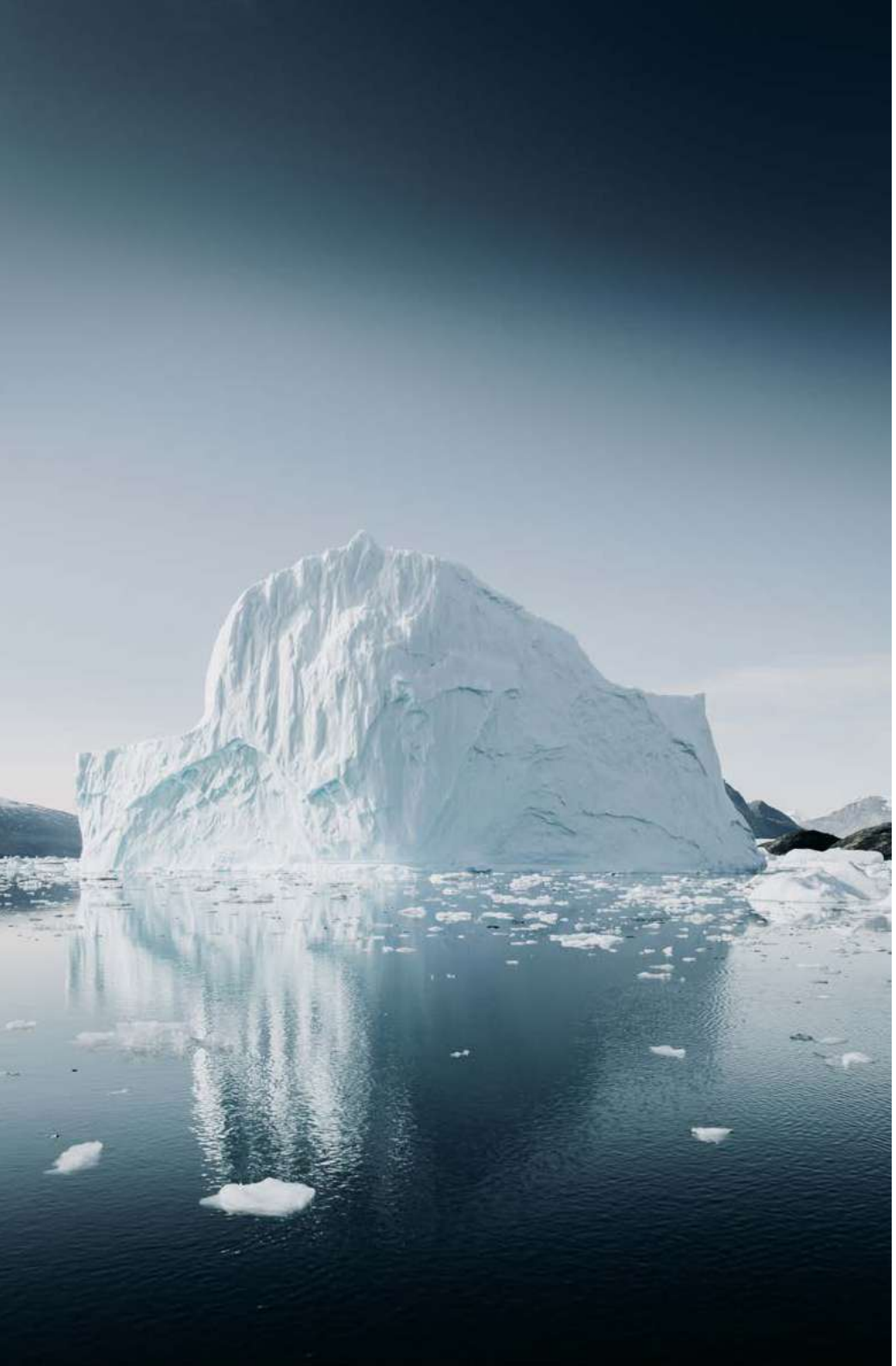
- Norway's Reindeer husbandry in a Globalizing North (ReiGH) project integrates perspectives from natural and social sciences as well as economics to identify key external and internal drivers and investigates their effects on the reindeer herding industry.

- The Czech Republic has several projects examining the role of microorganisms in Arctic soils and glaciers. Switzerland performs experimental and observational ecological research in Svalbard, Greenland and Siberia, in collaboration with local partners, to increase the understanding of the role of immigration of non-native species and climate change extremes on **plant and soil microbial diversity** and ecosystem functions in the New Arctic. Russia has a number of projects looking at marshes and peat lands and the risks of geo-biological threats, and to find solutions to environmental problems in the Arctic region.

- The ASM2-proposed Terrestrial Multidisciplinary distributed Observatories for the Study of Arctic Connections (T-MOSAiC) is an international pan-Arctic, land-based program of IASC that aims to understand the effects of warming on the land surrounding the Arctic Ocean and on the northern communities who live on those lands. Funding calls have now gone out in several countries, and the observation period is set to be concluded during 2021.

- Finland's Arctic Hydrology in a Changing Climate will study ecohydrology in seasonally snow-covered catchments in the Boreal, sub-Arctic and Arctic. Japan is also interested in the role of Arctic **water cycle** and its impact on the climate system particularly in the Northern Eurasian region. Several countries including Germany, USA, Japan, Italy, and Singapore are investigating the link between permafrost thaw and methane release. UNEP is working to develop a rapid response assessment of coastal and offshore permafrost.

- The Netherlands is studying the impacts of climate change on **bird migration** through several projects working together to track birds and model the distribution, food availability and migratory behavior in a changing environment. Researchers from the Czech Republic have installed trackers on Arctic terns to follow their 90,000 km migration to the Antarctic.



The Changing Marine Ecosystems and Environment

The Arctic marine environment is under rapid change, in its physical and biotic conditions. The gradual loss of sea ice, increase in temperature and acidity, migrating species, changes in productivity and compounding effects of additional ecosystem stressors are identified as contributing to significant impacts to Arctic species.

- The joint German-UK project Changing Arctic Ocean aims to understand how changes in the physical environment (ice and ocean) will affect the large-scale **ecosystem structure** and biogeochemical functioning of the Arctic Ocean. The project also evaluates potential major impacts and provides projections for future ecosystem services. Scientists from Canada are partnering with international scientists (e.g., Germany, the United Kingdom and Norway) to study the unique ecosystem associated with Arctic multi-year ice in the last region in the Arctic Ocean where it persists. The EU-funded ECOTIP project works to improve understanding of the causes, thresholds and consequences of ecosystem tipping cascades on Arctic marine biodiversity. ECOTIP is also developing methods to assess, monitor and predict these tipping cascades and engages in the co-creation of mitigation and adaptation strategies. The overarching objective of EU-funded FACE-IT is to enable adaptive co-management of social-ecological fjord systems in the Arctic in the face of rapid cryosphere and biodiversity changes. The German-lead PAN-Arctic Information System on Marine BIOta (PANABIO) aims to fundamentally improve understanding of climate change impacts on Arctic marine biota, with its first objective of creating assessments of past and current ecosystem status well under way. The project also strives to communicate climate change impacts to the public and strengthen international collaboration across the Arctic science community. Under the Belt and Road Initiative, China is actively collaborating with Russian researchers on marine chemistry, physical oceanography, ecological environment, marine geology, regional geology, oil and gas hydrates across the Arctic Ocean.

UNDERSTANDING POLLUTION IN THE ARCTIC ENVIRONMENT

Pollution is increasing in the Arctic both in terrestrial and marine ecosystems. Several projects are working to better understand where the pollution is coming from and how it is impacting society and the environment.

- For ASM2, France proposed a more comprehensive project on Arctic pollution which has since made significant progress. The Pollution in the Arctic project, in collaboration with international partners, has identified its next steps including understanding the role of pollution on climate warming in the Arctic, including interactions with clouds, the cryosphere and permafrost. Furthermore, the project is studying how natural biogeochemical cycles are perturbed by anthropogenic pollutants, including plastics, from local and distant sources, determining the impacts of pollutants on Arctic ecosystems and on human societies reliant on wildlife and working together with Indigenous Peoples in risk evaluation and assessment.

- Japan has a project assessing the impacts of Asian air pollution on the Arctic, and Russia is researching bioremediation methods for contaminated Northern marine environments. Thailand is studying the impact of climate change and marine debris including microplastics on marine communities around Svalbard. Norway has just begun a project looking at the impacts of artificial light on arctic marine organisms. Italy is in the early planning stages of a project examining the impact of climatic changes on biodiversity, contaminant distribution, and bioaccumulation and its effects on Arctic marine ecosystems.

UNDERSTANDING SOCIETY IN THE ARCTIC

- The Iceland-led SDWG and Arctic Council Chairmanship project on Gender Equality in the Arctic is in its third phase and is building a collaborative network of experts with the purpose of promoting and expanding the dialogue on **Gender Equality** in the Arctic. This includes the publication of a pan-Arctic report on gender, focusing on law and governance, security, environment, migration, violence, and empowerment. A French project aims to update and upgrade the Nordicity Index created in the late 1960s by Louis Hamelin, which considered factors including both natural and human dimensions to provide a measure of the degree of northernism in a community. Norway is leading Arctic Voices, an effort that gathers stories from the Western Arctic in the 19th century, a period when Arctic Indigenous Peoples and animals began experiencing increased contact with and influence from Europe and North America. The Arctic Voices project aims to reimagine **Arctic history** and shift it away from a White, male, foreign dominated understanding of the region towards one that includes Indigenous Peoples and women, as well as animals. Biological samples from Greenlandic residents have been collected and stored in various biobank facilities for many years. The establishment of a Danish Greenlandic register of these samples will help to strengthen health research for the Greenlandic People.

- Norway is working with Russia on several projects involving **Arctic societies**. Topics studied include: 1) the spatial differentiation of levels and forms of adaptation of populations to changes in natural, socio-economic, and environmental conditions in Eastern Arctic regions; 2) the role of volunteer organizations and how they adapt to changing legislation, political, cultural and societal conditions; 3) how material heritage affects people's lives, memories, and perspectives; 4) marine heritage as a value factor in the development of coastal areas; and 5) the impacts of social, household, and psychological factors on the health of Indigenous Peoples' reproductive health.

UNDERSTANDING LINKAGES BETWEEN ECOSYSTEM COMPONENTS, INCLUDING HUMANS

A great deal of work examines linkages between human society, public health, and various environmental processes in the Arctic, whether contaminants or a warming climate.

- Two projects led by ICC address linkages of Inuit culture and understanding of environmental systems: The Circumpolar Inuit Wildlife Strategy and the Alaskan Inuit Food Security Conceptual Framework. Japan's J-ARC Net promotes advanced and interdisciplinary research conducive to understanding **environmental-human interactions** and the sustainable development of the Arctic. The Czech Republic's Arctic Center is running a project investigating the impact of climate change and human activities on natural environments in the Arctic. Russia is conducting a comprehensive analysis of the relationship between historical, cultural, social and natural processes affecting wetlands using the example of the coast and deltas of rivers flowing into the Arctic Ocean. The USA's InteRFACE project focuses on how the **coupled, multi-scale feedbacks** among land processes, sea ice, ocean dynamics, coastal change, biogeochemistry, atmospheric processes, and human systems control the trajectory and rate of change across the Arctic coastal interface. Norway is studying the link between governance and Barents Sea fish populations with particular attention to questions of resource abundance, fishing rights, and environmental and market conditions.

- The Finland-led Pan-Eurasian Experiment (PEEX) is a multidisciplinary climate change, air quality, environment and research infrastructure program focusing on understanding **large-scale feedbacks and interactions** between the land-atmosphere-ocean continuum under the changing climate in the Northern Eurasian and particularly Arctic and Boreal regions.

THEME 3: RESPOND

OPERATIONALIZING SUSTAINABLE DEVELOPMENT, EVALUATING VULNERABILITY AND RESILIENCE, AND APPLYING KNOWLEDGE

The desired actions for this step are to recognize the necessity of knowledge-based decision-making and to establish a framework for taking effective measures.

Warming at a rate two to three times greater than the global average, the Arctic is experiencing drastic changes in the natural environment. The changes are visible in many natural phenomena and ecosystems, e.g. wildland fires, permafrost thawing, sea ice retreat, and their impacts on cultures and societies are becoming clearer. Further amplified Arctic warming will continue at least until mid-century and will likely occur regardless of any prompt action taken to reduce greenhouse gas emissions. The rate and amount of warming will depend critically on our collective efforts today and in the coming years to reduce greenhouse gas emissions.

It is, therefore, a matter of urgency to implement ambitious actions to mitigate climate change, adapt to its impacts, and support the sustainable future of the Arctic and its people. This approach must be informed by the best available science and knowledge.

ENVIRONMENTAL CHANGE IMPACTS AND FOOD SECURITY

A variety of projects look at the impacts of environmental change on Arctic livelihoods, particularly food security.

- **Impacts to Arctic food security:** The Nomadic Herders project co-led by the Saami Council is developing research methods and skills to conserve species, enhance biological diversity and reduce pasture degradation in reindeer herding regions globally, while sustaining resilience of ecosystems and livelihoods of reindeer herding communities. The EALLU Project, also co-led by Saami Council, focuses on Indigenous Traditional Knowledge on food as a foundation for diversification of local economies and new approaches to adapt to Arctic change and food insecurity. The Circumpolar Inuit Wildlife Committee is determined to promote, develop and maintain the Inuit right to self-determination and their culture, food sovereignty and sustainable use by providing a unified pan-Arctic Inuit voice concerning access, sharing, and management of wildlife resources. Russia is also working on several projects exploring new ways of cultivating healthy foods hydroponically without using soil and their Regional Arctic Cluster: Bioresources and Technologies aims to assess available resources and develop solutions for implementing innovations for production and promotion of local food products in the Arctic region. In September 2020, the ICC released Food Sovereignty and Self-Governance – Inuit Role in

Arctic Marine Resource Management, which links holistic and adaptive management strategies to ensure the food security, health, and well-being of Inuit throughout the Arctic for generations to come. The USA and Russia are carrying out an interdisciplinary research project focused on key issues for traditional livelihoods and the sustainable development of Indigenous communities in Chukotka, Alaska and Kamchatka in the face of climate change. The goal is for the communities to find ways to adapt. Japan is leading a project looking at the impact of warming on Arctic soils and how that impacts energy and food resources.

- **Impacts to Arctic Livelihoods:** The EU, Japan, Russia and Norway all have projects funded on impacts of changing coastlines and fjords, including invasive snow crabs, and are creating adaptive co-management strategies for coastal fisheries and coastal erosion. Norway is developing the first risk assessment for the Barents Sea Ecosystem. Norway is also leading the international ARCPATH project, which is working to improve climate prediction by reducing uncertainties and providing information as 'pathways to action' for Arctic regions. Several projects are dealing with changing ecosystems and their impacts on society, biodiversity, and species conservation such as CAFF's efforts to address wetland management and Russia's projects about the changing role of wetlands in Arctic societies. The Belmont Forum-funded HYPE-ERAS project aims to improve understanding of the interrelationships among the impacts of climate warming on hydrological regimes, river ice conditions, permafrost thaw, related landscape changes and the corresponding societal challenges of flood hazard, river ice road infrastructure, and loss of agricultural land by ground subsidence. The EU-funded Nunataryuk project is creating co-designed adaptation and mitigation strategies for communities in Northern Canada impacted by thawing permafrost and collapsing coastlines.

IMPACTS ON HUMAN HEALTH

A variety of projects look at the impacts of environmental change on Arctic livelihoods, particularly food security.

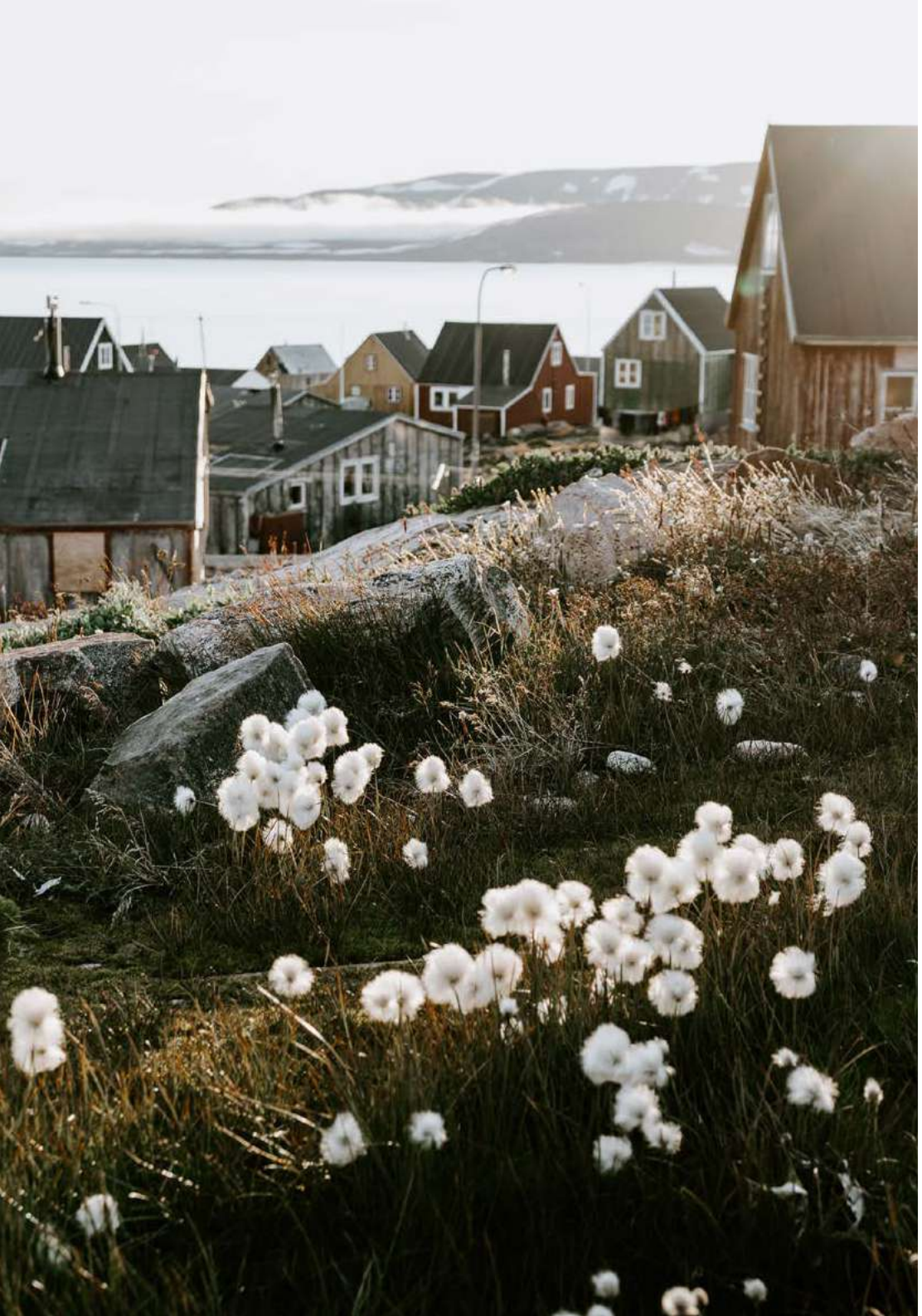
- **Environmental Impacts:** Pollution is an increasing problem in the Arctic. As mentioned, there are several projects looking at quantifying black carbon, persistent organic pollutants, and mercury. There are also a number of projects focusing on the impact and remediation of these contaminants. AMAP continues its work on Arctic Contaminants and Human Health and is working on reports focusing on mercury, persistent organic pollutants, and short-lived climate pollutants as well as an updated human health assessment and a study on marine litter and plastics. The Belmont Forum-funded ACRoBEAR is working to predict and understand health risks from wildfire air pollution and resulting diseases.

- **Well-being:** Iceland is working on reducing incidence of Type 2 diabetes by using nurse-guided educational therapy and intervention. The SDWG project One Arctic, One Health seeks to develop a collaborative network of Arctic One Health (human-animal-environmental health nexus) via knowledge sharing, table-top exercises, and collaborative investigations of One Health phenomena, such as disease outbreaks and natural disasters. SDWG is also working to identify and action projects to better understand the impact of COVID-19 in the Arctic and support the resilience of Arctic communities during and after the pandemic. The aims of SDWG's Local 2 Global project are to facilitate international collaboration between circumpolar communities in preventing suicides and supporting the mental wellbeing of all Arctic youth and communities, with a focus on Indigenous youth. Also working on this issue, the USA has created collaborative hubs for American Indian and Alaska Native Youth with the goal of developing and using preventive strategies that could sustainably reduce suicide rates of youth.

GOVERNANCE AND ETHICS

- Recognizing the importance of working with communities in the Arctic and respecting local cultures and traditional values, the USA has updated their Principles for the Conduct of Research in the Arctic and UArctic has developed ethical guidelines for conducting multidisciplinary Arctic research. ICC will bring together Inuit from across Inuit Nuunat (homelands), which spans Chukotka, Alaska, Canada, and Greenland and facilitate discussion to develop Circumpolar Inuit **principles/protocols** for equitable, ethical engagement and involvement of Indigenous Knowledge and communities. In 2018, Inuit Tapiriit Kanatami (ITK) released the National Inuit Strategy on Research (NISR) which promotes a shared understanding of the legacy of Inuit Nunangat research and connects this legacy to current research practices, defines Inuit expectations for the role of research in Canadian Inuit regions and communities, and identifies areas for participation and action between Inuit and the research community. Japan has a project that aims to present a vision of a resilient international system that can adapt to rapid environmental and socioeconomic change and geopolitical tensions, which can enhance predictability and stability for all stakeholders with involvement in the Arctic, including Arctic States/governments. Norway is looking at the impact of how international law influences and is influenced by changes in Russian shipping legislation.

- Other projects are looking at the **interaction between governance, development, and society**. The Arctic Governance Triangle: Government, Indigenous Peoples and Industry in change project aims to examine how large development projects like mining, production of electric power and aquaculture challenge traditional land and resource use, and examine types of governance arrangements established to regulate these relationships.



INDUSTRIAL DEVELOPMENT AND SOCIO-ECONOMIC ISSUES

- **Operational support** for Arctic industry is growing, as is the research needed to support these new tools. China is working on an Arctic Ice Ocean Prediction System to facilitate shipping traffic and other needs, and the USA and Canada work on the North American Ice Service to provide operational forecasts for sea ice navigation. The PolarView project provides sea ice information to maritime operators that minimizes delays, improves efficiency, evaluates and mitigates risk to vessels and the environment, and supports compliance with maritime regulations. Japan is working on a system for more effective use of Arctic Routes (e.g. Northern Sea Route, Northwest Passage) including safe navigation through ice. The EU-funded KEPLER project is a multi-partner initiative, built around the operational European Ice Services and Copernicus information providers, to prepare a roadmap for Copernicus to deliver an improved European capacity for monitoring and forecasting the Polar Regions. Through the EU-funded BlueAction project, Russia and other countries are working to provide industry and the population with new types of information services in the field of ecology and hydrometeorology.

- The EU-funded ArcticHubs project will identify and analyze both global **economic drivers** for the development of Arctic industrial centers, and **geopolitical trends** and factors in the Arctic that affect the development of various industries (tourism, mining and processing, fish farming, forestry) and Arctic cities (centers). Another EU-funded project, CHARTER, is an effort to advance adaptive capacity of Arctic communities to climatic and biodiversity changes through state-of-the-art synthesis based on thorough data collection, analysis and modelling of Arctic change with major socio-economic implications and feedbacks.

- Norway's SAMCoT develops robust **technology needed for industry operating in the Arctic** and contributes to the development of ISO standards for both land and sea operations. Norway is also looking at how the de-icing of Arctic coasts will impact marine biodiversity and their associated ecosystem services. The USA is updating existing and outdated engineering guidance, to include state-of-the-art design concepts, methods, and innovative tools utilized today for Arctic and sub-Arctic design and construction.

- **Tourism** is increasing dramatically in the Arctic and Norway is studying how this industry can create new and sustainable products in light of a changing Arctic. The Netherlands selected polar tourism as a priority topic of national relevance for its national research agenda.

- Russia has a variety of projects looking at various other aspects of **industrial applications** in the Arctic, including new uses for Arctic peat resources, improved construction of roads and structural foundations, bioremediation of Arctic coastal regions, developing new technological approaches for environmentally sound reuse of spent concrete in construction, and supporting the development of technological solutions to reduce the negative environmental impacts of mining while improving economic efficiency.

- The development of **sustainable energy** is also important in the Arctic region. Wind is such an example with both positive and negative impacts. Russia is leading an effort through the UArctic to establish a sustainable consortium of academic researchers and faculty members through project meetings and academic/research activities to enhance exchange of ideas and stimulate educated discussions about wind energy resources in remote areas of the Arctic region. The Saami Council is promoting a project assessing the impacts of operational wind farms in Northern Sweden on reindeer, habitat and reindeer husbandry, with early results indicating reindeer in both calving and winter grazing areas are negatively affected by wind farm developments.

- **Sustainable economic development** is a major theme that comes through various Arctic strategic plans. JUSTNORTH is a new EU Horizon 2020 funded project that seeks to create understanding on the potential for economic development in the North that is both sustainable and just by investigating how to reduce inequalities between Arctic stakeholders.

- **Risk prevention** is also an important area where research needs are increasing. The Maritime Preparedness and International Partnership in the High North (MARPART) is an international team of experts from 20 partner universities and organizations participating in regional, national and international maritime exercises to increase capacity to respond to marine incidents and to increase the effectiveness of education and personnel training to ensure emergency preparedness in the Arctic region. Iceland is analyzing how local people, scientists and disaster managers respond to the emergence of a new type of climate change-related hazard in Iceland where the findings will guide the development of more effective disaster management practices. The EU-funded ARCSAR network will address how the Arctic and North-Atlantic region is preparing to cope with security and safety threats that may result from increased commercial activity in the region including traffic through northern passages, cruise traffic, and offshore oil and gas activity.

THEME 4: STRENGTHEN

PREPARING THE NEXT GENERATION THROUGH CAPACITY BUILDING, EDUCATION, NETWORKING; AND RESILIENCE

The desired actions for this step are to recognize the urgent need and identify gaps in capacity building, education and networking, both in Arctic and global communities, and provide pathways of support.

The problems triggered by warming in the Arctic are long-lasting and will impact culture and society for generations. It is the responsibility of the current generation to pass on the knowledge needed to meet the challenges of the changing Arctic and to establish the network and infrastructure required for supporting the work of future generations.

The ASM3 process encouraged efforts to promote capacity building, education, and networking across the Arctic to build resilience and foster a diverse global research community, which includes Indigenous Peoples, early career researchers, minorities, and women. It is critical and beneficial to the wider research community to build and support capacity in education and skills for Arctic residents and the international community. It is also critical to recognize the importance for Indigenous Peoples and local communities to practice their knowledge systems and apply them to existing and future research and monitoring programs. It is important to ensure local partnering of research projects with institutions, as well as to make relevant results and new knowledge available and easily accessible for Arctic residents, businesses, and decision-makers in order to resolve societal challenges and foster long-term local and regional sustainable development.

Empowering Arctic residents is important for fostering a stable observation system that includes community-driven observation.

COLLABORATION, COORDINATION, SCIENCE CAPACITY AND NETWORKING

Since the ASM2, a significant amount of work has been done to increase collaboration, coordination and science capacity both in the Arctic and with non-Arctic countries.

- EU-funded INTERACTIII - International Network for Terrestrial Research and Monitoring in the Arctic continues to uniquely unite research stations in a Station Managers' Forum ensuring inter-comparability of information and excellent science support and in its next phase to stimulate new collaborations and improve information flow while creating new state-of-the-art educational resources to encourage young scientists.

- EU-PolarNet, funded by the EU, is the world's largest consortium of expertise and infrastructure for polar research and in the past five years has developed and delivered a strategic framework and mechanisms to prioritize science, advise the European Commission on polar issues, optimize the use of polar infrastructure, and broker new partnerships that will lead to the co-design of a polar research program that will deliver tangible benefits for society.

- Forum of Arctic Research Operators (FARO) is an organization for countries interested in sharing information and promoting dialogue on logistics and operational support for scientific research in the Arctic with recent topics of interest being risk management, carbon footprints, logistics sharing.

- The Northern Dimension Institute, a collaboration between the EU, Russia, Norway and Iceland, has created a think tank for scientific and educational collaboration of experts and researchers in the field of transport and logistics, environment, health and social welfare, and culture.

- Since ASM2, Spain has developed a network of the responsible staff from different ministerial departments and research institutions to ensure that Arctic activity is considered in Spain's political agendas creating the National Council for Arctic Affairs and aims to establish more formal Arctic scientific relationships with other countries. They are moving forward on Arctic activities including an Inter-ministerial Arctic working group, a Spanish Arctic Observatory, increased participation in international observing programs and international projects as a whole, and a Spanish National Policy on Polar Data.

- In partnership with Inuit, Canadian scientists are working together with the international science community (e.g., Germany, UK and Norway) to better understand the last permanently ice-covered region where old multiyear ice persists in the Arctic Ocean through their Last Ice program.

- Canada, Denmark, Norway, Russia and the USA are working together on scientific issues related to defining the continental shelf in the Arctic Ocean, including by participating at an annual workshop involving these five Arctic States.

- By hosting the European Polar Board (EPB) Secretariat and active partnership in EU-PolarNet, the Netherlands aims to strengthen and integrate Arctic observations and data-sharing.

- Portugal is creating and implementing a national research and innovation agenda for polar sciences and technologies, aiming to identify challenges and opportunities in the national scientific and technological system and to respond to the problems or needs of the different sectors of society.

- The US Fulbright Arctic Initiative, now with its third cohort, brings together a network of scholars, professionals and applied researchers from the USA, Canada, Denmark, Finland, Iceland, Norway, Russia and Sweden for a series of meetings and a Fulbright exchange experience.

- The Pan-Nordic Technology Transfer Collaboration is a network among knowledge and technology transfer offices in the Nordic countries that aims to synergize scientific solutions and technology to respond to climate change and marine environment in the Arctic.

- A US-based research coordination network Arctic-FROST fostered the creation of an international interdisciplinary collaborative network bringing together environmental and social scientists, local educators and community members from all circumpolar countries.

CONFERENCES AND MEETINGS

Interactions at conferences and meetings continue to play an important role in shaping international Arctic research. Although many meetings were postponed due to the Covid-19 pandemic, many moved online allowing for wider participation and engagement. Some of regular Arctic meetings have provided updates to the ASM3 process:

- Iceland will host the 15th Polar Law Symposium in 2022 to provide an overview of Polar Law activities. Findings will be published in the *Yearbook of Polar Law*.

- In October 2022, Switzerland will host the 3rd Open Science Conference of the International Partnerships for Ice Core Sciences (IPICS).

- PEI will bring its 5th international conference to Iceland, with themes focused on polar education relevant to Knowledge for a Sustainable Arctic, offering a direct opportunity for 50+ participants to develop deeper understandings of the region, its peoples and scientific research.

- The Arctic Science Summit Week (ASSW) was initiated by IASC in 1999 to provide opportunities for coordination, cooperation and collaboration between the various scientific organizations involved in Arctic research and to economize on travel and time.

- The Arctic Observing Summit (AOS) is a biennial summit providing community-driven, science-based guidance for the design, implementation, coordination, and operation of a sustained long-term international network of Arctic observing systems and provides a platform to address Arctic observing needs.

- International Congress of Arctic Social Sciences (ICASS) organized by IASSA provides an opportunity for Arctic researchers from around the world to share research results, develop collaborations and, increasingly, interact with Arctic community members, including Indigenous peoples.

- The UArctic Congress is held biannually in collaboration with Arctic Council, and it gathers together institute leaders, Indigenous representatives, academics, scientists and students around Circumpolar North and beyond with the next being held in May 2021 in Reykjavik, Iceland.

- International Maritime Organization (IMO) partners will host "Cryosphere 2021: International Symposium on Ice, Snow and Water in a Warming World" to discuss ongoing changes in all components of the Earth´s cryosphere, which are affecting the developed world, developing nations and Indigenous Peoples.

- The 4th International ICES/PICES/IOC/FAO Symposium entitled "The effects of climate change on the world's oceans" will examine the consequences of climate change in the world oceans and address gaps and insufficiencies in the base of evidence. This research will form the basis for proposals for priorities for future research, which will produce climate-ready policies that can help society adapt and protect the marine environment and living resources going forward.

EDUCATION, TRAINING, AND OUTREACH

Since the International Polar Year 2007-2008, there has been a growing recognition within the international polar community that education and outreach need to be an integral part of science projects. International organizations such as UArctic, APECS, and PEI have on-going activities in this area helping to provide international opportunities early in student education. Many countries and other organizations have activities in this important arena and have contributed them to the ASM3 process.

- **Short Courses, Field Schools and Workshops:** Russia and Norway have developed an International Autumn School on Marine Biotechnology and Biochemistry which aims at scientific, educational and socio-cultural exchange. Russia also hosts the Arctic Floating University which since 2012 has hosted more than 600 people, including 260 students, from 16 countries in 12 expeditions of the annual international scientific and educational marine expedition which provides research and training for students and postgraduates to gain knowledge and skills under real-life conditions of the Northern seas. Iceland hosts an annual Arctic microbial ecology field trip and research/discovery-based lab course that is designed and set up with the goal in mind that the students' results can be followed up on at the partner institutes and may lead to publishable discoveries. The MOSAiC School 2019 was a 6-week course to train and educate the next generation of Arctic system science experts, provide support to the MOSAiC teams; and to communicate the newly gained knowledge experience through MOSAiC Ambassadors' project. The IMO hosted Arctic Earth System Modelling Workshop was the first step in initiating an exchange and dialogue that explored and ensured commitment to, and developed recommendations for interoperable observation, prediction and management systems in Polar regions. Japan also provides a study course in the Arctic region at Japan-Russia Joint Research Laboratories established in Sapporo and Yakutsk for not only personnel in research institutions but also in government and industry.

- **International Higher Education and Early Career Opportunities:** The East Russia-Japan Expert Education Program continues for another 5 years and has recently created a Joint Master's Program on sustainable development of the Arctic. The Russian-Norwegian educational and scientific project ASTRA aims to establish long-term relationships between scientific groups to jointly study space weather at high latitudes, as well as to train a new generation of qualified young researchers. Future Arctic is a large doctoral school where 15 Icelandic and European doctoral students are trained in using the newest research techniques in environmental science, using a unique research infrastructure in Iceland to address question related to effects of warming on ecosystems. The IASC Fellowship Program engages early career scientists in the work of the IASC Working Groups, as well as help early career scientists get more involved in the process of taking research from results through to science policy recommendations.

- **National Higher Education:** Italy has recently established a PhD program in Polar Sciences to prepare students with in-depth scientific competences and original and innovative research activities for becoming experts on topics related to recent and past environmental and climate changes of the polar regions and high-altitude sites and a new Master Degree in Sustainable Development, Geopolitics of Resources and Arctic Studies to develop skills and expertise in the areas of the Green Economy and the geopolitics of resources and energy, highlighting the eco-sustainability

and a responsible use of the resources in the Arctic. The UK's Interdisciplinary Understanding for a Changing Arctic project addresses uncertainty in our understanding of the Arctic region by integrating doctoral training in specific disciplines with an educational program that fosters dialogue and learning across the natural sciences, social sciences, and the humanities.

- **Outreach:** Japan holds open seminars for personnel in industries and governments to provide the latest information of Arctic region in natural and social sciences and to promote new opportunities to get involved in solving problems in Arctic region. Iceland is working with various stakeholder groups to improve the general knowledge of natural science related phenomena amongst students as well as promoting the importance of natural science to Icelandic society; to build a bridge between science and community. The UNEP Rapid Response Assessment of Coastal and Offshore Permafrost has the goal to raise awareness about the importance of coastal permafrost environments that are undergoing profound change in response to climate warming. AMAP is preparing a report on "Climate Issues of Concern" for delivery in 2021, which will address recent developments in major climate indicators, extreme events and thresholds in the Arctic, the future of the Arctic climate, Arctic/Mid-latitude weather connectivity, climate change impacts on Arctic ecosystems and ecosystem feedbacks and trends, and effects and societal implications of Arctic climate change. The Barents Sea Leadership Training on Marine Litter project is aimed at raising awareness of representatives of Russian and Norwegian executive authorities, heads of enterprises and public organizations about the problem of Barents Sea pollution. ARCTIC FESTIVALS are annual events of Czech and Arctic science and culture that aim to deepen the already established contacts between Czech and Arctic scientists and artists and starting cooperation between new partners. As the sole Southeast Asian observer state in the Arctic Council, Singapore has been actively generating awareness of Arctic issues in our region by holding events that inform and engage members of the public, students, academics, researchers, government officials and businessmen.

RESOURCES

Several groups have been working together to create resources that will help to strengthen capacity in Arctic research.

- PEI, IASC, APECS and the Scientific Committee on Antarctic Research (SCAR) are working together to update the "Polar Science and Global Climate: An International Resource for Education and Outreach - The Polar Resource Book" which was created during the International Polar Year 2007-2008. The content will be updated and the new version will be digitized and made freely available through the PEI website.

- IASC has created the "State of Arctic Science 2020" which is a cohesive synthesis of international Arctic research activities and priorities, as gathered from the Arctic research community itself for use by Arctic science agencies, Arctic science managers, and Arctic science users and it is meant to be updated periodically.

- The EU-funded Polish-led Edu-Arctic was an innovative educational program attracting young people to natural sciences and polar research that has recently finished. It created innovative online tools for interactive open-access available for everyone to link Arctic research and school education in Europe.

- Through its One Stop Shop for Arctic Knowledge, UArctic will further develop a stable infrastructure for access to Arctic knowledge primarily representing the Arctic education and scientific activities of the higher education sector in and for the North.

- APECS, the INTERACT Station Manager`s Forum and the University Centre in Svalbard (UNIS) have collaborated on two publications on Arctic fieldwork. The INTERACT Fieldwork Planning Handbook will facilitate safe fieldwork and maximize the results of research and monitoring activities in the Arctic and other cold regions of the Northern Hemisphere. Whereas, the INTERACT Practical Field Guide contains information on best practices and specific safety tips for fieldwork in the Arctic.

FUNDING

National programs are working on various levels to strengthen capacity and Arctic research within their countries and where possible to help facilitate exchanges with other countries.

- The UK has developed funded exchange programs with Canada and Russia to foster and deepen practical Arctic science collaborations between researchers, universities, and research institutions.

- Germany and the UK have developed the Changing Arctic Ocean program, which supports 12 bilateral research projects.

- The USA's Navigating the New Arctic is a research funding program focused on the rapidly changing Arctic, its local and global effects, inclusive approaches to resilience and adaptation, and informing national security, economic development, and societal well-being. In 2019, it funded 21 new research projects and has since established a community office to coordinate these projects and facilitate connections with Arctic communities.

