IASC

The International Arctic Science Committee´s

2023 STATE OF ARCTIC SCIENCE REPORT

Arctic Lands Acknowledgement

The circumpolar Arctic is the home to many different Indigenous Peoples. As researchers and others who work or reside in the Arctic, we recognise these lands and waters as the predominantly traditional homelands of Indigenous Peoples. Wherever you may be reading this report, IASC honours and recognises 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, listen, read, respect, and continuously improve our 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 recognising 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.

Links

The SAS2023 Report is optimised for online reading. Links are only accessible in the online PDF version. If you are reading this report in printed format, please visit https://iasc.info/about/publications-documents/state-of-arctic-science

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Introduction

Photo by Yulia Davydova

The **IASC State of Arctic Science Report 2023** presents a cohesive synthesis of Arctic research activities and priorities with a large range of input and contributions touching upon all aspects of Arctic research. It is aimed at Arctic science agencies, managers, and users, including a wide range of decision-makers and policy-makers, to help all Arctic science stakeholders and rights-holders stay up to date on Arctic research.

Published annually since 2020 by the **International Arctic Science Committee (IASC)**, the report is updated by the members of several IASC or IASC-affiliated committees including the

- Five **IASC Working Groups** (Atmosphere, Cryosphere, Marine, Social and Human, Terrestrial);
- **International Science Initiative in the Russian Arctic** (ISIRA);
- **Arctic Data Committee** (ADC); and
- **Sustaining Arctic Observing Network** (SAON).

The IASC State of Arctic Science Report series contributes an important resource to the **Fourth International Conference on Arctic Research Planning (ICARP IV) process** for the period of 2022 – 2026. Therefore, a wider range of contributors from the **ICARP IV International Steering Committee** also update the report during the ICARP IV Engagement Phase in 2023 and 2024.

The content of the report is compiled by the researchers themselves and thus is not exhaustive. There are many other NGOs, IGOs, institutions, non-profits, Indigenous Peoples' organisations, private and public companies, and others around the world working in the Arctic knowledge space that are currently not participating in the preparation of this report.

IASC was founded in 1990 at a time of great geopolitical uncertainty, but also of hope, as a non-governmental, international scientific organisation, operating among its now 24 member countries. It works on a consensual 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 three years have now largely eased, the geopolitical situation that has arisen as a result of Russia's actions in Ukraine continues to create further short-term and also long-lasting uncertainties for research in the Arctic. The situation is seriously affecting international scientific collaborations and the ability of the international scientific community to carry out research and observations across vitally important areas of the Arctic. The impacts on scientific collaboration, data exchange and publications, conferences and events, travel and fieldwork, maintenance of experiments and long-term monitoring stations, exchange programs and secondments, funding decisions and international research expeditions are profound. The consequences are felt by national and international researchers of all career stages, however some of the greatest impacts are experienced by the Indigenous Peoples of the Arctic, many of whose lands, waterways, relations, hunting and gathering grounds, and communities span national boundaries.

The work of the **Arctic Council**, to which IASC is an observer, restarted with limited collaboration in June 2022, when seven Arctic nation states resumed limited continuation of projects and cooperation without Russian participation, based on the work plan that all eight Arctic nation states had approved in 2021, while the Russian Federation continued to implement its chairmanship program domestically.

In May 2023, during the 13th Arctic Council Meeting, Norway took over the Arctic Council Chairship for the period of 2023 to 2025, with a focus on promoting stability and constructive cooperation in the Arctic. In late August 2023, a consensus was reached by the Arctic States, in consultation with the Permanent Participants, on guidelines to resume the work of the Arctic Council at the Working Group level using written procedures. It is expected that work in the Council will further resume, albeit on a limited scale, when more details about the Norwegian Chairship activities are published.

Research in the Arctic relies on international collaboration, access, and continuous monitoring and data sharing among all regions of the Arctic to understand and to effectively respond to the climate crisis and other challenges in the Arctic. The principles of scientific freedom, research independence, and peaceful international cooperation are vital for researchers, Indigenous Peoples, and many others who are working together to understand and respond to the ongoing pressing climate, environmental, resource and social changes and challenges 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 must continually 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 prioritise 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) Process 2022 - 2026

Photo by Esther Horvath

ICARPs - 30 Years of Arctic Research Planning

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)** to be held in Boulder, Colorado, USA, in 2025. IASC's Founding Articles call upon IASC to periodically review the status of Arctic science.

