The International Arctic Science Committee´s

2022 STATE OF ARCTIC SCIENCE REPORT

Arctic Lands Acknowledgement

The circumpolar Arctic is the home to many different Indigenous Peoples. As researchers and others who are working in, or reside in, the Arctic we recognize these lands and waters as the mostly unceded traditional homelands of Indigenous Peoples. Wherever you may be reading this report, IASC honours and recognizes the place-based knowledge of Arctic Indigenous Peoples, and the ancestral and contemporary stewardship of their homelands. IASC encourages the Arctic science community to do the same.

It is the responsibility of each of us individually to learn, read, and gain better understanding of the Indigenous Peoples and cultures with which we engage. IASC encourages the Arctic research community to use their understanding to enhance engagement, partnerships, and co-production of knowledge with Indigenous Peoples.

IASC is also committed to recognizing that all knowledge and scientific systems (including Indigenous Knowledge, Traditional Knowledge and Local Knowledge), are equal and complementary, and should inform the work of IASC.

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Introduction

Photo by Irek Sobota

The IASC State of Arctic Science Report 2022 presents a cohesive synthesis of Arctic research activities and priorities with of a large range of input and contributions across all aspects of Arctic research. It is aimed at Arctic science agencies, managers, and users including a wide range of decision-makers and policymakers, to help all Arctic science stakeholders stay up to date on Arctic research.

Published since 2020 by the **International Arctic Science Committee (IASC),** it has been updated on an annual basis by the members of several IASC or IASC-affiliated committees including the IASC Working Groups (Atmosphere, Cryosphere, Marine, Social and Human, Terrestrial); the **International Science Initiative in the Russian Arctic (ISIRA);** the former **IASC Action Group on Indigenous Involvement**, the **Arctic Data Committee (ADC),** and the **Sustaining Arctic Observing Network (SAON)**. The content of the report is compiled by the researchers themselves and is not exhaustive.

There are many other NGOs, IGOs, institutions, non-profits, Indigenous Peoples' organizations, private and public companies, and others from countries around the world working in the Arctic knowledge space that are currently not included in the preparation of this report. A wider range of stakeholder and knowledge holders will be included in future versions of this report leading up to the **Fourth International Conference on Arctic Research Planning (ICARP IV)** in 2025, for which the **IASC State of Arctic Science Report series** (available on the IASC website under https://iasc.info/about/publications-documents/state-of-arctic-science) will contribute an important resource during the planning process.

IASC was founded in 1990 at a time of great geopolitical uncertainty, but also of hope, as a non-governmental, international scientific organization, operating among its now 24 member countries. It works on a consensus basis to encourage and facilitate international cooperation in all aspects of Arctic research, across all countries engaged in Arctic research and in all areas of the Arctic region. IASC is a connector – connecting scientists and other knowledge holders across international, disciplinary, and cultural boundaries and connecting those who do research with those who apply the outcomes of research to inform solutions to Arctic challenges.

While the challenges for Arctic research due to the Covid-19 pandemic in the last two years are starting to ease, the geopolitical situation that has arisen as a result of Russia's actions in Ukraine has created further short term and also long-lasting uncertainties for research in the Arctic. The situation is seriously affecting international scientific collaboration and the ability of the international scientific community to carry out research and observations across vitally important areas of the Arctic. The impact on scientific conferences and events, travel and fieldwork, exchange programs and secondments, funding decisions and especially international research expeditions has been profound. The consequences are felt by national and international researchers, and the Indigenous Peoples of the Arctic, many of whose lands, waterways and communities span national boundaries.

The work of the Arctic Council, currently chaired by the Russian Federation, has been paused since March 2022 when seven of the Arctic countries ("Arctic 7"- Canada, Finland, Iceland, Kingdom of Denmark, Norway, Sweden, and the United States) decided to temporarily pause their participation in Arctic Council activities. Some limited collaboration restarted in June 2022, when the "Arctic 7" resumed limited continuation of projects and cooperation without Russian participation based on the workplan that all eight Arctic states had approved in 2021, while the Russian Federation has informed that it continues to implement its chairmanship program domestically.

Research in the Arctic, and in particular climate research, relies on international collaboration, access, and continuous monitoring and data sharing among all regions of the Arctic to understand and effectively respond to the climate crisis and other changes in the Arctic. The principles of scientific freedom; of research independence; and of peaceful international cooperation are vital for the researchers, Indigenous Peoples and many others who are working together to understand and respond to ongoing pressing climate, environmental, resource and social changes across the Arctic. Due to these rapid changes in the Arctic, there are intricate links to near-term and long-term stewardship, security, and human-rights concerns of many nations involved in Arctic research, Indigenous Peoples, and the broader global community.

Those involved in Arctic research are having to adjust to the new challenging realities in forming partnerships and in creating meaningful international Arctic science collaboration. In looking for ways to continue to work effectively in the future, the annual **IASC State of Arctic Science Report** is a crucial tool for IASC to identify and prioritize common areas of interest. It will also assist in monitoring the practical effects of the new realities on Arctic research and collaboration over the coming years.

The Fourth International Conference on Arctic Research Planning (ICARP IV)

Photo by University of Colorado/Glenn Asakawa

In the lead up to its 35th anniversary in 2025, IASC is coordinating a multi-year planning process for the 4th International Conference on Arctic Research Planning (ICARP IV). IASC´s Founding Articles call upon IASC to periodically review the status of Arctic science. As a result, IASC has been organizing the International Conferences on Arctic Research Planning (ICARP) every 10 years to provide a forum for the Arctic research community to come together and to discuss and identify priorities for international and multidisciplinary science.

The first ICARP was convened in Hanover New Hampshire, USA in 1995, implementing the IASC Founding Articles' call for IASC to host such a conference periodically in order to "review the status of Arctic science, provide scientific and technical advice, and promote cooperation and links with other national and international organizations." Since then, it has been the role of IASC to coordinate this important meeting every decade.

ICARP II was held in Copenhagen in 2005 and developed twelve forward-looking science plans and resulted in several follow-up international projects and programs, mostly within the framework of the International Polar Year 2007-2008. ICARP III was in Toyama Japan in 2015 and provided a framework to further the development of cross-cutting, interdisciplinary, and trans-disciplinary initiatives for advancing Arctic research cooperation and applications for Arctic knowledge (see chapter Current Arctic Research Priorities). The IASC Strategic Plan (2018 – 2023) builds on the key priorities and overarching messages of ICARP III.

The ICARP IV process during 2022 to 2025 must be well planned and coordinated with other ongoing international activities. To ensure this, IASC is engaging our partners in Arctic research to enable a community-wide undertaking, with about 25 international organizations contributing to the process so far. ICARP IV will identify important research questions and priorities that cut across disciplines and knowledge systems, and that require new and innovative thinking and collaboration. ICARP IV will develop a vision for implementation alongside science plans for addressing these priorities. An integral aspect of the ICARP IV will be the inclusion of early career researchers, Indigenous Peoples, and local residents in the co-creation of priorities and science plans to address the key questions. ICARP I, II, and III focused the attention of the world's researchers toward the value of strategic international coordination in accelerating progress in addressing critical challenges. ICARP IV will build upon this concept by striving to achieve consensus and build collaborations among the leading scientific, academic, environmental, Indigenous and political organizations currently concerned with Arctic issues.

The focus of ICARP IV will be on important research questions that cut across many disciplines and knowledge systems. IASC is committed to recognizing that Traditional Knowledge, Indigenous Knowledge and academic scientific knowledge are coequal and complementary knowledge systems that all can and should inform the work of IASC and ICARP IV. Research efforts should provide improved understanding and predictive capabilities for the evolution of Arctic systems. Consideration will be given to providing relevant and useful information that people in the Arctic and those in more temperate and tropical regions need to have in order to adapt and prepare for the changing Arctic and its impact on global systems.