- The Dutch National Research Agenda added Polar Tourism to its lists of priorities for 2020 and plans to fund 4.5 million euro on research dealing with the topic.

- Japan's J-ARC Net promotes advanced and interdisciplinary researches conducive to understanding environmental-human interactions and creation of new academic fields regarding sustainable utilization and preservation of Arctic region.

- The Portuguese Polar Program (PROPOLAR) supports national polar research by funding annual calls for projects to be developed in the Polar Regions, covering key themes addressed in Arctic Ministerial and reinforcing international collaboration and science communication and dissemination.

- The Italian Arctic Research Program is developing actions included in a three-year program with a second call being released in autumn 2020, projects funded with the first call should have started their activities and the program supports the new PhD course in Polar Science opened in 2019 at Venice University.

INDIGENOUS AND LOCAL CAPACITY

There is a growing number of projects focusing on building capacity in the Arctic, both for the region as a whole and for strengthening the resources available for Indigenous Peoples. Several of these are mentioned in the Respond Theme and a few are additionally highlighted below.

- **Indigenous Capacity:** UArctic is working on Indigenization of its education activities and sharing the best practices and ethical guidelines among its members doing research and education. The Arctic Indigenous Virtual Arts Network (AIVAN) is an informal platform that unites Indigenous artists throughout the Arctic and beyond to share Indigenous wisdom through creative arts, exchange knowledge, traditional crafts techniques, and facilitate discussions on the place of Indigenous arts in the 21st century.

- Canada has established an Indigenous Community-Based Climate Monitoring Program to support Indigenous Peoples across Canada in community-based monitoring of climate indicators using Indigenous Knowledge and science to inform community adaption actions and to help address climate data gaps. Canada also published a strategic plan by the federal research granting agencies to co-develop with Indigenous Peoples an interdisciplinary research and research training model that contributes to reconciliation. The Canadian Rangers Ocean Watch (CROW) is beginning to build on relationships with Ranger groups in several communities to extend wintertime monitoring of oceanographic conditions to spring, summer and fall, in order to monitor year-round variation near northern communities. Polar Knowledge Canada is working with Indigenous rightsholders to co-develop a plan for the implementation of Canada's Science and Technology Framework 2020-2025.

- GEO developed a series of virtual hackathons in various Indigenous and under-represented communities with the intent of co-designing locally relevant earth observation-based challenges that are culturally appropriate to Indigenous beliefs and conceptions about diseases.

- **Local Capacity:** SDWG's Arctic Remote Energy Networks Academy (ARENA II) seeks to provide participants with the necessary knowledge-base, skills, and collaboration networks to develop clean energy projects in their own communities or regions. All 8 Arctic countries participate in the Arctic Coast Guard Forum (ACGF), an independent, informal, operationally-driven organization, not bound by treaty, to foster safe, secure, and environmentally responsible maritime activity in the Arctic that holds training exercises every fall. Norway has established the Competence Center for the Building and Construction Industry in the Arctic with the goal to help ensure that the necessary competence and capacity in education and research within the building and construction area are available in the Arctic. Norway and Russia are working together to identify bottlenecks in railway operation in the Kolarctic region which will increase the stability of railroad functioning in Arctic conditions.

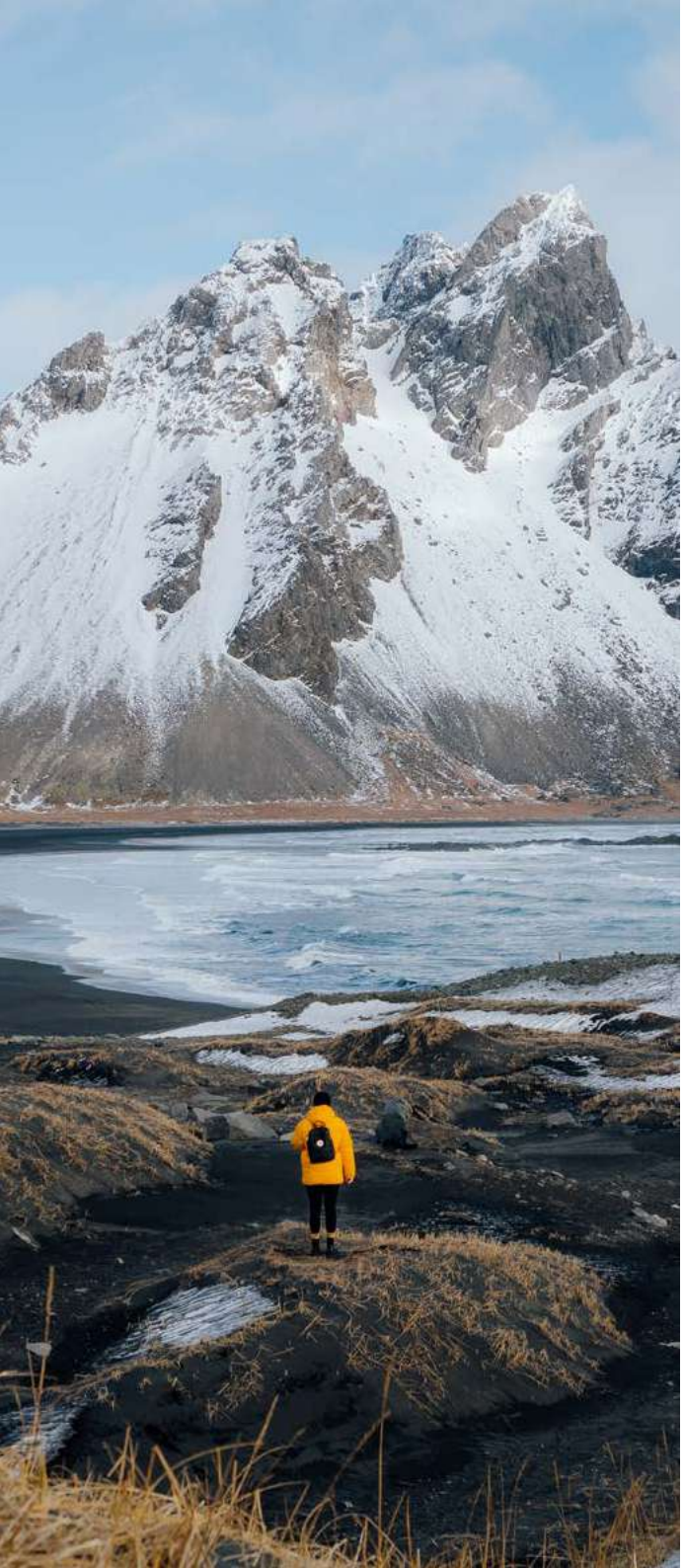
INFRASTRUCTURE AND DATA

- **Centers/Hubs:** Greenland and Denmark have established the International Arctic Hub to create a unique and unifying platform in Greenland for Danish, Greenlandic and international polar researchers as well as Arctic stakeholders. In addition, the National Centre for Climate Research develops existing research and creates new knowledge about climate change and its consequences for society and nature in the Danish commonwealth and covers research on the cryosphere, ocean and atmosphere, using models, satellite and in-situ observations. Denmark also hosts the Arctic Research Center (ARC) which focus on the melting cryosphere and its feedback on the climate system and effects on ecosystems and societies. Russia has added the Polar Geophysical Institute with its specialty in high-latitude physics to the Kola Arctic Geophysical Infrastructure Network for effective use and accessibility to researchers from other regions of Russia and counterparts from other countries. Russia has also created a basic research station for study and monitoring of model freshwater ecosystems in the Eastern sector of the Russian Federation Arctic zone.

- **Stations:** The SDWG is working on Arctic Hydrogen Energy Applications and Demonstrations (AHEAD) project, which will establish an international Arctic research station that only relies on renewable energy sources and provides a platform for international research collaboration as well as economic development for the local community. Polar Knowledge Canada is working with Canadian and international researchers, utilizing science and Indigenous Knowledge, to establish the Environmental Research Area of the Canadian High Arctic Research Station as an Arctic Flagship Monitoring Observatory Site, and as a hub for interdisciplinary research in the Arctic.

- **Icebreakers:** The EU-funded Arctic Research Icebreaker Consortium (ARICE) project aims to provide European researchers with better Arctic research icebreaker capacities by developing strategies to ensure the optimal use of the existing polar research vessels at a European and international level. The UK, Norway, and Italy have all acquired new icebreakers and Spain, Russia, and Japan have plans to do so in the near future.

- **Data Sharing and Products:** The EU contributed that ESA has established the Polar Thematic Exploitation Platform, which provides the necessary collaborative computing environment for collocating data, enhanced processing capabilities, and information and communications technology infrastructure, providing a complete cloud-based work-environment. Norway has established the Global Open Access Portal for Research Data and Publications on the Arctic and Antarctic (OPEN POLAR), which provides access to the latest research publications and the underlying data for research, education and decision making all in one portal. As part of Iceland's chairmanship of the Arctic Council, Iceland has proposed that a working group be created to organize research institutes, universities and the Arctic spatial data infrastructure to study surface elevation changes of glaciers in the Arctic based on Arctic digital elevation models. The Danish Meteorological Institute (DMI) will provide open access to its weather, ocean and climate data for Denmark and Greenland over the coming years, making data easily accessible to users. The EU-funded CAPARDUS will explore common processes and standards in a number of topics where data sharing is important in the Arctic, with the objective of designing a Common Practice System to strengthen knowledge about the region's social-environmental system. Since the ASM2, the Chinese Earth Big Data Science Project progressed to collect remote sensing data for monitoring environmental changes in the Arctic, Antarctic and Qinghai-Tibet Plateau and has established a data distribution system for sharing the data. The ICC and partners have created the Atlas of Community-Based Monitoring and Indigenous Knowledge in a Changing Arctic to inventory and map community-based monitoring and Indigenous Knowledge initiatives across the circumpolar North.



ASM3 IN NUMBERS

In total, 434 projects were submitted to support the goals of ASM3; 177 updates and 257 new projects. 8 were submitted by Indigenous organizations and 37 from other organizations with an interest in Arctic research and education, with the remaining 389 coming from countries (including the EU) (See Tables 1 and 2). Of the projects submitted by countries/EU, 82% were international with at least one other country collaborating on the project; with 43% having between 4 and 12 collaborating countries and 3 projects with 28 or more collaborating countries.

45 projects were created specifically in response to the ASM process, primarily for the Observe and Understand themes.

In this section, infographics show the breakdown of submissions per country/organization, the number of times countries were listed as collaborators, as well as the keywords and locations for research in the Arctic.

Regarding the location of projects, almost half were considered to be covering the Arctic in general (44%), Svalbard (27%), Russian Arctic (19%), and Greenland (18%) were also quite important locations for Arctic research. Conversely, few projects covered the Central Arctic Ocean (8%), the North Atlantic (5%), and North Pacific Ocean (4%).

Indigenous Knowledge was an important part of over a quarter of the projects submitted and almost as many were indicated as community-driven. Outreach was a component of almost half of the projects and education and capacity building were part of over a third of all projects.

Climate was important for most projects (54%), along with observations (45%), collaboration (45%), monitoring (41%). Ecosystems, biology, ecology and biodiversity were involved in one-third of projects submitted. Data management (30%) and outreach (26%) were also important parts of the projects submitted. Social science projects (31%) were not as prevalent as natural science projects (80%), with economic development (13%), culture (12%), food security (11%), and tourism (9%) being important topics.

Dive deeper into the projects on the ASM3 layer supported by the Japanese Arctic Data Archive System.

Figure 1. Keywords describing initiatives contributing to the ASM3 Themes

Country	Project Updates	New Projects	Total Submitted
Canada	10	4	14
China	13	1	14
Czech Republic	0	13	13
Denmark	7	12	19
Finland	8	2	10
France	3	1	4
Germany	5	4	9
Iceland	0	19	19
India	5	0	5
Italy	14	10	24
Japan	12	19	31
The Netherlands	2	2	4
Norway	18	28	46
Poland	3	0	3
Portugal	3	1	4
Republic of Korea	7	0	7
Russia	0	65	65
Singapore	7	2	9
Spain	5	7	12
Switzerland	0	1	1
Thailand	-	1	1
UK	4	10	14
USA	18	18	36
EU	17	8	25

Table 1. Projects Submitted per ASM3 Participating Country

Indigenous Organizations	Project Updates Submitted	New Projects Submitted	Total Submitted
ICC	4	0	4
Saami Council	4	0	4

International Organizations	Project Updates Submitted	New Projects Submitted	Total Submitted
AMAP	-	2	2
APECS	0	2	2
CAFF	-	4	4
GEO	0	1	1
IASC	1	5	6
IASSA	2	3	5
ICES/PICES	2	0	2
INTERACT	1	0	1
PEI	-	3	3
SAON	0	1	1
SDWG	0	6	6
UArctic	1	0	1
UNEP	1	1	2
WMO	0	1	1
Total Submitted	177	257	434

Table 2. Projects Submitted per ASM3 Participating Organizations.

PROJECT COLLABORATIONS **BY COUNTRY**

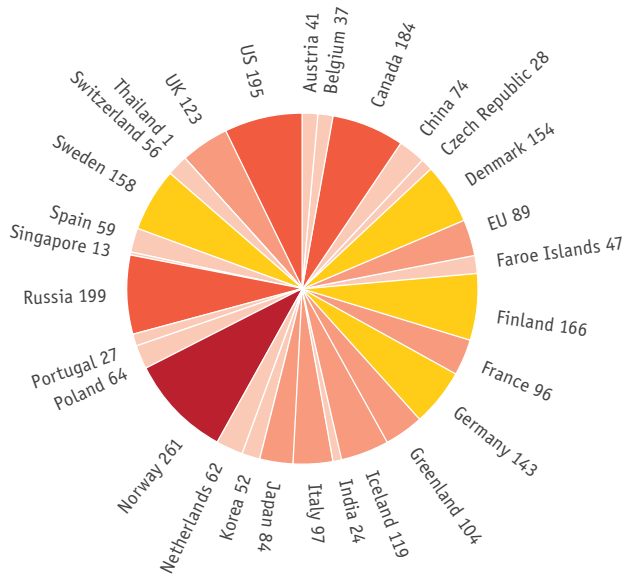


Figure 2. Number of Times a Country was Listed as a Collaborator on Projects Submitted by Countries/EU to ASM3

Norway was listed as a collaborator in 60% of all projects submitted, followed by Russia (46%), USA (45%), Canada (42%), Finland (38%), Sweden (36%), Denmark (35%), and Germany (33%).

PROJECTS SUBMITTED TO THE **ASM3 THEMES**

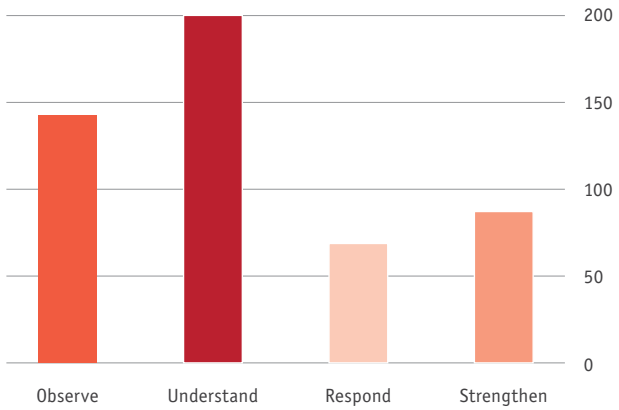


Figure 3. Number of SM3 Projects Submitted by all Participants to Each Theme

The Understand theme received the most projects (47%), followed by Observe (33%), Strengthen (20%) and Respond (16%) (some projects were submitted to more than one theme).

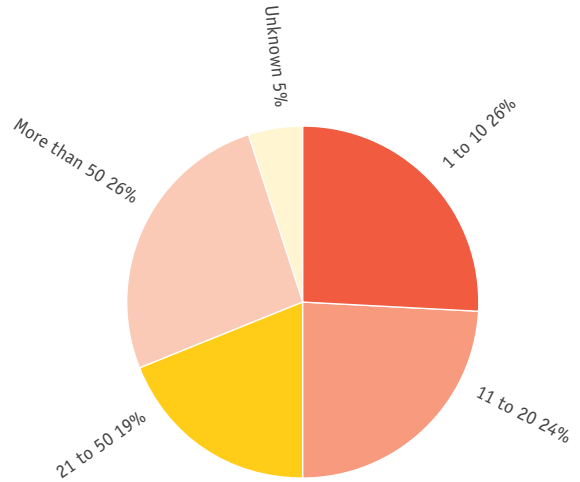


Figure 4. Number of Personnel involved in Projects Submitted by all Participants to ASM3

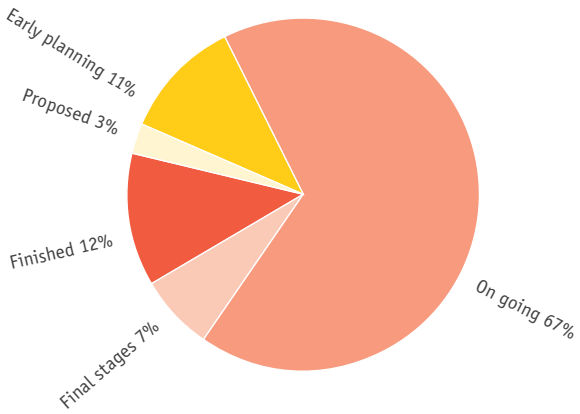


Figure 5. Stage of Projects Submitted to ASM3

02

JOINT
STATEMENT

JOINT STATEMENT

THIRD ARCTIC SCIENCE MINISTERIAL

Joint Statement of Ministers

On the occasion of the Third Arctic Science Ministerial

09 May 2021, Tokyo, Japan

We, the Ministers representing the eight Arctic States (Canada, the Kingdom of Denmark – here represented by Ministers of Denmark, the Faroe Islands and Greenland – Finland, Iceland, Norway, Russia, Sweden, and the United States), seventeen further States (Austria, Belgium, China, Czech Republic, France, Germany, India, Italy, Japan, Republic of Korea, the Netherlands, Poland, Portugal, Singapore, Spain, Switzerland, and the United Kingdom) and the representative of the European Union, as well as Arctic Indigenous leaders from six Arctic Indigenous Peoples Organizations (Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International, Inuit Circumpolar Council, Russian Association of Indigenous Peoples of the North, and Saami Council), have gathered to further enhance international cooperation in science, research and knowledge production to advance understanding of the Arctic region, and to support the role of science in policy and decision-making in the Arctic.

We reiterate our appreciation to the United States for organizing the first Arctic Science Ministerial in 2016 in Washington D.C., and for recognizing the important role that an international gathering of Ministers including collaboration from both Arctic and non-Arctic States and Arctic Indigenous Peoples and civil society can have in focusing global attention and highlighting the importance of international Arctic science and research cooperation.

We furthermore wish to express our appreciation to the governments of Germany and Finland as well as the European Union for organizing the second Arctic Science Ministerial in 2018 in Berlin, and for strengthening collaboration with a gathering of science Ministers from around the world — joined by Arctic Indigenous leaders — demonstrating the global importance of Arctic science cooperation and the important partnership role Indigenous Peoples must play in science and research. The second Arctic Science Ministerial further recognized the vital and valuable role of local communities in Arctic science and research.

We come together for the third Arctic Science Ministerial in the spirit of cooperation and acknowledge that science and science-based policy measures are increasingly urgent in the Arctic due to the current speed of climate change and that they are relevant for Arctic residents, including Arctic Indigenous Peoples, and the global community.

We recognize the enduring contribution to international Arctic science cooperation facilitated by the Arctic Council, which celebrates its 25th anniversary this year. The Arctic Council remains the leading forum for cooperation in the Arctic region, and reports and assessments by its Working Groups, have been instrumental in bringing Arctic issues to a global arena.

We recognize the value of an inclusive and diverse global Arctic research community that seeks to include all genders, ages, ethnic and cultural backgrounds, and in particular expertise from Arctic Indigenous Peoples, as well as the next generation of scientists and decision makers, and people from local communities.

We recognize the diverse knowledge systems continually developed and utilized by Arctic Indigenous Peoples, as well as the knowledge systems continually developed and utilized by local communities. We also recognize the need to meaningfully engage and partner with Indigenous Peoples to include the utilization of Indigenous Knowledge within international forums and agreements. We further acknowledge that Traditional Knowledge including Indigenous Knowledge and scientific research are both valid systems of knowledge that should complement each other within the context of collaborative and

co-produced research to ensure that we have the strongest evidence-based information to inform holistic decisions and policies. Respect and support for Indigenous partnership and co-production of knowledge in research programs and projects are imperative for enhancing the efficacy, impact, and usefulness of research for Arctic Indigenous Peoples, governments, and others. This may require governments and research institutions to partner with Indigenous Peoples to implement engagement processes that respect the status and role they play in decision-making in relation to research involving their people, communities, and homelands.

Climate change stemming from mostly outside the Arctic is among the greatest challenges confronting the Arctic. Because the Arctic plays a key role in the global climate system, we recognize the importance of data to inform global response to climate change. We welcome the recent achievements by the international research community that are relevant to the Arctic, including: the Intergovernmental Panel on Climate Change (IPCC) Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Global Assessment Report on Biodiversity and Ecosystem Services. We also welcome the United Nations Decade on Ocean Science for Sustainable Development (2021-2030) and the global Seabed 2030 initiative. Alongside these collaborative activities, the Arctic Science Ministerial science process will help support the implementation of the 2030 Agenda for Sustainable Development, the Paris Agreement, and the post-2020 Global Biodiversity Framework under the Convention on Biological Diversity, and the reports on pollution, chemicals and climate change by the Arctic Council Working Groups.

We welcome the entering into force, on 23 May 2018, as well as the continued implementation of the Agreement on Enhancing Scientific Cooperation in the Arctic, as negotiated under the auspices of the Arctic Council, and its relevance for improving international scientific cooperation.

We welcome the ongoing process to ratify the legally binding Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean, which upon entry into force will facilitate cooperation in scientific activities and establish a Joint Program of Scientific Research and Monitoring of the Central Arctic Ocean. We acknowledge the work that has been done to prepare for its implementation.[1]

Knowledge for a Sustainable Arctic is the main theme for the third Arctic Science Ministerial. Under this theme, four sub-themes identify the most urgent actions that can be met through international cooperation:

1. **Observe: implementing observing networks; data-sharing**
2. **Understand: enhancing understanding and prediction capability for Arctic environmental and social systems, for the global impact of these changes**
3. **Respond: operationalizing sustainable development, evaluating vulnerability and resilience, and applying Knowledge**
4. **Strengthen: preparing the next generation through capacity building, education, networking; and resilience**

Further information about the ASM3 Science Process and its outcomes can be found in the accompanying Science Report.

1

OBSERVE: IMPLEMENTING OBSERVING NETWORKS; DATA-SHARING

Reliable data about changes in the Arctic are more limited than for most other parts of the planet. Vast gaps of *in situ* data in the Arctic remain, and there are limited long-term and space-based observations. In addition, foundational geospatial mapping is a fundamental input to a better understanding of Arctic ocean and coastal ecosystems, but much of the Arctic is not surveyed or is inadequately mapped. As observations of a wide range of variables (such as wildlife, atmosphere, water, land, ice, snow, coastlines, oceans, as well as of social, cultural, and economic impacts) are required from a variety of observation platforms (such as marine, surface, upper air, and space-based), sustaining long-term *in situ* observation systems in the Arctic is demanding and requires considerable human and financial resources. International commitment is required to sustain critical pan-Arctic observation infrastructure, ocean and coastal mapping, a high level of coordinated campaign observations, and a focus on data management and sharing. For some observation systems, empowering Indigenous Peoples and other Arctic residents to engage in research and monitoring programs is important for fostering a localized observing system that includes community-driven observation. The urgency of these actions has become even clearer during the COVID-19 pandemic, apart from satellites and surface networks, which has amplified some of the existing weaknesses in sustaining long-term observational research.

Proposed Actions: We therefore intend to cooperate through the following actions: Explore opportunities for mapping as well as supporting the implementation of an enhanced observing system for sharing data and results and deepening collaboration among scientists, technical experts, Indigenous Peoples, and other Arctic residents. We recognize the need to support and integrate Indigenous and community-led observations and foster the co-production of knowledge based on their free, prior and informed consent, as appropriate. We recognize the role the Sustaining Arctic Observing Networks (SAON) initiative has already played and acknowledge that supporting implementation mechanisms identified by SAON will continue to generate long-term benefits for strengthening Arctic observation and data systems. We recognize the need for research partnerships to be built on equal respect, with mutually beneficial and transparent protocols for data governance and intellectual property rights built on ethical guidelines as outlined in the International Arctic Science Committee (IASC) Data Statement.

Long-term:

- Encourage the strengthening and cooperation of existing long-term observation programs essential to tracking atmosphere, cryosphere, ocean, coasts, terrestrial, social, and ecosystem change and responding to a warming climate, and encourage the expansion into areas and subdisciplines where monitoring is absent to sparse, including through a co-production process in remote communities.
- Promote planning for international cooperation in observational efforts to monitor the accelerating changes in the Arctic environment through national and international domain awareness platforms (satellites, stations, community-led observations, vessels, buoys, and other marine technology) through or in partnership with SAON.
- Support ongoing efforts from the IASC/SAON-led Arctic Data Committee and others to harmonize data collection and sharing, particularly those working to make Arctic data and metadata more consistent, discoverable, interoperable, ethically open and accessible, and respect the rights of Indigenous Peoples, as applicable, especially with data pertaining to Indigenous Peoples.

Near-term:

- Strengthen the work of SAON:
  - Encourage finalizing the Roadmap for Arctic Observing and Data Systems (ROADS) through the coordination and cooperation between national and international programs, small and large projects, and infrastructures, and prioritize implementation.
  - Promote the expansion of the ROADS efforts to also reflect priorities of Indigenous Peoples.
  - Encourage SAON to update a gap analysis of where Arctic observations are missing and recommend strategies to address priority gaps.

- Foster the development and Arctic deployment of new technologies, such as autonomous and interoperable tools for observations, share advances in technology innovation across the Arctic community of interest.
- Encourage the inventory of Arctic mapping gaps and develop operational coordination plans to acquire and share new data to support Arctic science and community resilience.

2

UNDERSTAND: ENHANCING UNDERSTANDING AND PREDICTION CAPABILITY FOR ARCTIC ENVIRONMENTAL AND SOCIAL SYSTEMS, FOR THE GLOBAL IMPACT OF THESE CHANGES

Changes in the Arctic are not only affecting the people who call the Arctic home and are inextricably linked to the Arctic environment and its resources, but actions outside the region continue to impact the Arctic environment and the changes occurring have cascading effects on the rest of the world. The effect of the loss of sea ice is speeding up coastal erosion and marine ecosystem change, which can have broader socio-economic impacts in the Arctic. Globally, changes in the Arctic significantly contribute to sea level rise, trigger extreme events and further accelerate global warming among other things. To understand the structure and dynamics of these complex systems we need focused and cross-cutting research, including Indigenous-led research, as well as long-term and multi-scale observations that fully represent the Arctic. Past climate archives, reliable predictions, and enhanced modelling capabilities for the Arctic are essential for developing effective mitigation and adaptation strategies. To progress from *Observing* to *Understanding* we must understand not only how the patterns are changing, but also how the biological and ecological mechanisms that determine the patterns are changing. We intend to strengthen international collaboration for Arctic science and research to enhance the assessment of ongoing change and to improve prediction for future change.

Proposed Actions: We therefore intend to cooperate through the following actions: Recognize the complexity of the system connecting all environmental and socio-economic components, and encourage further interdisciplinary, systemic approaches and co-production of knowledge. Advance the understanding of processes and mechanisms that underly the changes in patterns and their interactions.

Long-term:

- Encourage societally relevant research and co-production of knowledge on the impacts of thawing permafrost, rising sea levels, melting glaciers, shrinking snow coverage, coastal zone processes, ocean acidification, disappearing sea ice, increase of invasive species, altering biological and ecological systems, as well as effects of pollutants to inform response plans including mitigation of and adaptation to climate change.
- Foster efforts to improve modelling and prediction of Arctic environmental, societal, and economic change, including the role of the Arctic on global systems.

Near-term:

- Building on the success of international activities such as the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) Expedition and the Year of Polar Prediction (YOPP), promote the data analysis and synthesis of these initiatives and encourage similar efforts that require multinational cooperation to succeed.
- Encourage research efforts and co-production of knowledge that informs the prediction and mitigation of risks and hazards associated with Arctic change and that address the impacts of Arctic change such as pollution, infectious diseases, food security through activities of fisheries, and biodiversity, particularly those that impact human health and well-being and ways and means to address those impacts.
- Prioritize projects that investigate linkages and interactions among various environmental components and those that enhance our understanding of complex Arctic socio-ecological systems, including the role of humans as drivers of change.

3

RESPOND: OPERATIONALIZING SUSTAINABLE DEVELOPMENT, EVALUATING VULNERABILITY AND RESILIENCE, AND APPLYING KNOWLEDGE

Warming at a rate two to three times greater than the global average, the Arctic is experiencing drastic changes in the natural environment. The changes are visible in many natural phenomena and ecosystems, e.g. wildland fires, permafrost thawing, sea ice retreat, and their impacts on cultures and societies are becoming clearer. Further amplified Arctic warming will continue at least until mid-century and will likely occur regardless of any prompt action taken to reduce greenhouse gas emissions. The rate and amount of warming will depend critically on our collective efforts today and in the coming years to reduce greenhouse gas emissions. It is, therefore, a matter of urgency to implement ambitious actions to mitigate climate change, adapt to its impacts, and support the sustainable future of the Arctic and its people. This approach must be informed by the best available science and knowledge.

Proposed Actions: We therefore intend to cooperate through the following actions: Support the work of existing international groups producing scientific response frameworks. Prioritize research that enhances our understanding of complex Arctic socio-ecological systems, including the impact of humans as drivers of change while needing to adapt to change. Further recognize the need to utilize and apply Traditional Knowledge including Indigenous Knowledge into decision making for effective response measures to climate change.

Long-term:

- Encourage continuation of the critical work of the Arctic Council working groups and expert groups, World Meteorological Organization (WMO), United Nations Environment Programme (UNEP), IPCC, IPBES, International Maritime Organization (IMO), International Oceanographic Commission (IOC), and other groups that are producing important scientific assessment and synthesis products that inform response plans.

Near-term:

- Encourage the development and expansion of innovation and technology projects that support mitigation and adaptation to climate change.
- Foster research to support mitigation of and adaptation to climate change, preparedness and response, plans for search and rescue, pollution remediation, wildfires and other societally relevant climate change risks and hazards in the Arctic.
- Identify specific mutual research priorities and opportunities for community-led research, in co-leadership with Arctic Indigenous Peoples.
- Promote research efforts that support food security, conservation measures, and sustainable development in the Arctic.

4

STRENGTHEN: PREPARING THE NEXT GENERATION THROUGH CAPACITY BUILDING, EDUCATION, NETWORKING; AND RESILIENCE

We encourage efforts to promote capacity building, education, and networking across the Arctic to build resilience and foster a diverse global research community, which includes Indigenous Peoples, early career researchers, minorities, and women. It is critical and beneficial to the wider research community to build and support capacity in education and skills for Arctic residents and the international community. It is also critical to recognize the importance for Indigenous Peoples to practice their knowledge systems and apply them to existing and future research and monitoring programs. It is also critical to recognize the importance for local communities to practice their knowledge systems and apply them to existing and future research and monitoring programs. It is important to ensure local partnering of research projects with institutions, as well as to make relevant results and new knowledge available and easily accessible for Arctic residents, businesses, and decision-makers in order to resolve societal challenges and foster long-term local and regional sustainable development.

Proposed Actions: We therefore intend to cooperate through the following actions: Recognize the urgent need and identify gaps in support, capacity building, education, and networking, both in the Arctic and the wider global Arctic research community, and provide pathways of assistance. Encourage participation and active engagement in existing international Arctic education frameworks such as the Association of Polar Early Career Scientists (APECS), Polar Educators International (PEI), and University of the Arctic (UArctic).

Long-term:

- Develop strategies to recruit and retain early career Arctic researchers, professionals, and Indigenous Peoples.
- Encourage the development and application of bilateral and multilateral agreements that decrease bureaucratic barriers and increase accessibility of research and education facilities, particularly between Arctic and non-Arctic countries.
- Promote efforts that support scientific and educational collaborations, especially among early career researchers, both Arctic and non-Arctic, as these are needed to maximize joint benefits and avoid duplicated efforts.

Near-term:

- Encourage multinational participation in field station and ship-based research such as the Forum of Arctic Research Operators (FARO), Pacific Arctic Group (PAG), Svalbard Integrated Arctic Earth Observing System (SIOS), International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT) and Arctic Research Icebreaker Consortium (ARICE).
- Encourage the development of an Arctic strategic communications initiative in collaboration with organizations such as APECS and PEI focused on the global public and promote community-led projects, as well as citizen science, leading to a better understanding of the causes and consequences of climate, social and environmental change.
- Encourage active participation in the UArctic, and further develop, and support, the existing structures for education cooperation and mobility.

Cross-Cutting Proposed Actions: In addition to the theme-based actions, there are several cross-cutting actions that are critical to supporting Arctic science and research:

- Promote the creation of Arctic high-speed communication infrastructures that are necessary for most science projects as well as capacity building, training, and education activities at the community level, including in remote communities.
- Encourage entities conducting or supporting Arctic research to maintain and enforce an ethically open data policy that includes accessible repositories or ties into other existing repositories.
- Support efforts that promote inclusivity and diversity in Arctic Research.
- Encourage efforts to translate scientific and educational materials into other languages, particularly to and from Indigenous languages and Russian.
- Endorse existing national committees that work to coordinate international Arctic research efforts and, in the absence of such entities, encourage their development by drawing on existing collaboration frameworks where possible.

ARCTIC SCIENCE FUNDERS FORUM

Through the initiatives of the second Arctic Science Ministerial, the Arctic Science Funders Forum was officially established on 30 March 2020. We support the establishment of this Forum and encourage funding agencies involved in the Arctic Science Ministerial to collaborate on further bilateral and multilateral research efforts set forth by this Ministerial.

CONCLUSION

Through the proposed cooperative actions set forth by this third Arctic Science Ministerial, we demonstrate the importance that our respective governments, the European Union, and Arctic Indigenous Peoples Organizations place on supporting international cooperation in science, research, and knowledge production towards achieving a sustainable Arctic.

Elisabeth Bertagnoli
Ambassador, Austrian Embassy in Tokyo
Austria

Frank Arnauts
Ambassador of Belgium for Norway and Iceland, Ministry of Foreign Affairs
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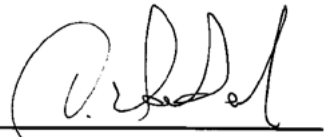

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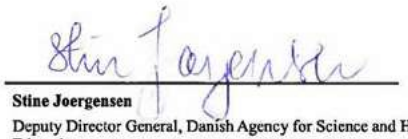

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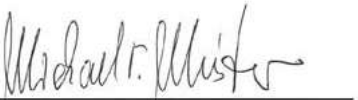

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Union Cabinet Minister, Ministry of Health and Family Welfare; Science and Technology; and Earth Sciences
India

Maria Cristina Messa

Minister, Ministry of Universities and Research

Italy

HAGIUDA Koichi

Minister, Ministry of Education, Culture, Sports, Science and Technology

Japan

Ingrid K. van Engelshoven

Demissionary Minister, Ministry of Education, Culture and Science

Netherlands

Henrik Asheim

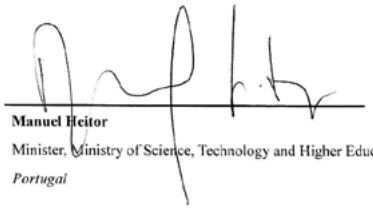
Minister, Ministry of Research and Higher Education

Norway

Paweł Milewski

Ambassador, Embassy of the Republic of Poland in Japan

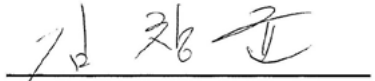
Poland



Manuel Heitor

Minister, Ministry of Science, Technology and Higher Education

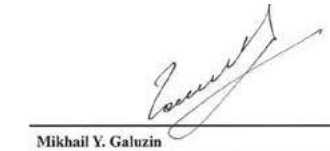
Portugal



KIM, Chang Kyun

Director General, Marine Policy Bureau, Ministry of Oceans and Fisheries

Republic of Korea



Mikhail Y. Galuzin

Ambassador Extraordinary and Plenipotentiary of the Russian Federation to Japan

Russian Federation

CHEE Hong Tat

Senior Minister of State for Foreign Affairs and Transport

Singapore

Rafael Rodrigo

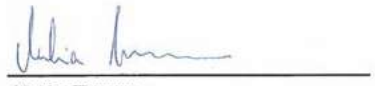
Secretary General of Research

Spain

Matilda Ernkrans

Minister for Higher Education and Research, Ministry of Education and Research

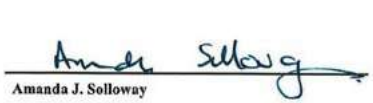
Sweden



Martina Hirayama

State Secretary for Education, Research and Innovation, State Secretariat for Education, Research and Innovation SERI

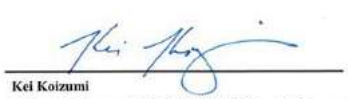
Switzerland



Amanda J. Solloway

UK Minister for Science, Research and Innovation, UK Government, Department for Business, Energy and Industrial Strategy

United Kingdom



Kei Koizumi

Acting Director and Chief of Staff, Office of Science and Technology Policy Executive Office of the President

United States of America

03

ARCTIC RESEARCH
OVERVIEWS

AUSTRIA

POINTS OF CONTACT

FEDERAL MINISTRY OF EDUCATION, SCIENCE AND RESEARCH (BMBWF)
CONTACT: DR. KAROLINA BEGUSCH-PFEFFERKORN;
AUSTRIAN POLAR RESEARCH INSTITUTE,
DIRECTOR: UNIV.-PROF. DR. WOLFGANG SCHÖNER.

ARCTIC RESEARCH POLICY AND GOALS

Austria's arctic research policy and goals are guided by the participation in EU programs and activities. For research, the Austrian Polar Research Institute (APRI), as the international representative of Austrian polar research, takes the role of a coordinating and promoting institution. The APRI is supported by many Austrian universities, the Austrian weather service ZAMG and research-based enterprises with a polar focus. It takes the role of international representative for Arctic Research Organizations, such as IASC (International Arctic Science Committee), European Polar Board (EPB) and the University of the Arctic (UArctic). Austria also has a strong background in Arctic remote sensing research participating in research activities of European Space Agency ESA.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

Austria has no funding program particularly focusing on polar regions. However, several funding institutions are open to arctic research proposals.