As a result, IASC has been organising the **International Conference on Arctic Research Planning (ICARP)** every ten years since 1995 to provide a forum for the Arctic research community to come together to discuss and identify priorities for international and multidisciplinary science.

ICARP I

Hanover, New Hampshire, USA, 1995

ICARP I brought together about 300 scientists and representatives of the community of funders, managers and users of Arctic science for intensive science planning discussions during **5 – 9 December 1995**. The goal was to reach agreement on science and implementation plans intended to guide international cooperation over the next 5 – 10 years to address a set of priority topics identified by the **International Arctic Science Committee (IASC)** and included in the 1994 IASC Science Agenda (which contained four broad themes and a large number of focused topics or science priorities). Because this Science Agenda was a living document, ICARP provided an opportunity for the development of new ideas for this agenda. Ten pairs of science and implementation plans were created:

Theme 1: Impacts of Global Changes on the Arctic Region and its Peoples

- Effects of Increased UV-Radiation
- Regional Cumulative Impacts - Barents Sea
- Regional Cumulative Impacts - Bering Sea

Theme 2: Arctic Processes of Relevance to Global Systems

- Mass Balance of Arctic Glaciers and Ice Sheets
- Terrestrial Ecosystems and Feedbacks on Climate Change

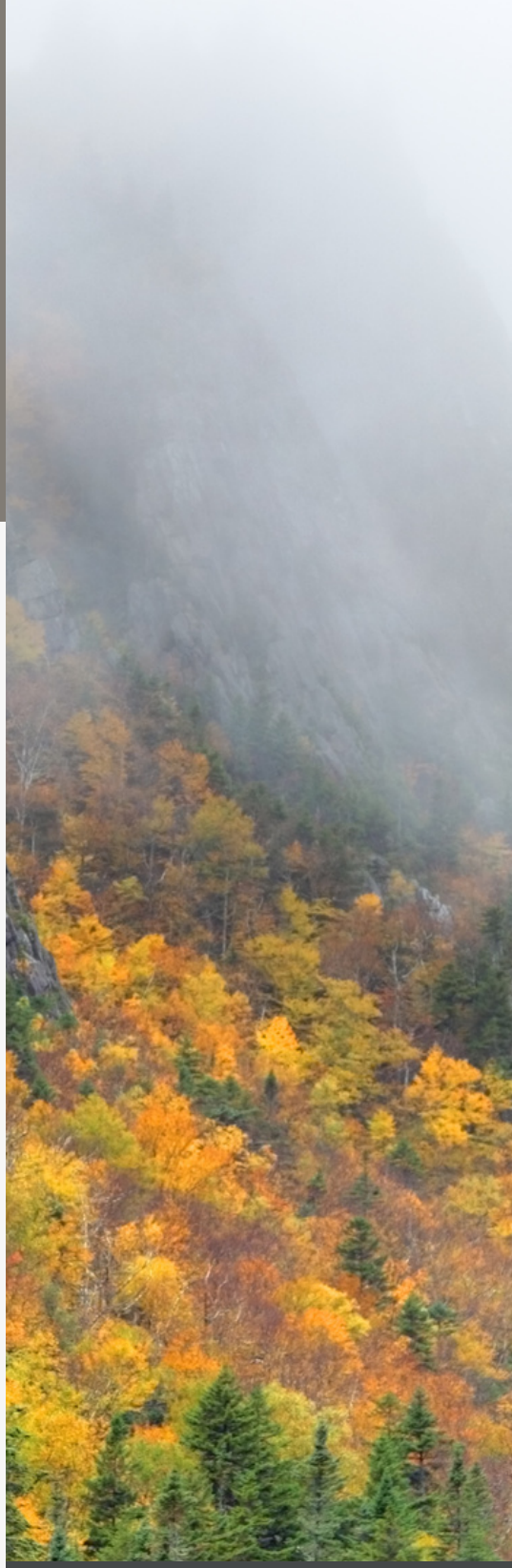
Theme 3: Natural Processes within the Arctic

- Arctic Marine / Coastal / Riverine Systems
- Disturbance and Recovery of Terrestrial Ecosystems

Theme 4: Sustainable Development in the Arctic

- Dynamics of Arctic Populations and Ecosystems
- Sustainable Use of Living Resources
- Environmental and Social Impacts of Industrialization on the Arctic

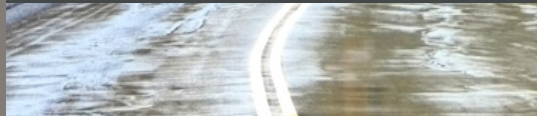
More information: ICARP website (icarp.iasc.info)



Final Report:

IASC (1996): Executive Summary, Arctic Systems: Natural Environment, Human Actions, Nonlinear Processes. IASC Report No. 3. Oslo: IASC.