For ICARP IV, a planning and consultation process was initiated in 2022 that will culminate at the ICARP IV conference to be convened in Boulder Colorado, USA in 2025, hosted by a consortium of US institutions, including the University of Colorado Boulder, University of Northern Iowa, University of Alaska Fairbanks, and Alaska Pacific University.

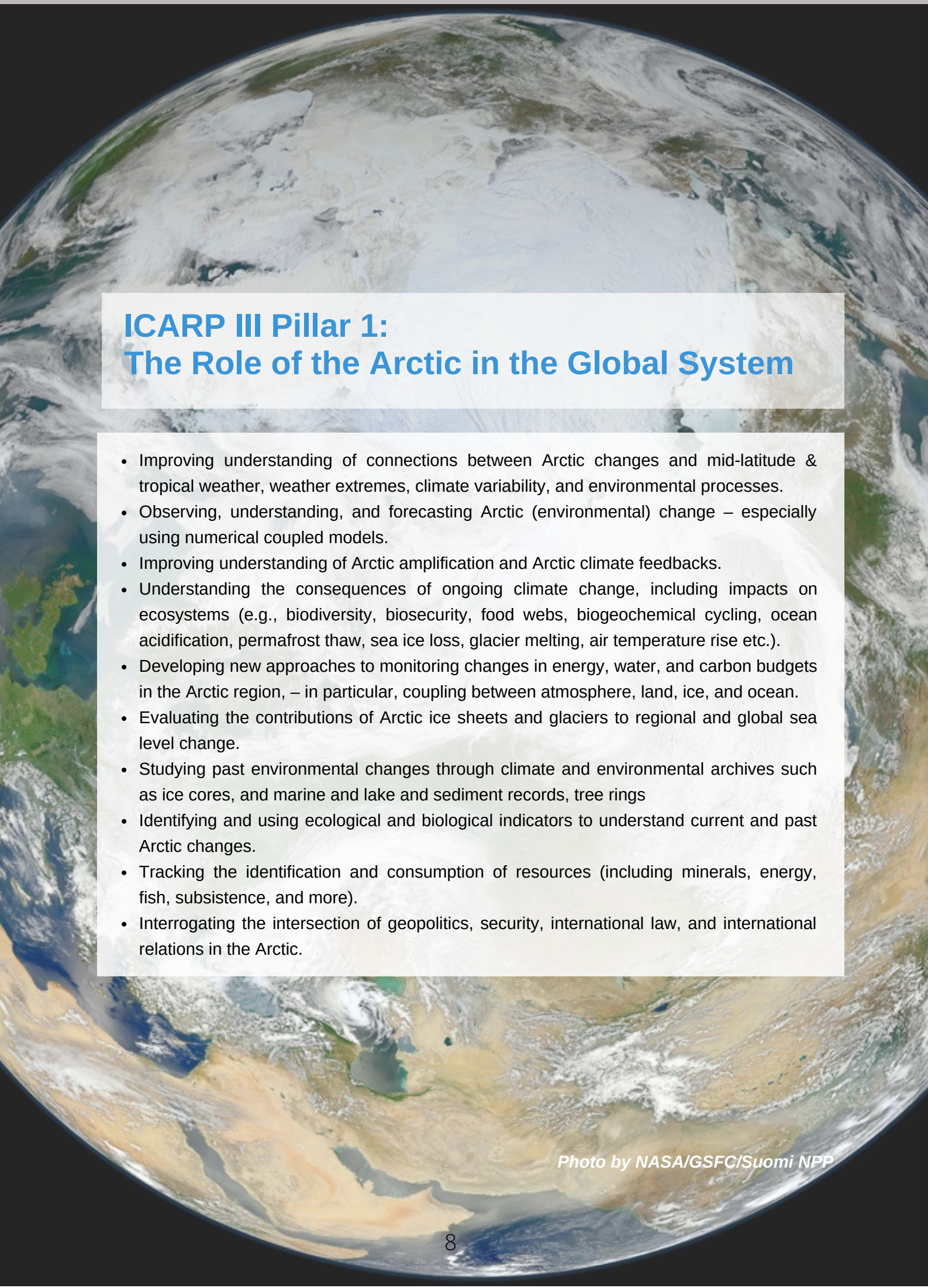
More information on ICARP IV is available here: https://icarp.iasc.info/

Current Arctic Research Priorities

Photo by Irek Sobota

Ongoing climate change is the predominant driving force for national research interests in the Arctic. IASC´s research priorities continue to be aligned with the pillars outlined in its third International Conference on Arctic Research Planning (ICARP III) report “Integrating Arctic Research - A Roadmap for the Future” published in early 2016 and can be distilled into topics with strong overlapping themes identified among Arctic and non-Arctic nations. To reflect ongoing natural and social changes in the Arctic, these highly interdisciplinary research areas presented below update the ICARP III pillars to 2022.

It should be noted that these priorities do not always flow from defined national Arctic research strategies. While some IASC member countries have strategic plans and policy frameworks, others do not have stated national Arctic research priorities.



ICARP III Pillar 1:
The Role of the Arctic in the Global System

- Improving understanding of connections between Arctic changes and mid-latitude & tropical weather, weather extremes, climate variability, and environmental processes.
- Observing, understanding, and forecasting Arctic (environmental) change – especially using numerical coupled models.
- Improving understanding of Arctic amplification and Arctic climate feedbacks.
- Understanding the consequences of ongoing climate change, including impacts on ecosystems (e.g., biodiversity, biosecurity, food webs, biogeochemical cycling, ocean acidification, permafrost thaw, sea ice loss, glacier melting, air temperature rise etc.).
- Developing new approaches to monitoring changes in energy, water, and carbon budgets in the Arctic region, – in particular, coupling between atmosphere, land, ice, and ocean.
- Evaluating the contributions of Arctic ice sheets and glaciers to regional and global sea level change.
- Studying past environmental changes through climate and environmental archives such as ice cores, and marine and lake and sediment records, tree rings
- Identifying and using ecological and biological indicators to understand current and past Arctic changes.
- Tracking the identification and consumption of resources (including minerals, energy, fish, subsistence, and more).
- Interrogating the intersection of geopolitics, security, international law, and international relations in the Arctic.

Photo by NASA/GSFC/Suomi NPP

ICARP III Pillar 2: Observing and Predicting Future Climate Dynamics and Ecosystem Responses

- Observing, understanding, and forecasting Arctic (environmental) change – especially using improved coupled numerical models and Earth system models
- Sustaining and developing long-term data sets, including paleolimnological and paleo-oceanographical approaches to validate Arctic predictive models.
- Monitoring greenhouse gases, trace gases and aerosols in the Arctic, with the aim to improve understanding of aerosol-cloud interactions, climate feedbacks, and the Arctic amplification.
- Investigating interactions and coupling processes at climate domain interfaces to improve understanding of Arctic amplification and Arctic climate feedbacks and improve regional climate models.
- Monitoring long-distance pollution transport to the Arctic (aerosols, trace gases, inorganic and persistent organic pollutants, radionuclides), and how this may respond to emission, deposition, and climate changes.
- Monitoring heat and energy transport in the atmosphere and ocean into and out of the Arctic (warm air intrusions, cold air outbreaks, variability of Atlantic and Pacific water in- and outflow, sea ice and ocean freshwater export).
- Developing new observing systems and capabilities, including improving coordination with spaceborne Earth Observation programs (see the New & Novel section).
- Monitoring future developments in the Central Arctic Ocean, including sea ice cover, commercial fishing potential and transportation routes, and exploitation of natural resources.
- Charting the greening & browning of the Arctic (large-scale, as well as microhabitats).
- Investigating life in (extreme) Arctic environments – disappearing ecosystems, resurrected ecosystems, adaptation strategies of populations and invasive species.
- Analyzing the changing Arctic Critical Zone in the framework of geosphere-biosphere interactions and permafrost thaw

Photo by Mariasilvia Giamberini

ICARP III Pillar 3: Understanding the Vulnerability and Resilience of Arctic Environments and Societies and Supporting Sustainable Development

- Better integrating Indigenous, Traditional, and Local Knowledge in research efforts and co-design/co-produce Arctic research strategies and projects with northern and Indigenous communities.
- Monitoring contaminants and pollutants (including plastics and pathogen pollutants) in all parts of the Arctic environment and understanding their sources from and impacts on Arctic societies.
- Improving understanding of the Arctic water cycle and its response to climate change.
- Understanding natural hazards and extreme weather (associated with climate change).
- Investigating the intersection of environmental sustainability, maritime technology, and shipping safety.
- Investigating the nexus of climate change, resilience, and adaptation in the context of Arctic environmental change.
- Promoting health and wellness – community vitality, adapting to a new Arctic, introduced species, including pathogens, vectors, and parasites, and holistic human-environment approaches.
- Fostering diversity, gender equality, and inclusion in Arctic research
- Researching both Arctic history and archaeology.
- Documenting coastal erosion and the impacts on carbon cycling, infrastructure, communities, ecosystems, and improve risk assessments for both the socio-economic system and ecosystems (e.g. floods, mass movements in land and solution of water resources).