The Austrian Academy of Sciences (ÖAW), which runs specific calls for proposals e.g. to Earth System Sciences ESS open for topics of Arctic research.

The Austrian Science Fund (FWF), is the main funding organization for basic research in Austria and is open for all disciplines of research.

The Austrian Research Promotion Agency (FFG), is the main funding organization for applied research, and has a specific program for space research including remote sensing.

The Federal Ministry of Education, Science and Research, which supports research within the framework of global budgeting of the universities and specific programs e.g. Sparkling Science, is tailored to promote research-education-cooperation.

Institutions of Arctic research (universities, Austrian Academy of Sciences, weather service ZAMG, enterprises) are coordinated via the Austrian Polar Research Institute (APR).

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

There is currently no Arctic research program defined by the Austrian research institutions involved. However, the Austrian Polar Research Institution clearly describes the contribution of the Austrian research community through its structuring into three major research foci/fields. The three research fields are

cryosphere and climate. With the response of the polar cryosphere to climate change being a key focus in climate research. Major research topics of APRI researchers on polar ice and climate include the response of the Ice Sheets and Ice Shelfs, smaller glaciers and snow cover on climate change, paleo-climate interpretation from ice cores and speleothems and permafrost/landscape hydrology changes in the Arctic.

Polar ecology. In which APRI scientists aims at providing fundamental understanding of the (a) the evolutionary, genetic, and ecological adaptation of organisms and communities in polar (marine, terrestrial, and ice/snow) environment and (b) of the role polar ecosystems play in global biogeochemical cycles and potential feedbacks to climate changes.

Social and cultural systems. Indigenous peoples have inhabited the arctic and subarctic regions for millennia. In recent centuries, the colonial reach of southern states and empires has changed the political and demographic situation of these regions significantly. Even more recently, economic migrants from the Global South have started to move north, contributing to the colorful ethnic and cultural mosaic that characterizes the "New North".

For the field of research-education program: *Sparkling Science supports cooperation projects between research and education institutions. Several of the projects supported were focused or included Arctic research topics.

The mystery and beauty of Arctic nature as symbolized by the stone balls at Champ Island (Franz Josef Land Archipelago)
Credit: W. Schöner

Measuring the ice thickness of a glacier in Greenland by ground penetrating radar
Credit: G. Weyss

ARCTIC RESEARCH INFRASTRUCTURE

Currently, Austria has no infrastructures (field stations, vessels aircraft) in the Arctic region. However, Austria is partner in EU funded programs such as Interact, where field sites in the Austrian Alps (e.g. Sonnblick Observatory) are incorporated.

However, Austrian research institutions are equipped with specific laboratory equipment, measurement and computing devices/centers (e.g. specific stable isotope labs, supercomputing clusters) relevant for and contributing to the international Arctic research.

BELGIUM

ARCTIC RESEARCH POLICY AND GOALS

The Belgian Federal State Secretary in charge of Science Policy, Thomas Dermine, is in charge of Polar research policies. Policies are developed in close cooperation with the Communities and the Regions, because of their overall competence for science, research and education.

As the Arctic Region is more than other regions hit by climate change and because of the fragility of its ecosystem, it is closely followed by the Environment Ministry.

Belgium has a long tradition of polar research. The Belgian Federal Science Policy has been actively supporting polar research since 1985. Over the years, the Belgian expertise has been strengthened in the various research areas ranging from marine biology to geophysics.

While Belgian polar research, for historical reasons, is mainly focussed on the Antarctic, there is an increasing interest in Arctic research. The expertise gained in the Antarctic can be applied to similar research questions in the Arctic to compare patterns and responses. Given that both poles are among the fastest warming regions of the globe and can act as sentinels for climate change, this comparative research approach is critical and should be developed as soon as possible.

A good example of Belgian Arctic research is the participation of Belgian researchers to the MOSAIC expedition in 2019. During this expedition, Belgian researchers have investigated the role of the Arctic pack ice into the regulation of greenhouse gas circulation and its impact on the distribution of Arctic fish.

Well managed data are the foundation of high-quality research and management. Data on disappearing and emerging Arctic ecosystems need to be appropriately organised, exchanged and coupled with data on the human environment.

Since the Last International Polar Year, Belgium has developed a leadership position in polar data management, with a strong focus on biodiversity data. Under Belgian guidance, Arctic and Antarctic data managers have initiated discussions to start working closer together.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

Arctic research is funded at federal (Belgian Science Policy Office) and regional level (Research Foundation Flanders and Fund for Scientific Research Wallonia-Brussels), however Belgium does not have a dedicated Arctic research programme.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

The expertise of Belgian researchers covers a wide range of topics in the fields of marine, terrestrial and freshwater biology, biogeochemistry and geophysics, glaciology, geology, hydrodynamics, climatology and human biology and medicine.

Some glaciology highlights:

- Contribution of polar researchers (ULB, VUB, Uliège) to the contribution of the Antarctic and Greenland ice sheets to future sea level rise.
- Contribution to IPCC AR6
- Multi-million year old record of Greenland vegetation and glacial history

During the first year-around expedition studying the Arctic Climate System (MOSAiC, 2019), Belgian researchers have investigated the role of the Arctic pack ice into the regulation of greenhouse gas circulation and its impact on the distribution of Arctic fish.

POINTS OF CONTACT

FRANK ARNAUTS AMBASSADOR
EMBASSY OF THE KINGDOM OF BELGIUM
TO NORWAY AND ICELAND, OSLO

New Belgica II research vessel
Credit: Freire Shipyard

Alaska 2019
Credit: Hauke Flores

ARCTIC RESEARCH INFRASTRUCTURE

VESSELS AND AIRCRAFT

The new Belgian RV BELGICA (Ice Reinforcement Class ICE-1C) will be able as of 2023 to operate in Arctic waters (latitude 80° north). The vessel, adapted to the existing modern marine research infrastructure, will serve as a platform for international collaboration. Capacity for scientists and crew: 28 + 12. It can support several research disciplines (fisheries, biology, chemistry, geology, etc.). It has a laboratory space of > 400m² (5 dry labs, 3 wet labs) and allows for research requiring the use of remotely operated and autonomous vehicles.

FIELD STATIONS

None

SATELLITES

None

CANADA

POINTS OF CONTACT

POLAR KNOWLEDGE CANADA_

ARCTIC RESEARCH POLICY AND GOALS

Canada supports scientific research and the integration of the knowledge gained into policy decisions, including those on the Arctic. Equally important is the need to work in partnership with Inuit and other Indigenous and northern communities to set the Arctic research agenda and support their self-determination in research. As outlined in its Arctic and Northern Policy Framework, Canada's approach recognizes the importance of international collaboration to address opportunities and challenges in the Arctic, such as climate change, environmental protection and social inequities. Supporting knowledge creation and evidence-based decision-making as essential pillars of sustainable growth and environmental stewardship is particularly relevant in the Arctic.

Nunavut, Yukon and the Northwest Territories' *Pan-Northern Approach to Science* provides their shared vision for a prosperous, healthy and sustainable North that benefits Northerners, Indigenous peoples, and all Canadians. Inuit Tapiriit Kanatami, the national representational organization for Inuit in Canada, released the *National Inuit Strategy on Research*, a pivotal document that identifies Inuit expectations in the areas of research governance, ethics, data and information ownership and control, capacity building, and priority setting, and advocates for a distinctions-based approach to the development and implementation of research policy for Inuit Nunangat research.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

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

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

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

Territories: The governments of Nunavut, Yukon, Northwest Territories play a key role supporting and delivering applied northern science. Indigenous organisation's representatives of Inuit and governments and co-management boards also make key contributions to Inuit Nunangat and northern science.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

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

ArcticNet: A Network of Centres of Excellence of Canada that is launching its North by North Research Program to strengthen the impact and effectiveness of Inuit Nunangat research for and led by Inuit.

PermafrostNet: A Canadian university-led strategic partnership research network focused on enhancing Canada's ability to monitor, predict and adapt to large-scale permafrost.

Qanuippitaa? National Inuit Health Survey: This initiative provides high quality, Inuit-determined and Inuit-owned data to monitor change, identify gaps and inform decision-making, leading to improved health and wellness among Inuit in Canada.

Strengthening Indigenous Research Capacity* (SIRC) Strategic Plan: *Setting New Directions to Support Indigenous Research and Research Training in Canada 2019-2022: Based on a national dialogue with Indigenous communities to develop an interdisciplinary Indigenous research and research

Taking core samples for community-driven research on permafrost degradation near Kugluktuk, Nunavut, Canada
Credit: Polar Knowledge Canada

Main Research Building at the Canadian High Arctic Research Station campus, Cambridge Bay, Nunavut, Canada. Credit: Janice Lang DRDC-DND

training model that contributes to reconciliation, this will be implemented by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada, and the Social Sciences and Humanities Research Council of Canada. It has four strategic directions: building relationships with First Nations, Inuit and Métis people; supporting research priorities of Indigenous peoples; creating greater funding accessibility to granting agency programs; championing Indigenous leadership, self-determination and capacity building in research.

ARCTIC RESEARCH INFRASTRUCTURE

POLAR CONTINENTAL SHELF PROGRAM (PCSP)

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

VESSELS AND AIRCRAFT

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

FIELD STATIONS

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

SATELLITES

- **RADARSAT Constellation** Mission consists of three satellites, evenly spread in the same polar orbit, allowing fine-scale temporal change detection and daily Arctic coverage.
- **SCISAT** data provides scientific satellite insight on the stratosphere, including the health of the ozone layer. SCISAT's solar-occultation instruments measure a wide range of gases, helping to monitor recovery of the ozone.

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

CZECH REPUBLIC

POINTS OF CONTACT

THE CENTRE FOR POLAR ECOLOGY

MINISTRY OF EDUCATION, YOUTH AND SPORTS

CZECH ACADEMY OF SCIENCES

ARCTIC RESEARCH POLICY AND GOALS

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

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

Ministry of Education, Youth and Sports. As a main science-funding national body the Ministry administers a number of funding programs. Funding is available basically on competitive grounds, where long-term infrastructure projects that provide services for diverse kinds of scientific research areas are evaluated once in

3-4 years and the provision of funding is dependent upon past results. Research activities in the Arctic are part of the large infrastructure project Czech Polar Research Infrastructure (acronym CzechPolar2) that overarches both Arctic and Antarctic research.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

The Centre for Polar Ecology (CPE) is in the department of the Faculty of Science, University of South Bohemia in České Budějovice. The main purpose of the CPE is ensuring regular university courses in Polar Ecology and similar science topics. In detail, the Centre is focused on extreme environment biology including microbiology- algology, botany, zoology-parasitology, physiology and molecular biology. The second research focus is covered by the collaboration of institutions in the Czech Republic including the Polar-Geo-Lab, Department of Geography, Masaryk University where research on the physical geography of Arctic regions including climatology, glaciology, geology, geomorphology and hydrology are conducted.

In addition to the courses, research is valued equally with education, including both biological sciences and Earth sciences.

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

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

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

Research station "Julius Payer" house in Longyearbyen
Credit: Vaclav Pavel

Research vessel "Clione" (motorsailer)
Credit: Vaclav Pavel

ARCTIC RESEARCH INFRASTRUCTURE

Technical equipment consists of instruments and technologies of the life science laboratories of Centre for Polar Ecology (CPE in České Budějovice), The Czech Arctic Josef Svoboda Station and its research station JULIUS PAYER HOUSE (78.22°N, 15.66°E) which is

located in Longyearbyen and provides housing for 10 people (up to 20 for short-term accommodation) complete with kitchen and bathroom (including a shower, washer and drier).

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

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

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

FIELD STATIONS

Field camp NOSTOC FIELD STATION (78.69°N, 16.46°E, 60 km from Longyearbyen) consists of four modular houses connected by a large tent. It accommodates up to 12 people and includes a kitchen, laboratory, technical facility (energy generators, basic workshop tools), and scuba diving equipment. There are also two additional containers (residential and storage) close to

the Pyramiden harbor (78.66°N, 16.39°E, 6 km south of Nostoc) where up to 4 persons may be accommodated.

VESSELS

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

DENMARK

POINTS OF CONTACT

MINISTRY OF HIGHER EDUCATION AND SCIENCE

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

The Ministry of Higher Education and Science funds a large number of grants that support Arctic research in the Kingdom of Denmark. Denmark does not have research programs exclusively targeted for Arctic science, but there currently exists three major funding bodies where proposals of Arctic science may apply for funding: *The Independent Research Fund* supports specific research activities within all scientific areas that are based on the researchers' own initiatives; *Innovation Fund Denmark* invests in advancing research into science and technology and facilitates innovative solutions that benefit Danish growth and employment; and *The Danish National Research Foundation* funds cutting-edge, curiosity-driven research-centres of Excellence. In addition to the public grants and funding bodies, the funding landscape in Denmark is characterized by a significant philanthropic tradition when it comes to private funding of Arctic research and infrastructure.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

Four of the major universities in Denmark (*Copenhagen University, Aarhus University, Aalborg University*, and *The 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 account for between 5% and 8% of the total.

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

Centre for Ice and Climate, Copenhagen University coordinates the logistics of The East Greenland Ice-core Project (EASTGRIP) which aims to drill and retrieve an ice core from the Northeast Greenland Ice Stream (NEGIS).

Centre for Permafrost (CENPERM) is a Centre of Excellence that investigates the biological, geographical and physical effects of permafrost thawing in Greenland – in the short and the long term.

Greenland Climate Research Centre, established as a joint venture between Denmark and Greenland, has expertise in oceanography and focuses on Arctic marine ecology and its interaction with Greenlandic society.

Programme for Monitoring of the Greenland Ice Sheet (PROMICE) was launched by The Danish Energy Agency DANCEA programme to assess changes in the Greenland ice sheet and is operated by the Geological Survey of Denmark and Greenland, Denmark's National Space Institute (DTU Space) and Asiaq Greenland Survey.

Camp Century Climate Monitoring Programme is led by the Geological Survey of Denmark and Greenland and includes installing automated climate sensors at the site, collecting ice-penetrating radar observations, and performing computer projections.

Greenland Mineral Resources Portal, operated by the Government of Greenland and the Geological Survey of Denmark and Greenland, is an entry point to all available information about mineral resources in Greenland.

ARCTIC RESEARCH INFRASTRUCTURE

- **Danish Centre for Marine Research** provides support for ship charter and for all marine research expeditions with the Royal Danish Navy.
- **GNET – Greenland GPS Network** stations are located along the Greenland ice sheet and monitor the changes in the ice sheet mass and are operated by the Technical University of Denmark.
- **Geomagnetic observatories in Greenland and Faeroe Islands** are conducted by DTU Space who are monitoring the Earth's magnetic field with a network of ground stations in Greenland, Faroe Islands and Denmark.
- **Greenland Telescope (GLT)** is a 12-meter radio antenna currently located at Thule Airforce Base in Greenland lead by DTU Space and Copenhagen University.

- **Isaaffik** is a user-driven web-portal that provides overview and supports collaboration on science and infrastructure in the Arctic regions.
- **Denmark is part of INTERACT Station Managers' Forum** which is a circum-arctic network of a ~ 90 terrestrial field bases in northern Europe, Russia, USA, Canada, Greenland, Iceland, the Faroe Islands and Scotland as well as stations in northern alpine areas.
- **Forum for Arctic Operators (FARO) secretariat** is located in Aarhus University, Denmark and is a country membership organization that promotes dialogue on logistics and operational support for scientific research in the Arctic.

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. R/V Dana is currently under reconstruction.
- **The Royal Danish Navy** has two arctic-capable ships at their disposal. The Navy provides room for scientists and limited ship time for research activities that require such.

FIELD STATIONS

- **Zackenberg 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 and is owned by The Government of Greenland and operated by Aarhus University.
- **Arctic Station** is located on the south coast of Disko Island in central West Greenland and is owned by the University of Copenhagen.
- **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 and is owned by the Greenland Government and operated by Aarhus University and the Danish Defense (the Arctic Command).
- **Sermilik Station** is located in southeast Greenland, about 20 km north of the small town Tasiilaq (Ammassalik) and is owned by University of Copenhagen.
- **Qaanaaq Sea Ice Winter Observatory** is owned by The Danish Meteorological Institute.
- **EGRIP Field Station** (East Greenland Ice drilling Project) is located on the North East Greenland Ice Sheet within the North East Greenland National Park and is owned by Centre for Ice and Climate, University of Copenhagen.
- **Arctic DTU Campus Sisimiut** is owned by the Technical University of Denmark and houses students who attend Arctic Technology as well as The Arctic Semester and Nordic Master in Cold Climate Engineering.

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 and the European Space Agency.

EUROPEAN UNION

ARCTIC RESEARCH POLICY AND GOALS

RESEARCH GOALS

The EU Arctic research and innovation policy contributes to three priorities identified in the Joint Communication on the EU Arctic policy adopted in 2016: 1) Climate Change and Safeguarding the Environment; 2) Sustainable Development; and 3) International Cooperation. The research and innovation policy is implemented through the EU Framework Programme for Research and Innovation (Horizon 2020 for 2014-2020, and Horizon Europe for 2021-2027) which provides funding opportunities to increase our knowledge about the Arctic and to promote innovation in and for the Arctic.

RESEARCH POLICY

The EU is a **major** investor and player in Arctic research, having invested over 200 million euros in Arctic research over the period 2014-2020. The EU supports the development and international access to **Arctic research infrastructure** through cooperation activities with non-EU countries. **Arctic research and observations**, which are essential to monitor and predict the evolution of rapid Arctic changes, influencing global climate system changes.

EU Framework Programmes for Research and Innovation offers a unique framework for International scientific cooperation, considering that five of the eight Arctic countries are either EU Member States (Denmark, Finland and Sweden) or associated countries to EU research programmes, (Iceland and Norway). In addition, EU has bilateral Science and Technology Cooperation Agreements with the remaining three Arctic countries (Canada, Russian Federation, and United States of America), and is open to participation of partners from all other countries.

The EU's Joint Research Centre (JRC) is also an important player in Arctic research. A significant number of investigations by JRC scientists have been carried out, resulting in peer-reviewed publications in scientific journals and JRC Science for Policy reports, covering the 3 pillars of the integrated EU Arctic Policy.

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 AND EDUCATION/ CAPACITY BUILDING INITIATIVES

The **Marie Skłodowska-Curie actions** (MSCA) provide grants for all stages of researchers' careers and encourage transnational, intersectoral and interdisciplinary mobility. The MSCA enable research organizations to host talented foreign researchers and to create strategic partnerships with leading institutions worldwide. By mid-2020, 55 MSCA grants supporting Arctic research for over EUR 40 million of EU funding had been awarded.

EU-PolarNet, (2.3M€), delivers a strategic framework and mechanisms to prioritize science, advises the European Commission on polar issues, optimizes the use of polar infrastructure, and brokers new partnerships that have led to the co-design of a European Polar Research Programme.

INTAROS (15.5M€), extends and, improves, Arctic observing systems, including community-based ones, contributing to creating an integrated data access platform.

APPLICATE (8M€), and **Blue-Action** (7.5M€), are exploring the predictability of Arctic climate and its impact on climate and weather at lower latitudes, improving models and leading to the co-design of better climate services with stakeholders.

NUNATARYUK (11M€), determines the impacts of thawing coastal and subsea permafrost, and develops adaptation and mitigation strategies for the Arctic coastal population.

iCUPE (2.5M€), improves the understanding of polar areas by combining integrated in-situ measurements, satellite observations and a modelling platform. It develops integrated, quality-controlled, and harmonized data, and develops novel data products, metrics, and indicators.

POINTS OF CONTACT

EUROPEAN COMMISSION
DIRECTORATE–GENERAL FOR RESEARCH AND INNOVATION

Sea-ice research in the Arctic Ocean
Credit: Stefan Hendricks, AWI

Ice enriched permafrost cliffs on the New Siberian Islands
Credit: Georg Schwamborn, AWI

ARCSAR (3.5M€) addresses the Arctic and North-Atlantic (ANA) region, preparing to cope with the security and safety threats that will result from increased commercial activity in the region, including traffic through the Northern passages, cruise traffic, and offshore oil and gas activity.

ECOTIP, (6.3M€), maps Arctic biodiversity and its response to external drivers, and the effects of expanding commercial activities in the Arctic under expected climate change conditions.

KEPLER (3M€), is built around the European Ice Services and Copernicus information providers, to prepare a roadmap for Copernicus to deliver an improved European capacity for monitoring and forecasting the Polar Regions.

FORCeS (8M€), explores how atmospheric aerosols affect climate, by bringing together measurement data and numerical models to quantify the near-term climate impacts of different aerosol emission pathways.

ARCTIC RESEARCH INFRASTRUCTURE

INTERACT (10M€) is a circum-Arctic network of currently 79 terrestrial field bases in northern Europe, Russia, US and Canada, as well as stations in northern alpine areas, offering access to its network of stations to interested scientists through the Transnational Access Programme.

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

SPACE INFRASTRUCTURE AND SERVICES

The **Copernicus programme** is an EU Earth observation program delivering public information services for environmental monitoring of atmosphere, climate change, marine environment, and land as well as for emergency and security crisis, based on space data products from the EU Sentinel satellites fleet.

Copernicus offers six public information product services to support the implementation of EU policies, research and economic development derived from space data with a full, free and open data policy.

- The Atmosphere service deals with atmospheric composition, air quality, ozone, solar radiations and also aerosols and pollutants transport;
- The Climate change service provides regional arctic reanalyses, seasonal forecasts and climate projections published in the European State of Climate Report;
- The Marine service in particular hosts an Arctic Ocean forecasting center in Norway to monitor sea ice coverage, thickness, drift, edge, type, icebergs, ocean circulation, waves, biogeochemistry and the situation is annually reported in the Ocean State Report;
- The Land service deals with land cover/land use and also energy budget (temperature, albedo), snow cover and information on the water cycle;
- The Emergency service is also key in the Arctic to act quickly in case of floods or fire;
- The Security service mainly deals with maritime surveillance and support to safety at sea.

The volume and variety of Earth Observation (EO) data available for the polar regions is growing rapidly, providing opportunities for more complex investigations. To fully process, analyze, disseminate and exploit these new EO data, the **European Space Agency** has established the Polar Thematic Exploitation Platform (PTEP) which provides collaborative computing environment for polar researchers.

THE FAROE ISLANDS

POINTS OF CONTACT

MINISTRY OF FOREIGN AFFAIRS AND CULTURE

ARCTIC RESEARCH POLICY AND GOALS

Generally, the Faroe Islands have experience and encourage full partnership in Arctic research cooperation, so the small countries and communities in the Arctic region can participate as full members.

The policy is to monitor and research the situation in our area and contribute as an active partner in the scientific projects that build up knowledge about the Arctic region.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

- **Public sector institutions**
- **Research Council Faroe Islands**
- **Governmental research funds in Denmark**
- **Research funds in the Nordic Council of Ministers**
- **Research funds in the European Union**
- **US - National Institutes of Health**

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

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

FAROESE GEOLOGICAL SURVEY

Jarðfeingi: www.jardfeingi.fo

- **InterAct.** Research infrastructure: 86 terrestrial research stations in the circumpolar Arctic focusing on environmental and climate change
- **GeoSchool.** Dissemination to Faroese schools on geoscience, including arctic issues in the Faroe Islands
- **EmodNET Geology.** Geological maps of European waters, including the Faroese and Arctic waters
- **EmodNET HRSM.** Bathymetric maps of European waters, including the Faroese and Arctic waters
- **IQUAME2500.** International Quaternary Map of Europe in scale 1:2.500.000
- **Museum geo-exhibition.** On geology in Arctic and Subarctic regions of Greenland, Iceland, Faroe Islands and Norway.

FAROE ISLANDS NATIONAL MUSEUM

Tjóðsavnið: www.tjodsavnid.fo

- **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, where vegetation and temperature data document changes in biodiversity and vegetation patterns, caused by climate change.
- **ITEX.** International tundra experiment, where the vegetation and phenology of selected plant species are monitored under the influence of experimental warming.

ENVIRONMENT AGENCY

Umhvørvisstovan: www.us.fo

- **Monitoring and Research.** Environmental contaminant trends and effects monitoring and research including air, water, soil, sediment and biota compartments, and legacy contaminant as well as pollutants of emerging Arctic concern.
- **Research.** Research into neobiota in the Faroes and potential impact of invasive alien organisms.
- **AMAP.** Monitoring and assessment of pollutants in the Arctic. Working group within the Arctic Council.
- **SEANA.** Monitoring the impact of shipping emissions upon atmospheric aerosols and the climate in the Arctic and North Atlantic atmosphere.

DEPT. OF OCCUPATIONAL MEDICINE AND PUBLIC HEALTH

Deildin fyri Arbeiðs- og Almannaheilsu: www.health.fo

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

UNIVERSITY OF THE FAROE ISLANDS

Fróðskaparsetur Føroya: www.setur.fo

- **West Nordic Studies.** Nordic Arctic joint educational program
- **Sustainability.** Sustainable sheep grazing in Nordic countries
- **CBird.** Promotes, facilitates, and coordinates conservation, management and research activities among circumpolar countries and improves communication between seabird scientists and managers inside and outside the Arctic
- **AMAP - Radioactivity monitoring.** Assessments of radioactivity from anthropogenic sources in the Arctic
- **Denmark and the new North Atlantic: Identity Positions, Natural Resources and Cultural Heritage.** Renegotiations of identities, climate change and globalization
- **Building Shared Knowledge capital to support natural resource governance in the Northern periphery.**
- **University of Arctic (UArctic).** Thematic Network on Teacher Education for Social Justice and Diversity.

FAROE MARINE RESEARCH INSTITUTE

Havstovan: www.hav.fo

- **Monitoring and research** of benthic and pelagic fish stocks, ocean currents and Essential Ocean Variables (including temperature, salinity, CO2, pH, plankton, and mammals in Arctic and Subarctic regions)
- **Blue-Action.** Arctic Impact on Weather and Climate is an EU H2020 project with the objective to actively improve our ability to describe, model, and predict Arctic climate change and its impact on Northern Hemisphere climate, weather and their extremes, and to deliver valuated climate services of societal benefit.
- **FARMON 2020.** Measuring the inflow of Atlantic water north of the Faroes and the outflow of overflow water through the Faroe Bank Channel. These flows form two of the main branches in the exchanges across the Greenland-Scotland Ridge.
- **Ecosystem based management of sand eels, demersal fish, and seabirds in Boreal regions in the Northeast Atlantic.** Funded by Nordic Co-operation.
- **Chondrichtyans in the Arctic and Subarctic regions of the North Atlantic.** Funded by Nordic Co-operation.
- **Seatrack.** Tracking seabird migration. Collaboration with Norwegian Polar Institute and Norwegian Institute for Nature Research.
- **Eurofleets+.** An alliance of European marine research infrastructure to meet the evolving needs of the research and industrial communities. EU-H2020 project. Coordination of polar research.

On the island of Mykines the density of Atlantic Puffin is estimated based on transect counts

ARCTIC RESEARCH INFRASTRUCTURE

VESSELS

- **R/V Jákup Sverri**
  A new multipurpose research vessel, built in 2020. Length 54.3 m, 1900 GT. Technical details can be found here.
- ***Other smaller vessels: Biofarið, Nýsan and Andrias Reinert***

RESEARCH PARK INOVA

Granskarasetrið iNOVA: www.inova.fo

- **iNOVA** is a facility located in Tórshavn where private enterprise and public institutions can access state-of-the-art laboratories, instruments, offices and an event location. Genetics. iNOVA houses a genetic sequencing facility used for the Faroese Genome Project FarGen and marine genetic research, among others.
- **Molecular Biology.** iNOVA houses a Mass Spec facility used in the monitoring efforts of the Environment Agency.
- **Human Health and Performance.** The university and the national hospital work together to measure effects on human metabolism.
- **Foodlab and Sensory lab.** Scientific product development in a food-producing region

FIELD STATIONS AND MONITORING

- **Fini-Station,** Faroese Geological Survey (Jarðfeingi)
- **Sornfelli** (Tjóðsavnið)
- **Koltur** (Tjóðsavnið)
- **AMAP, OSPAR, Gloria and CAFF Sites** (Fróðskaparsetrið, Tjóðsavnið, Umhvørvisstovan, Deildin fyri Arbeiðs- og Almannaheilsu)
- **Ramsar Sites** (Tjóðsavnið and Havstovan)
- **Havnadal and Tórshavn city centre Air Monitoring Sites** (Umhvørvisstovan)
- **Meteorological and Geohazard Monitoring on roads** (Landsverk)
- **Skopun Marine Coastal Station** (Havstovan, partner in H2020 Jerico-S3)

FINLAND

POINTS OF CONTACT

MINISTRY OF EDUCATION AND CULTURE

ACADEMY OF FINLAND

THE FINNISH NATIONAL COMMITTEE OF ARCTIC AND ANTARCTIC RESEARCH

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/INSTITUTIONS

In Finland Arctic research is carried out and education provided by several universities and research institutes and in many different disciplines. The Finnish research institutes are also well represented in various international networks that discuss Arctic questions. See more here.

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

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

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

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

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

Business Finland. Brings together and markets Finnish Arctic know-how globally and strengthens Finnish know-how related to Arctic environmental awareness, digitalization, and autonomy.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

The national research program ARKTIKO (2014–2020), 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 expertise in Finland is based in the education system where the position as an Arctic country is taken into account in teaching in all levels of education. The secretariat of the **University of the Arctic** is hosted by the University of Lapland, and UArctic is registered as a non-profit association in Finland.

Finland is co-funding the NordForsk Arctic research program (2016–2021) of Nordic Centers of Excellence that is a Joint Nordic Initiative. This program produces new knowledge about the opportunities and challenges of responsible development of the Arctic region.

Saana Fell at Kilpisjärvi, Finland in April
Credit: By Ximonic (Simo Räsänen)

Satellite receiver and Northern Lights at the Arctic Space Centre, Finland
Credit: Finnish Meteorological Institute. Tero Pajukallio/Diaidea

ARCTIC RESEARCH INFRASTRUCTURE

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

Ice model basins owned and operated by Aalto University and industry partners 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, 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.

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 Global Climate Observing System (GCOS) Reference Upper-Air Network (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 which was established to measure pollution fallout from the mining industry in the Kola-peninsula in Russia.

Natural Resources Institute Finland hosts tens of field stations in Finland, of which several are situated above the Arctic Circle. Arctic researchat 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 HIGHER EDUCATION AND RESEARCH-SERVICE STRATEGY, RESEARCH AND INNOVATION

MINISTRY OF EUROPE AND FOREIGN AFFAIRS
— SG/POLES & LEGAL AFFAIRS DEPARTMENT
/LAW OF THE SEA AND POLAR AFFAIRS

ARCTIC RESEARCH POLICY AND GOALS

The French National Roadmap published in 2016 defines the French research policy priorities in the Arctic. International cooperation in the Arctic and strengthening of scientific research for the benefit of Arctic environments and resilience are therein highlighted. France is committed to play an active role within the framework of international law and the Arctic governance forums to promote science-based policies. In the context of the UN Decade of Ocean Science, France has identified the Polar Oceans as key regions where ongoing environmental changes and increasing human pressures pose urgent challenges.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

The Research Alliance for the Environment (AllEnvi). AllEnvi gathers 12 scientific and funding organizations and 16 partners that are major players in scientific, economic and social aspects of environmental research (>15,000 researchers including ~500 Arctic researchers). AllEnvi supports Arctic research in the domains of Earth sciences, ecology and environment, technology, and humanities.

The French National Scientific Research Center (CNRS). In 2018, CNRS initiated a Polar Scientific Committee with the mission to foster transdisciplinary polar research across the different research institutes and organizations. Long-term support is also provided to joint international research initiatives: TAKUVIK, a joint research laboratory between CNRS and Université Laval (Canada) focused on Arctic research, the OHMI Nunavik, a joint collaboration with CEN on Arctic social sciences in the Canadian Arctic. In Siberia, CNRS is committed in networks involving several Siberian universities.

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

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

The National Research Agency (ANR). ANR is a major national funding agency for basic and applied research. As a partner of the Belmont Forum, ANR is currently funding Arctic projects in the context of the Collaborative and Research Action "Resilience in Rapidly Changing Arctic Systems". ANR is a member of the Arctic Funders Forum. ANR also funds research on Arctic climate by supporting researchers coming to France through the "Make Our Planet Great Again" program.

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

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

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

Secrétariat Général pour l'Investissement (Prime Minister). The SGPI currently supports three instrumentation projects contributing to sustained Arctic observations using ice-tethered platforms, ocean drifting floats and new drilling tools in ice, ocean and lakes.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

MAIN RESEARCH AREAS

France's main research initiatives in the Arctic are in line with the ICARP III priorities and concern all disciplines and domains of the natural and

Credit: Gregory Tran

Credit: Gregory Tran

social sciences. There is a strong involvement of the community in process studies involving the marine environment, the atmosphere, terrestrial and marine cryosphere, as well as the combined effects of physical and biogeochemical processes in the understanding of the polar environments, their evolution, and their link to current and future changes. French researchers are also largely contributing to improved understanding of the links between environmental and society changes and their implication for the well-being and resilience of Arctic communities. France dedicates a special effort to maintaining observations in the Arctic through different networks and collaborations, including developing observatories for bridging Indigenous and scientific knowledge, and contributes actively to improve Earth System Model performance in the Arctic.

PARTNERSHIP IN INTERNATIONAL RESEARCH INITIATIVES

- EC-Polar Cluster: France is a partner in most collaborative and research actions of the European Polar Cluster, in ERA-Planet Strand 4 (Polar areas and natural resources). Within the EU-Polarnet, CSA and CNRS coordinate the drafting of the "Integrated European Research Program".
- YOPP-WMO: France is member of the Steering Group of the WMO Polar Prediction Project and contributes to the Year of Polar Prediction.
- France is member of the European Polar Board through the IPEV and CNRS partnerships.

PARTNERSHIP IN INTERNATIONAL EDUCATION NETWORKS

- UVSQ is a member of the UArctic network and is a partner of the educational program EDU-ARCTIC.

ARCTIC RESEARCH INFRASTRUCTURE

OBSERVATION NETWORKS

France supports Arctic long-term and distributed interdisciplinary observations in the context of SAON and European projects contributing to Arctic observations in support of a future Arctic GEOSS.

VESSELS AND OTHER PLATFORMS

The French Oceanographic Fleet does not own vessels with ice-breaking capability but France is a partner in the trans-national access programs of H2020 Integrated Activity ARICE and HEMERA, coordinated by CNES, aiming to better coordinate use and access to balloons. The French aircraft fleet SAFIRE and the stratospheric balloon fleet regularly contribute to deployments in the Arctic. These infrastructures support field campaigns in several Arctic regions.

FIELD STATIONS

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

SATELLITES

In association with other national and European space agencies, CNES is a partner of major current satellite missions which have direct applications in the Arctic. France supports the European initiative to expand the Copernicus space component in the Polar regions, e.g. with several French scientists being members of the Mission Advisory Groups of the CMIR and CRISTAL candidate missions.

GERMANY

POINTS OF CONTACT

ALFRED WEGENER INSTITUTE, HELMHOLTZ CENTRE FOR POLAR AND MARINE RESEARCH

GERMAN ARCTIC OFFICE: VOLKER RACHOLD

ARCTIC RESEARCH POLICY AND GOALS

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

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

The Federal Ministry of Education and Research (BMBF) framework program **MARE:N (Coastal, Marine and Polar Research for Sustainability)** supports interdisciplinary sustainability research, including both natural and social sciences, in polar and marine issues. Main research foci in the Arctic include climate change and its impact on global climate processes.

Funded by the BMBF:

- The **Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI)** is the national polar institute. AWI concentrates on observational and modelling studies of all elements of the Polar Earth System in the Arctic and Antarctic.
- The **GEOMAR Helmholtz Centre for Ocean Research** is a leading center of oceanography and has worked for decades in the Arctic Ocean (Laptev Sea).
- The work of the **Institute for Advanced Sustainability Studies (IASS) Arctic Governance research group** focuses on political, legal, social, and economic interdependencies between processes, actors and systems within and beyond the Arctic.
- BMBF-funded entities, which, in turn, award financial support to individuals, include the **German Research Foundation (DFG),** and the **German Academic Exchange Service (DAAD).** DFG runs a Priority Programme titled, **"Antarctic Research with Comparable Investigations in Arctic Sea Ice Areas".**

The Federal Ministry for Economic Affairs and Energy (BMWi) funds the **Federal Institute for Geosciences and Natural Resources (BGR)**, and the **German Aerospace Center (DLR).** For five decades, the BGR's circum-Arctic terrestrial and marine geological research has been developing a comprehensive view on the geodynamic evolution of the Arctic continental margins. DLR conducts extensive research and development work in aeronautics, space, energy, transport, and security, and contributes to Arctic research through its satellite missions and remote sensing programmes.

The States of Germany cofund AWI, GEOMAR, DLR and DFG.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

International research projects coordinated by Germany (**AWI**):

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

Polar bear mother with cub exploring the MOSAiC camp
The photo taken by Esther Horvath (AWI) won the World Press Photo Award

MOSAiC change of shift on the sea ice
Credit: Michael Gutsche

- **Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC)** is the first year-round expedition into the central Arctic exploring the processes in atmosphere, sea ice and Arctic Ocean.
- **The interdisciplinary Master Program Polar and Marine Sciences (POMOR)** is a research-oriented two-year master's program at the Universities of Hamburg and Saint Petersburg (international accreditation until 2025).

LARGE NATIONAL RESEARCH PROJECTS

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

ARCTIC RESEARCH INFRASTRUCTURE

VESSELS

The research icebreaker **POLARSTERN**, operated by AWI is the most important tool of German Polar Research.

FIELD STATIONS

The AWI and the French Polar Institute Paul Emile Victor (IPEV) jointly operate the **AWIPEV Arctic Research Base** in Ny-Ålesund. It offers living quarters and workrooms for researchers focusing on basic research in environmental sciences.

The research station **"Samoylov Island,"** which is operated by the Siberian Branch of the Russian Academy of Sciences, is used for collaborative permafrost research.

AIRCRAFT

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

The German High Altitude and Long Range Research Aircraft (**HALO**), operated by DLR, will conduct three missions in the Arctic until 2021.

SATELLITES

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

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

GREENLAND

POINTS OF CONTACT

MINISTRY OF SCIENCE AND ENVIRONMENT
RESEARCH COORDINATOR STEN LUND

GREENLAND RESEARCH COUNCIL
CHAIR JOSEPHINE NYMAND

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 enhances Greenland's participation in international cooperative research initiatives.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

The Government of Greenland is the primary supporter of basic research in Greenland with funds distributed to various Greenlandic research institutions including the NIS – Greenland Research Council.