IASC (1996): Arctic Systems: Natural Environment, Human Actions, Nonlinear Processes. IASC Report No. 4. Oslo: IASC.



ICARP II

Copenhagen, Denmark 2005

ICARP II was held from **10-12 November 2005** and brought together more than 450 scientists, policy makers, research managers, Indigenous Peoples, and others interested in and concerned about the future of Arctic research. The conference was the culmination of a 24-month planning process involving over 140 scientists working to develop research plans around twelve critical research themes identified by the Conference Sponsors based upon input from the science and Arctic community at large. ICARP II was structured around twelve major areas of potential research needs, each of which was led by an international team of scientists and other experts (e.g., Elders and other leaders from Indigenous Peoples of the North). Conference participants concluded that since the ICARP I, there was a paradigm shift to a holistic and multidimensional perspective in the Arctic. This holistic perspective integrally included the human dimension, Indigenous insights, and a more complete integration of Arctic processes in the Earth system. The range of questions, issues, and gaps in understanding identified during the ICARP II process provided the underpinning for the Science Plans and for framing research perspectives for the decade or two ahead.

The **ICARP II process** developed **12 Science Plans (11 Science Plans and a Background Paper on Contaminants)** and resulted in several follow-up international projects and programs, mostly within the framework of the International Polar Year 2007-2008. The topics of the Science Plans were:

- Arctic Economies and Sustainable Development
- Indigenous Peoples and Change in the Arctic: Adaptation, Adjustment and Empowerment
- Arctic Coastal Processes
- Deep Central Basin of the Arctic Ocean
- Arctic Margins and Gateways
- Arctic Shelf Seas
- Terrestrial Cryospheric & Hydrologic Processes and Systems
- Terrestrial and Freshwater Biosphere and Biodiversity
- Modeling and Predicting Arctic Weather, Climate and Ecosystems
- Rapid Change, Resilience and Vulnerability in Social-Ecological Systems of the Arctic
- Arctic Science in the Public Interest
- The Fate and Implications of Contaminants in the Arctic

Final Report:
Bowden, S., Corell, R.W. Hassol, S.J. and C. Symon (2007): Arctic Research: A Global Responsibility. Canada: McCallum Printing Group.

More information: ICARP website (icarp.iasc.info)

ICARP III

Toyama, Japan
2015

ICARP III was an open process, with the opportunity for the wider Arctic community to contribute to the overall objectives. It provided a framework to: identify Arctic science priorities for the next decade; coordinate various Arctic research agendas; inform policy makers, people who live in or near the Arctic and the global community; and build constructive relationships between producers and users of knowledge. ICARP III built on the many comprehensive science plans that existed already and complemented those with processes to identify gaps that may have needed attention.

Engaging all partners, including funders, in shaping the future of Arctic research needs, ICARP III:

- produced a consensus statement identifying the most important Arctic research needs for the next decade;
- provided a roadmap for research priorities and partnerships and
- identified the potential and specific contributions of Arctic research partners to the International Polar Partnership Initiative

It was structured along scientific themes and included a series of events, culminating in a final conference at the Arctic Science Summit Week 2015 from **23 - 30 April 2015** in Toyama, Japan that brought together more than 700 international scientists, students, policy makers, research managers, Indigenous Peoples and others interested in developing, prioritising and coordinating plans for future Arctic research.

The overarching ICARP III research priorities were on:

- Role of the Arctic in the global system;
- Prediction of future climate dynamics and ecosystem responses;
- Improved understanding of the vulnerability and resilience of Arctic environments and societies.

ICARP III 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. The current **IASC Strategic Plan (2023 – 2026)** still builds on the key priorities and overarching messages of ICARP III.

More information: ICARP Website (icarp.iasc.info)

Final Report:

IASC (2016): Integrating Arctic Research - a Roadmap for the Future.

ICARP IV

INTERNATIONAL CONFERENCE ON ARCTIC RESEARCH PLANNING

About the ICARP IV Process

The ongoing **fourth ICARP process (ICARP IV)** lasting from **2022 to 2026**, considers the most urgent knowledge gaps and Arctic research priorities and needs for the next decade and explores avenues to address these research needs. It will identify important research questions and priorities that cut across disciplines and knowledge systems, and that require new and innovative thinking and collaboration, and will develop a vision for implementation alongside science plans for addressing these priorities. 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 peoples in the Arctic and those in more temperate and tropical regions need to adapt and prepare for the changing Arctic and its impact on global systems.