Photo by Susan Christianen

Major Ongoing & Upcoming Projects

International coordination is key for building public engagement, knowledge-sharing and impactful initiatives.

Examples of collaborative projects currently ongoing or upcoming in the Arctic research community include, but are not limited to:

- **ACRoBEAR** (Arctic Community Resilience to Boreal Environmental change: Assessing Risks from fire and disease): is a major international consortium project involving 10 research organizations across 7 nations, funded under the Belmont Forum. It aims to predict and understand health risks from wildfire air pollution and natural-focal disease at high latitudes, under rapid Arctic climate change, and resilience and adaptability of communities across the region to these risks. More information: https://bag.leeds.ac.uk/projects/acrobear/
- **ALPACA** (Alaskan Layered Pollution And Chemical Analysis): is a large international project that aims to address deficiencies and gaps in understanding of sources, processing, and impacts of air pollution under cold dark conditions. The project involved a major field experiment in Fairbanks, Alaska in Jan-Feb 2022. https://alpaca.community.uaf.edu
- **The Arctic Five:** a university alliance of 5 universities in Norway, Sweden and Finland to advance and share knowledge, education and innovations for the development of this shared region and a sustainable Arctic. More information https://arcticfive.org/

- **Arctic PASSION**: is an EU Horizon 2020 project. The key motivation is the co-creation and implementation of such a coherent, integrated Arctic observing system: the 'Pan-Arctic Observing System of Systems - pan-AOSS'. Arctic PASSION will improve and expand existing observational systems, emphasizing the inclusion of ILK and CBM, and streamline provision of data from observations to products for societal needs. More information: https://arcticpassion.eu/
- **ARTofMELT** (Atmospheric rivers and the onset of sea ice melt): expedition (planned 2023 on the Swedish icebreaker Oden) is targeting warm-and-moist air intrusions and the onset of sea ice melt. More information: https://www.polar.se/en/expeditions/artofmelt-2023/
- **CHARTER** (Drivers and Feedbacks of Changes in Arctic Terrestrial Biodiversity):is an EU Horizon 2020 project and aims to advance state-of-the-art knowledge on Arctic biodiversity change and social-ecological systems. More information: http://www.charter-arctic.org/
- **CRiceS** (Climate Relevant interactions and feedbacks: the key role of sea ice and Snow in the polar and global climate system): is an EU Horizon 2020 project that will deliver improved understanding of physical, chemical, and biogeochemical interactions within the ocean-ice-snow-atmosphere system that will lead to improved models that describe polar and global climate, enhancing the ability of society to respond to climate change. More information: https://www.crices-h2020.eu
- **EU Polar Cluster:** is a network of EU Horizon 2020 and a Framework Program 7 funded Arctic, Antarctic / Southern Ocean and Polar projects. More information: https://www.polarcluster.eu/
- **EU-PolarNet 2**: is the world's largest consortium of expertise and infrastructure for polar research. More information: https://eu-polarnet.eu/
- **European Space Agency (ESA) Polar Science Cluster:** joins several ESA-funded projects and activities and aims at promoting networking, collaborative research, and fostering international collaboration: https://eo4society.esa.int/communities/scientists/esa-polar-science-cluster/
- **FACE-IT** is an EU Horizon 2020 funded that aims to enable adaptive co-management of social-ecological fjord systems in the Arctic in the face of the rapid cryosphere and biodiversity changes. More information: https://www.face-it-project.eu/
- **INTERACT** (the International Network for Terrestrial Research and Monitoring in the Arctic) builds capacity and access to Arctic research stations. More information: https://eu-interact.org/