Danish public funding for Arctic research is provided through several Ministries, such as of Science, Energy, and Environment.

Foreign public funding is also provided through the European Union and the EU-Horizon 2020 Programme, UArctic, Research Council of Norway, US (via the National Science Foundation, National Oceanographic and Atmospheric Administration, Office of Naval Research, and NASA), Nordic Council of Ministers and Swiss National Science Foundation.

Private foundations, such as Aage V. Jensen Charity, Oak, Villum, and Carlsberg, also provide research funding.

Institutions include the University of Greenland, Greenland Institute of Natural Resources, Greenland Survey, Greenland National Museum & Archives, National Library and Groenlandica, H.M. Queen Ingrid's Hospital.

COORDINATING ORGANISATIONS

The Government of Greenland's Ministry of Science and Environment provides the coordinating function between the Minister and research Authorities and communities in and outside Greenland.

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

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

The International Arctic Hub has been established. The aim of the IAH is to facilitate National and International research on equal terms, and to involve the Greenlandic community in the scientific efforts.

CAPARDUS – Capacity-building in Arctic Standardization Development; understanding and implementation of Arctic standards, safe activities, emergency prevention and response, improved understanding and conservation of the environment.

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

Greenland Ecosystem Monitoring (GEM) is an integrated monitoring and long-term research program 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.

The 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.

Greenland Science Week bridges science and society, business and government, for networking and cooperation in multi-disciplinary Arctic science. It

Nuuk NERO, GINR (Greenland Institute of Natural Resources)
Credit: Katrine Ravndrup

Nuuk Ilimmarfik
Credit: Sten Lund

ARCTIC RESEARCH INFRASTRUCTURE

also creates a networking and cooperation platform for Greenlandic and international science.

The Fulbright Arctic Initiative, Health and Infrastructure Working Group, brings together a network of scholars, professionals and applied researchers, and will address public-policy research questions relevant to Arctic nations' shared challenges and opportunities.

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

Graduates in higher education doubled over a decade and continues in combination with an increasing completion rate and number of students. New education programs established in 2019-2020 include; Law, BEng in Fisheries Technology, economics and resource management, and international trade and marketing.

VESSELS

Greenland has the research vessel R/V Sanna as well as several smaller vessels. The Government allocated DKK 200 million for a new ocean-going R/V Tarajoq, delivery expected from Shipyard in 2021.

FIELD STATIONS

- Nuuk and the Kobbefjord (NERO) field station provide access to Low Arctic ecosystems in West Greenland with different biotopes such as dwarf-shrub heaths, fens, grasslands and lakes.
- Zackenberg (ZERO) is situated in the High Arctic in an area with continuous permafrost and comprises the drainage basin of the Zackenberg River.
- Daneborg Research Station is a part of Zackenberg Research Station which is owned by the government of Greenland. Aarhus University (Denmark) is responsible for running the station.
- Niaqornat conducts long-term studies of beluga and narwhals. Other studies of other game animals and of the environment local to this field station may also be considered.
- Villum Research Station is owned by the Greenlandic Government and operated by Aarhus University . Once the new station is fully operating, a database will be established for storage of all kind of scientific data. At present only atmospheric data are stored in a database.
- Sermilik Research Station provides a logistical base for ongoing glaciological, hydrological and geomorphological investigations of the Mittivakkat Glacier and its catchment.
- Arctic Station promotes Arctic research and university-level education within all aspects of environmental science.
- DTU Arctic Campus Sisimiut is part of several research projects in the Arctic or concerning Arctic issues, focuses on research-based knowledge and technology development in the Arctic.

FIELD SERVICE

Local providers offer various services including: logistics, transportation, security, technical support, monitoring and sanitation.

ICELAND

POINTS OF CONTACT

THE MINISTRY OF EDUCATION, SCIENCE AND CULTURE

THE ICELANDIC CENTRE FOR RESEARCH

THE ICELANDIC ARCTIC COOPERATION NETWORK

ARCTIC RESEARCH POLICY AND GOALS

Iceland places great emphasis on international collaboration in science, innovation and education, and increased mobility of researchers. Iceland supports strengthened research cooperation with other nations in the Arctic region, protection of flora and fauna, observation capabilities and pollution prevention, as well as the rights and well-being of Arctic Indigenous peoples.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

The Icelandic government provides national competitive funds that support Icelandic research on physical, biological, geological, chemical, climate processes in and around Iceland, as well as research on cultural heritage, society, economy, public health and societal challenges.

The Icelandic Centre for Research (Rannís) administers these national funds, as well as Iceland's participation in international and EU funded education, research and innovation programmes such as the EU Framework Programme for Research and Innovation (Horizon 2020). For more information please refer to the newly published report: Mapping Arctic Research in Iceland.

Icelandic Science and Technology Policy Council provides strategic direction for both national and international collaboration in research and innovation

International Arctic Science Committee (IASC) in Akureyri, hosted by Rannís.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

The Icelandic Meteorological Office, the University of Iceland and **the National Power Company in Iceland** and other agencies participate in research on the ongoing and future changes of glaciers in Iceland. The program involves monitoring of annual mass balance and changes of glacier terminus positions, mapping of glacier surfaces based on remote sensing from aircraft and satellites and projecting future changes with physical models. A large group of local people are involved in a long-standing community science initiative on the monitoring of the glaciers. This project utilizes the international GCW/CryoNet global cryosphere monitoring surface station network on the icecap Hofsjökull.

Iceland's Arctic Council Chairmanship (2019-2021) initiated collaboration between international research institutes, universities and the Arctic SDI to study surface elevation changes of glaciers in the Arctic based on the ArcticDEM. Additionally, the Icelandic Meteorological Office in cooperation with the national and international research community, will host the Cryosphere 2021 symposium. The symposium focuses on ongoing changes in all components of the Earth's cryosphere affecting the developed world, developing nations and Indigenous people.

The Marine and Freshwater Research Institute, with national and international universities and research institutes, researches the marine environment ecosystem including long-term monitoring of oceanographic conditions, primary and secondary production, and diversity and abundance of invertebrates, fish and marine mammals. Emphasis is on understanding how climate change impacts oceanographic condition and the marine biota.

The Stefansson Arctic Institute collaborates with the University of Iceland and other research institutes, nationally and internationally, on projects that address adaptation, resilience and impacts of climate change on Arctic societies.

Polar Law at the University of Akureyri is in interdisciplinary postgraduate program (LLM/MA/Diploma) drawing international law students from around the world

The Centre for Arctic Studies at the University of Iceland coordinates the university's Arctic research and education through its Arctic Initiative.

Audna, Technology Transfer Office, is a part of a Pan-Nordic collaboration network to bring scientific solutions and technology to respond to climate change in the Arctic.

5th International Polar Educators International Conference in Iceland in 2021, will promote the importance of natural science to Icelandic society through support from Icelandic educators.

The Arctic Circle Assembly in Iceland is the largest annual international gathering on the Arctic.

Carbfix Hellisheiði
Credit: Carbfix

Raising awareness and building capacity for science-based policy-making workshop (Rannis, APECS and AWI in October 2019). Credit: Álfrún G. Guðrúnardóttir, Rannis

The Icelandic Arctic Cooperation Network (IACN) facilitates cooperation amongst Icelandic public and private organizations, institutions, business and bodies involved in Arctic research, education, and innovation.

The Northern Research Forum (NRF) at the University of Akureyri provides an international platform for an effective dialogue on Arctic issues between members of the research community and a wide range of stakeholders.

The UArctic Congress will take place in Reykjavík in 2021 in conjunction with the Arctic Council Ministerial.

The SDWG Arctic Human Health Expert Group (AHHEG) and the **Social, Economic, and Cultural Expert Group (SECEG)** currently chaired by Iceland are leading research to identify the spread of COVID-19 and its impacts in the Arctic.

ARCTIC RESEARCH INFRASTRUCTURE

VESSELS

Iceland runs three ice-strengthened multi-purpose ocean vessels suitable for marine biological and oceanographic research as well as marine geophysical surveying.

- **R/V Árni Friðriksson** and **R/V Bjarni Sæmundsson** are operated by the Marine and Freshwater Research Institute and used for inshore and offshore research surveys.
- **Þór** is a multi-purpose vessel of the Icelandic Coast Guard equipped for a wide range of duties including hydrographic surveying and serves as a platform for a variety of research activities.

AIRCRAFT

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

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

FIELD STATIONS

Grímsfjall field station of the Iceland Glaciological Society (www.jorfi.is) is in the centre of the 7700 km2 Vatnajökull glacier It hosts a variety of geophysical equipment that monitors the active volcanoes beneath the glacier as well as isostatic rebound due to glacier thinning. It also serves as a base for mass balance and other glaciological research on Vatnajökull.

The Rif Research Station (RRS) provides access to a research area in Melrakkaslétta, including Iceland's northernmost point. The area allows research and monitoring within the field of natural science (e.g. vegetation, bird life, freshwater biology, coastal ecosystems, geology and geomorphology). RRS is an INTERACT station and is being developed as one of three monitoring stations for the Circumpolar Biodiversity Monitoring Program (CBMP) under the Arctic Council Working Group, Conservation of Arctic Flora and Fauna (CAFF).

China-Iceland Arctic Observatory (CIAO) Is the result of collaboration between the Polar Research Institute of China and the Icelandic Research Centre and is in northern Iceland.

SUPERCOMPUTING

The Icelandic and Danish Met Offices operate a supercomputer in Iceland running numerical weather prediction models. This cooperation provides a basis for expanded weather and climate services in the Arctic on which integrated research on past and future climate change can build upon. This collaboration will be expanded in 2023 when the Netherlands and Ireland join the cooperation under the name of United Weather Center – West.

INDIA

POINTS OF CONTACT

MINISTRY OF EARTH SCIENCES

NATIONAL CENTRE FOR POLAR AND OCEAN RESEARCH

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, marine biology and atmospheric science. Scientific research is implemented by the Ministry of Earth Sciences through the National Centre for Polar and Ocean Research (NCPOR), which is a research and development institute under the Ministry.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

The Ministry of Earth Sciences through its autonomous institute - National Centre for Polar and Ocean Research - funds the Indian Arctic Program, which provides support for all logistical and scientific research activities associated with India's Arctic research station "Himadri" and Gruvebadet atmospheric laboratory located in Ny-Ålesund, Svalbard. The Ministry also supports Arctic research grants to Indian Universities.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

The Kongsfjorden-Krossfjorden system in west Spitsbergen is considered as a natural laboratory to understand local variability in the Arctic as well as ecosystem shifts due to climate change. NCPOR has been continuously monitoring Kongsfjorden since 2010 for understanding response of the fjord to climate variability at different time scales. The fjord is being monitored at close spatio-temporal scales especially in the summer season to decipher the changes in water masses, biota and other chemical parameters. One of the major constraints in such a study has been the difficulty in reaching the location during the harsh Arctic winter and obtaining near-surface data. A major milestone in India's scientific endeavors in the Arctic region has been achieved on the 23rd July, 2014 when a team of scientists successfully deployed IndARC, the country's first multi-sensor moored observatory in Kongsfjorden, roughly half way between Norway and the North Pole. IndARC is programed to collect sea truth data at close temporal scales even during the harsh Arctic winter. The fjord is also being monitored for presence of emerging pollutants and micro-plastics.

The infrastructure at the Gruvebadet atmospheric laboratory is dedicated to understanding various atmospheric parameters like monitoring clouds, precipitation, humidity profiles, etc. The facility houses instruments like the Micro Rain Radar, Ceilometer, Radiometer Profiler, etc. that are being operated continuously streaming data to NCPOR for the last several years. Our confidence in measurements of polar precipitation is low due to the lack of data and the difficulty in separating real precipitation from drifting snow. In order to achieve this goal, a Micro Rain Radar was installed at the Gruvebadet observatory that collects precipitation characteristics at every one-minute interval will help to understand the high latitude precipitation characteristics. The Gruvebadet observatory also serves as an excellent platform for instruments like the quartz crystal microbalance, photo acoustic soot spectrometer, transmissometer, micro aethalometer, high volume sampler, optical particle counter etc. used for the detailed characterization of aerosols.

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 Feringbreen and VestreBroggerbreen glaciers in Ny-Ålesund, Svalbard during summer and winter seasons. Indian researchers have also conducted DGPS and GPR surveys on the glacier to delineate the snout and thickness and volume of ice. Mass balance is also being estimated through preparation of a digital elevation model. Measurements on glacier velocity and ice thickness enable Indian scientists to compute ice flux rates. Snout position is also being monitored by using differential GPS. In addition, Indian researchers have embarked on a mission to target larger glaciers in the Arctic for comparative studies with the Himalayan region.

Monitoring Permafrost
Credit: NCPOR

Environmental survey including plastic pollution
Credit: NCPOR

MoUs have been established with various national universities for jointly undertaking research and supervision of doctoral programs in the field of polar sciences. It is anticipated that this will bring in more trained personnel for polar research to take up larger scientifically and logistically challenging programs covering the entire Arctic. NCPOR is also a member of UArctic.

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 staffed for nearly 180-200 days per year. To date, Himadri has provided base support to over 300 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 and Megha-Tropiques and SARAL with CNES, France.

ITALY

POINTS OF CONTACT

NATIONAL RESEARCH COUNCIL OF ITALY (CNR),
DEPARTMENT OF EARTH SYSTEM SCIENCE AND ENVIRONMENTAL TECHNOLOGIES

ARCTIC RESEARCH POLICY AND GOALS

Italy's Arctic policy aims at increasing knowledge of change in the Arctic, its impacts and feedbacks, through scientific monitoring, multidisciplinary research, and by enhancing international scientific cooperation. This policy was stated in the Italian Arctic Strategic agenda and is implemented by the National Research Council of Italy (CNR), in collaboration with universities and research organizations, including the Italian Space Agency (ASI), National Institute for Oceanography and Experimental Geophysics (OGS), National Institute for Geophysics and Volcanology (INGV), Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Italian Navy Hydrographic Institute. Italy's overarching Arctic research goal is to gain the knowledge needed to understand climate and mitigate its impacts, increase the resilience of natural systems and society, and enable sustainable ecosystem-based management.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

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

CNR supports research activities in the Arctic, such as atmospheric sciences and climate change, geology and geophysics, marine and terrestrial ecosystems, and paleoclimate studies.

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

INGV supports space weather research as well as marine, paleomagnetic and paleoclimatic studies.

OGS supports oceanographic research, particularly along the Fram Strait and in Spitzbergen.

ENEA sustains the activities of the Thule Observatory, contributing to atmospheric physics research.

Ministry of Foreign Affairs and International Cooperation supports international collaborative research projects in the Arctic.

Italian Navy Hydrographic Institute supports oceanographic investigations.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

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

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

MELT. The project aims to strengthen and integrate observations on the interconnected processes involved in climate change by monitoring and investigating Arctic changes along a longitudinal transect.

HIGH NORTH. The benchmarks of the program are ocean knowledge, exploration, new technology, education and monitoring of unsurveyed areas up to the Arctic ice edge. Activities include bottom mapping, water column and seabed features, sub-bottom profiling, acoustic and optical imaging, and remote sensing.

METROLOGY FOR THE ARCTIC. Since 2016, based on a growing collaboration between metrology and environmental sciences (promoted by EURAMET, WMO and National Institutes/Funding agencies), specific actions were developed to improve metrology in the Arctic region (in particular Ny-Ålesund and Svalbard).

ACZ-DYNAMICS. Changes in the Arctic Critical Zone, and their related impacts on ecosystem function and associated biogeochemical fluxes,

The CNR Arctic Station Dirigibile Italia – Ny-Ålesund, Svalbard
Credit: M. Mazzola

The R/V Laura Bassi
Credit: PNRA

are investigated, focusing on the contribution of land ecosystems to the carbon budget.

CNR-ENI. The cryosphere in a changing Arctic project tackles the fundamental mechanisms driving carbon release from Arctic soils across the land-atmosphere-ocean system in three hotspots: Svalbard, Siberia and Alaska.

The Ph.D. Programme in Polar Sciences aims to prepare students with in-depth scientific competences and original and innovative research activities for becoming experts on topics related to recent and past environmental and climate changes of the polar regions.

ARCTIC RESEARCH INFRASTRUCTURE

FIELD STATIONS

CNR Arctic Station 'Dirigibile Italia'. The Arctic station, located in Ny- Ålesund, Svalbard, is a multidisciplinary research station operated by the CNR that can host up to seven scientists in its laboratories and offices. Active since 1997, it is named after Umberto Nobile's airship Italia, used in the 1928 expedition.

The Amundsen-Nobile Climate Change Tower. This facility is connected to the Italian Arctic Station in Ny- Ålesund. The tower is 33 m high and is equipped with instruments to investigate surface radiation and energy budgets and PBL dynamics.

Gruvebadet Atmospheric Laboratory is a modern laboratory equipped with atmospheric and aerosol instrumentation.

Thule Observatory. Inside the THAAO Observatory, ENEA and INGV operate an aerosol/temperature lidar, a water vapor emission spectrometer, and carry out surface radiation and aerosol measurements.

ISACCO network. INGV manages a specially modified GNSS network on Svalbard to monitor and model the upper atmosphere and ionospheric scintillation.

SATELLITE OBSERVATIONS

COSMO-SkyMed is an ASI satellite constellation consisting of four medium-sized satellites equipped with microwave high-resolution synthetic aperture radar operating in the X-band.

VESSELS

In 2019 a polar research vessel was acquired by Italy for the Italian Polar Community. The R/V "Laura Bassi" is managed by a Consortium of the OGS, CNR and ENEA and was operated in Antarctica during the 2019-2020 campaign. A first Arctic Campaign is foreseen for summer 2022.

OTHER INFRASTRUCTURES

SIOS (Svalbard Integrated Arctic Earth Observing System). Italy is member of SIOS, whose goal is coordinating and developing existing and new research infrastructure on Svalbard, in support of the pan-Arctic observing system. SIOS also coordinates open data, transnational access, logistics and training activities.

IADC (Italian Arctic Data Center). This interoperable data center manages Arctic data and observations and is strongly connected with the SIOS Data Management System. The center is operated by the CNR in cooperation with all the other Italian research institutions.

JAPAN

POINTS OF CONTACT

MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE, AND TECHNOLOGY

NATIONAL INSTITUTE OF POLAR RESEARCH

JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY

HOKKAIDO UNIVERSITY

ARCTIC RESEARCH POLICY AND GOALS

In 2015, the Government of Japan adopted its first comprehensive and strategic Arctic policy, Japan's Arctic Policy. The policy clearly states that Japan will: (1) make use of its strength in science and technology, (2) give full consideration to the Arctic environment and ecosystem, as well as (3) ensure the rule of law and promote international cooperation. It is important for Japan to play a leading role for sustainable development in the Arctic with foresight and policy based on science and technology. Japan focused on the Arctic policy as one of the main topics of the Third Basic Plan on Ocean Policy, approved by the Cabinet in May 2018, in order to accelerate addressing Arctic issues. In June 2019, the Councilors' Meeting of the Headquarters for Ocean Policy made recommendations on Arctic policy to specify priorities for the Government to advance the three thematic pillars of Japan's Arctic Policy; Research and Development, International Cooperation, and Sustainable Use. Based on these recommendations, the Arctic Challenge for Sustainability II (ArCS II) was launched in June 2020 as a new national Arctic-research project following on from ArCS (2015-2020).

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

MEXT initiated the 5-year national flagship research project of Arctic Challenge for Sustainability II (ArCS II) in the fiscal year 2020, 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 HU**

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

- The new Japanese Arctic Research Project "Arctic Challenge for Sustainability II (ArCS II)" was launched in June 2020, following the former Project "ArCS" (2015-2020). The new project sets 11 research programs under the following four strategic goals for accelerating Arctic Research.
  - **Advanced Observation of Arctic Environmental Change**
  - **Improvement of Weather and Climate Prediction**
  - **Impact of Arctic Environmental Change on Society**
  - **Legal/Policy Response and Research Implementation for the Sustainable Arctic**

  ArCS II also promotes two priority subjects; "Capacity Building and Research Promotion" and "Strategic Dissemination of Arctic Information." The former subject aims to develop young researchers and human resources who will play active parts in Arctic issues in the future through international research exchanges and overseas fellowship programs. For supporting these programs, ArCS II operates research infrastructures; Field stations, Research vessels, Satellites (described below 4.), and the Arctic Data Archive System (ADS). ADS plays a role as Japan's coordinated data archive system for Arctic research, covering a variety of observed and simulated data, with around 3 million accesses in 2019, most from abroad, as a part of the Global Earth Observation System of Systems (GEOSS) Portal.
- JAMSTEC undertakes the development of technologies related to an autonomous underwater vehicles (AUV) for Arctic Ocean observations. During an Arctic expedition with R/V MIRAI in 2017, JAMSTEC carried out a field test of a compact prototype of such AUV. They are planning to develop underlying technologies for position monitoring of the AUV beneath sea ice and also for its highly-accurate navigation system, with the aim of the practical operation in the Arctic Ocean.
- Principal investigators from HU are currently leading two Belmont Forum Collaborative Research Actions. RACArctic focuses on the 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.

R/V MIRAI and oceanographic observation
Credit: JAMSTEC

New NIPR research station in Ny-Ålesund relocated in 2019
Credit: NIPR

ARCTIC RESEARCH INFRASTRUCTURE

VESSELS

Using R/V MIRAI, JAMSTEC's ice-strengthened research vessel Polar Class 7, Japan primarily conducts oceanographic research and mooring-based observations during the summer, in the Pacific sector of the Arctic Ocean. Studies of the Arctic Ocean marine ecosystem and fisheries are occasionally carried out by T/S Oshoro-maru owned and operated by HU. In addition, Japan has decided to construct an Arctic region research ship with icebreaker capacity as a new international research platform for the Arctic with functions and performance that will facilitate participation in international Arctic region observation programs.

FIELD STATIONS

Field observations are carried out by Japanese researchers based at research stations in the Arctic under the cooperation of respective home countries. Since 1991 NIPR has continued to operate Ny-Ålseund Research Station in Svalbard, Norway, as a core Arctic research station for environmental studies. In addition, Japanese researchers use Poker Flats Research Range in Alaska, USA, Ice Base Cape Baranova in Severnaya Zemlya and Spasskaya Pad Scientific Forest Station in Yakutsk, Russia, Canadian High Arctic Research Station (CHARS), Cambridge Bay, Canada and Centre d' Études Nordiques (CEN), Canada. At these stations, scientists are pursuing environmental research across a variety of disciplines in cooperation with research institutes from other countries. In Iceland, geomagnetically conjugate point to Syowa station, Antarctica is located, NIPR has been operating two auroral stations since 1983.

Affiliated in the EISCAT (European Incoherent Scatter) Scientific Association in 1996, NIPR has been pursuing geospace, and atmospheric sciences in the Arctic with use of the world-largest tri-static incoherent scatter radars in northern Fenno-Scandinavia as a representative institute to Japan. Since 2017 NIPR has also been contributing to the implementation of EISCAT_3D, an ESFRI-Landmark granted project, to construct the next-generation cutting-edge incoherent radar system replacing the existing EISCAT mainland radars.

SATELLITES

The Japan Aerospace Exploration Agency (JAXA) operates the "GCOM-W(SHIZUKU)" satellite to make one-full-day observation images of the Earth. As SHIZUKU flies over the polar regions every 100 minutes, and thus the entire area of the Arctic Ocean can be observed daily with high resolution, one-day images are created, and the data shared publicly. The "ALOS-2(DAICHI 2)" satellite detects changes of permafrost, ground, boreal forest, and sea ice in the Arctic, and its weekly observation data are delivered to MOSAiC international scientific polar expedition from September 2019 to September 2020. "GOSAT(IBUKI)" and "GOSAT-2(IBUKI-2)" observe carbon dioxide, methane, and carbon monoxide to monitor permafrost thaw and wildfires over Alaska. They make intense observations over the validation site in Fairbanks in addition to nominal grid observations. The "GCOM-C(SHIKISAI)," observes aerosols, clouds and ocean color, snow and ice distribution, and snow properties in the Arctic region since December 2017. JAXA is planning to launch several new satellites in coming years; "ALOS-3", a successor of DAICHI's optical mission, in Japanese Fiscal Year (JFY) 2020; "ALOS-4," a successor of DAICHI-2, in JFY2021; and "GOSAT-GW," a successor of SHIZUKU and IBUKI-2, in JFY2023.

THE REPUBLIC OF KOREA

POINTS OF CONTACT

KOREA POLAR RESEARCH INSTITUTE

ARCTIC RESEARCH POLICY AND GOALS

The principal research and policy goals of Korea's Arctic endeavors are: (1) to establish the foundation of knowledge to address climate change and other current global issues; (2) to lay the groundwork for exploring sustainable business opportunities in the Arctic; and (3) to expand partnerships and improve domestic schemes for Arctic activities as a responsible partner. These goals are reflected in the 2018-2022 Policy Framework for the Promotion of Arctic Activities of the Republic of Korea.

Korea's pursuit of Arctic science stems from two central reasons. The first is a desire to better understand and address the globally important issues of the Arctic. Secondly, recognizing Korea's geographical proximity to the Arctic, Koreans have long since understood that events occurring in the Arctic also impact the Korean peninsula, whether through climate change, altered weather patterns, the migration of fish stocks, Arctic shipping route or other economic factors.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

Ministry of Oceans and Fisheries

The Ministry of Oceans and Fisheries (MOF) supports KOPRI's major in-house and ministry-commissioned projects such as the 'Korea-Arctic Ocean Observation System (K-AOOS)', 'Development of KPOPS-Earth and Its Application to the High-impact Weather Events originated from the Changing Arctic Ocean and Sea Ice', 'Korean Arctic Marine Geosciences Expedition (AMAGE)', 'Study on remote sensing for quantitative analysis of changes in the Arctic cryosphere', and 'Advancement into unexplored area in North Greenland through animal evolution research'.

Ministry of Science and ICT

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

Korea Polar Research Institute

The Korea Polar Research Institute (KOPRI), a statutory and government-funded research institution, is the lead agency for Korea's national polar program for both the Arctic and the Antarctic.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

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; and observation, simulation and prediction modelling of the Arctic. Key projects include:

1) Korea-Arctic Ocean Observing System (K-AOOS) The objectives of K-AOOS are to identify key environmental parameters (physical and 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, Future Prediction and development Techniques of useful biomaterials (CAPEC) The objectives of CAPEC are to detect and understand circum-Arctic permafrost environmental change, to develop a prediction model for future change, and to develop practical technologies based on permafrost observation nodes.

3) Development of KPOPS-Earth and Its Application to the High-impact Weather Events originated from the Changing Arctic Ocean and Sea Ice The objective of KPOPS is to tackle the high-impact weather and climate events in the Arctic and East Asia caused by rapid changes in the Arctic ocean and sea ice by advancing diagnosis and forecast technologies based on an earth system model.

4) Korean Arctic Marine Geosciences Expedition (AMAGE) 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.

Overview of the Arctic Dasan Station
Credit: KOPRI

IBRV Araon, Conducting research over the Arctic sea ice
Credit: KOPRI

5) Advancement into unexplored area in North Greenland through animal evolution research This project aims at advancing into unexplored areas in North Greenland by a momentum coming from the early animal evolution research which has been carried out since 2016. The field base established for palaeontological and geological research in Peary Land will be used for multidisciplinary Arctic research in the area, including paleoclimatology, ecology, microbiology, and atmospheric science.

In addition, as an advocate of international cooperation in Arctic research, the Republic of Korea is putting its effort in promoting research collaboration and also to providing future generations of polar scientists with networking opportunities. Some of the key examples are the international fellowship programs provided by KOPRI, which includes:

1) The Arctic Science Fellowship Program is open to early career scientists from Arctic countries (i.e. Canada, Denmark (Including Greenland and the Faroe Islands), Finland, Iceland, Norway, Russia, Sweden and the United States) and researchers who are of Arctic indigenous heritage, who wish to visit and conduct research at KOPRI for a period up to 3 months.

2) The Asian Polar Science Fellowship Program aims to support Asian polar scientists to join either KOPRI headquarters or a KOPRI-organized field research program in the Arctic or Antarctic.

ARCTIC RESEARCH INFRASTRUCTURE

VESSEL

The icebreaker research vessel Araon supports multidisciplinary scientific research encompassing geophysics, biology and oceanography.

FIELD STATION

The Arctic Dasan Station is located in Ny-Ålesund, on the island of Spitsbergen in Norway.

OBSERVATION NODES

With the support of international collaborators, KOPRI operates six pan-Arctic observation nodes:

- **Cambridge Bay, Canada**
- **Council, Alaska, USA**
- **Svalbard, Norway**
- **Nord station, Greenland**
- **Storhofði, Iceland, and**
- **Baranova, Russia**

THE NETHERLANDS

POINTS OF CONTACT

DUTCH RESEARCH COUNCIL (NWO),

MAIN CONTACT PERSON: DICK VAN DER KROEF,
DIRECTOR NETHERLANDS POLAR PROGRAMME

ARCTIC RESEARCH POLICY AND GOALS

The Netherlands Polar Policy operates the Netherlands Polar Programme as its instrument for Arctic research funding. This programme funds high-standard scientific research that adds to knowledge-based policy. The programme has its own strategy (Pole Position-NL). As of 2019, there were four priority themes: (I) Polar cryosphere and oceans, (II) Climate and environmental impacts on polar ecosystems, (III) Economic activities in the polar regions, and (IV) Social-cultural structure and legal policy. The new strategy is due by December 2020.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

The Netherlands Polar Programme secured funding for 2021-2025 and introduced a "rolling budget" for financial continuity. It is supported by five Ministries (Education, Culture and Science; Foreign Affairs; Economic Affairs and Climate Policy; Agriculture, Nature and Food Quality; and Infrastructure and Water Management) and the Dutch Research Council, which operates the program. In addition, the Dutch Research Council operates numerous general instruments to which polar researchers can apply as well. A significant share of polar research is funded decentralized by nine universities and two national institutes (count 2016-2020). The Dutch Research Council has longstanding partnerships with the UK (BAS) and Germany (AWI) concerning logistical and scientific cooperation.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

- In 2019, the Netherlands Polar Programme opened a call for proposals for policy-related polar research projects, which resulted in two major consortium projects. The first concerns Arctic migratory bird ecology, while the second focuses on ice-atmosphere-ocean interactions. Both projects include knowledge policy interaction strategies to deliver evidence-based policy. The Dutch Research Council recently funded two more large projects on Arctic bird ecology and glaciology.
- *The Netherlands secured funding for a dedicated call on polar tourism, funded as a national priority via the Dutch National Science Agenda. This invites, in particular, the social sciences to come with funding proposals, which offers a window of opportunity for interdisciplinary and collaborative research.
- *The Belmont Forum's Collaborative Research Action 'Understanding sustainability and resilience in rapidly changing Arctic climate-socio-ecological systems' resulted in two projects with Dutch presence via the Dutch Research Council's contribution.
- *The Dutch Research Council has a 'Money follows Cooperation' scheme with the respective sister organisations in Norway (2019) and Switzerland (2020). In addition, researchers from all Arctic countries can apply for funding at NWO as co-applicants under this scheme under specific conditions.
- *The second national scientific expedition to Edgeøya, Spitsbergen has been postponed to August 2021 in the slipstream of COVID-19. The original passenger list included forty Dutch and ten international researchers, fifty tourists, and the Minister of Education, Culture and Science. This is the follow-up of the successful *citizen science* expedition in 2015.
- *A new Memorandum with the Alfred Wegener Institute was signed in 2019 and witnessed by their majesties the King and Queen of the Netherlands. The Netherlands participates in the MOSAiC flagship via its Memorandum and three research projects.
- *The Memorandum with the British Antarctic Survey will be renewed in 2021. The Netherlands is exploring additional collaborations to capitalise the value of shared infrastructure, agendas and science.

Minister Ingrid van Engelshoven announces participation aboard the SEES expedition
Credit: Dutch Ministry of Education, Culture and Science

Dutch and Russian Arctic ornithologists on fieldwork in Taimyr, Northern Russia. Credit: Job ten Horn

- The Netherlands Polar Programme is currently developing a new research and funding strategy, *Pole Position-NL*, due in December 2020.
- The ARICE expedition on sub-sea permafrost in the Beaufort Sea (Free University of Amsterdam) has been postponed to autumn 2021.
- *The Netherlands has extended its offer to host the European Polar Board for another five years at the Netherlands Organisation for Scientific Research (NWO) in The Hague until 2025.
- *The Netherlands has become full member to the Arctic Funders Forum and the Svalbard Integrated Arctic Observation System (2019) as well as PAME, IASC and FARO (2020).
- *Note: * indicated international initiatives.*

ARCTIC RESEARCH INFRASTRUCTURE

- The Netherlands has developed the Mobile Laboratory concept that has been successfully implemented at the Dutch Dirck Gerritsz Laboratory at Rothera Station in Antarctica and aboard the *Polarstern* during MOSAiC 2019-2020. It ambitions to further the mobile laboratory concept elsewhere in the Arctic, both land-based and seaborne, for example in Ny-Ålesund, Spitsbergen.
- Access to the *Polarstern* and other Alfred Wegener Institute facilities via a Memorandum of Understanding with the Dutch Research Council.
- Smaller investments can be requested in funding calls-for-proposal of the Dutch Research Council.

FIELD STATIONS

The Netherlands Arctic Station, Ny-Ålesund, Spitsbergen.

NORWAY

POINTS OF CONTACT

RESEARCH COUNCIL OF NORWAY
FUNDING RESEARCH AND INNOVATION AND ADVISES THE GOVERNMENT ON RESEARCH POLICY AND STRATEGIES

NORWEGIAN POLAR INSTITUTE
RESEARCH INSTITUTE AND A DIRECTORATE

ARCTIC RESEARCH POLICY AND GOALS

The objective of Norway's Arctic research is to support quality research to acquire the knowledge needed to implement policy, manage economic activity, and support knowledge-based environmental and resource management. International cooperation is a high priority. Governmental policy guidelines for Norwegian Arctic research and higher education are given in Norway's Arctic Strategy, the Long term plan for research and higher education 2019-2028 and Strategy for research and higher education in Svalbard. Research priorities are also given in the Policy for Norwegian Polar Research (2014-2023) and the Research Strategy for the Ny-Ålesund Research Station (2019).

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

The total Norwegian funding of polar (Arctic and Antarctic) research is more than 200 Million EUR, including investments in research infrastructure. A majority of the funding is for Arctic research. Most of the funding is from the ministries as general university funds and core institute grants, while about 20% is channelled through the Research Council of Norway. There are more than 1900 polar researchers who perform over 950 man-years. Around 70 research institutions carry out polar research.

The High North Research Centre for Climate and the Environment (*The Fram Centre*) in Tromsø, consists of approximately 500 scientists from 21 institutions involved in interdisciplinary research in the fields of natural science, technology and social sciences.

UNIS - The University Centre in Svalbard *is the largest research institution in Svalbard* and offers higher education courses in Arctic disciplines. The Arctic Safety Centre at UNIS opened in 2019 and contributes to a safe and sustainable human activity in the high Arctic trough research and offers courses in Arctic safety.

UiT - The Arctic University of Norway is Norway's largest Arctic research institution and offers education in all polar research disciplines.

Sámi University of Applied Sciences contributes to strengthen and develop Sámi societies, industries, languages and culture.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

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

The Nansen Legacy project (2018 – 2023) is a large research effort to explore and establish a holistic understanding of a changing Arctic ocean and ecosystem. Project leader is from UiT The Arctic University of Norway (UiT).

The Institute of Marine Research's *The Barents Sea and Arctic Ocean Ecosystem Programme is a long-term partnership with the Russian institute PINRO. It is a comprehensive monitoring survey of a marine ecosystem that gathers marine data, commercial fish stocks, and biodiversity information.

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

At the Bjerknes Centre for Climate Research one of four research themes is Polar Climate. The theme is dedicated to understanding change and providing predictability in the Arctic earth system.

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

The Birkeland Centre for Space Science (*BCSS*) at the University of Bergen is dedicated to the coupling of Earth with space through the Arctic.

The Norwegian Mapping Authority's Geodetic Earth Observatory in Ny-Ålesund, Svalbard
Credit: Helge Tore Markussen, Norsk Polarinstitutt

The Norwegian Research Vessel "Kronprins Haakon" in Fram Strait, 2019
Credit: Aleksander Eeg, Norsk Polarinstitutt

Sustainable Arctic Marine and Coastal Technology (*SAMCoT*) at the Norwegian University of Science and Technology is targeted toward developing robust technology for sustainable exploration and exploitation of the Arctic region.

The Centre for Integrated Remote Sensing and Forecasting for Arctic Operations (*CirFA*) at UiT focuses on methods and technologies to reliably detect, monitor, integrate, and interpret multi-sensor data that characterize the physical environment of the Arctic.

ARCTIC RESEARCH INFRASTRUCTURE

VESSELS AND AIRCRAFT

Norway has several research vessels supporting Arctic research, including two which can operate in ice-infested waters; FF Kronprins Haakon and FF Helmer Hansen.

Field stations and other selected infrastructure

- Ny-Ålesund in Svalbard is a permanent Norwegian research station for climate and environmental research which hosts national and international research projects and programmes. Ny-Ålesund serves as an observatory, laboratory, and field base for Arctic research.
- Kjell Henriksen Observatory in Svalbard is an optical observatory that studies the middle- and upper atmosphere.
- EISCAT, the *European Incoherent Scatter Scientific Association* conducts research on the lower, middle, and upper atmosphere and ionosphere. Two of the world's ten incoherent scatter radars are located in Norway, one in Longyearbyen and the other in Tromsø.
- COAT, the *Climate-ecological Observatory for Arctic Tundra* in Northern Norway and in Svalbard is a system for long-term adaptive terrestrial ecosystem monitoring that is based on food-web theory.
- SIOS, *Svalbard Integrated Arctic Earth Observing System*, is a regional research infrastructure consortium hosted by Norway. The goal is to establish an observing system that will improve knowledge of environmental and climatic changes in the Arctic.
- NORMAP, the *Norwegian Satellite Earth Observation Database* for Marine and Polar Research, provides scientists with access to remote sensing products based on data collected north of 55°N.
- INES, *Infrastructure of Norwegian Earth System Modelling* develops and sustains the Norwegian earth system modelling capability including routinely providing simulations for the IPCC assessments.
- The Norwegian Mapping Authority's *geodetic observatory in Ny-Ålesund* plays a key role in providing reference frames and global earth observations.
- The Zeppelin Observatory in Ny-Ålesund, Svalbard, monitors global atmospheric gases and long-range transported contaminants to the Arctic
- Andøya Space Center operates sounding rocket launch bases at Andøya and Ny-Ålesund for polar atmospheric research.