The **ICARP IV process** is a **community-wide undertaking** engaging Arctic researchers, Indigenous Peoples, policy makers, residents, and other interested parties from around the world and is well coordinated with other ongoing international activities (e.g. the UN Decade of Ocean Sciences for Sustainable Development). So far, 26 international organisations are contributing to the process. ICARP I, II, and III focused the attention of the world's researchers toward the value of strategic international coordination for accelerating progress in addressing critical challenges.

ICARP IV builds upon this concept by striving to achieve consensus and build collaborations among the leading scientific, academic, environmental, Indigenous, local resident and political organisations currently concerned with Arctic issues. An integral aspect of the ICARP IV is the inclusion of early career researchers, Indigenous Peoples, and Arctic residents in the co-creation of priorities and science plans to address key questions. The focus of ICARP IV is on important research questions that cut across many disciplines and knowledge systems. IASC is committed to recognising that Traditional Knowledge, Indigenous Knowledge, and academic scientific knowledge are equal and complementary knowledge systems that can, and should, inform the work of IASC and ICARP IV.

ICARP IV Engagement Phase in 2023 and 2024

The ICARP IV process is seeking community input throughout 2023 and into 2024 through a diverse set of engagement activities worldwide. One of the main goals for the ICARP IV engagement process is to be truly inclusive, diverse, and engaging to ensure that the scientific priorities for the next decade are firmly grounded on the advice and needs of Arctic scientists and science organisations, Indigenous Peoples and Arctic residents, stakeholders, and rightsholders.

Individuals of all career stages, groups, networks, institutions, and organisations are encouraged to contribute to the ICARP IV engagement process by:

- Participating in an ICARP IV engagement events throughout the two years
- Seeking endorsement for organising their own activity (in-person and online) (e.g. workshops, sessions at conferences, sharing circles, webinars, etc.)
- Submitting ICARP IV relevant outcomes from your own research projects
- Submitting documents that are relevant for the ICARP IV process
- Participating in the ICARP IV Survey (later in 2023)
- Participating in the IASC-European Polar Board Webinar Series (later in 2023)

All input provided throughout the ICARP IV engagement process will be collected by the IASC Secretariat and will inform the work of the Research Priority Teams and International Steering Committee. This will ensure your input is included in the development of the ICARP IV research priorities and implementation plans.

More information on the ICARP IV Engagement Process is available on the **ICARP IV website**.

ICARP IV Research Priority Teams

The ICARP IV International Steering Committee is convening **Research Priority Teams** on several topical areas between **2023 and 2025** to