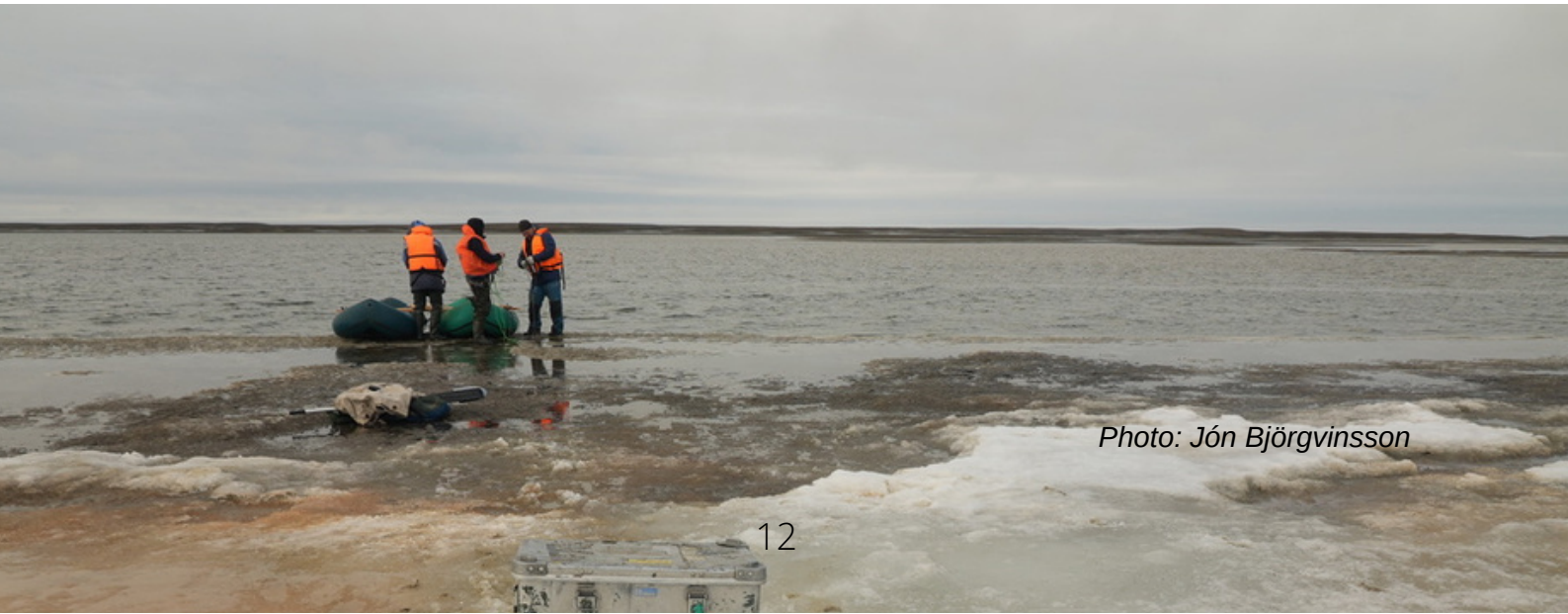


Photo: Jón Björgvinsson

- **International Tundra Experiment (TEX)** studies effects of warming on vegetation and soil.
- **JUSTNORTH** is an EU Horizon 2020 project that investigates different dimensions of ethical systems and justice in the economic development in the Arctic. More information: https://justnorth.eu/
- **MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate):** The expedition part successfully concluded on 12 October 2020, but the data analysis and inclusion in climate models has started and will continue for several more years. The one-year long drift with the Arctic sea ice on the research icebreaker Polarstern was a major multinational field experiment. It provided unprecedented multi-season datasets on high Arctic energy budgets, clouds, atmospheric composition, sea ice, ice-atmosphere interactions, ocean properties, ecology, biogeochemistry and more. The first scientific conference was held in Potsdam (Germany) from 25 – 29 April 2022. More information: https://mosaic-expedition.org/
- **The Nansen Legacy:** works towards a holistic understanding of the changing climate and ecosystem of the northern Barents Sea and adjacent Arctic Ocean – from physical processes to living resources, and from understanding the past to predicting the future. The project disposes over 350 days of ship time between 2018 and 2022, using the ice-going research vessel Kronprins Haakon. Together with an array of oceanographic moorings, glider, and satellite observations, allows for collecting unique, synoptic and interdisciplinary seasonal and inter-annual time series data. More information: https://arvenetternansen.com/
- **Navigating the New Arctic (NNA)**: is an US NSF-funded project that tackles convergent scientific challenges in the rapidly changing Arctic, that are needed to inform the economy, security and resilience of the Nation, the larger region and the globe
- **Nunataryuk**: is an EU Horizon 2020 funded project studying coastal catchments in permafrost areas, coastal erosion and impacts on carbon cycling, and science for socioeconomic adaptation. More information: https://nunataryuk.org/
- **PolarRES (Polar Regions in the Earth System):** is a EU Horizon 2020 project. It aims to provide new insights into key local-regional scale physical and chemical processes for atmosphere-ocean-ice interactions in the Arctic and Antarctic, their responses to, and influence on, projected changes in the global circulation. More information: https://polarres.eu
- **Polar to Global Online Interoperability and Data Sharing Workshop** (online): co-convened by the IASC-SAON Arctic Data committee is a bimonthly event that brings together polar researchers and Indigenous representatives to develop concrete guidance, standards, methods, and tools to make data FAIR (Findable Accessible Interoperable and Reusable). Significant progress is made towards an international standard for metadata sharing and catalogue federation.
- **SIOS (Svalbard Integrated Arctic Observing System)**: aims to realize an international observing system for long-term measurements in and around the archipelago of Svalbard addressing Earth System Science questions. More information: https://sios-svalbard.org/
- **Synoptic Arctic Survey (SAS**) and **Distributed Biological Observatory (DBO)**: are Projects coordinating Arctic marine observations for international and interdisciplinary benefit. More information: https://synopticarcticsurvey.w.uib.no/ and https://dbo.cbl.umces.edu/

- **T-MOSAiC (Terrestrial Multidisciplinary Distributed Observatories for the Study of Arctic Connections):** extended the activities of MOSAiC to coordinate complementary activities relevant to coastal connections, terrestrial sciences, and Arctic communities. T-MOSAiC has been formulated as a research and synthesis project to provide an integrated, cross-disciplinary evaluation of how the changing Arctic Ocean affects terrestrial environments, from the coastal zone to the continental interior. A new renovated project is under discussion at some IASC WG's and should be implemented in 2023. More information: https://www.t-mosaic.com/
- **Truth and Reconciliation in the Nordic Countries (TRiNC)**: studies what happens, when the TRC model, which has evolved as a measure to create and secure peace and stability after armed conflict or civil war, moves into a Scandinavian context. The project studies how core concepts such as reconciliation, truth, violence, and sovereignty may transform in the meeting between political representatives of indigenous people and national minorities meet with state representation. More information: https://www.diis.dk/en/projects/trinc-truth-reconciliation-in-the-nordic-countries
- **Year of Polar Prediction (YOPP)**: aims to enable improvements in environmental prediction capabilities for the polar regions and beyond. The final summit will be held in Montreal/Canada at the end of August 2022. One of the ongoing activities is YOPPsiteMIP - a process-based model intercomparison project- to deepen the understanding of representation of polar processes in models. A key part of this framework is the provision of data in a common format for both observations and models. More information: https://www.polarprediction.net/

Long-term monitoring continues to be crucial to building improved understanding of the Arctic, and yet monitoring initiatives are still sparse in Arctic science, especially in the Russian Arctic. For example:

- Building on the success of the Pacific Distributed Biological Observatory, new sibling coordinated marine observational networks are being established in the Davis Strait-Baffin Bay area and in the Atlantic Arctic region (Atlantic-DBO). Both these new initiatives have been kicked-off and will strengthen regional coverage as well as pan-Arctic collaboration and coherence.
- Several programs at stations such as in Ny-Ålesund, Cambridge Bay, Zackenberg Station, Rif Field Station are studying atmospheric, ecosystem, Critical Zone, marine and climate variables.
- Numerous long-term monitoring programs continue in the western Canadian Arctic across the taiga-tundra ecotone with long term climate, water, permafrost, and ecosystems studies. This includes decadal observations and research at the Trail Valley Creek Research Observatory https://www.trailvalleycreek.ca/
- A special ice platform in Russia for long-term studies of atmosphere, sea-ice, and ocean interactions in the Central Arctic Basin is under development.
- Projects are monitoring migratory and native bird populations around the Arctic (e.g., Greenland, Svalbard, and Siberia) and around the world (e.g., Arctic Migratory Bird Initiative).

- Surveys and re-surveys monitoring mountain vegetation in the Arctic: **GLORIA (Global Observation Research Initiative in Alpine environments**) sites, e.g. in Zackenberg/Greenland and Iceland
- **Circumpolar Arctic Fox Sentinel Network (CAFSN):** has been proposed in response to circumpolar rabies and lice outbreaks and will be discussed at the Arctic Fox symposium on Svalbard in Aug 2022 https://www.npolar.no/arrangement/arctic-fox-conference-2022/
- **Circum-Arctic Vegetation Map (CAVM):** is an international effort to map the vegetation and associated characteristics of the Arctic using a common base map, as an important point of reference for comparisons across the Arctic. More information: https://www.geobotany.uaf.edu/cavm/
- **Arctic Vegetation Archive (AVA):** is an international effort to consolidate and standardize vegetation plot data into a pan-arctic vegetation archive. This unique database will provide baseline data for species distribution and plant biodiversity analysis. More information: https://www.caff.is/flora-cfg/ava
- Many monitoring projects in the Arctic harness polar orbiting, globally observing satellites, this includes airborne and field calibration efforts at several Arctic test sites.
- **Greenland Ecosystem Monitoring (GEM)**: is an integrated monitoring and long-term research program on ecosystems and climate change effects and feedbacks in the Arctic. The program has both a terrestrial and a marine component and is focused at two locations in West- and Northeast-Greenland. More information: https://g-e-m.dk/
- **Integrated Carbon Observation System (ICOS**): providing high-quality European climate and greenhouse gas data – some sites in Scandinavia and Greenland. More information: https://www.icos-cp.eu/
- **Greenlandic Fjord ecosystems in a changing climate (GreenFjord)**: studies the socio-cultural and environmental interactions in a joint project of EPFL, UniL, ETHZ, WSL, UZH co-funded by the Swiss Polar Institute. More information: https://greenfjord-project.ch
- Several new satellite missions for monitoring Arctic environmental change and provide support for shipping and industry have been launched or are under development (e.g. NASA ICESat-2, EU Copernicus CIMR, CRISTAL, and ROSE-L, Jaxa AMSR3, NISAR)

New & Novel Arctic Research

Photo by Donghoon Kim

The most prevalent theme in novel Arctic research is the emergence and development of new technologies and capacities which facilitate more interdisciplinary efforts. For example:

- Using modern metagenomic and proteomic approaches to build better ecosystem and biodiversity understanding (both marine, terrestrial, and inland waters).
- Polar tree-ring dating, and climate studies are emerging tools which give insight into modern impacts of extreme weather events on terrestrial environments.
- Development and advancement of autonomous vehicles and observing platforms, like autonomous (under-ice) ocean monitoring with passive and active acoustics, gliders, airborne drones, and sail drones to collect enhanced information on the spatial and temporal variability of key physical and chemical processes occurring at high latitudes.
- The Arctic in winter can serve as a proxy for the frozen moons of Jupiter and Saturn.
- Novel isotopic measurement methods for trace elements such as mercury and osmium provide new insights for ice core climate studies as well as quantifying modern pollution.
- New, modern research stations in areas of northern Canada (Canadian High Arctic Research Station), Russia (special ice platform, Snowflake Station) will soon provide local logistical and laboratory support. These stations are supported by smaller observatories such as at Trail Valley Creek in the Inuvialuit Settlement of the western Canadian Arctic.
- Bioprospecting and biotechnology approaches, including environmental DNA and nanopore sequencing, are being applied to the Arctic.
- In Finland, the Aalto Ice Tank has been renovated to study wave propagation through sea-ice cover.