SATELLITES

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

Norway participates in *Copernicus* and in the European Space Agency (ESA) satellite initiative, *Earth Explorers*. The Norwegian satellites NorSat-1 and NorSat-2 are used for vessel detection, space weather and marine communication.

POLAND

POINTS OF CONTACT

COMMITTEE ON POLAR RESEARCH, POLISH ACADEMY OF SCIENCES (CPR-PAS)

POLISH POLAR CONSORTIUM (PKPOL)

CENTRE FOR POLAR STUDIES (CPS)

ARCTIC RESEARCH POLICY AND GOALS

Poland's Arctic research policy is guided by the "Strategy for Polish Polar Research – a concept for the years 2017–2027" prepared by the PKPol and CPR-PAS and legitimated by the Ministry of Science and Higher Education. Four main areas of Polish Arctic research are: (1) the acquisition of more in-depth knowledge of the abiotic components of the Arctic environment, and better understanding of forcings and natural processes and their relations in Arctic, (2) advanced diagnosis of the state of the Arctic ecosystems and identification of essential driving factors influencing their changes; (3) achieving a better understanding of the determinants, course, and consequences of processes related to human activity in polar conditions, and the social dimension of the Arctic; (4) embarking on broader applied research focused on the use of advanced technology in extreme conditions, testing materials, equipment and technical systems, and using Polish polar platforms for space research.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

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

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

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

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

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

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

Polish Polar Station in Hornsund (South Svalbard) operated by Institute of Geophysics Polish Academy of Sciences
Credit: Joanna Perchaluk

RV Oceania – research vessel operated by Institute of Oceanology Polish Academy of Sciences
Credit: Katarzyna Deja

ARCTIC RESEARCH INFRASTRUCTURE

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

VESSELS

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

RESEARCH STATIONS

Polish Polar Station, Hornsund, Southern Svalbard [77°00'N,15°33'E] est. in 1957. Since 1978, this station has been operated as a year-round research facility by the Institute of Geophysics PAS. It is a modern research platform with well-equipped laboratories and satellite communication offering accommodation for 20 scientists in addition to the staff. Continuous observations include: meteorology, air pollution, glaciology, geophysics (e.g., seismology, geomagnetism, atmospheric electricity), permafrost, geomorphology, and the physical oceanography of the fjord system. The Hornsund station is involved in an international cooperation as a member of the INTERACT network and offers local logistical support, field instrumentation, and lab facilities.

UNIVERSITIES FIELD STATIONS IN SVALBARD

- **Stanisław Baranowski Polar Station** of the University of Wrocław (est. in 1971; nicknamed *Baranówka*) is located near the Werenskiold Glacier in southern Spitsbergen.
- **Nicolaus Copernicus University** (in Torun) Polar Station (est. in 1975, nickname *Hahut*) is located in the northern part of Kaffiøyra, northwest Spitsbergen.
- **Adam Mickiewicz University** (in Poznan) Polar Station (*AMPUS*) - the station consists of two modern cabins that are located on the eastern coast of Petuniabukta, Billefjorden, in central Spitsbergen.
- **Maria Curie-Sklodowska University** (in Lublin) Polar Station uses buildings of an abandoned mining settlement Calypsobyen, Bellsund in southern Spitsbergen.

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

PEOPLE'S REPUBLIC OF CHINA

POINTS OF CONTACT

MINISTRY OF SCIENCE AND TECHNOLOGY

ARCTIC RESEARCH POLICY AND GOALS

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

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

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

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

National Natural Science Foundation of China (NSF). Following the geoscience development plan, NSF establishes priority research topics, such as in ocean and atmospheric science, ice sheet/ice shelf interaction, subglacial remote sensing, and information management.

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

China Meteorological Administration (CMA). CMA focuses on Arctic meteorological observations, modelling, and analysis. It funded the development of the FengYun meteorological satellite constellation.

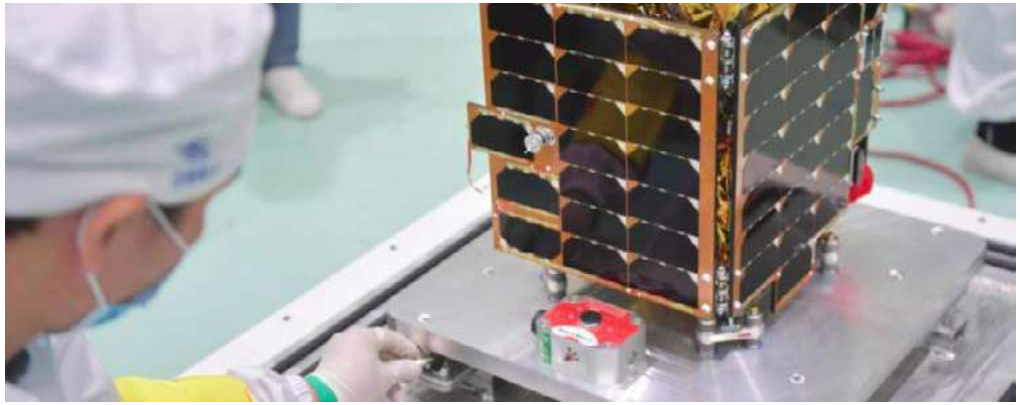
MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

Northern Hemispheric Cryosphere Change, Its Effects and Adaptive Strategy Project. 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. Focusing on Arctic amplification phenomenon and ocean forcing effects, they analyse the critical physical processes and interaction mechanisms among sea ice, ocean, and atmosphere that result in Arctic amplification.

***Polar Environment and Climate Change (PECC).** To understand the physics of rapid climate and environmental change in the Arctic and Antarctic and to uncover their connection with and feedback to the global Earth system and to contribute to the global society, PECC will coordinate the research resources in China and seek widely for collaborations with global communities.

China's icebreaker Xue Long 2
Credit: JiMei University



BNU-1
Credit: http://www.ecns.cn

ARCTIC RESEARCH INFRASTRUCTURE

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

VESSELS

MV Xuelong was built in the Ukraine in 1993. In 2007, it was ice-strengthened to CCS Ice Class B1 (capable of proceeding at 1.5 knots in 1.1 m ice with 0.2 m snow depth) and can carry two helicopters. The vessel has laboratories for marine physics, chemistry, biology, and meteorology, as well as a data processing centre.

Xue Long 2 is China's first domestically built polar research icebreaker, with a total length of about 122.5 m and displacement of nearly 14,000 tons. "Xue Long 2" is equipped with deep and medium water multi-beam system, deep-sea shallow stratigraphic profiler, biological reserve evaluation echo integrator system, underwater omni-directional sonar, ultra-short baseline, 10000 m sounder and other acoustic equipment.

FIELD STATION

The first Chinese Arctic scientific research field station, "Yellow River," was established in July 2004 at 11°56'E, 78°55'N in Ny-Ålesund, Spitsbergen, Norway. The 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.

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.

CBERS-01/02/02B/02C/04 investigates Earth resources with multi-spectral, moderate resolution and large swath imaging. The satellites are especially designed to resolve the broad range of space and time scales involved in the monitoring of earth's environment and resources.

HJ-1A/1B/1C is a constellation that investigates environmental conditions and forecasts hazard information. The constellation can carry out large-scale, all-weather and 24 h dynamic monitoring for the ecological environment and disasters. These satellites are equipped with four remote sensors, comprising a more complete earth observation remote sensing series.

FY-1A/1B/1C/1D/2C/2D/2E/2F/3A/3B/3C/4 is a polar-orbiting and geostationary constellation that provides measurements of atmospheric conditions. The new generation FY-4 satellites are designed with an enhanced imagery scanning capability, desirable for monitoring small and medium scale weather systems.

Ice Pathfinder satellite is specifically designed to study polar climate and the environment in rapidly changing polar regions by providing high-quality, high-frequency multi-spectral remote sensing data. The satellite has rrecentlyy started its Arctic observation mission, during which is expected to achieve a full coverage of the Arctic in seven days.

PORTUGAL

POINTS OF CONTACT

MARIA JOÃO PINTO

TIAGO SABORIDA

MARIA GERMANA SANTOS

ARCTIC RESEARCH POLICY AND GOALS

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

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

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

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

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

Portugal has a long history of navigation, including the Polar and Sub-Polar regions. Following the 4th International Polar Year 2007-08 Portugal started the implementation of a national program for Polar research - the Portuguese Polar Program (PROPOLAR) - created within the Portuguese Foundation for Science and Technology (FCT, I. P.). PROPOLAR opens annual calls for Polar research projects and has funded 26 projects in the Arctic and Sub-Arctic since 2013 focusing on themes such as atmospheric aerosols, terrestrial and marine biogeochemistry, permafrost and ecosystem dynamics, bird ecology, and marine zooplankton.

Portugal has been a member of the European Polar Board since 2006, the Forum of Arctic Research Operators since 2014 and the International Arctic Science Committee since 2015. For the first time, Portugal will host the Arctic Science Summit Week (ASSW) in March 2021, in Lisbon. FCT, I. P. is also committed to the IASC cross-cutting program T-MOSAiC (Terrestrial Multidisciplinary distributed Observatories for the Study of Arctic Connections) with the international secretariat being hosted at the University of Lisbon and with two Portuguese on the Steering Committee (the Chair and a member). Portugal is represented in Polar scientific organizations such as the International Permafrost Association and the International Association for Cryospheric Sciences, and in international programs such as the Global Terrestrial Network for Permafrost (GTN-P/IPA/GCOS), with a Portuguese scientist on the Steering Committee. Portuguese research institutions participate in the EU Arctic cluster projects EU-POLARNET and NUNATARYUK. Portuguese research in the Arctic has been essentially conducted via partnerships with Canadian, Icelandic and Norwegian institutions. A MoU with Spain on Polar research was signed in 2009 and has been implemented mainly in the Antarctic, with a new cooperation strategy being fostered for the Arctic.

In 2017 FCT, I. P. initiated the process of developing a Research & Innovation Agenda in Polar Sciences and Technologies, a strategic document that is to be completed by the end of 2020 and that has mobilized experts from R&D institutions and companies in the identification of challenges and opportunities in the national scientific and technological system, especially in medium and long-term perspectives.

Portugal is leading the Atlantic Interactions Initiative, a new intergovernmental initiative to unleash the potential of the Atlantic for Society to be implemented through the Atlantic International Research Centre (AIR Centre). It fosters knowledge-driven solutions for Atlantic and Global Societal challenges that require interdisciplinary research and innovation of complex Earth systems through cooperation targeting the Atlantic. Within this strategy the Polar Regions play a key role, since they are deeply inter-related with Atlantic Ocean processes and dynamics and influence the whole circum-Atlantic region. Portugal's contribution to Arctic science will hence be mainly associated to the AIR Centre and fostered within its flagship initiatives, as follows:

UAV remote sensing for lake colour analysis and vegetation mapping near Kuujjuarapik, Nunavik (Canada)
Credit: Ana Padeiro

Monitoring coastal erosion in Yukon (Canada). Project Nunataryuk.
Cooperation University of Lisbon, Alfred Wegener Institute and Geological Survey of Canada. Credit: Gonçalo Vieira

- The development of a collaborative scientific infrastructure designated ***Atlantic Pole to Pole Observation System of Systems (APPOSS)*** to set-up an holistic framework to provide the required measurements and to deliver the required services to cope with the identified user needs in Atlantic regions; and
- An ***All Atlantic Constellation of small satellites*** which will use polar orbits, whereas is planning to have key data/images downlinking location in the polar region.

The national framework for supporting Polar science implemented during the last 13 years has enabled a steady growth of the Portuguese scientific community in conducting Arctic research and promoted international cooperation with Arctic and non-Arctic nations.

ARCTIC RESEARCH INFRASTRUCTURE

VESSELS

Not applicable.

FIELD STATIONS

Not applicable.

SATELLITES

Not applicable.

REPUBLIC OF SINGAPORE

POINTS OF CONTACT

NATIONAL UNIVERSITY OF SINGAPORE

NANYANG TECHNOLOGICAL UNIVERSITY

SINGAPORE MARITIME INSTITUTE

MARITIME AND PORT AUTHORITY OF SINGAPORE

METEOROLOGICAL SERVICE SINGAPORE

MINISTRY OF FOREIGN AFFAIRS

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) increase 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 resulting from new sea routes, and by balancing sustainable economic development with environmental concerns and the needs of local communities.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

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

Nanyang Technological University (NTU). The Climate and Ecology Groups at NTU's Asian School for the Environment and Earth Observatory of Singapore are exploring the earth structure beneath the Arctic, researching the sensitivity of Arctic land ice to climate variability and its future impact to the sea levels of Singapore, the response of large Arctic Rivers to global change, and the impact of land-use change on biodiversity. NTU's School of Civil and Environmental Engineering is investigating wave-ice interactions and modelling of oil spills in arctic waters.

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 of Singapore (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 promote 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.

Sam Tan N.Parks and Norwegians
Credit: National Parks Board, Singapore

Study visit
Credit: Ministry of Foreign Affairs, Singapore

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING 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 program, 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 trends and developments in Ocean and Environmental Governance as well as International Regulation of Shipping. Among the issues studied under this program are developments in the regulation of shipping activities in the Arctic including the Polar Code, and oil spill preparedness response and cooperation.

ARCTIC RESEARCH INFRASTRUCTURE

Technology Centre for Offshore and Marine, Singapore (TCOMS). Jointly established by the Agency for Science, Technology and Research (A*STAR) and the National University of Singapore (NUS) in Oct 2016, TCOMS is a national R&D center focused on the Marine & Offshore industry. TCOMS's state-of-the-art deep-water ocean basin is scheduled for completion in Q1 2021. When completed, it will be capable of integrating numerical simulations with physical testing to develop innovative and more cost-effective solutions to operate in challenging environments such as those in the Arctic.

RUSSIA

POINTS OF CONTACT

RUSSIAN MINISTRY OF SCIENCE AND HIGHER EDUCATION

RUSSIAN MINISTRY OF FAR EAST AND ARCTIC DEVELOPMENT

FEDERAL SERVICE FOR HYDROMETEOROLOGY AND ENVIRONMENTAL MONITORING

ARCTIC RESEARCH POLICY AND GOALS

- **Socio-economic development**
- **Development of infrastructure, science and technology**
- **Ensuring environmental and national security**
- **The Northern Sea Route and its infrastructure**
- **Human resources and competence development**
- **Geological prospecting and subsurface exploration**
- **Support indigenous minorities, preserve traditional trades and crafts, and protect the environment**

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

Ministry of Science and Higher Education of the Russian Federation. Funds basic scientific research and expeditionary research. Supports research and development work on a competitive basis.

Supports targeted civilian research and development projects, provides grants to support young Russian scientists and leading scientific universities.

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

Ministry of Economic Development of the Russian Federation. Conducts applied economic research to achieve practical goals in key areas of economic development in the Russian Arctic.

Ministry for the Development of the Far East and the Arctic of the Russian Federation. Performs functions in the creation and functioning of territories of advanced socio-economic development in the Arctic zone of the Russian Federation, as well as the elaboration of state policy and statutory regulation in the field of Russian Arctic zone development.

Russian Ministry of Energy. Considers issues of governmental support for Arctic hydrocarbon resource development, oil and gas mechanical engineering development for the northern territories, vessels and marine equipment supply for the shelf projects and the Northern Sea Route development.

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

SCIENTIFIC FOUNDATIONS/ORGANIZATIONS

The Russian Science Foundation supports projects of fundamental, exploratory, and applied research in the Arctic.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

Currently there are about 100-150 international programs, projects and grants underway each year in the Russian Arctic.

- Basic Principles of the State Policy of the Russian Federation in the Arctic for the period up to 2020 and further on
- State Development Strategy of the Russian Arctic zone and ensuring national security
- State program Social and Economic Development of the Russian Arctic Zone
- Concept of sustainable development of the indigenous peoples of the North, Siberia, and the Far East
- Comprehensive program of expeditionary research on the Svalbard archipelago
- Program of marine expeditionary research by organizations under the Russian Ministry of Science and Higher Education (regarding the Arctic seas)
- Program of scientific and technical cooperation in the Arctic and northern regions
- Interdepartmental program of scientific research and observations on the Svalbard archipelago.
- Arctic Council Chairmanship program

Arctic-M No.1 launch (February 28, 2021, Baikonur Cosmodrome)

Nuclear icebreaker «Arktika» reached the North Pole (October 3, 2020)

ARCTIC RESEARCH INFRASTRUCTURE

At present there are about 10 international scientific centers for Arctic research operating at Russian universities.

12 scientific organizations from Roshydromet, the Russian Ministry of Natural Resources and the Russian Academy of Sciences are conducting research, including internationally, on the Svalbard archipelago (Norway).

VESSELS

The years 2019-2020 alone saw more than 20 Arctic marine research expeditions conducted on scientific expedition vessels and 6 voyages of the Floating Arctic University, which involved more than 1,000 scientists from 40 Russian and 20 foreign scientific organizations.

The Russian icebreaker fleet counts 40 ships; 5 of them are nuclear-powered. In the next few years, three universal nuclear-powered icebreakers are to join Rosatomflot.

A concept of the Great Arctic Regatta project has been prepared as a unique event which is a northern sailing yacht race combined with scientific research and cultural events.

The Russian Federation expresses its readiness to develop large-scale expedition research in the Arctic Ocean basin by organizing research projects similar to “TransArktika-2019” and involving specialists from foreign research centers.

The seasonal Arctic expedition “North-2021” started on April 1. In the coming years, it will be possible to expand research into the high-latitude Arctic environment and supplement the data of Roshydromet’s observation network by commissioning a new research vessel - the ice-resistant platform “North Pole”.

FIELD STATIONS

Every year there are 4-5 international polar stations functioning in the country, 6-8 international scientific laboratories have been established for Russian Arctic research.

There is a stationary ground network of 52 operating stations providing hydrometeorological information.

Year-round Russian drifting stations conduct a comprehensive research program in oceanography, glaciology, meteorology, aerology, geophysics, hydrochemistry, hydrophysics and marine biology.

Modern coastal research infrastructure in the Arctic regions of the Russian Federation includes the Russian Research Center (Svalbard Archipelago), research stations (Samoilovsky Island), “The Ice Base of Cape Baranov”, a hydrometeorological observatory (Tiksi), a network of research stations (Yamal Peninsula) and other facilities.

The test grounds called “Yary” and “Khanovey” were set up and developed on a comprehensive study of the dynamics of changes in natural conditions in the Arctic regions. In 2020, a project to create the Varandey test ground was developed to elaborate adaptation programs for existing and planned infrastructure facilities.

An experimental model of an autonomous automatic meteorological station “Arktik-Meteo” was designed and created.

SATELLITES

As part of the highly elliptical hydrometeorological space system 2 Arktika-M satellites and 3 Electro L satellites will provide all-weather monitoring of the surface of the Arctic Ocean land and seas as well as continuous and reliable communication and other telecommunication services.

SPAIN

POINTS OF CONTACT

SPANISH POLAR COMMITTEE

SPANISH AGENCY FOR RESEARCH

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.
6. Aligns with the Arctic strategies developed by the EU and encourages active participation in the design and development of corresponding policies.
7. Considers the option of becoming a full member of the Barents Euro-Arctic Council (BEAC), taking into account, among other factors, the EU's involvement in BEAC, and the major energy resources existing in the Barents region. Spain is currently an observer at the CBSS (Council of the Baltic Shore States).
8. Fosters the creation, within the framework of the EU Council, of a specialized commission devoted to polar issues (CPOLAR) as part of the EU's Common Foreign and Security Policy (CFSP).
9. Promotes the necessary measures for free, safe, and environmentally-friendly trans-Arctic maritime transit, in strict compliance with the 1982 UNCLOS and the IMO's International Code for Ships Operating in Polar Waters (Polar Code), the natural multilateral framework for managing navigation issues, including polar navigation.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

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

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING 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.

Greenland
Credit: Marc Oliva

Svalbard
Credit: Antonio Quesada

Biodiversity of Arctic Terrestrial and Freshwater Ecosystems. CLIMARCTIC. The initiative is aimed at studying the effects of climate change on the diversity and genetic functional attributes (nutrient and carbon cycling) of a High Arctic terrestrial microbiome in soils, wetlands and lakes.

Ice Thickness of Svalbard and Greenland Glaciers. The goal is to follow and forecast the ice dynamics and mass balance changes of small glaciers in the Arctic, as a consequence of climate change.

Arctic glaciers and their contribution to sea-level-rise. The goal is to estimate the iceberg calving and submarine melting in Arctic tidewater glaciers combining oceanographic, glaciological and remote sensing observations with modelling of glacier thermo-mechanics and fiord water circulation.

Biocomplexity and functioning of the cryptogamic cover in arid and polar regions (crypto-cover) The main goal is to increase the knowledge about diversity, photosynthetic performance under natural conditions and annual growth of lichen components of the Arctic tundra and their response in a climate warming scenario.

Diversity and geomicrobiology of polar microbial ecosystems (ROCK_EATERS). The project is aimed at characterizing and comparing the dynamics of colonization and weathering processes along microbial primary succession processes in glacier forefields and lava flows.

Satellite observations, modelling and prediction. Assess the impact of the new SSS satellite data in a data assimilation system. Improve European capacity for monitoring and forecasting the Polar Regions. To derive new sea ice and snow emissivity models to improve the satellite measurements of those variables.

Global change effects in terrestrial and inland water ecosystems across time. This initiative aim is to provide long-term paleoecological records to understand arctic ecosystems responses (processes and long-term dynamics) to current to global change (e.g. climate, air pollution, connectivity).

Glacier response to changing climate conditions in the past- PALEOGREEN. To reconstruct glacial oscillations and climate variability from lake sediments since the Last Glacial Maximum.

Ecophysiological and evolutionary roots of multiple stress tolerance in plants- EREMITA. The project aims to test the hypothesis for a trade-off between productivity potential versus multiple stress tolerance in terrestrial plants across the phylogenetic scale, and searches for its mechanistic bases. Ecophysiological and molecular traits in plant species from the most extreme (stressful) environments, including the Arctic, are being studied.

Interactions atmosphere-ice-ocean. To identify atmospheric aerosols emitted in the Arctic, their biological origin and their impact on the indirect radiative effect.

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

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

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, Iceland, Canada, Svalbard and Siberia. New polar vehicles, such as a wind sledge developed by a Spanish explorer as are the means for ultrapure sampling, have been successfully working in the Arctic and Antarctic.

RESEARCH VESSELS

RV Hespérides (Polar Ship Lloyd Ice Class 1C), and **RV Sarmiento de Gamboa** (certified under category C of the Polar Code) have been operating in both polar regions. A new polar vessel is expected to be purchased in next few years.

SWEDEN

POINTS OF CONTACT

MINISTRY OF EDUCATION AND RESEARCH

THE SWEDISH RESEARCH COUNCIL

THE SWEDISH RESEARCH COUNCIL FORMAS

THE SWEDISH POLAR RESEARCH SECRETARIAT

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 also to play a leading role in international polar research.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

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

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

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

The Swedish Polar Research Secretariat. The Secretariat's primary mission is to organize and provide infrastructure for polar research expeditions. The Secretariat runs the research-equipped icebreaker Oden, and when needed lease other ice breakers for polar expeditions, the field station Abisko, and two research stations on Antarctica, *Swea* and *Wasa*.

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

All major universities have departments for polar research. Stockholm University is responsible for the research station at Tarfala Valley where glacier expansion and retreat are monitored. Umeå University has a department for social science and humanities on polar regions and conditions. Göteborg University has a research station for marine research which includes the polar waters. At Göteborg there are also a number of scientists with a focus on Antarctica.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

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

In 2018, a collaborative expedition with the United States (National Science Foundation) using icebreaker *Oden* focused on enhanced understanding of biogeochemical processes contributing to cloud formation in the Arctic. These are of crucial importance to improve the knowledge of the weather system and will enhance weather and climate predictions. The expected enhanced process understanding will support the interpretations of the data collected during the MOSAiC Expedition. The cruise will also contribute to the data collection of the WMO campaign Year of Polar Prediction (YOPP). During 2019 an expedition to Greenland was performed. Due to the Covid-19 crisis all expeditions during 2020 have been suspended. Sweden has an earlier commitment to supply Polarstern I during MOSAiC and is planning to perform this despite other activities being closed.

Another strong Swedish focus in field-based science has involved a multi-year pan-Arctic field campaign investigating the effects of past, present and future climate change on Arctic ecology with specific focus on Arctic islands as ecological refuges.

Photo caption: Oden during the Petermann Expedition 2015

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

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

Regarding capacity building, all universities and university colleges with research on polar issues also have programs for teaching in these areas. The scientific research programs have graduate students in all these areas.

ARCTIC RESEARCH INFRASTRUCTURE

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

VESSELS

Research-equipped icebreaker Oden, and aided by other Swedish and international icebreakers as required.

The research equipped Swedish icebreaker Oden is 108 meters long and displaces 13 kilotons.

FIELD STATIONS

Abisko Scientific Station, The Tarfala Research Station, SITES.

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

The Tarfala Research Station, run by Stockholm University, in the Tarfala Valley, has been systematically monitoring the major glaciers since 1910, and annually monitoring the largest glacier since 1946. Starting in 1980, all glaciers in the valley have been monitored.

Swedish Infrastructure for Ecosystem Science (SITES), funded by the Swedish Research Council, is nationally coordinated infrastructure for terrestrial and limnological field research. The research locations are situated along a gradient from arctic, to sub-arctic, to temperate climate zones.

UPPER ATMOSPHERE STUDIES

European Incoherent Scatter Scientific Association, (EISCAT) operates three incoherent scatter radar systems in Northern Scandinavia to study the interaction between the Sun and the Earth as revealed by perturbations in the ionosphere and the magnetosphere. The system is currently being upgraded to EISCAT_3D, which is a multistatic radar with five antenna systems to measure the geospatial environment and its coupling to the Earth's atmosphere from its location in the auroral zone at the southern edge of the northern polar vortex. EISCAT_3D is planned to be up and running from 2021.

SWITZERLAND

ARCTIC RESEARCH POLICY AND GOALS

Switzerland's great commitment to the Arctic finds its origins in the nature of the Swiss landscape, which – like the Arctic – has been shaped by ice ages and is composed of mountain ranges with disappearing glaciers. Thus, the Swiss research community interweaves high-altitude with high-latitude knowledge. Its scientific excellence lies in the research on climate conditions and ecosystems in mountain and Polar Regions, e.g. to measure the impact of human-induced changes on the environment and the global climate. Research has set interdisciplinary goals, which are achieved by means of international and multi-stakeholder collaborations, through international science programs such as in the framework of the International Arctic Science Committee (IASC). In 2017, Switzerland was granted the status of "Observer State" to the Arctic Council, in recognition of the country's long-standing commitments to research excellence and to peaceful international cooperation for the advancement of scientific knowledge and for the mitigation of the environmental and socio-economic impact of the changes happening in the Arctic.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

In Switzerland, research funding to institutions and individuals is awarded through a competitive system and according to qualitative assessment criteria. Mandated by the Swiss federal authorities, the Swiss National Science Foundation (SNSF) supports basic science in all academic disciplines. The government also provides funding to the research institutes within the Domain of the Federal Institutes of Technology as well as to thirty other research institutes.

Switzerland was fully associated to Horizon 2020 and is linked to the climate and polar topics currently underway. Swiss researchers contribute significantly to flagships scientific projects of the EU Research Framework Programs, such as Beyond EPICA (search for oldest ice on Antarctica to reconstruct climate history) and CHARTER (drivers and feedbacks of changes in Arctic terrestrial biodiversity).

The Swiss Polar Institute (SPI), established in 2016, offers funding to researchers to complement the available SNSF funding to cover logistical and fieldwork expenses. SPI also funds Swiss participation in international initiatives such as MOSAiC or ICE Memory and organizes scientific expeditions with international participation as well as health and safety training courses. The SPI further performs targeted research expeditions. It represents Switzerland in Arctic logistics organizations such as FARO and takes part in EU PolarNet.

The Swiss Committee on Polar and High-Altitude Research (SCPHAR), of the Swiss Academies of Arts and Sciences, coordinates the polar and high-altitude research community. In addition, it represents Switzerland in international scientific organizations, such as IASC.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

The Swiss Arctic science landscape is very diverse, with scientific activities spreading over thirteen academic institutions in areas such as glaciology, climatology, atmospheric sciences, biology, geophysics, geology and ethnology. Four research foci were identified in the Swiss Polar Institute's Science Plan, based on current strength of the science community and future research topics:

1. **Cryosphere through time – processes, feedbacks and responses,**
2. **The carbon, nitrogen, water cycle nexus – past, present, future,**
3. **Biodiversity and ecosystem functions, and**
4. **Technology in extreme environments.**

Further, an increasing interest of the social sciences and humanities in Arctic research is developing. A selection of recent and future research activities is highlighted below:

Arctic Century Expedition. The Swiss Polar Institute is partnering with Geomar (Germany) and AARI (Russia) for an interdisciplinary expedition to the northern Russian islands in the Kara sea, planned for late summer 2021.

POINTS OF CONTACT

SWISS COMMITTEE ON POLAR AND HIGH ALTITUDE RESEARCH

SWISS POLAR INSTITUTE

FEDERAL DEPARTMENT OF FOREIGN AFFAIRS

Sphinx Observatory above the Jungfraujoch
Credit: Jungfraubahnen 2019

Swiss atmospheric measurement container alongside other projects' containers on Polarstern during MOSAiC. Credit: Manuel Ernst

ARCTIC RESEARCH INFRASTRUCTURE

MOSAiC. During the one-year-long Multidisciplinary drifting Observatory for the Study of Arctic Climate expedition (2019-2020), Swiss scientists focused on atmospheric studies, snow observations and sea ice remote sensing, contributing to three major themes of the expedition.

IPICS 2021. Polar and high-altitude ice cores provide unique information about past climate and environmental conditions as well as direct records of the composition of the atmosphere on timescales from decades to hundreds of millennia. In October 2022, Switzerland will host the 3rd Open Science Conference of the International Partnerships for Ice Core Sciences (IPICS).

WGMS. For more than a century, the World Glacier Monitoring Service (WGMS) and its predecessor organizations have compiled and disseminated standardized data on glacier fluctuations. The WGMS annually collects glacier data through its scientific collaboration network active in more than 30 countries.

FIELD STATIONS ON GREENLAND

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

FIELD STATION IN THE RUSSIAN ARCTIC

Chokurdakh Station (71°N, 147°E) is a tundra field station in northeastern Siberia, located in the Kytalyk Nature Reserve, 100 km south of the Arctic Ocean. The field station belongs to the EU-INTERACT station network. The University of Zurich performs biodiversity and ecosystem functioning field work at the station since 2009. Significant research infrastructure has been contributed to the station through Swiss funding.

JUNGFRAUJOCH FIELD STATION IN SWITZERLAND

Research Station and Sphinx Observatory at Jungfraujoch provides the infrastructure and support for international scientific research carried out at an altitude of 3,000-3,500 m above sea level in a high alpine climate and environment, accessible by the Jungfrau railway. The station is used to test instrumentation in harsh climatic conditions before employment in the Arctic.

SATELLITES

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

UNITED KINGDOM

POINTS OF CONTACT

NATURAL ENVIRONMENT RESEARCH COUNCIL ARCTIC OFFICE

ARCTIC RESEARCH POLICY AND GOALS

To support independent and rigorous research of the highest quality to address the most important questions. To better understand the role the Arctic plays within the global system (past, present and future), as well as to develop practical responses in the face of unprecedented change. The UK's approach recognizes that increasing international and multidisciplinary collaboration is vital for tackling the most pressing research questions.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

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

UKRI & Research Councils, such as those for Engineering and Physical Sciences, Arts and Humanities and Economic and Social research, support a range of research activities in the Arctic. All the Research Councils and Innovate UK sit within United Kingdom Research and Innovation (UKRI). As a result, there are increasing opportunities for multi-disciplinary, inter-Council funding and research.

Government Departments, such as the Department for Business, Energy and Industrial Strategy (BEIS), the Foreign and Commonwealth Office (FCO), the Ministry of Defence, the Department for Transport and their delivery agencies provide support to facilitate research, often in coordination with other partners. In partnership with BEIS the Meteorological Office supports and delivers significant climate modelling research. BEIS directly supports the UK-Canada and UK-Russia Arctic Bursaries Programmes. The UK Science and Innovation Network (BEIS & FCO) actively supports the UK's bilateral and multilateral Arctic collaborations with Arctic States including Russia, Finland, Norway and Canada.

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

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

NERC Changing Arctic Ocean: Implications for Marine Biology and Biogeochemistry. This £20m program (2017-2022) explores the effects of changes to the physical environment (ice and ocean) on the marine ecosystem and the associated biogeochemical functioning of the Arctic Ocean. Its 16 projects involve 170 investigators from 15 countries in addition to the UK and Germany. Three seasons of science cruises in the Barents and Greenland Seas have been completed, as well as additional field work in other locations. The programme is substantially funded through the UK's first at-scale Arctic research collaboration with BMBF (Germany).

The EU Polar Cluster is a gathering of 14 large interdisciplinary Arctic-centric projects funded by the EU. UK universities and research centers have broad participation within most of these projects, including at the highest levels of coordination and management.

MOSAiC. The UK was the first formal MOSAiC partner outside the expedition organisers of Germany, Russia and the US. With over a £2m financial investment from BEIS and NERC, seven teams of UK-based researchers conducted research on this unique expedition to the Arctic Ocean in 2019-20.

Centre for Polar Observation and Modelling (CPOM) operates as a multi-site center studying polar latitudes. It leads international efforts to measure and predict the sea level contribution due to the polar ice sheets, partners with space agencies to provide scientific leadership for polar satellite missions, produces and distributes unique and widely-used records of Earth's sea ice and ice sheet thickness change, and supports the land ice and sea ice elements of the UK Earth System Model. 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.

The new polar research vessel, RRS Sir David Attenborough
Credit: Rich Turner

UK Arctic Research Station, Ny-Ålesund, Svalbard
Credit: British Antarctic Survey

ARCTIC RESEARCH INFRASTRUCTURE

VESSELS & AUTONOMOUS VEHICLES

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

- The ice-strengthened vessel **RRS *Sir David Attenborough*** will provide a step-change in the ability to carry out complex and multi-task research in polar regions on entering service. The **RRS *James Cook*** and **RRS *Discovery*** are 'blue water' vessels capable of Arctic work.
- Research centers such as the National Oceanographic Centre, British Antarctic Survey, and the Scottish Association for Marine Sciences operate a fleet of autonomous vehicles, and develop new capabilities, including under-ice endurance, navigation and capability.

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) are operated by BAS; and a BAe-146 large atmosphere research aircraft is managed by the Facility for Airborne Atmospheric Measurements.

FIELD STATIONS

- **Ny-Ålesund.** The UK Arctic Research Station in Ny-Ålesund, Svalbard (Norway) is funded by NERC and operated by BAS. It provides facilities and accommodation for researchers to carry out environmental science research. Access by international researchers is welcome through partnership with UK teams or through the EU's **INTERACT** program.
- **Remote Field camps:** The UK has the expertise to organise and deliver remote field camps, on glacial ice, sea ice and land within remote and difficult-access regions of the Arctic.

SATELLITES

- The UK is a key partner in current and planned satellite systems including, through CPOM CryoSat2 operated by the European Space Agency (ESA) which measures the thickness of sea ice and monitors changes to the Greenland ice sheet and its successor, CRISTAL, which is in development by ESA and the European Commission. Data used from other satellites includes:
- **Sentinel-1 and Sentinel-3 (ESA) monitoring sea ice, glaciers and ice sheets.**
- **ERS-1, ERS-2, and ENVISAT (ESA) in determining recent changes to the Arctic.**
- **Terrasar-X (DLR)**
- **ICESat-1 and ICESat-2 (NASA)**
- **ALOS (JAXA)**
- **AltiKa (CNES-ISRO)**

UNITED STATES OF AMERICA

POINTS OF CONTACT

INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

U.S. ARCTIC RESEARCH COMMISSION

ARCTIC RESEARCH POLICY AND GOALS

U.S. Arctic policy focuses on scientific observing and research on climate, the environment, and other topics, involves Indigenous communities, and promotes international scientific collaboration. Policy implementation increases understanding of the Arctic, which supports science-informed decision-making.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

National Aeronautics and Space Administration (NASA). The Earth Science Program is a comprehensive, global approach to Earth System Science. The program's observations, research, and modeling of Arctic oceans, atmosphere, ice, permafrost, carbon, and ecosystems strive to understand the Arctic and its role in the global system, thus improving our knowledge of Arctic change, impacts, and resilience.

National Science Foundation (NSF). NSF supports basic research that advances understanding of engineering, physical, biological, geological, chemical, education, social and cultural processes in the Arctic, and the interactions and connections of oceanic, terrestrial, atmospheric, biological, and human systems within the Arctic and between the Arctic and global systems.

National Oceanic and Atmospheric Administration (NOAA). NOAA's research: (1) supports sea ice, weather, and water forecasts and warnings; (2) strengthens scientific understanding of oceanic, ice, atmospheric, and ecosystem processes; (3) enhances national and international partnerships; (4) improves stewardship and management of ocean and coastal resources; and (5) advances resilient and healthy communities and economies.

Department of the Interior (DOI). Protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities and special commitments to Alaska Natives and other Indigenous Peoples.

Department of Energy (DOE). Supports research on Earth system predictability aligned with DOE's science and energy missions. DOE strives to understand and quantify the drivers, interactions, and feedbacks of the Earth system components, with dedicated Arctic research based on long-term observations, field experiments, system modeling, simulations, uncertainty characterization, and data analytics.

Department of Defense (DOD). The U.S. Army Cold Regions Research and Engineering Laboratory provides basic and applied research and engineering solutions. The Office of Naval Research (ONR) supports research to better understand and predict the physical environment of the Arctic Ocean at a variety of time and space scales via new technologies and integrated models.

Department of Health and Human Services (DHHS). The National Institutes of Health and the Centers for Disease Control and Prevention conduct and support research to improve human health in the Arctic.

Department of Homeland Security (DHS). Supports the Arctic Domain Awareness Center, a center of excellence, hosted through the University of Alaska.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

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

The DOE supports sustained research on cloud-aerosol-turbulence interactions using the Atmospheric Radiation Measurement (ARM) facilities; the Next Generation Ecosystem Experiment-Arctic (NGEE-A) to investigate interactions between permafrost and ecology; and a hierarchy of exascale-class high-resolution regional system models that analyze interdependencies of physical, biogeochemical, cryospheric, and human components of the Arctic system.

The NASA supports the ICESat-2 and GRACE Follow-on Missions, the Oceans Melting Greenland and Arctic-Boreal Vulnerability Experiment field campaigns, and the joint NASA-European Space Agency Arctic Methane Challenge; seven global networks with surface-based measurements, including 30+ field stations; and the international science and education program Global Learning and Observations to Benefit the Environment.