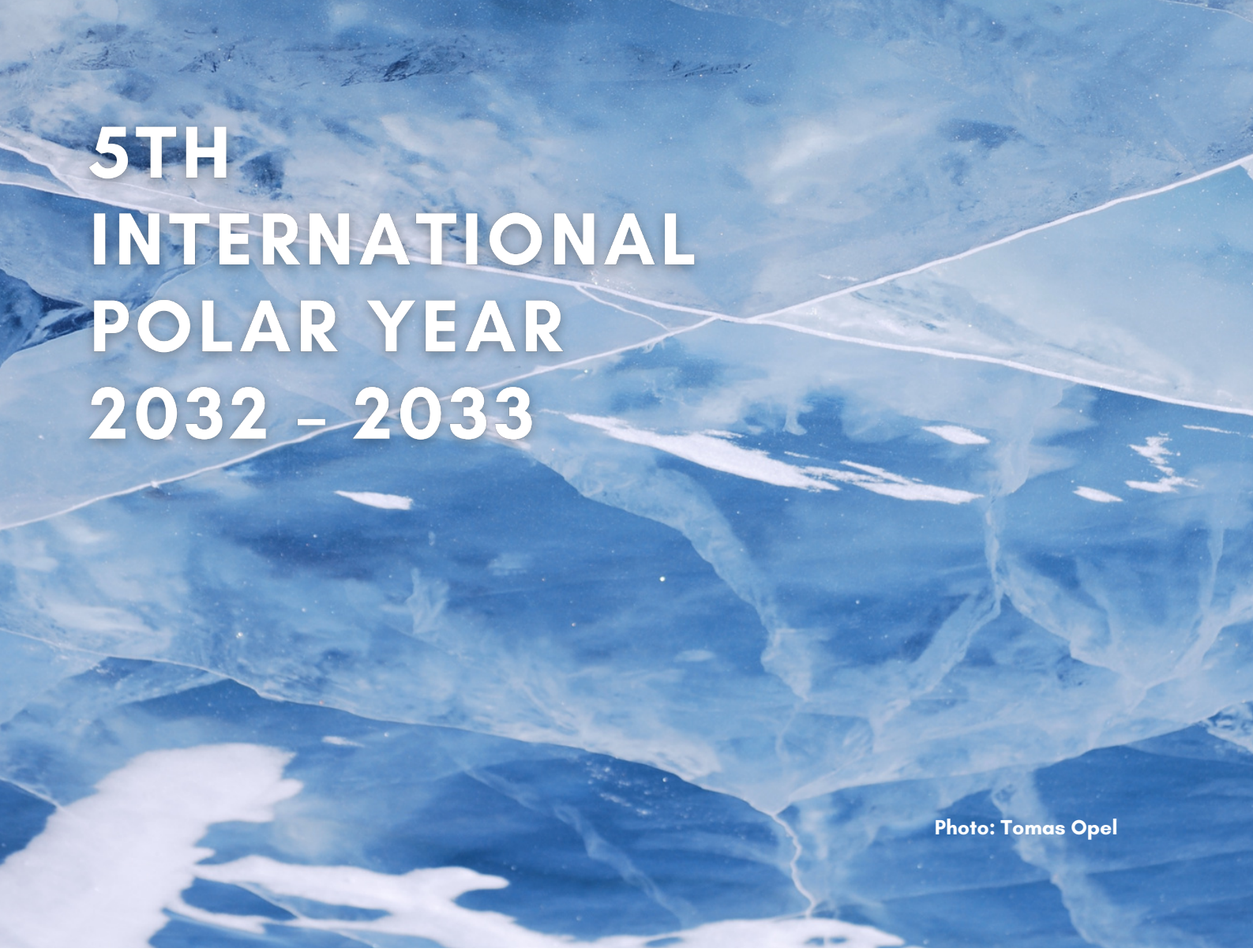
- review and summarise the wider community input provided for their topic areas (or organise own engagement activities);
- define knowledge gaps and research priorities for their topic areas; and
- develop science and educational, outreach and communication plans;
- suggest recommendations for implementation of the research priorities.

Seven topic areas for the Research Priority Teams have been identified:

- Topic Area 1: **The Role of the Arctic in the Global System.**
- Topic Area 2: **Observing, Reconstructing, and Predicting Future Climate Dynamics and Ecosystem Responses.**
- Topic Area 3: **Understanding the Vulnerability and Resilience of Arctic Environments and Societies and Supporting Sustainable Development.**
- Topic Area 4: **Scientific Cooperation and Diplomacy.**
- Topic Area 5: **Co-Production of Knowledge and Indigenous-led Methodologies.**
- Topic Area 6: **Preparing Present and Future Generations through Education, Outreach, Communication, Capacity Building, and Networking.**
- Topic Area 7: **Technology, Infrastructure, Logistics, and Services.**

The preliminary results of the Research Priority Teams work will be presented at the **ICARP IV Summit / ASSW 2025** in **Boulder, Colorado, USA (21 - 28 March 2025)**, followed by a community-wide public consultation phase, with the aim to finalise the outcomes of the Research Priority Teams work by the end of 2025. The results will then contribute to the final report of the ICARP IV process published in 2026.

More information on the ICARP IV Research Priority Teams is available on the **ICARP IV website**.



5TH INTERNATIONAL POLAR YEAR 2032 – 2033

Photo: Tomas Opel

The ICARP IV process is aimed at helping to define the Arctic research priorities for the **5th International Polar Year** in **2032-33**. Since 2021, an interim planning group comprised of representatives from both polar regions including IASC, the **Scientific Committee on Antarctic Research** (SCAR), **World Meteorological Organization** (WMO), **International Science Council** (ISC), **University of the Arctic** (UArctic), **International Arctic Social Sciences Association** (IASSA), the **Association of Polar Early Career Scientists** (APECS), the **European Polar Board** (EPB) as well as several of the Permanent Participants of the Arctic Council have been engaging in early discussions on planning. In December 2022, a joint statement from the partners confirmed that preparatory work had started.

Over the last year the discussions gained momentum and a growing number of international, Arctic and Antarctic partners are now involved. In summer 2023, the organisations have been working on a concept note and a timeline for the 5th IPY that will undergo a consultation phase in 2023 / 2024, with the objective to ensure that expectations and suggestions from the polar research community and other relevant stakeholders with an interest in the IPY are included. More information will be available in late autumn 2023 on the **IASC website**.