- In Svalbard, the establishment of new Critical Zone observatories for the interdisciplinary study of rock-soil-permafrost-water-biosphere interactions, to be possibly extended to a larger circum-Arctic region through the activity of the IASC Terrestrial Working Group **ACZON project (Towards an Arctic Critical Zone Observation Network)**.

Remote sensing (both satellite and airborne) technology and techniques have been highlighted:

- Historical archive data is being combined with current data to understand past changes.
- There is broad support for further development and use of unmanned airborne vehicles. Airborne laser ranging and high-resolution satellite stereo imagery are enabling studies of glacier mass balance and snow cover. These platforms provide detailed high-resolution perspectives of the surface and its evolution in areas where satellite measurements are obscured by cloud cover.
- Many countries are investing in new satellite platforms to improve observational and processing capabilities, which are complemented by on-the-ground measurements. These will include new and essential observations of lake surface elevations across the Arctic, among others. Remote sensing of land- and sea-ice properties were widely noted.
- Drone borne mapping and quantification of vegetation composition and biomass, as well as mapping snow depth and reflectivity across large tundra domains.

New methodologies and techniques are also enabling new science. For example:

- Development of a highly accurate digital model of the Earth (**Destination Earth** - https://digital-strategy.ec.europa.eu/en/policies/destination-earth). It will help monitor, model, and predict natural and human activity, and develop and test scenarios for more sustainable development.
- Development of global climate simulations at ultra-high resolution (km-scale grid spacing)
- Application of next generation, hyper-resolution models for understanding the interactions of climate, permafrost and surface water will allow improved understanding of changes in water at the scales needed to answer questions from local communities across the Arctic.
- Methodologies for knowledge co-production in the Arctic: Arctic social sciences working in collaboration with Indigenous and Local Knowledge holders and communities are well positioned to address this challenge and pioneer transdisciplinary and post-disciplinary ways of thinking and knowing. Acting on that knowledge to co-produce and co-design sustainable and viable solutions is an imperative for this body of scholarship e.g., identifying a road map for a green transition for Arctic communities. This entails among others more research focusing on developing start-ups, small scale entrepreneurship etc. in economic sectors such as culture, food, gastronomy, and tourism.
- Results will be shared with Indigenous and other local communities in an accessible format (including translations into the language spoken by the knowledge holders / community. All branches of sciences should be able to respectfully engage with Indigenous Knowledge in the pursuit of new insights, acknowledging the Indigenous ownership of knowledge and the need for compensation of knowledge holders.

- Convergent research: deeply interdisciplinary work focusing on addressing grand challenges and broad questions yields profound discoveries.
- Uncertainty (emulation) statistical model analysis is being used to identify key weaknesses and uncertainties in climate modelling capabilities. This has applications, for example, to understand changes in the Arctic coastal environments and their relevance for safety and resilience of Arctic maritime transportation, offshore energy production, and fisheries; to improve prediction products; and to understand the value of additional Arctic data on quality of Arctic forecasts.
- Establishment of new technologies and applications in the Arctic, like unmanned aerial or underwater platforms

Emerging new and novel research themes include:

- **OneHealth**, a cross-cutting, interdisciplinary initiative recognizing the interconnection of human, animal, and environmental health has significant traction in the Arctic, especially within a context of sustainable development. One Health is captured under the Arctic Council Sustainable Development Working Group (SDWG) One Arctic, One Health project (https://sdwg.org/what-we-do/projects/one-health-iii/). Most recently, a working group on Arctic biosecurity was initiated jointly between the Human Health and Sustainable Development working groups on Arctic Council.
- Plastics in the aquatic and terrestrial environment.
- Research focusing on sea ice, particularly the shift from multi-year to first-year ice – and more generally, research on other transitioning systems.
- Investigations of the role ocean circulation plays in ice sheet mass loss in Greenland and its consequences for sea level rise.
- The impacts of increased liquid precipitation on the ground carbon budget, ice and snow process and the production and lifestyle of Indigenous people
- The growing influence of both Atlantic and Pacific inflows into the Arctic Ocean
- An emphasis on interdisciplinary approaches to understanding human-environment relations in the Arctic, with emphasis on assessments concerning economic systems.
- Air pollution in the Arctic, both as a driver of Arctic climate change and from the point of view of local sources and impacts – broadening the research on potential drivers of Arctic change and impacts on local communities.
- The effects of permafrost thaw and rising temperatures on the changes of the Arctic Critical Zone and corresponding impacts on natural resources.
- Intersectionality: focus on different/multiple experiences of marginalization to help elicit social inequalities in the Arctic.
- The role of extractive industries in society and resource extraction and sustainability Arctic Socioeconomic Amplification: feedback, amplification, and loop effects between empowerment of Arctic communities & increased geopolitical/economic interest in the Arctic.
- Diverse other social science topics, including sustainable tourism and small-scale business development, mobility, connectivity, human rights, globalization, science diplomacy and climate change effects on health in the Arctic

Emerging Arctic Research Issues

Photo by Gabe Lewis

Many of the areas of emerging Arctic research are nuanced and expanding upon the broadly stated priorities listed above under “Current Arctic research priorities”.

Coupled Arctic Systems

- Arctic people (both indigenous and settler) are a key component of coupled Arctic systems, both as persons who are impacted by the effects of Arctic change and as drivers of change.
- Coupled Arctic systems include biogeochemical cycles and natural emissions; terrestrial water fluxes; terrestrial-atmosphere carbon fluxes; relationships between atmospheric processes, water, ice, and ocean; coupling between the stratosphere and lower atmosphere; and understanding the role of Critical Zone dynamics and complex Arctic water and biological systems. Understanding how these interactions will respond in a warming Arctic is a priority. Especially at the scales of interest to Arctic communities.
- A better understanding of Arctic amplification is also emerging, both in the present Arctic and during past warming, as well as societal impacts of rapid warming.
- Improving knowledge of coupling between the Arctic and the large-scale global climate system, including mid-latitude – Arctic linkages, water, ocean and atmospheric heat fluxes, and tropical-Arctic linkages with respect to climate variability and via teleconnections
- Improved representation of interactions across system boundaries in regional and global models with a focus on the coastal zone.

- Understanding interplay of the biological pump, the marine food web, ecosystem stressors, and fish stocks (in the Central Arctic Ocean).
- Integrated ecosystem assessments - examining linkages between biodiversity and environmental change through space and time.
- Studying other processes like:
    - Cryospheric controls on tundra nutrient cycling
    - Fjord and ocean productivity
    - Shifts in primary production in response to sea-ice and climate change
    - Drivers and impacts of ocean acidification
    - Drivers and impacts of permafrost thaw
    - Impacts of rapid permafrost thaw on surface water systems
    - Coastal landscape transformation
    - Impact of snow and ice dynamics on sea ice mass balance
    - Influence of upwelling on the sea ice freezing and thawing process in the continental slope area

Pollution: Sources, Sinks, and (Societal) Impacts

- Arctic aerosol and trace gases: Several nations have identified emerging issues around improving knowledge of Arctic aerosol sources and impacts, including aerosol-cloud interactions, and in the context of local pollution sources and associated societal impacts. Wildfires as sources of Arctic pollution are also identified, as well as issues around the impacts and processing of mercury pollution in the Arctic.
- In addition, plastic contamination and litter in the Arctic and evaluation of the impact of plastics, emerging pollutants (such as UV filters in personal care products and pharmaceutical products), and pathogens were also mentioned as of significant concern by multiple countries.
- There are ongoing projects focusing on air quality in the Arctic. A major activity under the PACES initiative has been the ALPACA field campaign, which took place in Fairbanks, Alaska during January-February 2022. This experiment is elucidating new understanding on sources, chemical processing, and impacts of PM2.5 and trace gas pollution under polluted, cold, dark conditions.
- Recognition of “pathogen pollutants”; pathogens transported from subarctic into Arctic regions
- Expanded research into the consequences for Arctic human and wildlife health (e.g., pathogens & climate change).