Aurora Borealis silhouettes at NSF's Summit Station, Greenland.
Credit: August Allen

Joanne Speakman, an Indigenous student, and member of the NASA ABoVE research team, assists with ground validation of vegetation. Credit: NASA/ABoVE

The ONR supports the Arctic Mobile Observing System (AMOS) program to develop a marine-based mobile observing system that includes 2-way communications, under-ice vehicle navigation, and long-duration autonomy to collect environmental variables. ONR Global created the International Cooperative Engagement Program for Polar Research, a framework agreement that facilitates research between military and governmental entities.

NOAA supports a number of Arctic observation networks and monitoring and has developed targeted strategies for rapid advancement and application of emerging science and technology -- unmanned systems, artificial intelligence, 'omics, cloud, data, and citizen science -- contributing to Arctic research. NOAA engages broad audiences, including through an Alaska-wide education and capacity building effort, engaging Indigenous communities, and professional development opportunities for students.

The DOI's US Geological Survey is modernizing and standardizing telemetry data collected from Arctic wildlife species. The National Park Service supports the conservation and knowledge of natural and cultural resources via the Shared Beringian Heritage Program. The Bureau of Ocean Energy Management supports the Arctic Marine Biodiversity Observation Network.

ARCTIC RESEARCH INFRASTRUCTURE

VESSELS

NSF's **R/V *Sikuliaq*** is global class, ice-capable research vessel. NOAA conducts Arctic research aboard ***Oscar Dyson, Ronald H. Brown, Rainier,*** and ***Fairweather.*** The U.S. Coast Guard operates the **USCG *Healy,*** a medium icebreaker with science systems supported by NSF, and the **USCG *Polar Star,*** a heavy icebreaker. Plans for new heavy icebreakers are in progress.

FIELD STATIONS

Toolik Field Station, Beaufort Lagoon Ecosystem, Bonanza Creek and Northern Gulf of Alaska are NSF-supported Long-Term Ecological Research (LTER) sites in Alaska that host biological and physical sciences. TFS is also a full service research station that provides logistical support for dozens of different disciplines and hundreds of researchers.

Utqiagvik, Alaska hosts a DOE Atmospheric Radiation Measurement facility, the NOAA Barrow Atmospheric Baseline Observatory, and the Barrow Arctic Research Center/Environmental Observatory.

Oliktok Point, Alaska, which hosts research sponsored by Sandia National Laboratories, DOE, and NOAA, has been proposed as a site for a High Arctic Research Station.

Summit Station, atop the Greenland Ice Sheet, and managed by NSF in cooperation with the Government of Greenland, supports meteorology, atmospheric chemistry, glaciology and astrophysics research, long-term atmospheric monitoring by NOAA, and the Greenland Ice Sheet Project 2 (GISP2) deep ice core.

SATELLITES

The United States operates polar-orbiting satellites and shares satellite missions with other countries, providing daily Arctic-wide observations (e.g., sea ice; terrestrial snow cover; terrestrial ecosystem properties; atmosphere, cloud, and ocean properties) critical for Arctic- and global-system science, weather forecasts, polar transportation, national security, and monitoring climate change impacts on society.

GWICH'IN COUNCIL INTERNATIONAL

POINTS OF CONTACT

GWICH'IN COUNCIL INTERNATIONAL

ARCTIC RESEARCH POLICY AND GOALS

Gwich'in Council International (GCI) participates in, and supports, research and activities to advance effective decision-making on issues affecting the Gwich'in Nation. GCI's research initiatives currently focus on renewable energy, health and well-being, social and economic development, and wildland fires.

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

GCI's membership consists of two representative bodies in Canada and one in the United States: Gwich'in Tribal Council (GTC), representing the beneficiaries of the Gwich'in Land Claims Settlement Act in the NWT, the Vuntut Gwitchin First Nation (VGFN), a self-governing First Nation in Old Crow, and the Council of Athabascan Tribal Governments (CATG), representing Gwich'in communities in Alaska. Each membership body has their own departments, staff, and priorities for research, as well as protocols for how external researchers must engage.

We continue to advocate for investment in our capacity to participate and lead in science, to be fully engaged in research, and setting research priorities from within our communities. Research and science must be meaningful and relevant to Arctic communities, which requires building authentic relationships, investing in capacity at the local level, and finding ways to bridge understanding.

ARCTIC RESEARCH FUNDERS/INSTITUTIONS

Gwich'in Council International receives funding from the Government of Canada and our membership organizations, as well as in-kind and other contributions from other Arctic states and organizations. GCI and Gwich'in membership bodies partner with governments, non-governmental organizations, and academic institutions on research initiatives.

MAJOR ARCTIC RESEARCH AND EDUCATION/ CAPACITY BUILDING INITIATIVES

Gwich'in Council International prioritizes work at the Arctic Council's Sustainable Development Working Group, the Conservation of Flora and Fauna (CAFF) and the Emergency Prevention, Preparedness, and Response (EPPR) Working Groups. We also carry out work and look for ways to build capacity within Gwich'in communities, including through hiring, special projects, knowledge sharing, and events.

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

In the Yukon, the Vuntut Gwitchin First Nation undertakes research, education, and capacity building, including on climate change, the documentation, preservation and promotion of language and culture through the Heritage Research Branch, monitoring, assessment, and research on natural resources, and activities specific to caribou.

In the Northwest Territories, the Gwich'in Renewable Resources Board (GRRB) conducts or participate in wildlife research studies in the Gwich'in Settlement Area. See here. In addition, the Gwich'in Tribal Council's Department of Heritage (formerly the Gwich'in Social and Cultural Heritage Institute) conducts research in the areas of culture, language and traditional knowledge so that this body of knowledge is recorded and available for future generations and the development of programmes appropriate for Gwich'in needs. See here.

ARCTIC RESEARCH INFRASTRUCTURE

Gwich'in communities are located in Alaska, USA and the Yukon and Northwest Territories, Canada, and are focal points for research not only because of physical infrastructure but most importantly the people who are based there and hold expertise, knowledge, language, and practices integral to understanding relationships within the ecosystem. Across the Gwich'in Nation, Elders and culture bearers hold Indigenous Knowledge, and Gwich'in scholars are increasingly recognized in western academic systems with graduate and post-graduate degrees.

Records and archives are held in communities as well as in repositories outside of communities, including at the Northwest Territories Archives and the Alaska Native Language Archive.

THE INUIT CIRCUMPOLAR COUNCIL (ICC)

The Inuit Circumpolar Council (ICC) is an international, Indigenous non-governmental organization founded by the late Eben Hopson, Sr. from Utqiagvik, Alaska in 1977, representing approximately 180,000 Inuit of Alaska, Canada, Greenland, and Chukotka (Russia). The organization holds Consultative Status II at the United Nations Economic and Social Council and is a Permanent Participant at the Arctic Council. Applications are awaiting approval for consultative status at the International Maritime Organization (IMO) and for observer status at the Intergovernmental Panel on Climate Change (IPCC).

To thrive in their circumpolar homeland, Inuit speak with a unified voice on issues of common concern and combine their energies and talents towards protecting and promoting their way of life. ICC works collectively to address issues of concern to Inuit and is guided by Indigenous Knowledge[1] (IK). Recognizing that both IK and science are necessary for building evidence-based information for use in decision-making and policy, much of our work aims to bring together these distinct knowledge systems.

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

An important national and global priority is addressing food security and food sovereignty. The Circumpolar Inuit Wildlife Committee promotes, develops and maintains Inuit rights to self-determination and their culture, food sovereignty and sustainable use by providing a unified pan-Arctic Inuit voice concerning access, sharing, and management of wildlife resources, Our 2020 report on *Food Sovereignty and Self-Governance: Inuit Role in Managing Arctic Marine Resources* builds on our Alaskan *Inuit Food Security Conceptual Framework: How to Assess the Arctic From an Inuit Perspective* and aids in educating and directing research to apply a holistic (ecosystem based) approach to understanding the Arctic.

These reports provide important indicators for ecosystem health, food security, and food sovereignty. Within the wealth of information put forward by Inuit through these two reports, the interconnectivity between everything within the Arctic, understanding people as part of the ecosystem, is stressed. This work has aided ICC in encouraging national and international research and monitoring initiatives to take on a holistic food security approach to monitoring and understanding the Arctic. Both reports are crucial resources for discussions and actions on climate change, biodiversity, language, health, monitoring, self-determination, cumulative effects and the need to take on holistic approaches by bringing together Indigenous Knowledge and science.

This work has aided ICC's efforts in multiple international forums, such as the Sustainable Arctic Observing Network (where we have encouraged and educated on how to apply a food security approach to monitoring); the Convention on Biological diversity (where we have utilized the indicators and important points stressed through these reports to provide feedback and direction within the development of the Post 2020 Global Biodiversity Framework); within the Coastal Expert Monitoring Group, an initiative under the Arctic Council's Conservation of Arctic Flora and Fauna working group (where we have developed a platform that will support a co-production of knowledge approach through bringing together Indigenous Knowledge and Science).

ICC works at many levels to advocate for environmental stewardship and has brought the vision of Inuit led management and monitoring to the international community. ICC maintains a strong voice, bringing attention to the human dimensions of climate change on an international level, providing

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

POINTS OF CONTACT

WWW.INUITCIRCUMPOLAR.COM

contributions to research and policy. For example, in 2008, ICC produced the report '*The Sea Ice is our Highway: An Inuit Perspective on Transportation in the Arctic*' for the Arctic Marine Shipping Assessment. More recently, ICC is working to define and implement international regulations and is working with signatory nations to build Indigenous Knowledge into the science programme of an international treaty to take a precautionary approach to commercial fisheries in the Central Arctic Ocean. ICC is engaged with monitoring initiatives through national programmes, Arctic Council initiatives, and the Sustaining Arctic Observing Networks (SAON). Under SAON, ICC and partners created the online Atlas of Community-Based Monitoring (CBM) & Indigenous Knowledge in a Changing Arctic. The atlas is a searchable inventory that maps CBM projects across the circumpolar Arctic. The atlas was expanded to include Inuit mental health and wellness programs.

ICC is participating in the expert review of the 6th IPCC assessment report draft chapters, providing input to the Polar Regions cross-chapter lead authors and has contributed a section written in first-person by Indigenous Peoples.

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

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

As shared above, our work is strongly guided by IK. While there is growing awareness of the importance of IK, a continued top down approach has created a gap where institutional inequities inhibit meaningful involvement of Indigenous peoples that can provide direction on how to meaningfully engage this important knowledge system and ensure inclusion of Indigenous communities. There is a pressing need for institutions to adapt in order to understand and address challenges across scales. This adaptation requires the involvement and utilization of IK, along with science, to inform circumpolar research, assessments, observation/monitoring programs and governance.

In response to these challenges, ICC will facilitate the development of Circumpolar Inuit protocols/guidelines for equitable, ethical engagement and involvement of Indigenous Knowledge and communities. The first phase of this work has resulted in a synthesis report of Inuit rules, guidelines, protocols and values that guide the engagement of Inuit communities and our knowledge. The final product will be used to develop a proposed process and outline for the Arctic Council and provide a specific example tailored to one of the six working groups. The process will be used in other forums, such as the Intergovernmental Policy on Biodiversity and Ecosystem Services. The results will ultimately be made available to all nations with an interest in the Arctic. This work will also further aid in advancing efforts in bringing together Indigenous Knowledge and science through a co-production of knowledge approach.

THE INUIT CIRCUMPOLAR COUNCIL (ICC)

SAAMI COUNCIL

The Saami Council is an Indigenous Peoples Organization founded in 1956; it was the first pan-Sámi institution. The Saami Council is one of the oldest, still operating, indigenous peoples' organizations on the world. It has nine member organizations based in Finland, Norway, Sweden and the Russian Federation. The Saami Council has since its foundation been a spearhead in Saami political and cultural development.

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

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

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

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

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

The Saami Council is one of six Permanent Participants of the Arctic Council. The Arctic and Environment Unit participates in the activities of the Arctic

POINTS OF CONTACT

WWW.SAAMICOUNCIL.NET

Council and its working groups to promote the Sámi perspective and interests. The Saami Council also participates in the work of the UN Convention on Biological Diversity (CBD), United Nations Framework Convention on Climate Change (UNFCCC) and the Sustainable Development Goals.

Healthy and productive ecosystems, both terrestrial and marine, are still the foundation for the Sámi culture and identity. The protection of the natural resources and the environment, as well as sustainable development is therefore a high priority for the Saami Council. As the international interest in the Arctic has increased over the past two decades, we have identified the need of a Sámi Arctic strategy to guide the Saami Council's work in this area. We play a major role in pushing for indigenous peoples' rights and sustainable development in the Arctic. Therefore the strategy was created to solidify the Saami Council as an active partner for the civil Sámi society, governments, NGOs, IGOs, and others that, through international cooperation, operate in the Arctic. The strategy aims to serve as a tool for implementing long-term, sustainable programs that improve access for the Sámi people to the same opportunities that are afforded to other Arctic inhabitants. The Saami Council's Arctic Strategy addresses, among others things, climate change and environmental protection in the Arctic. The Sámi people hold unique knowledge about living and thriving in our part of the Arctic region – we call it the indigenous knowledge. In a rapidly changing Arctic, we do also need science and research to help us understand all the implications of change.

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

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

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

AMAP

ARCTIC MONITORING AND ASSESSMENT PROGRAMME

MISSION STATEMENT

AMAP is mandated to monitor and assess the status of the Arctic region with respect to pollution and climate change issues; document levels and trends, pathways and processes, and effects on ecosystems and humans, and propose actions to reduce associated threats for consideration by governments; produce sound science-based, policy-relevant assessments and public outreach products to inform policy and decision-making processes.

MAJOR ACTIVITIES

The Arctic Monitoring and Assessment Programme (AMAP) is a program designed to deliver sound science-based information for use in policy- and decision-making. Its assessment activities are internationally coordinated, subject to rigorous peer-review and make use of the most up-to-date results from both monitoring and research.

The AMAP program is implemented in the circum-Arctic region.

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

Since its establishment in 1991, AMAP has produced a series of high quality reports and related communication products that detail the status of the Arctic with respect to climate and pollution issues and that include policy-relevant science-based advice to the Arctic Council and governments.

The AMAP work plan for 2019-2021 lists these deliverables:

- "Climate Issues of Concern"
- AMAP will produce an assessment of mercury in the Arctic.
- A review of the interaction between climate change and POPs in the Arctic.
- Short-lived Climate Pollutants (SLCP): AMAP will produce an assessment delivery in 2021.
- An updated human health assessment, including the consideration of health effects of dietary transitions in Arctic populations and risk communication.
- The Arctic Council is developing a "Marine Litter Regional Action Plan" (ML-RAP). AMAP is preparing a Monitoring Plan and Monitoring Guidelines that will be a contribution to and referenced in the Arctic "Marine Litter Regional Action Plan".

ORGANIZATION STRUCTURE

AMAP is one of six working groups under the Arctic Council.

POINTS OF CONTACT

WWW.AMAP.NO

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APECS

ASSOCIATION OF POLAR EARLY CAREER SCIENTISTS

MISSION STATEMENT

AThe Association of Polar Early Career Scientists (APECS) is an international and interdisciplinary organisation for undergraduate and graduate students, postdoctoral researchers, early career professionals, early career faculty members, educators and others interested in the polar and alpine regions and the wider cryosphere. APECS provides a platform for promoting collaborations and exchange among its members and with the wider polar research community, endeavouring to create a continuum of leadership in polar sciences.

MAJOR ACTIVITIES

APECS' goals include creating opportunities for the development of innovative, international, and interdisciplinary collaborations among current early career polar researchers as well as recruiting, retaining and promoting the next generation of polar enthusiasts. Specifically we aim to:

1. **Create a network of polar researchers across disciplines and national boundaries to meet, share ideas and experiences, and develop new research directions and collaborations.**
2. **Provide the opportunity for career development for both traditional and alternative polar and cryosphere professions**
3. **Promote education and outreach as an integral component of polar research and to stimulate future generations of polar researchers**

APECS and its National Committees organize in-person and online events, and activities (e.g. workshops, panel discussions, summer school, networking events). Recent Arctic-focused training opportunities include the MOSAiC School 2019 (6-week training for 20 early career researchers on the Russian icebreaking research vessel Akademic Fedorov), an APECS-APPLICATE Online Course 2019 on "Advancing Predictive Capabilities of Northern Hemisphere Weather and Climate" and a workshop on "Raising awareness and building capacity for science-based policy making" for 30 early career researchers in October 2019 in Reykjavik, Iceland.

APECS released its Strategic Plan 2021-2025.

APECS' major activity in 2021 is finding a new host for the International Directorate.

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

Major Arctic-related activities / events:

- **APECS International Polar Week March and September, each year (upcoming: 14-20 March 2021)**
- **APECS/YESS/YOPP Workshop at ASSW2021 (21-22 March 2021)**
- **APECS-ARICE Technical Online Training (March/April 2021)**
- **APECS International Online Conference 2021 (12 May 2021)**

In addition, the APECS Project Groups and National Committees are organizing more Arctic-related activities and projects. APECS is involved in EU projects such as APPLICATE, ARICE, INTERACT and a new Arctic focussed EU project to be announced soon.

ORGANIZATION STRUCTURE

The APECS leadership is comprised of early career researchers that are interested in and committed to furthering the activities and the future directions of the organization. An Executive Committee (one President and 4 Vice-Presidents plus ExOfficios) and a Council lead the organization, supported by the International Directorate. Within the Council members are either individual Council members and/or representatives of APECS National Committees and early career partner organizations. The APECS International Directorate is currently located at the Alfred Wegener Institute in Potsdam/Germany and is seeking a new host in 2022. To better respond to the needs of specific countries, APECS has National Committees, which are linked to and a vital part of the international APECS network. Some National Committees are just getting started, others are well established, with leadership structure, regular events and a large membership.

POINTS OF CONTACT

WWW.APECS.IS
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CAFF

CONSERVATION OF ARCTIC FLORA AND FAUNA

MISSION STATEMENT

CAFF's mandate is to address the conservation of Arctic biodiversity, and to communicate its findings to the governments and residents of the Arctic, helping to promote practices which ensure the sustainability of the Arctic's living resources.

MAJOR ACTIVITIES

CAFF works to fulfill its mandate through various monitoring, assessment and expert group activities. The outcomes of its work provide data, advice and policy recommendations to supprot informed decision making to resolve challenges arising from trying to conserve the natural environment and permit regional growth. This work is based upon cooperation between all Arctic countries, indigenous organizations, international conventions and organizations, and is guided by the Actions for Biodiversity 2013-2021: implementing the recommendations of the Arctic Biodiversity Assessment, and biennial Work Plans.

To successfully conserve the natural environment and allow for economic development, comprehensive baseline data is require, including the status and trends of Arctic biodiversity, habitats and ecosystem health. CAFF is developing the framework and tools necessary to create a baseline of current knowledge, and to provide dynamic assessments over time. This evolving, sustainable and responsive approach can produce more regular, timely and flexible analyses.

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

The Actions for Arctic Biodiversity 2013-21: Implementing the recommendations of the Arctic Biodiversity Assessment (ABA) guides how the Arctic Council addresses biodiversity. A new action plan for the coming years has been delayed due to the COVID-19 pandemic related challenges, including delays in international processes informing our work. Key actions in phase 4 of the ABA (2021-2023) include the development of a new plan, as well as completing projects, implementing strategies and plans developed in early phases, evaluating progress, and designing follow-up. Focus will continue over ongoing CAFF actions that address

- **Mainstreaming biodiversity;**
- **Ecosystem services;**
- **Communications and outreach;**
- **Adaptation to climate change;**
- **Coordination of long-term biodiversity monitoring;**
- **Stressors on biodiversity e.g., invasive species and pollution;**

ORGANIZATION STRUCTURE

CAFF is the biodiversity working group of the Arctic Council and consists of National Representatives assigned by each of the eight Arctic Council Member States, representatives of Indigenous Peoples' organizations that are Permanent Participants to the Council, and Arctic Council observer countries and organizations. The CAFF Working Group operates by the Arctic Council Rules of Procedures.

POINTS OF CONTACT

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GEO

GROUP ON EARTH OBSERVATIONS

MISSION STATEMENT

The Group on Earth Observations (GEO), a global partnership of governments and organizations, envisions a future wherein decisions and actions for the benefit of humankind are informed by coordinated, comprehensive and sustained Earth observations.

MAJOR ACTIVITIES

Arctic GEOSS

This activity is led by Sustaning Arctic Observations Networks (SAON), a GEO Participating Organization. The Strategy for Arctic GEOSS describes the following three goals:

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

SAON has developed guidelines for contributing to SAON's Roadmap for Arctic Observing and Data Systems (ROADS) to be organized around Essential Arctic Variables (EAVs). These are conceptually broad observing categories identified for their criticality to achieving Arctic societal benefit. EAV's are defined by their observing system requirements, which are technology-neutral and should transcend specific observing strategies, programs or regions. They are implemented through specific recommendations based on best available technology and practices.

GEO Indigenous Alliance

The GEO Indigenous Summit, organised by the GEO Secretariat and the GEO Indigenous Alliance, was held online 7-9 December 2020. The event brought together all those involved and interested in Indigenous-led EO innovation. The following recommendations and next steps emerged following the summit, and complement the existing pathways of the GEO Indigenous Alliance:

- Promote EO data and tools to enhance inter-generational transfer of knowledge;
- Advocate EO technologies that enhance Indigenous ecological practices and stewardship of Indigenous cultural heritage;
- Encourage the GEO community to co-design GEO tools in partnership with Indigenous peoples, integrating Indigenous language, knowledge systems and cultural values;
- Increase the number of Indigenous students who participate in experiential learning, research and scholarship opportunities across the GEO community;
- Advocate the use of the CARE (Collective benefit, Authority to control, Responsibility, and Ethics) Principles for Indigenous Data Governance, developed by the Global Indigenous Data Alliance in 2019;
- Raise the visibility and role of Indigenous knowledge for disaster risk reduction and climate action; and
- Support the empowerment of Indigenous women and youth through EO data, tools and services.

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

The GEO Knowledge Hub

The GEO Secretariat has been working on development of the GEO Knowledge Hub. The GEO Knowledge Hub (GKH) is a central digital repository providing access to codified knowledge involving the application of Earth observations for solving societal challenges. Emphasizing a co-design/co-production strategy, the GKH is concerned with detailing all development phases of applications featuring Earth observations, elaborated in an open science environment, which support management of the environment and sustainable development. Thus, it contains documentation linking: (a) research papers and reports describing methods used and results; (b) software algorithms and cloud computing resources used for processing; (c) in situ and satellite imagery data used; and (d) results for verification.

ORGANIZATION STRUCTURE

GEO, formally established at the Third Earth Observation Summit in February 2005, is a partnership of more than 100 national governments and in excess of 100 Participating Organizations. Membership in GEO is open to all member States of the United Nations and to the European Commission. Membership in GEO is contingent upon formal endorsement of the 2016-2025 Strategic Plan. Ministers of the GEO member governments meet periodically to provide the political mandate and overall strategic direction for GEO. The Mexico City Ministerial Declaration from the GEO Ministerial Meeting in 2015 saw world leaders commit to support open Earth observation data for the next decade. Mexico City Ministerial Declaration, November 2015. The more recent Canberra Ministerial Declaration, November 2019, may be found here.

POINTS OF CONTACT

EARTHOBSERVATIONS.ORG

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IASC

INTERNATIONAL ARCTIC SCIENCE COMMITTEE

MISSION STATEMENT

The International Arctic Science Committee (IASC) is a non-governmental, international scientific organization. The Founding Articles committed IASC to pursue a mission of encouraging and facilitating cooperation in all aspects of Arctic research, in all countries engaged in Arctic research and in all areas of the Arctic region. Overall, IASC promotes and supports leading-edge interdisciplinary research in order to foster a greater scientific understanding of the Arctic region and its role in the Earth system. Rather than defining human and environmental boundaries, IASC tries to bridge those boundaries. IASC is also committed to recognizing that Traditional Knowledge, Indigenous Knowledge, and "Western" scientific knowledge are coequal and complementary knowledge systems, all of which can and should inform the work of IASC.

MAJOR ACTIVITIES

IASC convenes the Arctic Science Summit Week, an important annual gathering of Arctic research organizations, to provide opportunities for coordination, cooperation and collaboration among scientists, students, policy makers, and other professionals. In even-numbered years, the ASSW includes the Arctic Observing Summit (AOS) which aims to provide community-driven, science-based guidance for the design, implementation, coordination, and long-term operation of Arctic observing systems.

Since 2020, IASC publishes an annual "State of Arctic Science" report.

IASC hosts the International Conferences on Arctic Research Planning (ICARP) every 10 years to "review the status of Arctic science, provide scientific and technical advice, and promote cooperation and links with other national and international organizations." The ICARP III in 2015 included a two-year long bottom-up process that resulted in the report, "Integrating Arctic Research – a Roadmap for the Future". Planning has started for the next ICARP IV in 2025.

More IASC activities are described in its annual IASC Bulletin.

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

The upcoming ASSWs will be: ASSW 2022: Tromsø, Norway | ASSW 2023: Vienna, Austria | ASSW 2024: United Kingdom.

The IASC Working Groups support a wide range of international and interdisciplinary scientific activities. The list of upcoming projects funded by IASC can be found on the IASC website.

The IASC Action Group on Carbon Footprint is currently working on recommendations for minimizing the carbon footprint of IASC-related activities. As an organization promoting research and transnational access in the Arctic, we have a duty to mitigate the impacts of our activities, as well as to lead the way.

IASC is also working with international partners to support for example the Arctic Council Working Groups and their project, the Arctic Science Funders Forum and the International Agreement on Enhancing Arctic Scientific Cooperation by among others providing objective and independent scientific advice on issues of science in the Arctic.

IASC continues to promote and involve the next generation of scientists working in the Arctic through its IASC Fellowship program, which includes, since 2020, an IASC Indigenous Fellowship.

ORGANIZATION STRUCTURE

Any country which supports Arctic research is welcome to be an IASC member country. Currently, IASC has 23 member countries and receives member contributions which fund its activities. Iceland hosts and supports the IASC Secretariat (2 full-time staff and an operating budget). IASC is an Observer to the Arctic Council and an Affiliate Member of the International Science Council.

POINTS OF CONTACT

WWW.IASC.INFO

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IASSA

INTERNATIONAL ARCTIC SOCIAL SCIENCES ASSOCIATION

MISSION STATEMENT

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

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

MAJOR ACTIVITIES

The IASSA objectives and research and policy goals are:

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

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

10th International Congress of Arctic Social Sciences (Arkhangelsk, Russia, June 15-19, 2021)

Developing network and knowledge sharing opportunities through supporting research coordination networks: Arctic-FROST, Arctic-COAST, Percs-Net, US NAF NNA programs, Horizon 2020 research and planning activities, national and international research plans, including initial preparations for ICARP IV.

Support Arctic Council activities by supplying expertise in various projects and initiatives, including ECONOR, Gender Equality in the Arctic, Arctic Human Development Report, Arctic Resilience Forum, as well as language, wellbeing and Indigenous Knowledge-focused projects.

ORGANIZATION STRUCTURE

IASSA is governed by the Council and President. IASSA has working groups.

POINTS OF CONTACT

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ICES/ PICES

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

INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA

MISSION STATEMENT

To advance and share scientific understanding of marine ecosystems and the services they provide and to use this knowledge to generate state-of-the-art advice for meeting conservation, management, and sustainability goals. ICES Annual Report 2019, Strategic Plan, Advisory Plan, and Science Plan.

ICES is an intergovernmental organization with 20 member countries: Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Russian Federation, Spain, Sweden, United Kingdom, and United States of America.

MAJOR ACTIVITIES

- Provides vision and leadership across a range of disciplines, providing high-impact marine science
- A platform for cooperation between member countries and engagement with strategic partners
- Identifies and communicates expertise, training, monitoring, data, and process needs
- Identifies and promotes science priorities
- Evolves the advice and data management to remain relevant to policy and management
- Embeds approaches to quality assurance, reproducibility, and transparency into science, data, and advice
- Effectively shares evidence and advice with requesters and society
- Arranges relevant and impactful Annual Science Conferences and training programs
- Publishes effective ICES publications, data portals and services, and web sites
- Highlights the relevance and benefits of ICES approach
- ICES is a network of 6000 experts from 700 institutes and organizations in 20 member countries and beyond. More than 2800 experts participate in our activities annually.

Our products: Ecosystem and fisheries overviews; ICES advice on the marine ecosystem to governments and international regulatory bodies that manage the North Atlantic Ocean and adjacent seas; Data used in science and advisory products; Science highlights; Viewpoints; Training; Publications; Conferences; Symposia.

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

Activities are conducted jointly with PICES and other relevant groups:

- Joint AMAP/ICES/PICES International Symposium on Plastics in the Arctic and Sub-Arctic Region, Online 2021
- 2020 PICES Annual meeting workshop: "How does the Pacific Arctic gateway affect the marine system in the Central Arctic Ocean (CAO)?"
- 2021 ICES Annual Science Conference and PICES Annual Meeting, with various Arctic related theme sessions.
- 5th ICES/PICES/IOC/FAO Symposium on Climate Change and Impacts on the World's Oceans, Norway, 2023

ORGANIZATION STRUCTURE

ICES has a formalized structure to carry out its functions, including: - a governing COUNCIL, the principal decision and policy-making body of ICES, consisting of delegates from the member countries, - an executive committee of the Council, the BUREAU, consisting of 7 elected delegates, - a FINANCE COMMITTEE responsible for overseeing ICES' financial matters, consisting of 5 appointed Council delegates - an ADVISORY COMMITTEE, translating ICES science into advice on the sustainable use and protection of marine ecosystems, consisting of national representatives from the 20 member countries. - a SCIENCE COMMITTEE, providing a dynamic and credible marine science programme, consisting of national representatives from the 20 member countries. - a DATA AND INFORMATION GROUP, providing advice on all aspects of data management, and - the SECRETARIAT, providing secretarial support to the ICES community, with headquarters in Copenhagen, Denmark, and consisting of a staff of 70, representing 30 different countries.

POINTS OF CONTACT

WWW.ICES.DK
INFO@ICES.DK

ICES/ PICES

NORTH PACIFIC MARINE SCIENCE ORGANIZATION

MISSION STATEMENT

PICES promotes and coordinates marine research to advance scientific knowledge through the collection and exchange of information and data on the North Pacific Ocean and ecosystems by conducting research on the status and trends of the ocean environment and its interactions with human activities and atmospheric processes. PICES coordinates science to assess the future state of ecosystems as influenced by climate variability and change and human activities.

MAJOR ACTIVITIES

- Provides vision and leadership on scientific issues and identifies research priorities and appropriate approaches for their solution;
- Plans, coordinates, and implements integrated, interdisciplinary research programs and related activities to be undertaken through the national efforts of the member countries;
- Promotes the collection and exchange of data and information related to marine scientific research;
- Assesses ecosystem status and trends and projects future changes;
- Synthesizes scientific information and makes it available to a broad user community and the public;
- Responds to requests from the member countries and other organizations to provide advice on scientific issues;
- Develops capacity within the scientific communities of the member countries; and
- Fosters partnerships with other organizations and programs that share a common interest.

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

Arctic related activities are conducted jointly with ICES and other relevant groups:

- Joint AMAP/ICES/PICES International Symposium on Plastics in the Arctic and Sub-Arctic Region, Reykjavik, Iceland, 28-30 September 2020
- 2020 PICES Annual meeting, virtual workshop W4: “How does the Pacific Arctic gateway affect the marine system in the Central Arctic Ocean (CAO)?”
- 2021 ICES Annual Science Conference and PICES Annual Meeting, with various Arctic related theme sessions.
- 5th ICES/PICES/IOC/FAO Symposium on Climate Change and Impacts on the World’s Oceans, [Bergen, Norway,] 2023

ORGANIZATION STRUCTURE

The Governing Council (GC) is the decision-making body of the Organization composed of national representatives from the 6 member nations. A Science Board and a Finance and Administration Committee are the two Executive Committees of the organization. Scientific Committees are established by the Science Board with the approval of the GC, as ongoing groups responsible to the Science Board for the planning, direction, and oversight of major themes within the Organization’s general scientific aims. The PICES Secretariat carries out the day to day administrative functions of the organization.

POINTS OF CONTACT

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INTERACT

INTERNATIONAL NETWORK FOR TERRESTRIAL RESEARCH AND MONITORING IN THE ARCTIC

MISSION STATEMENT

NTERACT is pan-arctic network of 88 terrestrial field bases with a main objective to build capacity for identifying, understanding, predicting and responding to diverse environmental changes throughout the wide environmental and land-use envelopes of the Arctic.

MAJOR ACTIVITIES

INTERACT provides access to 53 research stations in all Arctic countries for scientists from all over the world through its transnational access program. At present, INTERACT has sent more than 1000 scientists to do field work in the Arctic. INTERACT also ensures best practices at the research stations e.g. by decreasing the impact on local environment and by training visitors in field safety through its Station Managers' Forum. INTERACT's Data Forum are enhancing data availability from the research stations and is also guiding stations in data management to ensure that the FAIR principle is being used. INTERACT produces educational and outreach material for everything from elementary school kids to University students to the general public. Finally, INTERACT works with industry and companies, local and indigenous communities and policy advisors on societal challenges in the Arctic with global impacts such as extreme weather events, increased tourism, transport and communication, pollution.

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

INTERACT has an annual call for its transnational access program. The next call will be out in September with a deadline in October 2020 for next summer's field season. In addition to the physical access when scientists actually go to the research stations, there is also another modality that is especially useful during the current COVID-19 pandemic which is remote access. It basically means that the staff at the research stations are taking samples for the scientists and send them back to the scientists.

ORGANIZATION STRUCTURE

INTERACT has been funded through the EU 7th framework program (2011-2016) and the EU Horizon 2020 program (2016-2020 and 2020-2023). INTERACT consists of a general assembly which includes representatives from all the research stations and organizations involved in the project. This group meets annually and decides on the structure and operation of the consortium as a whole. The project also has a Daily Management Group that runs the day to day business supported by the INTERACT Secretariat.

POINTS OF CONTACT

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PEI

POLAR EDUCATORS INTERNATIONAL

MISSION STATEMENT

Connecting polar education, research, and the global community: PEI is an essential network of international educators and researchers developing deeper understanding of current polar sciences for global audiences. By leading dialogue and collaboration, PEI aims to highlight and share the global relevance of the polar regions.

MAJOR ACTIVITIES

P E I i s a growing and essential network of polar education organgxations, polar educators in schools, museums, universities and informal learning environments and polar researchers with a commitment to education and outreach, co-ordinating learning events and activities, lessons, workshops, initiatives and programs worldwide. As the leading international polar education network, PEI works diligently to make clear the distinctions between the Arctic and Antarctic as separate regions with unique characteristics and influences. By connecting educators and researchers and helping to align polar scientific research and educational goals* PEI strengthens understanding of polar science and environmental change. PEI communicates with its members, polar educators and the wider community via rfc PEI Website sharing news, blogs, articles, videos, and via & Social Media through posts and opportunities. PEI provides opportunities to connect at PEI International Conferences: Portugal 2013, Germany 2015, Italy 2017, UK 2019 and Iceland (date TBC), and represents polar education at major polar research events. PEI creates and collaborates in partnerships, science conferences and collaborative education projects to promote polar education creating posters, presentations, and education and communication workshops (e.g. IPY, AGU, EGU, Polar2018), conducting masterclasses, professional development and training and co-ordinating and promoting outreach events, partnerships, and innovative learning opportunities.

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

1. Polar Resource Book - PEI gq working with IASC, APECS & SCAR proposes to share a digital version of Polar Science and Global Climate (IPY 2010) - The Polar Resource Book online, for use and evaluation, review and updating and subsequent republication.
2. 5th PEI Conference, Iceland - PEI will bring its 5th international conference to Iceland, with themes focused on polar education relevant to Knowledge for a Sustainable Arctic, offering an interdisciplinary understanding of the region, its peoples and scientific research for educators and researchers.
3. A global conversation connecting Education, Indigenous Knowledge & Arctic Research - Working with the ASM organizing committee, PEI proposes to generate and co-ordinate a global conversation about education and the Arctic to identify patterns and opportunities for co-operation.
4. A host nation for PEI Secretariat - opportunity for Arctic Partnerships PEI seeks to establish a stable administrative base from which the PEI network can work with partners to support and share mechanisms connecting research, Arctic places and the people within them, to people and places outside of the Arctic.

ORGANIZATION STRUCTURE

PEI is an unfunded network of dedicated individuals, currently working on a voluntary basis, united by a shared passion for encouraging others to learn about the polar regions. PEI's organizational structure consists of: an elected Council representing the voting membership, an elected Executive Committee, working groups and committees and a Global Advisors Group, a growing international membership of individual educators and organisations. Currently, it has no secretariat or individual officers. Until we secure a secretariat there is a limit to what can currently be achieved but we have a structured, strategic plan and are ready to grow.

POINTS OF CONTACT

WWW.POLAREDUCATOR.ORG

POLAREDUCATORS@GMAIL.COM

SAON

SUSTAINING ARCTIC OBSERVING NETWORKS

MISSION STATEMENT

SAON's vision is a connected, collaborative, and comprehensive long-term pan-Arctic Observing System that serves societal needs. SAON's mission is to facilitate, coordinate, and advocate for coordinated international pan-Arctic observations and to mobilize the support needed to sustain them.

MAJOR ACTIVITIES

SAON has three goals and SAON's guiding principles support its work across these:

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

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

These ongoing and upcoming activities will address Goal 1:

- SAON's Roadmap for Arctic Observing and Data Systems (ROADS) process will identify Essential Arctic Variables, identified by their importance to multiple information user groups and applications, where Arctic Indigenous collaboration is critical for the success of the process and outcome.
- The Polar Observing Asset working group (POAwg) will provide technical guidance for sharing information about observing activities.

These ongoing activities within the Arctic Data Committee are addressing Goal 2:

- Polar Data Discovery Enhancement Research (POLDER)
- Polar Semantics Working Group
- Data policy group

ORGANIZATION STRUCTURE

SAON's Goals 1 and 2 are addressed through the SAON Committee on Observing and Networks (CON) and the Arctic Data Committee, respectively. Goal 3 is addressed through the SAON Board. SAON has an Executive Committee and a Secretariat.

POINTS OF CONTACT

WWW.ARCTICOBSERVING.ORG
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SDWG

SUSTAINABLE DEVELOPMENT WORKING GROUP

MISSION STATEMENT

The Sustainable Development Working Group (SDWG) is one of the six working groups of the Arctic Council. Its mission is to: Propose and adopt steps to be taken by the Arctic States to advance sustainable development in the Arctic, including opportunities to protect and enhance the environment, and the economies, cultures and health of indigenous communities and of other inhabitants of the Arctic, as well as to improve the environmental, economic and social conditions of Arctic communities as a whole. (From SDWG Terms of Reference 1998)

MAJOR ACTIVITIES

SDWG 2019-2021 work plan includes the following activities:

- Arctic Children-Preschool Education and Smooth Transition to School
- Arctic Food Innovation Cluster (AFIC)
- Arctic Hydrogen Energy Applications and Demonstrations (AHEAD)
- Arctic Indigenous Youth, Climate Change and Food Culture (EALLU) II
- Arctic Remote Energy Networks Academy (ARENA) II
- Blue Bioeconomy in the Arctic Region
- Gender and Equity in the Arctic (GEA) III
- Local 2 Global: Circumpolar collaboration for suicide prevention and mental wellness
- One Arctic, One Health
- The Economy of the North 2020 (ECONOR IV)
- Zero Arctic: Concepts for carbon neutral Arctic construction based on tradition
- COVID-19 in the Arctic
- Arctic Resilience Action Framework

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

Additional activities included in the SDWG work plan that have not yet started, include:

- Solid Waste Management in Small Arctic Communities
- Arctic Children: Preschool and School Education
- Survey of Living Conditions in the Arctic (SLiCA) II

In addition, the following activities have introduced for consideration by the SDWG:

- Arctic Demography Index
- Digitalization of Linguistic and Cultural Heritage of Indigenous Peoples of the Arctic
- Arctic – Territory, Environment and Culture (ATEC)
- Sustainable Arctic Finance
- Centre for Applied Research and Traditional Knowledge of Reindeer Husbandry
- Circumpolar Water-Energy-Food (WEF) and Indigenous Livelihoods Assessment

ORGANIZATION STRUCTURE

The SDWG is a subsidiary body of the Arctic Council. Its membership includes representatives of the Arctic States (Canada, Kingdom of Denmark, Finland, Iceland, Norway, Sweden, Russian Federation, United States) and Permanent Participants (Aleut International Association, the Arctic Athabaskan Council, the Gwich'in Council International, the Inuit Circumpolar Council, the Saami Council, and RAIPON – the Russian Association of Indigenous People of the North). The SDWG is chaired by the Arctic State that holds the chairmanship of the Arctic Council. Arctic Council Observers are also invited to participate in SDWG meetings and activities. The SDWG is supported by an Executive Secretary currently based in Ottawa, Canada.

POINTS OF CONTACT

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UARCTIC

UNIVERSITY OF THE ARCTIC

MISSION STATEMENT

Empower the people of the Circumpolar North by providing unique educational and research opportunities through collaboration within a powerful network of members.

MAJOR ACTIVITIES

UArctic is a network of over 200 members who focus on joint education (e.g. Circumpolar Studies), research and outreach. These include both on-site and online course deliveries in all levels, North2North mobility program and joint research and other project activities. Most of these activities are done in over 50 thematic networks, which are networks focusing on topical Arctic themes. These thematic networks include partners from all Arctic nations and beyond and often work in cooperation with other Arctic organizations.

UArctic promotes the networking and collaborations and one way of doing that is through the UArctic Congress which is organized every second year in the Arctic Council chairmanship country as one of the Arctic Council chairmanship's events (2020 Congress in Reykjavik was postponed to May 2021 due to Covid-19).

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

Within Thematic Networks there are several Master's and PhD courses to be organized as online or postponed to 2021, same with several workshops and Conferences. Also UArctic Congress was postponed to May 2021.

Two new online repositories were initiated in spring 2020: Arctic Learning Resources which lists different types on materials and courses for online delivery, and secondly a repository of ethical guidelines in conducting research on Indigenous lands, the later one will continue with a case study and expand to broader ethical guidelines (this is also ASM2 project).

Communication is important for such a large network and more work will be done for that e.g. in sharing short video interviews on joint activities and on new exciting research results.

ORGANIZATION STRUCTURE

UArctic is a decentralized organization, with offices, programs and other functions hosted at member institutions.

POINTS OF CONTACT

WWW.UARCTIC.ORG

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UNEP

UN environment programme

UN ENVIRONMENT

MISSION STATEMENT

UNEP is the leading authority that sets the global environmental agenda and promotes the implementation of the environmental dimension of sustainable development within the UN system. Our mission is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

MAJOR ACTIVITIES

Our work includes assessing global, regional and national environmental conditions and trends; developing international and national environmental instruments; and strengthening institutions for the wise management of the environment.

We categorize our work into seven broad thematic areas: climate change, disasters and conflicts, ecosystem management, environmental governance, chemicals and waste, resource efficiency, and environment under review. In all of our work, we maintain our overarching commitment to sustainability.

UNEP works on Arctic related issues, by its engagement in the activities of the Arctic Council, and through GRID-Arendal, the Centre of Excellence on Polar and Cryosphere Environmental Assessment and Early Warning with Particular Focus on the Arctic, that is leading and/or participating in ongoing and future Arctic projects. CCAC is working on black carbon; cooperation between AMAP and Minamata Convention; BSR Secretariat is also working on Arctic issues. Examples listed below.

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

- GRID-Arendal is coordinating the development of a Rapid Response Assessment to assess critical research gaps related to Arctic coastal permafrost
- GRID-Arendal is leading the University of the Arctic's Thematic Network on Arctic Plastic Pollution
- GRID-Arendal is preparing an Atlas of Arctic Permafrost to be launched in April 2022
- UNEP and GRID-Arendal are partners in the organization of the Arctic Marine Plastics Symposium
- UNEP and GRID-Arendal are preparing a Rapid Response Assessment on global wildfires and plan to include a section on Arctic wildfires, an area of interest to EPPR and AMAP

ORGANIZATION STRUCTURE

Headquartered in Nairobi, Kenya, UN Environment Programme is led by a Senior Management Team that's chaired by our Executive Director. We work through our divisions, regional, liaison and out-posted offices, plus a growing network of collaborating centres of excellence. UNEP is working together with many Secretariats of Conventions relevant to the Arctic such as Minamata and BSR. On Arctic related activities, WCMC and GRID-Arendal are the key centres of excellence. GRID-Arendal, located in Arendal, Norway, have a dedicated programme for Polar and Climate projects.

POINTS OF CONTACT

WWW.UNENVIRONMENT.ORG

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WMO

WORLD METEOROLOGICAL ORGANIZATION

WORLD METEOROLOGICAL ORGANIZATION

MISSION STATEMENT

WMO works to facilitate worldwide cooperation in the design and delivery of meteorological services, foster the rapid exchange of meteorological information, advance the standardization of meteorological data, build cooperation between meteorological and hydrological services, encourage research and training in meteorology, and expand the use of meteorology to benefit other sectors such as aviation, energy, agriculture and water management.

MAJOR ACTIVITIES

As a specialized agency of the United Nations, WMO is dedicated to international cooperation and coordination on the state and behaviour of the Earth's atmosphere, its interaction with the land, cryosphere and oceans, the weather and climate it produces, and the resulting distribution of water resources.

UPCOMING ARCTIC RELATED ACTIVITIES/NEW INITIATIVES

The WMO Arctic related activities are structured in three main areas as detailed below:

Infrastructures

- Global Cryosphere Watch - Cryosphere Observing Harmonized Requirements and Capabilities (CRYORA)
- Arctic Hydrological Cycle Observing System (Arctic-HYCOS)

Services

- Arctic Climate Forums, the Arctic Regional Climate Centre Network (ArcRCC-Network)

Research: climate, weather, environment

- Climate and Cryosphere (CliC) Project of the World Climate Research Programme (WCRP)
- Polar Prediction Project (PPP) of the World Weather Research Programme (WWRP)
- Global Atmosphere Watch (GAW) arctic activities

ORGANIZATION STRUCTURE

See more here.

POINTS OF CONTACT

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04

ASM3
WEBINAR SERIES

ASM3 WEBINAR SERIES

The ASM3 webinar series was designed to increase the transparency of the Arctic Science Ministerial science process and to provide additional opportunities for scientists, Indigenous Peoples, and Arctic research stakeholders to further engage with the science and proposed actions leading up to the Third Arctic Science Ministerial in Tokyo, Japan in May 2021. The webinar series was a joint cooperation between the ASM3 Organizers in Iceland and Japan and the European Polar Board (EPB). The webinar series received 1200 registrations and 1000 attendees participated throughout the webinar series. The webinar, *Indigenous interests in ASM3*, received the highest attendance with 221 attendees. Webinar recordings, reports, and transcripts can all be found on the ASM3 website.

INTRODUCTION TO THE ASM3 SCIENCE PROCESS

The introductory webinar provided an overview of the Arctic Science Ministerial process from ASM1 and ASM2 as well as an outline of the expectations and intended outcomes of the ASM3 webinar series. The webinar was opened by Minister Lilja Alfreðsdóttir Icelandic.

- **Opening Remarks**
  Minister Lilja Alfreðsdóttir, Iceland
- **Review of the Introduction Webinar Program**
  Lindsay Arthur, Organizing Committee, Iceland
- **Introduction of the European Polar Board**
  Renuka Badhe, Executive Secretary
- **Review of ASM1**
  Fran Ulmer, ASM1 Representative
- **Review of ASM2**
  Karin Lochte, ASM2 Representative
- **Review of ASM3 Science Process**
  ASM3 Organizing Committee Co-Chairs, Hiroyuki Enomoto and Embla Eir Oddsdóttir
- **ASM3 Webinar Series: What to expect**
  Lindsay Arthur, Organizing Committee, Iceland
- **Questions & Answers**

ADDRESSING GAPS AND BARRIERS IN INTERNATIONAL ARCTIC SCIENCE RESEARCH

The organizers of the ASM3 stressed the need to develop specific action items resulting from ASM3 to advance international scientific collaboration. In an effort to develop recommended actions that people perceive as useful next steps, a survey was sent to participating countries, Indigenous Peoples, and international science organizations asking respondents to identify the opportunities, barriers, and gaps to increased international Arctic research. Building on this survey, a special online workshop on the gaps and barriers in international Arctic research was held. The webinar opened with a summary of the feedback received from the survey, followed by a panel of speakers who presented recent synthesis reports on research gaps and lessons learned from projects that have navigated many international barriers. After the panel, workshop participants broke out into sessions addressing a) data and infrastructure, b) education and capacity building, c) sustained observations, d) societally relevant research, and e) visas, permits, and other bureaucratic hurdles. The aim of these breakout sessions was to develop and prioritize actions needed to address challenges and barriers to international Arctic research efforts more effectively. In keeping with the open and inclusive framework of the ASM3, a survey was put out asking for additional input in case people were not able to participate in the online workshop or had points to share following the online event. The results from the online survey were combined into the workshop outcomes and are summarized in a report. The aim of this report was to serve as the basis for suggested next steps that could guide actions moving forward after ASM3.

- **Opening Remarks**
  Hiroyuki Enomoto and Embla Eir Oddsdóttir, ASM3 Science Advisory Board Co-Chairs
- **Panel on research gaps and lessons learned from projects that have navigated many international barriers.**
  Moderator: Renuka Badhe, Executive Secretary, EPB
  - IASC State of the Arctic Science Report 2020
    Panelist: Hiroyuki Enomoto, IASC Executive Committee
  - Saami Council Arctic Strategy: Building Knowledge in Sápmi, A List of Knowledge Gaps and Research Needs
    Panelist: Elle Merete Omma, Head of EU Unite, Saami Council
  - UArctic Report on Scientific Cooperation within the Arctic: Understanding the Bottlenecks in Cross-Border Research
    Panelist: Lars Kullerud, President of UArctic
  - Lessons Learned from the MOSAiC Expedition
    Panelist: Anja Sommerfeld, Project Manager MOSAiC, AWI
  - Methods Used by INTERACT to Overcome International Barriers
    Panelist: Prof Terry V Callaghan CMG, Sheffield University, UK and Tomsk State University, Russia
- **Breakout sessions**
  - Data Management and Research Infrastructure
    Moderator: Henry Burgess, Reporter: Peter Pulsifer
  - Education and Capacity Building
    Moderator: Mia Bennett, Reporter: Louise Huffman
  - Sustained Observations
    Moderator: Karin Lochte, Reporter: Rodica Nitu
  - Societally Relevant Research
    Moderator: Andrey Petrov, Reporter: Embla Eir Oddsdóttir
  - Visas, Permits, and other Bureaucratic Hurdles
    Moderator: Fran Ulmer, Reporter: Hugues Lantuit
- **Report back from each breakout session**
- **Wrap-up**

INDIGENOUS INTERESTS IN ASM3: KNOWLEDGE FOR A SUSTAINABLE ARCTIC

This webinar brought together a panel of Indigenous leaders to discuss the ASM. The importance of inclusion of the knowledge of Indigenous peoples in Arctic science and research and the important role this has on sustainability was discussed. A background of previous efforts and insights around the question "Why is it important for Indigenous Peoples to be involved in Arctic science and research?" were shared. This was followed by a panel sharing how a holistic approach to Arctic Science builds equity and cooperation in the Arctic. The discussion from this webinar formed the basis for guidance on steps moving forward from ASM3.

- **Opening Remarks**
  Lindsay Arthur, Iceland Ministry of Education, Science and Culture
- **Review of the Program**
  Dr. Liza Mack, Executive Director, Aleut International Association
- **Arctic Greeting**
  Lena Susanne Gaup, Kautokeino/Guovdageaidnu, Arctic Norway
- **Keynote speakers:**
  Monica Ell-Kanayuk, President, Inuit Circumpolar Council Canada
  Haliehana Stepetin, Ph.D. candidate in Native American Studies, UC Davis
- **Panel discussion: Why is it important for Indigenous communities to be involved in Arctic science and research?**
  Topics - Gaps in Arctic science, co-production of knowledge, Indigenous engagement in science, Indigenous institutions, language and connection to knowledge, Indigenous education, digitization, inclusion of youth, self-determination, goals for participation in the ASM3 process, etc
  - Panelists:
    Gunn-Britt Retter, Saami Council
    Victoria Buschman, Inuit Circumpolar Council (ICC)
    Sally Swetzof, Aleut International Association (AIA)
    Chief Bill Erasmus, Arctic Athabaskan Council (AAC)
    Grigory Ledkov, Russian Association of Indigenous Peoples of the North (RAIPON)
- **Moderated Q&A with panelists and review of next steps, questions from the audience**
- **Closing**
  Sally Swetzof, Aleut International Association (AIA)

THEME 1, OBSERVE: IMPLEMENTING OBSERVING NETWORKS; DATA-SHARING

The first of the ASM3 theme-based webinars began with a presentation of the Science Advisory Board (SAB) and the science process, which included synthesizing Arctic Research Overviews, ASM2 project updates, new projects contributed to ASM3, a survey on international collaboration and cooperation, online feedback forms and ASM3 research community workshops. The four ASM3 themes are inter-related and should be considered steps of an iterative process to enhance international Arctic research collaboration: Observe, Understand, Respond, and Strengthen. SAB member, Hajo Eicken, presented an overview of contributions to Theme 1: Observe, which included an introduction to the importance, relevance and urgency of observations in the Arctic and recent progress and next steps for Sustaining Arctic Observing Networks (SAON). The overview was followed by presentations highlighting projects submitted to the Observe Theme ranging from a new bottom-up internationally coordinated Arctic Ocean synoptic survey, new mapping and monitoring projects, efforts to coordinate community-based monitoring and Indigenous Knowledge sharing and new technology developed to use unmanned ocean vehicles for scientific data collection. The webinar ended with next steps needed to enhance observations presented by SAB member, Sandy Starkweather, that addressed actions needed to scale out and scale-up observation efforts.

- **Overview of Theme 1: Observe – Progress since ASM2 and Upcoming Projects**
  Hajo Eicken, ASM3 Science Advisory Board Member
- **Highlights from Theme 1: Observe**
  - Synoptic Arctic Survey (SAS)
    Øyvind Paasche, Bjerknes Centre for Climate Research and NORCE, Chair of SAS Scientific Steering Committee
  - Mapping the Arctic: Filling Gaps in the Arctic Geospatial Foundation to Support Research & Sustainability
    Ashley Chappell, NOAA
  - GLIDER. Unmanned ocean vehicles, a flexible and cost-efficient offshore monitoring and data management approach
    Salve Dahle, Akvaplan-niva
  - Atlas of Community-Based Monitoring & Indigenous Knowledge in a Changing Arctic
    Noor Johnson, in cooperation with Inuit Circumpolar Council
  - Arctic Biodiversity Data Service (ABDS) and Circumpolar Biodiversity Monitoring Programme
    Catherine Coon, CBMP Co-Chair
- **Recommended Actions to Increase International Observations and Data Sharing**
  Sandy Starkweather, ASM3 Science Advisory Board Member

THEME 2, UNDERSTAND: ENHANCING UNDERSTANDING AND PREDICTION CAPABILITY FOR ARCTIC ENVIRONMENTAL AND SOCIAL SYSTEMS, FOR THE GLOBAL IMPACT OF THESE CHANGES

SAB member Mia Bennett lead the Theme 2: Understand webinar with a detailed overview of advances since ASM2 and new directions of research to improve our understanding of changes in the Arctic in both natural and social systems. An emerging area of research that addresses linkages and interactions of ecosystem components was presented, as well as progress on predictive capabilities. Following the overview, several projects were highlighted that included research on sea-level rise, climate predictions and the potential impacts on society, plastic and marine debris pollution in the Arctic, co-designing adaptation and mitigation strategies to address impacts from thawing permafrost and coastal erosion and understanding biodiversity changes and impacts on communities. SAB member Henry Burgess summed up the webinar with recommendations for continuing to enhance our understanding of Arctic change, environmental risks, global weather and climate patterns, and on the importance of developing respectful and empowering partnerships.

- **Overview of Theme 2: Understand – Progress since ASM2 and Upcoming Projects**
  Mia Bennett, ASM3 Science Advisory Board Member
- **Highlights from Theme 2: Understand**
  - PROjecTing sEa-level rise: from iCe sheets to local implicaTions – PROTECT
    Gaël Durand, CNRS – IGE, Project Lead
  - ARCPATH: Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies
    Prof. Brynhildur Davíðsdóttir, University of Iceland
  - Linkage between Arctic, climate change, and marine debris
    Suchana Apple Chavanich, Chulalongkorn University
  - NUNATARYUK: co-designed adaptation and mitigation strategies for thawing permafrost and coastal erosion in Northern Canada
    Prof. Dr. Hugues Lantuit, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Project Lead
  - CHARTER: Global effort (China, Russia, Canada, Iceland, etc.) to understand how climate and biodiversity changes will impact arctic communities and their adaptive capacity
    Bruce Forbes, Arctic Centre, University of Lapland, Project Lead
- **Recommended Actions to enhance Arctic understanding and prediction capability**
  Henry Burgess, ASM3 Science Advisory Board Member

THEME 3, RESPOND: OPERATIONALIZING SUSTAINABLE DEVELOPMENT, EVALUATING VULNERABILITY AND RESILIENCE, AND APPLYING KNOWLEDGE

Embla Eir Oddsdóttir, ASM3 Science Advisory Board Co-Chair, began the Theme 3: Respond webinar with progress made since ASM2 including the increase in social science research and the importance of meaningfully involving Indigenous as well as local communities and perspectives in research. She also highlighted the lack of risk and risk assessment projects submitted to this theme. Following the overview presentation several projects were highlighted including work on resilience and changing hydrology, permafrost and boreal ecosystems, dealing with mental health issues and youth suicide in the Arctic, and the impacts of COVID-19 on research. Liza Mack, Indigenous Arctic Knowledge Holder representative to the SAB, summed up the webinar with several actions and next steps that could be taken to create research to help respond to the changing Arctic.

- **Overview of Theme 3: Respond – Progress since ASM2 and Upcoming Projects**
  Embla Eir Oddsdóttir, ASM3 Science Advisory Board Co-Chair
- **Highlights from Theme 3: Respond**
  - HYdrology, PErmafrost, and resilience in Eastern Russian Arctic and Subarctic (HYPE-ERAS)
    David Gustafsson, Swedish Meteorological and Hydrological Institute, Sweden
  - Arctic Community Resilience to Boreal Environmental change: Assessing Risks from fire and disease (ACRoBEAR)
    Steve Arnold, University of Leeds, UK
  - ARC-NAV: Arctic Robust Communities-Navigating Adaptation to Variability
    Abigail York, Arizona State University, USA
  - Local 2 Global
    Selma Ford, ICC
  - COVID-19 in the Arctic
    Jennifer Spence, SDWG Executive Secretary
- **Recommended Actions for responding to Arctic Change**
  Liza Mack, ASM3 Science Advisory Board Member

THEME 4, STRENGTHEN: PREPARING THE NEXT GENERATION THROUGH CAPACITY BUILDING, EDUCATION, NETWORKING, AND RESILIENCE

The Theme 4 Strengthen webinar was led by Andrey Petrov, ASM3 SAB member, who discussed the urgent need and existing gaps in capacity building, education, and networking, both in Arctic and global communities, to provide pathways of support. Projects highlighted in this webinar including education resources for educators, a platform for cloud computing with publicly available Arctic research data, efforts to develop new agricultural methods to produce healthy food in extreme cold climates and the National Inuit Strategy on Research. Henry Burgess, SAB member, wrapped up the webinar with several practical suggestions for strengthening Arctic research and education efforts.

POST-MINISTERIAL REVIEW: JOINT STATEMENT AND ACTIONS

The final webinar was a review of the ASM3 science process and the final outcomes of the Ministerial.

- **Overview of Theme 4: Strengthen – Progress since ASM2 and Upcoming Projects**
  Andrey Petrov, ASM3 Science Advisory Board Member
- **Highlights from Theme 4: Understand**
  - Edu-Arctic – Innovative educational program attracting young people to natural sciences and polar research
    Dr. Agata Godzik, Poland
  - Polar Thematic Exploitation Platform
    David Arthurs, Polar View
  - Arctic Foods Innovation Cluster, AFIC
    Lyubov A. Zarubina, AFIC Project Coordinator, Northern Arctic Federal University, Russia
  - National Inuit Strategy on Research (NISR)
    Tim Argetsinger, Inuit Tapiriit Kanatami
  - Polar Educators International
    Julia Dooley, PEI
- **Recommended Actions for strengthening Arctic capacity building, education, and networking**
  Henry Burgess, ASM3 Science Advisory Board Member

05

MOVING
FORWARD

MOVING FORWARD

The ASM3 science process sought wide-reaching input from participating countries, Arctic Indigenous Peoples' organizations, international organizations engaged in Arctic science and education, as well as the scientific community. The ASM3 Science Advisory Board used this input to outline efforts needed to further enhance cooperation in international Arctic science and research. This section details the key final outcomes of this process with suggestions to improve international science cooperation in the Arctic and close gaps and barriers in research.

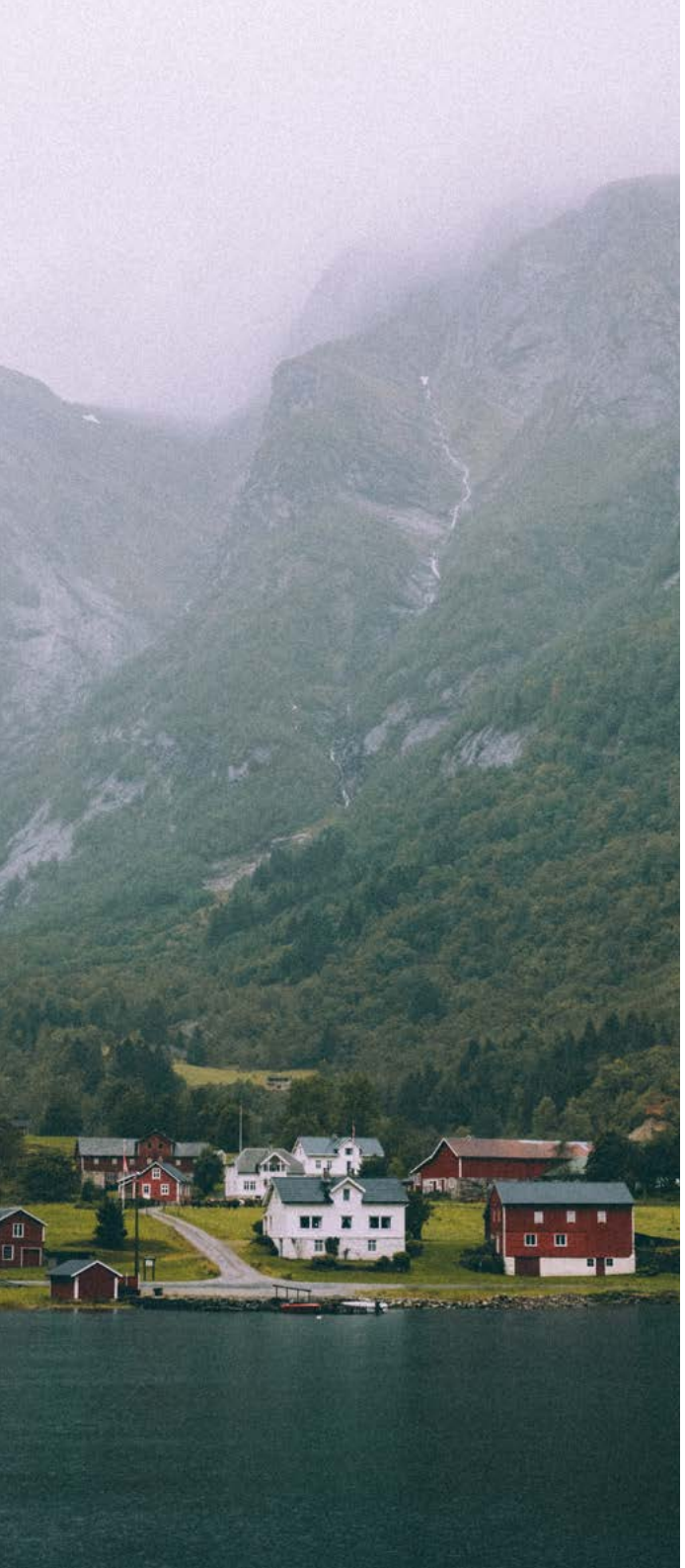
The opportunities identified are not exhaustive, nor a consensus of the ASM3 participants, but are intended to serve as useful resources to facilitate increased international collaboration in developing and advancing the goals of the ASM.

OBSERVING

Overall, observing the Arctic has improved since ASM2 and the number of activities has increased. However, additional efforts are needed to fill critical gaps in data coverage and in operationalizing the routine deployment of autonomous observing platforms, particularly in remote and difficult-to-access areas.

Support for long-term projects that foster meaningful partnerships with Indigenous Peoples as well as local communities is crucial. Community-driven observation provides more resilient research, especially when faced with global disruptions such as COVID-19. Strengthening community-driven research could elevate observation capacities, enhance research outcomes, and strengthen partnerships with the scientific research community across the region. More can be done to increase respect and support for Indigenous self-determination in Arctic research and expand community-driven observing projects that are truly co-designed and co-managed in partnership with Indigenous Peoples. Some specific recommendations to support these efforts are:

- Advance and financially contribute to SAON's Roadmap for Arctic Observing and Data Systems (ROADS) process and the additional important priorities from the Arctic Observing Summit (AOS) **Call to Action** summarized here in brief:
  - » Support ROADS Expert Panels to advance implementation of key observing targets - namely shared Arctic variables identified through inclusive, participatory processes aimed at maximizing societal benefits to Arctic and non-Arctic countries alike;
  - » Contribute **funding for equitable participation of Indigenous Peoples** in the ROADS process and observing system implementation, drawing on principles of co-production of knowledge and co-management of observing assets;
  - » Mobilize **national points of contact** to align and support global and Arctic observing programs, in combination with direct national contributions to the SAON Secretariat to facilitate integration;
  - » Recruit experts from different nations to SAON and AOS so that additional capacity is built in the form of international secretariats or **support structures**;
  - » Expand the ROADS effort such that it reflects Indigenous priorities, drawing on, for example, an **Indigenous food security lens** to develop a more holistic understanding of changes underway and to support adaptive decision-making;
  - » Contribute **funding support for Indigenous Peoples** to engage across activities scaled from the local to the international;
  - » Support capacity-building at the local level to increase the **resilience of observing** programs co-organized with Indigenous Peoples as well as with local communities.



- Work with SAON's Committee on Observations and Networks to update the **inventory of Arctic Observation** efforts and identify gaps as well as areas of overlap and duplication and to develop a mechanism to incorporate smaller project observations into the larger context;
- Link observations to their operational uses, making them more sustainable by connecting value-added knowledge and services to **Arctic communities**;
- Respect and support **Indigenous self-determination** in Arctic research, develop meaningful partnerships, support the co-production of knowledge, ensure observing efforts include sufficient funding to support equitable Indigenous and northern community involvement; recognize and support Indigenous and community-led research;
- Support Indigenous organizations and Arctic communities in providing practical tools and guidelines to enable **more effective and respectful research relationships** with Indigenous Peoples and Arctic residents, such as the ICC's Equitable, Ethical Engagement project;
- Develop a **consensus for pan-Arctic priorities** for proposed and existing observation activities and projects as a framework for engagement and funding;
- Promote the development of **new observing technologies** to fill spatial and temporal gaps while reducing their energy footprint;
- Promote efforts such as the Circumpolar Biodiversity Monitoring Programme (CBMP), which develops comprehensive frameworks to guide and harmonize Arctic biodiversity monitoring, and bottom-up projects such as the Synoptic Arctic Survey (SAS), which will provide a **platform for cooperation** of all ship-based observations in the Arctic ocean; and
- Develop strategies to **adapt to disruptions in observing capacity**, such as those implemented by the Svalbard Integrated Observing System (SIOS), which was able to quickly adapt to major international disruptions from the COVID-19 pandemic.

DATA

For many years, a vision for a shared, publicly accessible system of Arctic observations and data has been discussed. All countries working in the Arctic are encouraged to have and enforce an open data policy with accessible repositories or contribute to another country's repository. Recently, the Arctic and Polar data communities have come together to better understand the Arctic data system, requirements, and possible ways forward. This has been achieved through a number of activities including the Polar Data Forum series, EU-PolarNet, the AOS, the emerging SAON ROADS process, and other initiatives. The following points identify priorities that can help facilitate data sharing:

- Analyze the **state of international Arctic research data** to reduce duplication of data collection and identify areas where more data is needed to identify future priority areas for research funding;
- Provide added resources to **support data community building**, expanding education and training, coordination and engagement, and promote the creation of interfaces between existing, effective, well established initiatives to accelerate progress;
- Recognize the importance of and follow practices relating to **ethical and appropriate use and sharing of Indigenous Knowledge and data about Indigenous Peoples and communities**, such as the CARE Principles for Indigenous Data Governance (Collect benefit, Authority to control, Responsibility and Ethics) and other national or regional protocols such as those identified in the National Inuit Strategy on Research.
- Considering CARE principles, facilitate culture change from proprietary data models to **data as a common good**. This requires enhancing outreach, changing funding policy, and rewarding data publication in addition to using and promoting data attribution and citation as part of research practice;
- Encourage efforts to **standardize international data** collection protocols and procedures to increase data compatibility and comparability;

- Work to ensure that the research community is aware of **existing resources** such as data centers, working groups, conferences, and training material including where and how data should be submitted for long-term curation;
- Increase the level of resources available to enhance a **F**indable, **A**ccessible, **I**nteroperable, and **R**eusable (FAIR) **data culture**, practices and implementation by starting with the most achievable aspects (**F**indable and **A**ccessible while working towards full implementation;
- Work in partnership with Indigenous Peoples and their representative organizations to develop necessary policy and funding frameworks to ensure that Indigenous research priorities, **Indigenous Knowledge** and observations of the Arctic form an integral part of the broader Arctic data ecosystem.

RESEARCH PLANNING

Fundamental Arctic research topics including sea ice, ice sheet dynamics, changes in ecosystems, weather and climate remain critical areas to support. Growing international efforts have significantly advanced our understanding of the impacts of changes in these areas and, with proper support, will continue to do so. There are other areas, representing both traditional science topics and emerging interdisciplinary and transdisciplinary topics, where more focus could be placed to meet societal needs and understand societal change. Some areas of research where more emphasis is needed are:

- Investigating the **impacts of melting glaciers, ice sheets, sea ice, and permafrost** on Arctic communities;
- Developing **research-driven risk assessments** coupled with climate change scenarios;
- Fostering **coordination efforts** between small-scale ecosystem research projects to broaden our understanding across the Arctic landscape;
- Focusing more research efforts on the source, fate and **impact of pollution** in the Arctic, including plastic debris;
- Emphasizing research that examines **Arctic social systems**, their transformations and sustainable development;
- Increasing studies in **Arctic geology**, particularly those needed to understand the slow spreading of the tectonic plates and sub-sea volcanoes and seepages; and
- Encouraging research investigating **the linkages** between various components of the Arctic system, including natural, physical and social sciences.

EDUCATION AND OUTREACH

Education and outreach are critical to building a sustainable Arctic, developing the workforce required to address research needs, creating awareness of the global impact of changes happening in the Arctic and strengthen resilience towards changes both in the natural and social system. Education and outreach are broad terms that encompass everything from formal education (i.e. classrooms) to informal education (i.e. museums, science centers, non-traditional programs, etc.) to casual conversations. The following efforts may support further development in these areas:

- Utilize **mobility exchanges like the** UArctic north2north program (both between Arctic regions and between Arctic and non-Arctic regions) and travel scholarships, and allow for more flexibility for exchanges;
- Strengthen and utilize education and training efforts such as the UArctic;
- Enhance the **stability of newer international networks** such as PEI and APECS;
- Value educators and embed them in Arctic science from the beginning stages of planning research projects and support programs focused on **teacher training** and re-training;
- Establish programs involving researchers, Indigenous organizations/communities, and educators to **create learning opportunities and knowledge exchange** between the Arctic and communities world-wide;
- Fund infrastructure that directly supports education, such as Arctic **high-speed communication** infrastructure;
- Provide **funding for translation** for both resources and meetings, especially for Indigenous languages; and
- Support **international education and training opportunities** and the participation in international Arctic research expeditions, particularly for early career researchers.

INDIGENOUS CAPACITY BUILDING

Indigenous rights holders and representative organizations and communities now often take the lead in developing research and policy initiatives. However, their human, organizational and financial resources are limited and require considerable and urgent investment. The urgency of these challenges has been greatly exacerbated by the COVID-19 pandemic that revealed an acute need to develop sustainable infrastructures reliant on locally-based human and physical capital in order to facilitate research and foster co-production of knowledge with Indigenous Peoples and local communities. Similarly, research programs and scientists need capacity, funding, training, and appropriate planning to properly work with Indigenous Peoples and Arctic residents in full partnership and in line with co-production approaches. To help build capacity, the following efforts are recommended:

- Support **culturally-appropriate** learning and training opportunities for Indigenous Peoples emphasizing **youth** involvement and assuring diversity;
- Support cultural education and training of scientists and scientific program managers to build **successful partnerships with Indigenous Peoples**;

- Enhance communications and **dialogue** between Indigenous Peoples, Arctic residents, and researchers to ensure that international efforts are more efficient, effective, informed and inclusive;
- Advance measures to respect and support **Indigenous self-determination** in Arctic research such that research can address their priorities and needs;
- Provide **greater financial contributions** to research and education efforts initiated by Indigenous Peoples and encourage cooperation with international researchers; and
- Support Indigenous organizations in their efforts to develop **ethical guidelines**, and share guidelines and best practices for research in Indigenous communities.

INTERNATIONAL EFFORTS

The breadth of international projects that collaborating countries submitted to the ASM3 process indicates the wide range of research and partnerships already ongoing in the Arctic. Continuing to support these efforts and others that focus on facilitating international cooperation should be a priority. Examples of international efforts to address the main pressing challenges created by climate change are listed below:

- Support IASC's efforts in assessing the State of Arctic Research and other synthesis and coordination activities;
- Promote involvement in organizations such as IASSA, **UArctic**, **APECS**, **PEI** and others whose mission is to enhance our understanding of the changing Arctic;
- Develop **mechanisms** to help researchers from different countries find new international collaborators;
- Stimulate the implementation of the Agreement on Enhancing Scientific Cooperation in the Arctic by encouraging the community to report issues, challenges and solutions to the competent national authorities for the agreement;
- Foster the creation of a **handbook** on visa requirements, licensing, and permitting in the Arctic to facilitate cooperation and provide a resource for researchers new to the Arctic;
- Continue to support the internationalization of coordination efforts such as INTERACT, **EU-PolarNet**, and ARICE;
- Collaborate through the Arctic Science Funders Forum in efforts facilitating international cooperation, better aligning national and international projects, and developing flagship projects addressing societally urgent research;
- Encourage robust projects that **build on ASM recommendations** and are open to international collaboration;
- Create **funding opportunities** for international exchanges and participation in expeditions; and
- Facilitate **international access** to national research infrastructure, such as research stations, facilities, and data.

NEXT STEPS

The suggested efforts presented here were built on input from participating countries, Arctic Indigenous Peoples' organizations and international organizations, as well as the scientific community. The list is not exhaustive but offers ideas for how to make progress on the outcomes from the 3rd Arctic Science Ministerial. Organizations and individuals with missions to support Arctic research may use these points and incorporate them into strategic plans, priority documents and funding opportunities.

To help facilitate this progress, **an international ASM working group** of representatives from participating countries and organizations may be useful. In lieu of an ASM Secretariat, such a group could be chaired by the

host of the subsequent ASM and actively engage in tracking and encouraging cooperative progress between ministerial meetings, and report back on that progress to ministers at the next ASM.

Complementary reports:

- IASC 2020 State of Science: Arctic Science Report
- Sámi Arctic Strategy 2019: Annex: Building Knowledge in Sápmi, A List of Knowledge Gaps and Research Needs
- UArctic Report on Scientific Cooperation within the Arctic: Understanding Bottlenecks in Cross-Border Research
- National Inuit Strategy on Research (NISR)

Several **resources** were created during the science analysis in the ASM3 process and are available on the ASM3 website. These include a **list of international funding and exchange opportunities for researchers, resources for Indigenous participation in national research programs, national Arctic science priority and strategy documents** and a database of over 400 Arctic research projects, many of which are public and open for international collaboration. Full use of these tools for enhancing international collaboration is strongly encouraged.