Observing, Forecasting, Prediction, and Predictability

- Prediction of sub-seasonal to seasonal processes in the coupled Arctic system
- Prediction of integrated vegetation, snow, permafrost, lakes, and streams at scales of interest to Arctic communities
- Supporting new and more diverse Arctic research teams and participating in establishing new Arctic observing networks.

- Arctic scientists are making significant efforts to integrate different monitoring approaches and observing systems. Important coordination is promoted via the Sustaining Arctic Observing Networks framework and the Arctic Observing Summit.
- Machine learning and artificial intelligence for extracting information and identifying processes and feedback loops in big data sources associated with satellite observations and model simulations.

Societally Relevant Arctic Research

- The IASC Social & Human Working Group has a work plan that identifies scientific foci including Arctic residents and change; historical perceptions and contemporary representations of the Arctic; securities, governance, and law; natural resource(s) / use/exploitation and development: past, present, future; and human health and well-being.
- Focus on resilience and adaptation of Arctic communities to climate change.
- Research ethics related to Arctic research – as well as data and metadata management.
- Healing processes, strategies for achieving spiritual strength, decolonization, reconciliation, and restorative justice, especially for Indigenous Peoples.
- Geopolitics and circumpolar governance, as well as Arctic legal governance.
- Gender equality in Arctic research.
- Arctic infrastructure including connectivity.
- Arctic economic and technological futures.
- Sustainability: Arctic sustainability in a global context, the UN Sustainable Development Goals and the Arctic, the politics of sustainability, just transitions to sustainability and sustainable Arctic cities.
- Societally relevant Arctic research results are provided to the working groups of the Arctic Council, their programs, and incorporated into their assessment reports.
- Building better dissemination channels of Arctic information to the public: for example, a growing number of citizen science projects with Arctic focus can help lead to a deeper understanding of the causes and consequences of climate and environmental change beyond the typical diffusion of scientific knowledge (e.g. the newly established International Arctic Hub in Greenland https://arctichub.gl/)
- Tourism and the environmental effects of tourism in the Arctic and beyond.

Current Gaps in Research and/or Data

Photo by Irek Sobita

There is a recognized need by the international scientific community to develop an integrated observing network for the Arctic and to make Arctic data and metadata more easily available internationally. There is a need to design or refine monitoring programs in support of societal benefit, including fundamental understanding of the Arctic system. **SAON´s Roadmap for Arctic Observing and Data Systems (ROADS)** proposes to develop broadly beneficial implementation strategies that are organized around **Shared Arctic Variables (SAVs)**. Such an approach is intended to merge the needs and extend the benefits of the observing and data system across Indigenous communities, researchers, and decision-makers in the region and globally.

The **Arctic Horizons Report**, a community workshop report funded by the US National Science Foundation Arctic Social Sciences Program, points out that, “The Arctic is a testbed for interdisciplinary research, a ‘critical region of inquiry.’ … This research takes place at multiple scales ... and requires that we work across disciplines and regions; the local and the global both need to be supported, and the places of their intersection located.”

Spatial (and Temporal) Coverage

While field stations facilitate research, research infrastructure also limits Arctic science. Cross-site comparisons are needed to determine how generalizable individual findings are.

- coverage in ground-based network measurements is lacking. Data coverage and availability of data from the Russian Arctic, including Siberia are particularly lacking. The current geopolitical situation will exacerbate this further.
- Research gaps include the Central Arctic Ocean (and the related potential for commercial fisheries and other potential ecosystem services), as well as other areas of the Arctic with limited data coverage, such as the East Siberian Sea and Canadian Arctic waters. More studies like MOSAiC are needed there that address the coupled atmosphere-sea ice-ocean system and feedbacks with the ecological and biogeochemical systems, together with long-term observatories that can detect and discern seasonal and interannual variability and trends.
- Subarctic terrestrial regions in Canada are not well studied despite meeting the definition of North (permafrost and discontinuous permafrost)
- The longer-term need to develop year-round sampling capabilities and sampling of the land-sea interface was also mentioned by multiple countries. Ensuring high-quality climate and water data collection during the winter at remote, unmanned stations, is urgently needed.
- Widespread and regular atmospheric vertical profile information is severely lacking.
- The coverage of some satellite observations at high latitudes is limited. The area close to the North Pole (the so-called Pole Hole at typically 87-88°N) is not observed by most sensors but becomes increasingly important in an Arctic with less sea ice. Additionally, high levels of cloud cover often obscure the surface and lower atmosphere from satellite view.
- There is a lack of cloud and lower atmosphere measurements (e.g., energy budget, aerosols) outside the summer ‘fieldwork’ season.
- It is important to bring consistency to Arctic studies across countries, this includes physical ground properties (soil, water, snow etc.) and biodiversity (methods of sampling etc.)
- There is a need for reliable measurements in order to predict on a sub-seasonal-to-seasonal basis sea-ice thickness at high resolution over large spatial scales.
- In glaciology, data are very limited for constraining ice motion at high elevations on the Greenland Ice Sheet, submarine melt rates at tidewater glacier termini, densification of firn, and seasonal cycles of snow mass and associated long-term, seasonally resolved measurements within glacial fjords and adjacent shelves.
- Long-term observations, research continuity, and comparative analyses in all disciplines are needed.
- Improved understanding of the spatiotemporal patterns of Arctic climate change, including meteorological observations, paleoclimate data, reanalysis products and climate models, is needed to quantify regional patterns (and drivers), as well as the impact of Arctic changes on global climate.

Interdisciplinary Data Exchanges

- There is a need for enhancing cross-disciplinary understanding and exchange of data across many disciplinary boundaries. Interfaces where improvements could be made include atmospheric and cryospheric disciplines, terrestrial and cryospheric research, oceanographic and cryospheric science, sea-ice science and biogeochemistry, permafrost science and microbiology, whole-system Critical Zone processes, observations and numerical simulations, and opportunities to consider how the role of data sharing and generation is integral to Arctic science diplomacy, to name a few.
- Indigenous knowledge is integral to co-produced knowledge generation.
- It is important to improve collaboration of research groups studying (High) Arctic landscape system transformation related to climate change; coordinated ecological, cryospheric, atmospheric, and hydrological monitoring are necessary to improve understanding of Arctic change (e.g., tundra greening/browning and climate change).
- There is a need for multi-component (land, ice, ocean, atmosphere) integrated observations and models of coupled coastal zone dynamics and processes.
- Research that is multi-, inter-, or transdisciplinary needs more time and adjusted funding schemes to mature than standard disciplinary projects. This is specifically true for projects that include Arctic communities or other stakeholders.