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ACRONYMS

ACRONYMS

ABDS	Arctic Biodiversity Data Service
ABoVE	Arctic Boreal Vulnerability Experiment
ACAP	Arctic Contaminants Action Program
ACGF	Arctic Coast Guard Forum
ACRoBEAR	Arctic Community Resilience to Boreal Environmental change: Assessing Risks
AHEAD	Arctic Hydrogen Energy Applications and Demonstrations
AIVAN	Arctic Indigenous Virtual Arts Network
AMAP	Arctic Monitoring and Assessment Programme
AOS	Arctic Observing Summit
APECS	Association of Polar Early Career Scientists
APPLICATE	Advanced Prediction in Polar regions and beyond: modelling, observing system design and LInkages associated with a Changing Arctic climaTE
ARCPATH	Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies
ArcRCC-N	Arctic Regional Climate Centre Network
ARCSAR	Arctic and North Atlantic Security and Emergency Preparedness Network
Arctic-FROST	Arctic FRontiers Of SusTainability: Resources, Societies, Environments and Development in the Changing North
ARENAII	Arctic Remote Energy Networks Academy
ARC	Arctic Research Center
ARICE	Arctic Research Icebreaker Consortium
ASM	Arctic Science Ministerial
ASM1	1st Arctic Science Ministerial
ASM2	2nd Arctic Science Ministerial
ASM3	3rd Arctic Science Ministerial
ASSW	Arctic Science Summit Week
ASTRA	Arctic Space TRAining
CAFF	Conservation of Arctic Flora and Fauna
CAPARDUS	Capacity-building in Arctic standardization development
CAPEC	CircumArctic Permafrost Environment Change Monitoring, Future Prediction and development Techniques of useful biomaterials
CARE	Collect benefit, Authority to control, Responsibility and Ethics
CBMP	Circumpolar Biodiversity Monitoring Programme
CHARTER	Changes in Arctic Terrestrial Biodiversity
CLEO	Circumpolar Local Environmental Observation Network
COSMOS	Continuous Soot Monitoring System
COVID-19	Corona Virus Disease 2019
CROW	Canadian Rangers Ocean Watch
CryoSat-2	Earth Explorer CryoSat mission 2
DBO	Distributed Biological Observatory
DMI	Danish Meteorological Institute
EALLU	'herd' in Sámi
EastGRIP	East Greenland Ice-core Project
ECOTIP	ECOogical TIPping cascades in the Arctic Seas
Edu-Arctic	Engaging students in STEM education through Arctic research
EPB	European Polar Board
ESA	European Space Agency
EU	European Union
EU-PolarNet	European network to co-develop and advance European Polar Research
FACE-IT	Future of Arctic Coastal Ecosystems – Identifying Transitions
FAIR	Findable, Accessible, Interoperable, and Reusable
FAO	Food and Agriculture Organization of the United Nations
FARO	Forum of Arctic Research Operators
GEO	Group on Earth Observations

ACRONYMS

GIOS	Greenland Integrated Observing System
GLIDER	Unmanned Ocean Exploration Project
GRACE-FO	Gravity Recovery and Climate Experiment Follow-On
HYPE-ERAS	HYdrology, PErmafrost and resilience in Eastern Russian Arctic and Subarctic
IASC	International Arctic Science Committee
IASSA	International Arctic Social Sciences Association
ICASS	International Congress of Arctic Social Sciences
ICC	Inuit Circumpolar Council
ICE-ARC	Ice, Climate, Economics – Arctic Research on Change
ICES	International Council for the Exploration of the Sea
ID Arctic	Interdisciplinary study of Arctic sea ice changes and impacts for the society
IMBIE	Ice sheet Mass Balance Inter-comparison Exercise
IMO	International Maritime Organization
INTAROS	Integrated Arctic Observation System
INTERACT	International Network for Terrestrial Research and Monitoring in the Arctic
InteRFACE	Interdisciplinary Research for Arctic Coastal Environments
IOC	Intergovernmental Oceanographic Commission of UNESCO
IPCC	Intergovernmental Panel on Climate Change
IPICS	International Partnerships for Ice Core Sciences
ISAR-6	6th International Symposium on Arctic Research (ISAR-6)
ISO	International Organization for Standardization
ITK	Inuit Tapiriit Kanatami
J-ARC Net	Japan Arctic Research Network Center
JUSTNORTH	Towards Just, Ethical and Sustainable Arctic Economies, Environments & Societies
KEPLER	Key Environmental monitoring for Polar Latitudes and European Readiness
LEO	Local Environmental Observation Network
MARIS	Multi-Parameters Arctic Environmental Observations and Information Services
MARPART	Maritime Preparedness and International Partnership in the High North
MOSAiC	Multidisciplinary drifting Observatory for the Study of Arctic Climate
NASA	National Aeronautics and Space Administration
NGEE Arctic	Next-Generation Ecosystem Experiment
NISAR	US and Indian Space Research Organisation (ISRO) Synthetic Aperture Radar (SAR)
NISR	National Inuit Strategy on Research
OPEN POLAR	Global Open Access Portal for Research Data and Publications on the Arctic and Antarctic
PANABIO	PAN-Arctic Information System on Marine BIOta
PEEX	Eurasian Pan-Eurasian Experiment
PEI	Polar Educators International
PICES	North Pacific Marine Science Organization
PPP	Polar Prediction Project
PROPOLAR	Portuguese Polar Program
PROTECT	PROjecTing sEa-level rise: from iCe sheets to local implicaTions
RADARSAT	Radar Satellite
RECAP	REnland ice CAP project
ReiGH	Reindeer husbandry in a Globalizing North
ROADS	Roadmap for Arctic Observing and Data Systems
SAMCoT	Sustainable Arctic Marine and Coastal Technology
SAON	Sustaining Arctic Observing Networks
SAS	Synoptic Arctic Survey
SCAR	Scientific Committee on Antarctic Research

ACRONYMS

SDWG	Sustainable Development Working Group
SIDFEx	Sea Ice Drift Forecast Experiment
SIOS	Svalbard Integrated Arctic Earth Observing System
T-MOSAiC	Terrestrial Multidisciplinary distribute Observatories for the Study of Arctic Connections
THAAO	Thule High Arctic Atmospheric Observatory
UArctic	University of the Arctic
UK	United Kingdom
UNEP	United Nations Environment Programme
UNIS	University Centre in Svalbard
US	United States
USA	United States of America
WMO	World Meteorological Organization
WWRP	World Weather Research Programme
YOPP	Year of Polar Prediction

07

APPENDIX

APPENDIX

ARCTIC OBSERVING SUMMIT
CALL TO ACTION

The international **Arctic Observing Summit (AOS)** continues to form an important conduit for providing guidance for an international network of Arctic observing systems. A significant improvement in Arctic observation and monitoring has already been achieved thanks to major programs by different nations, but the key messages from AOS need to continue to be considered for the future work. The AOS 2020 identified two priorities in a Call to Action to the ASM3 process.

1. Sustaining Arctic Observing Networks (SAON), through its Roadmap for Arctic Observing and Data Systems (ROADS), is uniquely positioned to help align different observing and data stewardship efforts such that they address societal benefits and urgent information needs from the local to the global level. We call upon countries represented in ASM3 to support SAON through direct national contributions to the Secretariat and ensure that the ROADS process is properly resourced to take up the priorities outlined in the AOS Conference Statement and the SAON Strategic Plan. The resourcing strategy should be a combination of a common effort of the countries participating in ASM3 as well as support from individual countries and major international organizations. Specifically, we ask that (a) ROADS Expert Panels be properly resourced to advance implementation of key observing targets - namely Shared Arctic Variables identified through inclusive, participatory processes aimed at maximizing societal benefits to Arctic and non-Arctic countries alike; (b) funding be provided for equitable participation of Indigenous Peoples in the ROADS process and observing system implementation, drawing on principles of co-production of knowledge and co-management of observing assets; (c) national points of contact be mobilized to align and support global and Arctic observing programs, in combination with direct national contributions to the SAON Secretariat to facilitate integration; and (d) by detailing experts from different nations to SAON and AOS additional capacity is built in the form of international secretariats or support structures.

2. Arctic Indigenous Peoples are essential to Arctic observing activities through their holistic understanding of Arctic change in combination with their potential to help guide and codevelop observations at the observations at the local level. We call upon ASM3 participating countries to expand the ROADS efforts such that it reflects Indigenous worldviews and knowledge, drawing on, for example, an Indigenous food security lens to improve our holistic understanding of changes underway and to support adaptive decision-making. Substantial funding is needed for Indigenous experts, knowledge holders, and youth to engage across activities scaled from the local to the international. As demonstrated by the Covid-19 pandemic, greater resilience of sustained observing programs and Indigenous communities requires support for capacity-building at the local level, amongst scientists, and within monitoring/research programs. Regionally focused, inclusive initiatives to advance coordination of observations are particularly deserving of support.

3RD ARCTIC SCIENCE MINISTERIAL RESEARCH COMMUNITY WORKSHOPS
EXECUTIVE SUMMARY

Compiled by ASM3 Science Advisory Board members Mia Bennett (APECS), Henry Burgess (IASC), and Andrey Petrov (IASSA), with assistance from Allen Pope (IASC).

ABOUT THE WORKSHOPS

In an effort to engage the broader Arctic research community in the 3 rd Arctic Science Ministerial (ASM3) process, IASC, IASSA, and APECS convened two ASM3 Research Community Workshops on 15 June 2020. All those who work in the realm of Arctic research were encouraged to participate, including researchers, managers, Arctic Indigenous Peoples, Arctic residents, partners, educators, policymakers, and other stakeholders. Participants contributed as individuals rather than as representatives of larger organizations, institutions, or demographic groups. The majority of participants were active researchers, which should be noted in interpreting the workshops' outcomes. Further ASM3 processes will aim to more directly engage Arctic Indigenous Peoples.

Each two-hour workshop started with an introduction to the ASM3 process and the goals of the workshop before continuing to hour-long small group breakout discussions involving six to eight people. Each group was dedicated to one of the four ASM3 subthemes, with each group discussing the same provided seven questions (see Appendix). The workshops concluded with each group briefly reporting their key takeaways back to the whole group. An online survey featuring the same guiding questions was also disseminated to collect contributions from those unable to participate in the workshops.

With approximately 200 workshop participants (out of over 300 registrants), there were more discussions than can be captured in any one summary. Rather than presenting a status report from the Arctic research community, this executive summary summarizes the workshop discussions in a way that responds to the needs and recommendations for actions and outcomes from the ASM3.

CROSS-THEME NEEDS AND RECOMMENDATIONS

Bridging barriers:

- The research community seeks a renewed commitment to the Agreement on International Arctic Science Cooperation with a timeframe and specifics on implementation.
- Foster interdisciplinary Arctic research engaging both the natural and social sciences in order to better understand and respond to change.
- Conduct research at macro/international scales when appropriate (i.e., for COVID-19 and oil spills) while still attending to micro-scales (i.e. subsistence lifestyles).
- Leverage existing international virtual and actual initiatives and networks to promote large-scale collaborative Arctic research.
- Encourage transgenerational collaboration, especially with youth.
- Communicate science across linguistic and digital barriers.
- Increase capacity for pooling resources (i.e., chartering flights and boats) in social sciences and related fields, in the same way that some natural science researchers already do.
- Commit to renewed practical action to connect Arctic research to global research initiatives, in particular to help fill gaps in global knowledge.
- Build smarter research programmes which promote opportunities thatm span multiple disciplines, cross borders, and engage traditional and local knowledge (TLK), making them the norm rather than the exception.

Improving (political & financial) support for Arctic research:

- Nearly all groups underscored the importance of long-term funding, inter/multi/trans-disciplinary research, and transparent and accessible data sharing.
- Decision-makers are asked to commit to solving practical issues that are holding back research collaboration, or areas which need political will to solve.
- Improving information, removing barriers, simplifying bureaucracy and streamlining processes around crossing borders, transporting samples, sharing data, securing visas and obtaining research permits.
- The last five years have seen more productive integration of Indigenous communities and rights-holders with scientists and researchers, who are engaging more with policymakers. Yet, more needs to be done. There is a need to increase and sustain funding for this research and foster these relationships over time to continue to observe Arctic change.
- There is a perceived lack of political support for Arctic research, political suspicion around international collaboration in the Arctic, and uncertainty regarding the impacts of changing geopolitics. The international research community seeks stronger support for international Arctic science from policy and decision makers.
- Support SAON's "Roadmap for Arctic Observing and Data Systems" (ROADS) process with financial and human resources.
- Science should be actively supported and improving information, removing barriers, simplifying bureaucracy and streamlining processes around crossing borders, transporting samples, data-sharing, securing visas and obtaining research permits are all important elements which will make a practical difference.

Advancing the data ecosystem:

- The data gap in the Arctic is of a different magnitude to that in many other regions of the world as it is more pressing, significant, and requires more international collaboration to solve. If the data problem remains unsolved, decision-makers risk missing tipping points, making uninformed decisions, and under- or overestimating risk.
- There are misaligned priorities and procedures and therefore difficulties regarding access, exchange, and mobility of physical and digital data. The research community recommends increased harmonization of research programs, procedure and regulations among countries, as well as clearer and simplified procedures and implementation.
- Promote circumpolar data sharing and interoperability standards, require ethically produced and managed data and data sharing (FAIR & CARE Data Principles), and do so in partnership with Indigenous communities with them as key contributors and audiences.
- Adopt common standards for measurements, release data freely and continuously, and, above all, extend and upgrade the instrumentation, data sharing and collections to new regions.

Enhancing the engagement of Indigenous Peoples & local communities

- Arctic research must focus on developing sustained and reciprocal relationships with Indigenous Peoples, facilitate knowledge co-production and co-design, and foster effective, respectful, and equitable engagement that:
  - » Recognizes the sovereignty, distinctiveness, diversity, and inherent value of Indigenous knowledge systems.
  - » Recognizes and promotes Indigenous Peoples' ownership, control, access, and possession over their knowledge and data.
  - » Necessitates knowledge co-production and involves communities at the beginning of the research process.
  - » Provides equitable investment in Indigenous Knowledge systems and funding for Indigenous scholars, knowledge holders, and communities and organizations, including for conducting their own research.
  - » Ensures that benefits of research for communities are prioritized and that changing needs are understood.
  - » Recognizes and understands the variety and diversity of Indigenous communities and the heterogeneity of issues and conditions across Arctic countries and regions.

Responding to COVID-19:

- The COVID-19 pandemic is severely impacting Arctic research and it is crucial to consider health and safety issues for both communities and researchers.
- There is increasing need (both scientifically and logistically, during and post-COVID-19) for participatory observation and citizen science involving Indigenous and local residents, who can provide in-situ observations that can be compiled to provide a pan-Arctic view.

ACTIONS TO BETTER OBSERVE THE STATUS OF ARCTIC CHANGES

Arctic engagement:

- Involvement and leadership of Indigenous Peoples and local residents is crucial for long-term observations.
- ASM3 could push for any project that has existed for > 3 years to be mirrored by a local project.
- Barriers should be removed in compensating local informants/observers and ensuring that their contributions are seriously considered and integrated into research.

How the science gets done:

- Evidence-based knowledge should be central in dealing with natural hazards, risk assessment, and decision making
- Long-term observations remain a vital tool in understanding the pace and impact of change
- Observing and modeling scientific communities should collaborate more
- Arctic researchers require:
  - » Streamlined procedures
  - » Improved mobility and accessibility of data and samples
  - » Improved pooling of infrastructure logistics
  - » More exchanges of researchers and students

Research topics:

- Promote Shared Arctic Variables within observing systems.
- Amass more year-round and especially wintertime observations of biogeophysical processes and changes in the Arctic Ocean; this could be encouraged during the UN Decade of Ocean Science (2021-2030).
- Improve and develop monitoring and observing programs. Examples of focus areas mentioned by workshop participants include:
  - » Climate change and weather prediction
    - › Improve meteorological data collection and build denser networks of marine, terrestrial, and seismic observing stations to close spatial gaps
    - › Engage people with knowledge of sea ice and weather patterns to observe sea ice loss, coastal erosion, and permafrost degradation
    - › Provide early warnings to better predict potential cascading effects
  - » Public health, food security, and their relations to the environment and economy (i.e. agriculture, climate change, etc.)
  - » Interdisciplinary studies of the cryosphere and living in cold regions
  - » Ecological and biogeochemical forecasts, feedbacks, and interactions
  - » Marine biodiversity and marine mammals
  - » Terrestrial snow cover
  - » Basic observations for the opening of the Arctic Ocean

ACTIONS TO BETTER UNDERSTAND LOCAL AND GLOBAL IMPACTS

Indigenous engagement:

- Appreciation, learning, and use of local languages is important to understand the true value of Indigenous Knowledge.
- Work with Indigenous partners to identify ethical protocols for research.
- Encourage research entities to directly employ Indigenous Knowledge holders and push governments and funding agencies to fund Indigenous communities to work with their own knowledge.
- Devise practical research approaches which benefit scientists and local/Indigenous communities through fair reward, education, training and employment.
- Be mindful of the complicated history of scientific involvement in the Arctic, particularly with regard to relationships with Indigenous communities
- Help identify proper and respectful ways of contacting and engaging Indigenous and local communities, especially for early career/new researchers, in order to better disseminate results of research in Arctic communities.

Building better partnerships:

- Enhance collaboration between natural and social science communities.
- Look to bilateral collaboration as a model for international collaboration.
- Discrepancies in regional data makes comparisons difficult - the research community needs support to build a centralized repository for protocols that support measuring data in a comparable way (rather than only after data collection), coding, and producing metadata, as well as to establish a forum for regional statistics agencies.

Research planning:

- Conferences and events should be opened up to Northern communities and hosted there when possible and practical.
- Emphasize community-based, co-designed, participatory research with Indigenous communities to ensure the local relevance of Arctic science
- More focus on and investment in social and human sciences is critical for understanding change across health, economics, politics, connectivity, and education.
- Consider establishing "information hubs" within government agencies or professional organizations to improve awareness of processes and protocols for Arctic research

Example of research topics requiring greater focus:

- Impacts of Arctic change on local communities
- Impacts of technology, infrastructure, and climate change mitigation/adaptation
- Greater social science and humanities focus on the social, political and economic systems and integration of Arctic areas into national and global systems and processes
- Impacts of economic development (especially of natural resource extraction).
  - » Pollution (noise, invasive species, biofouling), tourism, maritime development, search and rescue, income inequality, natural resource management
- Interrelationships between environment and human health (COVID-19, food security)
- Sea ice dynamics, ocean-sea ice-atmosphere interactions, long-range transport of contaminants, changes in trends of climate forcers, carbon cycle, glaciology, impacts of added freshwater, changing light conditions, nutrient flux, migratory species, changing migration/phenology of flora

ACTIONS TO BETTER RESPOND TO THE CHANGES BASED ON A SHARED UNDERSTANDING:

Creating common ground:

- Convey rapid Arctic climate change, its cascading effects, and the need for risk assessment to policymakers - perhaps as part of the ASM3 Joint Statement.
- Involve Indigenous Peoples and Indigenous Knowledge in responses to change.
- Require a conceptual framework for a long-term Arctic monitoring programme combining research, governance, infrastructural, environmental, and socio-economic elements to inform the development of a long-term operational system.
- Improve connection of Arctic research to global research initiatives and fold lessons from the Arctic into those initiatives
- Sharpen understanding of the heterogeneity of Arctic countries and sub-regions down to localities, as focusing on collaboration to describe northern areas as unified or even under one "Arctic" umbrella can detract from rather than add to understanding
  - » Realize that experience from one part of the Arctic cannot automatically be transferred to responding and policymaking in another
- Rely on evidence-based observations to avoid responding 'in the dark'

Research capacity:

- Researchers should make results relevant to local communities and global society, provide opportunities for local communities to contribute to research, leave positive economic footprints, and encourage knowledge transfer.
- Lower barriers to international cooperation and access
- Move beyond only aligning projects/programmes from different countries and actually create joint collaborative research
  - » Encourage funding schemes for international collaboration that maximise impact, foster productive, and lasting working relationships, and build an evidence base.
  - » Create more specific funding schemes for cross-border and international collaboration and synchronize funding cycles in different countries, for example via the Forum of Arctic Research Funders.
- Different languages were also identified as a key barrier to research
- Involve Indigenous and local communities in data analysis and modeling that guide understanding of and responding to change.
- Increase involvement of early career researchers in assessment and policymaking.

ACTIONS TO BETTER STRENGTHEN THESE EFFORTS THROUGH EDUCATION AND CAPACITY-BUILDING FOR FUTURE:

Education:

- Improve international cooperation in polar education. Recognize that successful programs are often spurred by enthusiastic individuals (e.g. Science in the Classroom (USA-Russia) and ARCTIS (UK-Russia)). Support these champions and their related organizations.
- Encourage collaboration between universities and local communities (i.e. Nunavut Arctic College) and within tourism industry, as it is often a driver of economic development
- Remember venues outside the classroom to engage and educate the public, such as museums.
- Strengthen communication to ensure that policymakers have adequate understanding of Arctic social sciences and natural sciences research.
- The Arctic should appear much more consistently in education for young people and others, in particular before they reach university.
- The next generation of Arctic researchers should be nurtured and institutions supported to build connections to incentivize international connections.
- Promote education to support collaboration across borders, sectors, and disciplines.

Accessibility:

- Holding research community events in multiple time zones promotes inclusivity, but translation into Russian would be helpful as Russian Indigenous Peoples often don't speak English.
- Include smaller organizations and expand beyond governmental level, such as by providing more financial and logistical support for local and community workshops
- Improve connectivity and mobility, including supporting technology and internet access.
- Better physical and technological links with Arctic communities are essential for the long-term interests of both communists and the research community.

Building cooperation:

- Build bridges between governments and research councils to the local communities hosting researchers.
- Strengthen connections between educators and researchers as well as between researchers and communities.
- Strengthen cross-communication and collaboration between social and natural scientists in Arctic research
- Recognise the huge research potential of non-Arctic countries in Arctic research and find better ways of folding them into priority setting and international initiatives.
- Foster intersectional research incorporating different demographics (i.e., across gender and age) groups in gender and age.

APPENDIX

Refocus on communities:

- Educate the whole Arctic research community on best practices in know edge sharing and community-based research.
  - » Provide funding, training, and opportunities for scientists to share data with communities.
  - » Provide seed money to strengthen the preparatory work leading to joint projects, community engagement, and our ability to address the needs of Indigenous/local communities, so that they are able to not only participate and benefit from the research, but develop their own research questions and initiatives too.
- Promote and support the active and ongoing inclusion of Indigenous communities in Arctic researchStrengthen ethical and legal frameworks for engaging Indigenous communities
- Research best-practice pedagogy for Arctic communities including using Indigenous education models and enhancing remote education and distance learning
- Use UN/Arctic SDGs as pedagogical frameworks for teaching about sustainable development
- Build digital platforms for local residents to raise issues and interact with Arctic researchers
- Distribute scientific knowledge back to the local level to promote capacity-building and education and expand outward to share lessons with Indigenous communities outside the Arctic.
  - » Compare and share experiences of "hazard-scapes" at local and regional levels.
- Create international guidelines for researchers to ensure that community-driven institutions and traditional and local knowledge holders are involved in identifying gaps, data collection, and co-management of projects and programmes

Workshop & Survey Guiding Questions:

1. How has international collaboration contributed to major advances of our understanding of topics in this theme? In what areas would more collaboration aid in further advances? Please give specific examples.
2. Related to this theme, how have Indigenous Knowledge and/or engagement with Arctic residents been a part of setting directions for Arctic research? Describe and discuss your experiences.
3. Related to this theme, what do you think are the barriers to international collaboration? Do you have any suggestions on how those barriers could be lowered or removed? Please give specific examples. (For example, we know funding is a limitation, but what specifically would facilitate your research beyond "more funding"?)
4. Related to this theme, what do you wish policy makers understood more about Arctic research?
5. Related to this theme, what do you think are the most important Arctic research topics that require international collaboration?
6. Related to this theme, what do you hope comes out of the ASM3 that would help make major advancements that would make a difference for Arctic research?
7. Overall: What other questions should the ASM3 organizers be asking?

Notes from the workshops
Survey Responses
Workshop 1 opening
Workshop 1 sharing back
Workshop 2 sharing back

THE SIXTH INTERNATIONAL SYMPOSIUM ON ARCTIC RESEARCH (ISAR-6)

SUMMARY STATEMENT FROM THE ASM3 SPECIAL SESSION*

The Arctic is experiencing rapid environmental changes, creating far-reaching environmental, societal, and economic challenges for people living in the region. The consequences of these changes are global, influencing the weather, ecosystems, and human societies well beyond the region. Despite our increased knowledge of the underlying physics that drives these changes, many atmospheric, marine, and terrestrial processes are not fully understood; especially the roles of clouds, aerosols, sea ice, greenhouse gases, land processes, ozone depletion, solar activity, and other factors involved in Arctic change.

The International Symposium on Arctic Research (ISAR), a quasi-biannual interdisciplinary symposium on a wide range of topics in Arctic research, recently held its sixth meeting (ISAR-6). It was originally scheduled to commence in March 2020 in Tokyo, but the symposium urgently moved online due to the start of the COVID-19 pandemic. Despite the limitation of not meeting in person, the interactive discussion between participants was made available through an online presentation system.

ISAR has been a forum where international researchers from various disciplines can bring their latest findings to a cross-disciplinary discussion on the ongoing changes in the Arctic, and their far-reaching effects. It has proved to be an indispensable setting for furthering our understanding of the complexities of the climate, environment, and social systems of the Arctic. ISAR-6 included a special session to present and discuss scientific contributions to the Third Arctic Science Ministerial (ASM3), aimed to provide an opportunity to inform policymakers of essential issues.

Recommended Actions or the research topics to be focused

We focused on the activities where an improved and better-coordinated international scientific effort can provide opportunities to advance understanding, and increase the ability to meet societal challenges and opportunities. The actions and topics are grouped by four themes defined for this special session.

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

- It is necessary to support the Sustaining Arctic Observing Networks (SAON) and its roadmap if we are to improve international efforts for coordinating observations and data management. Setting up an expert panel to determine the essential observation elements for each region will be the next step.
- The Svalbard Integrated Arctic Earth Observing System (SIOS), an international consortium to develop and maintain a regional observing system, is a successful example of coordinating observation and research.
- The amount of data in the Arctic is growing, and many observing systems have been established. However, the funding is mainly dependent on

*This document is not a comprehensive summary of the whole symposium, but summarizes the contributions in the special session S20, titled "Scientific Contributions to the Third Arctic Science Ministerial", with a focus on specific action items. The summary is based on the presentations and exchanges on the ISAR online platform and a virtual meeting discussion, as well as the survey form inputs from the presenters and ISAR participants.

time-limited projects, thus impacting its sustainability. Arctic observing systems should be advanced under the sustainable funded programs and better coordinated with the operational monitoring systems.

- Adequate funding mechanisms should be established to support a data management system for multidisciplinary Arctic data, through which the Arctic data must be available openly.
- The COVID-19 pandemic has shed light on the vulnerability of the Arctic observations. Stronger cooperation between the scientists and more involvement of the Indigenous and local communities are needed, to avoid the loss of long-term observation and important data.
- The research infrastructures of countries should be easily accessed and open for collaborations. It is important to maintain such schemes to access and share the facilities, not only to provide opportunities for the research community, but also as a potential solution for human resources. Such communications will be necessary for future planning of large international projects like MOSAiC.
- Hi-speed internet connection is one of the infrastructures now of high demand for the Arctic. It is crucial to have a stable and fast connection for observing, education, and many other activities.

2. Understanding Regional and Global Dynamics of Arctic Change

- Current research priorities based on IASC Working Groups reporting are: The role of the Arctic in the global system, observing and predicting future climate dynamics and ecosystem responses, understanding the vulnerability and resilience of Arctic environments and societies, and supporting sustainable development.
- It is necessary to revisit the value of basic natural sciences, even though some of them are seemingly not directly connected to societal problems. They are often indispensable to fill the knowledge gap in order to understand the Arctic system.
- Prediction capability has room for improvements, and continuous improvements of numerical models are necessary, as well as the full use of computational engineering. After the YOPP ends in 2022, a post-YOPP program would be needed to make further advances.

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

- The dataset on fish/food resources, contaminants/pollutants in the Arctic ecosystem, and Indigenous Knowledge are important for the evaluation of vulnerability and resiliency. Successful approaches to interact with the indigenous knowledge are the inclusion of Indigenous communities in observation and outreaches.
- An accurate understanding of the pros and cons of ongoing changes is important in responding to changes. Wildfire, permafrost thawing, glacial river flood, loss of sea ice, and landslide were examples of serious impacts of changing climate and environments on human society, whilst the sustainable exploitation of the abundant natural resources within the Arctic, and shorter global trade routes (e.g. Northern Sea Routes), are examples of positive influence.
- We need to improve decision-making by cross-weaving knowledge systems, co-management, and community-driven environmental monitoring to increase the number of Arctic resource managers and scientists who can facilitate, implement and operationalize participatory approaches to natural resource management and monitoring in practice.

4. Capacity Building in the Arctic. Contribution of Science and Engineering, Private Sector and the Local Communities

- The importance of education for younger generations living in the Arctic should be stressed. There were also good lessons from the COVID-19 pandemic, which showed the potential of online education.
- Useful Arctic Knowledge (UAK) is an example of projects to advance capacity building aiming to contribute to building cross-disciplinary competence and use of modern data collection and dissemination methods. It expects to have a positive impact on cooperation among the science, business, and public sectors.
- It is essential to develop human resources in the Arctic through the co-production of knowledge with Indigenous communities. It can positively impact the future capacity of observations and research, and the mitigation and adaptation to the changes.
- Language is one of the obstacles, especially for collaboration with indigenous people. Their original languages should be respected, but communication is more difficult without an international language.

Conclusion

As shown in the discussion throughout the symposium, interdisciplinary gathering connects researchers, knowledge, data, and projects, which is a key to study the Arctic on large spatial and long temporal scales. It is expected to enhance the communication with the Arctic local communities and policymakers so that the collaboration and co-production of the knowledge will be accelerated, and scientific findings can be conveyed more smoothly.

08

ANNEX

ANNEX

THIRD ARCTIC SCIENCE MINISTERIAL
PROGRAM

DAY 1

Saturday 8 May 2021 | 19:00-22:00 JST (UTC+9)

19:00 OPENING

19:05 Welcoming address by the ASM3 co-chairs

- HAGIUDA Koichi, Minister of Education, Culture, Sports, Science and Technology, Japan
- Lilja D. Alfreðsdóttir, Minister of Education, Science and Culture, Iceland

19:05 Welcoming video message by SUGA Yoshihide, Prime Minister, Japan

19:25 Reporting from Science Advisory Board co-chairs

- Icelandic Representative: Embla Eir Oddsdóttir (Icelandic Arctic Cooperation Network)
- Japanese Representative: Dr. ENOMOTO Hiroyuki (National Institute of Polar Research, Japan)

19:40 THEME 1: OBSERVE

Moderator: IKUKAWA Hiroshi, Director-General of Research and Development Bureau, Ministry of Education, Culture, Sports, Science and Technology, Japan

19:40 Introduction by Science Advisory Board

- Arctic Observing Summit (AOS) Representative: Dr. Hajo Eicken (International Arctic Research Center, University of Alaska Fairbanks)

19:45 Countries/ Indigenous Peoples' Organizations statements (9)
India, Inuit Circumpolar Council (ICC), Italy, Japan, Republic of Korea, Portugal (pre-recorded video), Russian Federation (pre-recorded video), Sweden, United Kingdom

20:25 General discussion

20:40 10-minute break

20:50 **THEME 2: UNDERSTAND**

Moderator: IKUKAWA Hiroshi, Director-General of Research and Development Bureau, Ministry of Education, Culture, Sports, Science and Technology, Japan

20:50 Introduction by Science Advisory Board

› Association of Polar Early Career Scientists (APECS) Representative: Dr. Mia Bennett (The University of Hong Kong)

20:55 Countries/ Indigenous Peoples' Organizations statements (9)

› Austria (pre-recorded video), Belgium (pre-recorded video), China (pre-recorded video), Denmark, France, Germany, Gwich'in Council International (GCI), Switzerland, United States

21:35 General discussion

21:50 **CLOSING OF DAY 1**

Moderator: IKUKAWA Hiroshi, Director-General of Research and Development Bureau, Ministry of Education, Culture, Sports, Science and Technology, Japan

21:50 Closing of Day 1 and announcement of Day 2

21:50 Group Photo

THIRD ARCTIC SCIENCE MINISTERIAL
PROGRAM

DAY 2

Sunday 9 May 2021 | 19:00-22:00 JST (UTC+9)

19:00 OPENING OF DAY 2

19:00 Summary of Day 1

› Lilja D. Alfreðsdóttir, Minister of Education, Science and Culture, Iceland

19:05 Keynote speech from co-hosting countries

› Japan: Dr. SUGIYAMA Shin (Hokkaido University)

› Iceland: Dr. Joan Nymand Larsen (Stefánsson Arctic Institute)

19:25 THEME 3: RESPOND

Moderator: Stefán Haukur Jóhannesson, Ambassador of Iceland to Japan

19:25 Introduction by Science Advisory Board

› Icelandic Representative: Embla Eir Oddsdóttir (Icelandic Arctic Cooperation Network)

19:30 Countries/ Indigenous Peoples' Organizations statements (7)

Arctic Athabaskan Council (AAC), Faroe Islands, Finland, Greenland (pre-recorded video), Poland, Russian Association of Indigenous Peoples of the North (RAIPON), Spain

20:05 General discussion

20:20 10-minute break

20:30 THEME 4: STRENGTHEN

Moderator: Stefán Haukur Jóhannesson, Ambassador of Iceland to Japan

20:30 Introduction by Science Advisory Board

› IASSA Representative: Dr. Andrey Petrov (The University of Northern Iowa)

20:35 Countries/ Indigenous Peoples' Organizations statements (9)

› Aleut International Association (AIA), Canada (pre-recorded video), Czech Republic, European Union, Iceland, Netherlands, Norway, Saami Council, Singapore

21:15 General discussion

21:30 5-minute break

21:35 CLOSING

Moderator: Stefán Haukur Jóhannesson, Ambassador of Iceland to Japan

21:35 Joint Statement presentation

21:50 › IKUKAWA Hiroshi, Director-General of Research and Development Bureau, Ministry of Education, Culture, Sports, Science and Technology, Japan

21:40 Signing of the Joint Statement by the Ministers/HoD

21:45 Announcement of ASM4 by the Russian Federation/France

21:50 Closing remarks by the ASM3 co-chairs

› Lilja D. Alfreðsdóttir, Minister of Education, Science and Culture, Iceland

› HAGIUDA Koichi, Minister of Education, Culture, Sports, Science and Technology, Japan

22:00 END OF THE MINISTERIAL

THIRD ARCTIC SCIENCE MINISTERIAL
HEADS OF DELEGATION LIST

HOST COUNTRIES REPRESENTATIVES

ICELAND	Minister, Ministry of Education, Science and Culture, **Lilja D. Alfredsdottir**
JAPAN	Minister, Ministry of Education, Culture, Sports, Science and Technology, **HAGIUDA Koichi**

COUNTRIES/GOVERNMENTS REPRESENTATIVES

AUSTRIA	Ambassador, Austrian Embassy in Tokyo, **Elisabeth Bertagnoli**
BELGIUM	Ambassador of Belgium for Norway and Iceland, Ministry of Foreign Affairs, **Frank Arnauts**
CANADA	Minister of Northern Affairs, Crown-Indigenous Relations and Northern Affairs, **Daniel Vandal**
CHINA	Vice Minister, Ministry of Science and Technology, **Wei Huang**
CZECH REPUBLIC	Deputy Minister for Higher Education, Science and Research, Ministry of Education, Youth and Sports, **Pavel Dolecek**
DENMARK	Deputy Director General, Danish Agency for Science and Higher Education, **Stine Joergensen**
EUROPEAN UNION	Commissioner for Innovation, Research, Culture, Education and Youth, European Commission, **Mariya Gabriel**
FAROE ISLANDS	Permanent Secretary, Ministry of Foreign Affairs and Culture, **Poul Geert Hansen**
FINLAND	Ambassador, Embassy of Finland in Japan, **Pekka Orpana**
FRANCE	(For Day 1) Director General for Research and Innovation, French Ministry of Higher Education Research and Innovation (MESRI), **Nicolas Chaillet** (For Day 2) French Ambassador for the Poles and Maritime Issues, French Ministry of Europe and Foreign Affairs (MEAE), **Olivier Poivre d'Arvor**
GERMANY	Parliamentary State Secretary, Federal Ministry of Education and Research, **Michael Meister**
GREENLAND	Minister for Education, Culture, Sports and Church, **Peter Olsen**
INDIA	Union Cabinet Minister, Ministry of Health and Family Welfare; Science and Technology; and Earth Sciences, **Harsh Vardhan**
ITALY	Minister, Ministry of Universities and Research, **Maria Cristina Messa**

COUNTRIES/GOVERNMENTS REPRESENTATIVES

NETHERLANDS	Demissionary Minister, Ministry of Education, Culture and Science, **Ingrid K. van Engelshoven**
NORWAY	Minister, Ministry of Research and Higher Education, **Henrik Asheim**
POLAND	Ambassador, Embassy of the Republic of Poland in Japan, **Paweł Milewski**
PORTUGAL	Minister, Ministry of Science, Technology and Higher Education, **Manuel Heitor**
REPUBLIC OF KOREA	Director General, Marine Policy Bureau, Ministry of Oceans and Fisheries, **KIM Chang Kyun**
RUSSIAN FEDERATION	Ambassador Extraordinary and Plenipotentiary of the Russian Federation to Japan, **Mikhail Y. Galuzin**
SINGAPORE	Senior Minister of State for Foreign Affairs and Transport, **CHEE Hong Tat**
SPAIN	Secretary General of Research, **Rafael Rodrigo**
SWEDEN	Minister for Higher Education and Research, Ministry of Education and Research, **Matilda Ernkrans**
SWITZERLAND	State Secretary for Education, Research and Innovation, State Secretariat for Education, Research and Innovation SERI, **Martina Hirayama**
UNITED KINGDOM	UK Minister for Science, Research and Innovation, UK Government, Department for Business, Energy and Industrial Strategy, **Amanda J. Solloway**
UNITED STATES OF AMERICA	Acting Director and Chief of Staff, Office of Science and Technology Policy, Executive Office of the President, **Kei Koizumi**

INDIGENOUS PEOPLES' ORGANIZATIONS REPRESENTATIVES

ALEUT INTERNATIONAL ASSOCIATION (AIA)	Unable to attend
ARCTIC ATHABASKAN COUNCIL (AAC)	Unable to attend
GWICH'IN COUNCIL INTERNATIONAL (GCI)	Director, **Evon Peter**
INUIT CIRCUMPOLAR COUNCIL (ICC)	Chair, **Dalee Sambo Dorough**
RUSSIAN ASSOCIATION OF INDIGENOUS PEOPLES OF THE NORTH (RAIPON)	President, **Yury Khatanzeyskiy**
SAAMI COUNCIL	President, **Christina Henriksen**


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Tokyo, Japan
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