International Data Sharing

- The ownership, control, access to and possession of data must be tackled in equity-based exchanges between Indigenous rights holders and scientists. There is a need to make polar science as accessible as possible by ensuring access to documents and data, developing databases of scholarship and scholars, and respecting the data sovereignty of Arctic communities. This may also require infrastructure investments in all aspects of network building, ranging from transportation routes to telecommunications and internet services.
- Special attention is needed for supporting international efforts to make Arctic data and metadata easily accessible, with the implementation of web portals and archives (e.g., within international networks such as **INTERACT**, permanent data archives such as **PANGAEA**, and research infrastructure such as **SIOS**) to facilitate data access.
- There is only limited consistent and one-point access for meteorological archive data, although Arctic reanalysis are now available (e.g. **Arctic System Reanalysis** and **European Copernicus Arctic Regional Reanalysis**).
- Data sharing and in-situ data access are not universally available across the Arctic.
- While coordination has improved in the data management community in recent years, there is a need for connecting the research community to those efforts and related activities.
- There are many efforts working to coordinate and align data (e.g., the **Polar Data Forum,** the **Arctic Data Committee,** the recently EU-awarded Arctic **GEOSS initiative, SIOS, INTERACT**, and many others) but insufficient funding and personnel relative to the scope of the task are available to be able to support implementation and follow-through.

Research Approaches & Infrastructure

- International scientific cooperation is underway in many research areas and there are numerous examples of joint and multilateral programs, but there is need for infrastructure support (e.g., innovative technologies, new terrestrial observatories, new icebreaking platforms, etc.).
- There is a lack of base funding, funding stability, and prioritization of sustained baseline monitoring.
- Arctic scientists should further build cross-disciplinary, interdisciplinary, and convergent research practices within the scientific community and other stakeholders.
- A need to explore a gap in Arctic research – 'sex, gender and intersectional analysis of the research content'. More information: https://ec.europa.eu/info/publications/gendered-innovation-2-how-inclusive-analysis-contributes-research-and-innovation_en
- There is a further need for increased emphasis on co-producing research with Indigenous, Traditional, and Local Knowledge holders, for recognizing and validating the priorities of Northern residents and communities, and for more engagement of scientists in Arctic community vulnerability assessments. This will require a commensurate emphasis on research ethics and data sovereignty, but also on capacity sharing.
- Often, there is limited Northern infrastructure and capacity; many research projects still require equipment, labs, personnel, and training from lower latitude institutions.

Focus on Transitions in Arctic Natural and Human Systems

- Ongoing environmental change is a feature of the Arctic, and it can be anticipated that all its spheres will be dramatically transformed within this century. It is an enormous challenge just to document these transformations – let alone to act on them in a manner informed by scientific, political, cultural, economic, and Indigenous perspectives. Although many countries prioritize Arctic research, the current levels of monitoring and research are clearly insufficient to meet these challenges.
- Increased connectivity in the Arctic transforms the research Arctic scientists can do, as well as the lives of Arctic residents (e.g., communication, mobility, and telemedicine).
- Long-term ecosystem monitoring and sustainability of natural resources are important in order to understand the roles and functions of those resources in supporting sustainable development and resilience in the Arctic.
- What impacts do new influences or technologies (e.g., expanded tourism, renewable energies, multimedia, digital communication, improved infrastructure) have in the Arctic? What is the impact of increased regional autonomy and Indigenous empowerment in some but not all parts of the Arctic? How should these changes be informed and contextualized by colonial pasts and present? What does a just transition to sustainability look like in and for Arctic communities?

Emerging Issues Concerning International Science Cooperation

Photo by Veronique Dubos

International cooperation is key to studying Arctic systems, many of which know no boundaries. Arctic systems involve the inhabitants of the Arctic who should be involved as stakeholders in international science cooperation, in particular Indigenous rightsholders' organizations. Arctic research does and should continue to involve extensive international collaboration, and barriers, including geopolitical boundaries, high cost-distances, and socioeconomic disparities need to be overcome.

As already remarked in the Introduction to this 2022 State of Arctic Science Report, while the challenges for Arctic research due to the Covid-19 pandemic in the last two years are starting to ease, the geopolitical situation that has arisen as a result of Russia's actions in Ukraine has created further uncertainties for research in the Arctic. The situation is seriously affecting international scientific collaboration and the ability of the international scientific community to carry out research and observations across vitally important areas of the Arctic.

Research in the Arctic relies on international collaboration, access, and continuous monitoring and data sharing among all regions of the Arctic to understand and effectively respond to the climate crisis and other changes in the Arctic.

Science Planning & Coordination

- International cooperation is critical in developing widespread networks with comparable measurements. However, outside of the main long-term surface observatories, international cooperation often remains largely opportunity driven and less strategic.
- Institutionalized cooperation is rare and information at times hard to find for scientists, Indigenous peoples, and other stakeholders.

- Improved collaboration among Asian, European, and North American nations, as well as countries with emerging Arctic interests such as India and Singapore, are of value to maximize joint benefits and avoid duplicated efforts.
- **SAON** provides an on-going vehicle for collaboration on Arctic observing and data systems. It is now strategically partnered with several funded efforts to support the implementation of its 10-year Strategic Plan.
- Support for bilateral connections between non-Arctic institutions and field stations in Arctic countries is a promising place to start.
- New collaboration between Canadian, Inuit and UK institutions is beginning through **CINUK** in order to carry out interdisciplinary research across the Canadian Arctic.
- **MOSAiC** is an important success story in developing a major multi-disciplinary and international field project to deliver unprecedented data and science from the bottom-up but ensuring that international critical mass and momentum is maintained is a major challenge.
- There is growing cooperation in international research initiatives via Horizon 2020 projects. **INTERACT** and the **Arctic Research Icebreaker Consortium (ARICE)** connect researchers around the Arctic. **SIOS** promotes integration along the Svalbard Archipelago. The **Pacific Arctic Group (PAG)** is also an effective mechanism for improving international cooperation. Yet, other means of providing for cooperation among institutions in different countries are needed.
- The new Roadmap for **Arctic Observing and Data Systems (ROADS)** process was designed and developed by SAON as an approach to coordinate observations based on shared societal benefits and provide clear inputs to funding agencies as well as policymakers.
- Coordination organizations and research infrastructure bodies (polar clusters, polar boards, the **Forum of Arctic Research Operators**, **IASC,** etc.) are important for engaging the breadth of the Arctic research community, reducing the risks arising from data fragmentation and disconnected knowledge generation.
- Arctic inhabitants are not only facing rapid socio-ecological change but are relevant partners in international science activities in providing Local and Indigenous Knowledge to researchers for co-creating understanding and calls for action of changing Arctic systems. Such collaborations in both the natural and social sciences need to be actively improved.
- Cooperation with and involvement in programs that do not necessarily only focus on the Arctic, but where Arctic research can benefit from (e.g., through access to new technology such as uncrewed aircraft systems).

Funding

Aligning national and international funding

- It is challenging, but crucial, to align national funding mechanisms to enable large multinational efforts. International collaborations are limited when there is a lack of international funding vehicles.
- The **Belmont Forum** facilitates funding by using a framework guided by individual national needs, but it is also inherently limiting because such decisions on research priorities can lead to overly complex and elaborate approaches. More information: https://www.belmontforum.org/

- The nascent **Arctic Science Funders Forum**, an outcome of the 2nd Arctic Science Ministerial, is a multilateral discussion platform to coordinate, enhance, and initiate new collaborative scientific activities in the Arctic; it also aims to be a gateway for information about international funding calls for Arctic research. More information: https://iasc.info/cooperations/arctic-science-funders-forum
- The **EU framework** and **Svalbard Science Forum** are examples of effective mechanisms to support international programs.
- More joint funding calls from two or more national funding councils would be very helpful. For example, the **Canada-Inuit Nunangat-United Kingdom (CINUK) Arctic Research Program** has recently funded 13 projects focused on areas across the Inuit Homeland in northern Canada. The CINUK Program will increase understanding of and address the environmental, social, economic, cultural, and engineering/infrastructure impacts of climate change in the Canadian Arctic. The program covers a wide range of issues, including hydrology, wildlife health, country foods, ecosystem health, safe travel, search and rescue, renewable energy, community health, coastal erosion, plastics and pollution, for example https://www.arctic.ac.uk/research/canada-inuit-nunangat-united-kingdom-arctic-research-programme-2021-2025-cinuk/
- Participation in strong international research networks has been and will continue to be essential for small nations and countries with developing Arctic research programs.
- Bilateral programs (e.g. the **UK-Canada Arctic Bursary program**, introduced in 2017, or the **UK-NERC Changing Arctic Ocean Program** with bilateral funding and projects between the UK and Germany) have been highly successful in stimulating research and collaboration. Through the **German Federal Ministry of Education and Research** and the **Russian Ministry of Research**, a number of joint research projects and expeditions on marine and polar research had been funded.

Funding challenges

- There has been a shift in research project solicitations and funding streams towards more multi- and interdisciplinary scholarship
- Funding remains tight for the maintenance/continuation of (long term) observational networks despite being considered a high priority.
- The lack of funding programs and streams within Arctic research funding structures that support international collaborations in social sciences, humanities, and/or interdisciplinary work. Without addressing this gap, advancing social sciences, health research, and humanities scholarship in the Arctic will be, at the very least, challenging.
- There is a need to continue to support excellence in scientific research, on Arctic/polar topics, as well as in related areas. This can be done by encouraging emerging sound practices, such as the sharing of data, field methodologies, and access to research stations, but most importantly by funding national and international projects based on open calls to which a broad array of research groups can apply, and which can be evaluated based on scientific criteria and merit.

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- Apart from some topics that require major investments, it is vital to support small to medium-size projects that enable the future development of innovative research questions

Engagement and Participation of Indigenous Communities

- Funding for the engagement and participation (e.g. through higher education research scholarships) of Indigenous people in research planning and executive is critical to the generation of more equitable outcomes yet identifying funding mechanisms for this support continues to be an issue.
- The lack of funding for the inclusion of Indigenous rights holders and for enabling co-production of Arctic knowledge must be tackled by all national and international stakeholders. Funding schemes must be established that transparently support the participation of non-academic stakeholders and Indigenous rights holders in a transdisciplinary manner.

Diversity, Equity, and Inclusion

- Recruiting and retaining a more diverse research community is a critical challenge for Arctic science. One approach is creating knowledge exchange opportunities, such as Fellowship programs and shared PhD programs which actively promote to under-represented communities.

Access

- Access to data and objects, including acquisition, collection, transportation and repatriation of data, information, historical materials, archaeological artifacts, etc. is another key issue. Cross-border and sometimes intra-country mobility of data and objects can be difficult or impossible, which impedes knowledge discovery. Collaboration with Indigenous rightsholders must be sought to conduct culturally appropriate research on these sensitive topics.
- Physical access to communities, and frequently a long-term presence, are necessary for most social science research; this remains difficult in many current funding structures.
- Open and timely data sharing is growing and critical. Yet, data management remains challenging. It is important to ensure common data policies and practices across nations, as well as to provide funding and resources to enable broad access to data.
- Providing platforms and protocols for scientific cooperation, including data and metadata sharing, facilitates research across the Arctic. This includes adhering to ethical and cultural protocols of data collection, inclusion of Indigenous Peoples in research planning, implementation, interpretation and dissemination, following, inter alia, research protocols developed by Indigenous Peoples' organisations, such as the ICC Circumpolar Inuit Protocols for Equitable and Ethical Engagement.
- The important roles of research infrastructure, networks, and field stations have been discussed earlier in this report.

Legal Framework

- Arctic researchers welcome efforts by IASC, IASSA, and UArctic to promote the recently adopted Agreement on Enhancing International Arctic Scientific Cooperation (Arctic Science Cooperation Agreement). The main leitmotif of this agreement is to improve access to data, places, and information, as well as to remove procedural obstacles to Arctic research. Scientists are especially interested in both how the agreement is applied to the states that are party to the agreement, and any impacts it has on researchers from non-party states. The implications for the current geopolitical challenges on the implementation of the agreement will have to be considered.
- Current best practices include reaching out to Arctic countries and organizations to create memoranda of understanding and collaborative partnerships, following established procedures for applying to enter exclusive economic zones for shipboard research, and these efforts are in addition to implementing the Arctic Science Cooperation Agreement. Enhanced agreements to share infrastructure and logistical support could help to remedy some of the current obstacles.
- Given the diversity of the Arctic regions, cultures, and environments, Arctic scientists achieve the best results by working in international teams and consortia with scholars from multiple Arctic and non-Arctic jurisdictions and Northern residents, bringing together broad interdisciplinary experiences, expertise, and funding. The Arctic research community places high hopes in the implementation of the Arctic Science Cooperation Agreement.
- The Arctic Science Cooperation Agreement provides an unusual opportunity to promote and find support for inter- and transdisciplinary international research suited to understanding complex Arctic problems.
- There needs to be more widespread attention paid throughout Arctic and non-Arctic countries to the highest ethical practices related to Arctic research, with enforced international standards for policies/ethics/guidelines for research that will improve engagement with local and/or Indigenous issues/ communities (e.g. ITK National Inuit Strategy on Research).
- The marine research community emphasizes the importance of international access to exclusive economic zones, particularly in data-sparse Arctic regions, as a priority (part XIII of the UN Convention on the Law of the Sea UNCLOS).
- The Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean is also seen as an important milestone for Arctic environmental protection as well as an impetus for expanded research in the Central Arctic Ocean. It is protective of the Arctic (up to a point with a 16-year moratorium in place) as well as being a mechanism to stimulate additional internationally coordinated research (with due regard for local and Indigenous knowledge).

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Conclusion

Photo by Irek Sobota

The Arctic – a unique and globally important region – is also a rapidly changing region. More than ever before, we (Arctic, non-Arctic, and Indigenous and northern residents) need to continue to build the understanding of the Arctic, including systems, and the connections between systems. Bigger than any one discipline or country can hope to address individually, IASC leads by bringing together science disciplines and international collaboration, prioritizing science over nationality.

The State of Arctic Science 2022 is expected to provide benefits by identifying priorities, linkages, and gaps in the current work of the international Arctic research community. For example:

- Arctic research must be truly interdisciplinary, and indeed convergent, in order to meet both Arctic and global challenges.
- The Arctic research community must improve its efforts to respect and implement the priorities, voices, and contributions of Indigenous Peoples and other Arctic residents.
- International and interdisciplinary cooperation are critical to studying Arctic systems and should be encouraged and expanded.
- Arctic data sharing, discoverability, access, and re-use continue to be difficult challenges, but improvements in these areas will be crucial for future success when it comes to long-term monitoring.
- Current levels of Arctic monitoring and research are insufficient to meet the grand challenges facing the Arctic, despite the hard work and investments of both Arctic and non-Arctic countries.

The State of Arctic Science 2022 remains an initial effort to describe the status of the scientific endeavor at high northern latitudes. Building on the foundation of ICARP III, IASC has compiled this report out of broad, bottom-up contributions from the IASC scientific community. Arctic change is accelerating, and Arctic science is vast, and so this report simply summarizes - some of the highlights of Arctic research.

This report adds value and is a useful contribution for researchers, policymakers, and all research stakeholders by setting out the state of Arctic science.

While this report is static, Arctic research is vibrant and evolving. Therefore, IASC will update this report on an annual basis in the future.

The **IASC State of Arctic Report Series** is available on the IASC website under **https://iasc.info/about/publications-documents/state-of-arctic-science**

Email **info@iasc.info** and find out more about IASC at **www.iasc.info.**

State of the Arctic Science Report & Who is it For?

The IASC State of Arctic Science Report 2022 presents a cohesive synthesis of Arctic research activities and priorities with of a large range of input and contributions across all aspects of Arctic research. It is aimed at Arctic science agencies, managers, and users including a wide range of decision-makers and policymakers, to help all Arctic science stakeholders stay up to date on Arctic research.

The IASC State of Arctic Science Report 2022 and the IASC State of Arctic Science Report series are available on the IASC website (**iasc.info**).

Photo: Susan Christianen, Extreme Design Lab

IASC 2022 State of Arctic Science Report (SAS)
Online version available on the IASC website
https://iasc.info/about/publications-documents/state-of-arctic-science

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