IASC-SCAR Statement on the 5th International Polar Year

Published on 13 December 2022

Following their recently renewed partnership agreement, the International Arctic Science Committee (IASC) and Scientific Committee on Antarctic Research (SCAR) are pleased to confirm that preparatory work has started for a **5th International Polar Year (IPY)** in **2032-33**. Organising the 5th IPY 25 years after the last IPY in 2007-08 reflects the urgent need for coordinated international research to tackle the biggest challenges of polar research, for both the Polar Regions themselves and for the world as a whole.

Aside from IASC and SCAR, the initial planning efforts for the 5th IPY are currently supported by the World Meteorological Organization (WMO), International Science Council (ISC), University of the Arctic, International Arctic Social Sciences Association (IASSA), the Association of Polar Early Career Scientists (APECS) and other partners worldwide representing both poles. Together, this initiative aims to build an IPY that reflects the aims, objectives and needs of each organisation, the international research community, as well as Indigenous Peoples and other residents of the Polar Regions and wider stakeholders. Over the coming years, many individuals, stakeholders and rightsholders working on, having an interest in, or residing in the Polar Regions will be encouraged to participate and help shape this large community effort.

In the lead up to the 5th IPY, SCAR and IASC are also pleased to announce a joint SCAR-IASC Polar Conference in 2030.

We look forward to sharing the next steps with you from 2023 onward and encourage organisations that want to get engaged in the initial planning process to contact the IASC Secretariat (info@iasc.info) and the SCAR Secretariat (info@scar.org) for more information.

CURRENT ARCTIC RESEARCH PRIORITIES

Photo by Susie Allison

Ongoing climate change is the predominant driving force for national research interests in the Arctic, and has significant, cascading effects on Earth's biological and societal spheres. IASC's research priorities continue to be aligned with the pillars outlined in its **3rd 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 2023.

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 and tropical weather, weather extremes, climate variability, and environmental processes.
- Improving understanding of Arctic amplification and Arctic (and polar) climate feedbacks.
- Understanding the consequences of ongoing climate change, including impacts on ecosystems (e.g., biodiversity, biosecurity, food webs, biogeochemical cycles, atmospheric composition, 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, cryosphere, and ocean.
- Evaluating the contributions of Arctic ice sheets and glaciers to regional and global sea level change and the impacts of glacier melt on ocean mixing and circulation.
- Studying past environmental changes through climate, geological and environmental archives such as ice cores, marine and lake sediment records, tree rings.
- Identifying and using ecological, biogeochemical and biological indicators to understand current and past Arctic changes.
- Tracking the identification and consumption of resources (including minerals, energy, fish, subsistence foods, and more).
- Interrogating the intersection of geopolitics, security, international law, and international relations in the Arctic.

Photo by Allan Buras

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 and Earth system models.
- Sustaining and developing long-term data sets, including paleo-limnological and paleo-oceanographical approaches to frame current Arctic change and 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 Arctic amplification.
- Investigating interactions and coupling processes at climate-domain interfaces to improve understanding of Arctic amplification, Arctic-related feedbacks, and the interactions between different components of the climate system (atmosphere, ocean, cryosphere, land surface, hydrological systems, ecosystems), improving the representation of these coupled processes in regional climate models.
- Monitoring long-distance pollution transport to the Arctic (aerosols, trace gases, inorganic and persistent organic pollutants, microplastics, 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 ground-based observing systems and capabilities, including improved coordination with spaceborne Earth Observation programs and modelling communities and opportunities for collaboration to generate large-scale, standardised in situ validation datasets.
- Monitoring future developments in the Central Arctic Ocean, including sea ice cover, commercial fishing potential and transportation routes, and exploitation of natural resources.
- Monitoring changes in biodiversity and ecosystem functioning from microhabitats to pan-Arctic scale, including improved understanding and attribution of the drivers of biodiversity and ecosystem change
- Developing AI-based methods for filling data gaps in Arctic regions.
- Investigating life in (extreme) Arctic environments – disappearing ecosystems, resurrected ecosystems, adaptation strategies of Arctic and migratory populations, and invasive species.
- Analysing the changing Arctic Critical Zone in the framework of geosphere-biosphere interactions and permafrost thaw.
- Investigating ecosystem state and permafrost (in)stability under climate and land cover change, including improved quantification of greenhouse gas fluxes from thawing permafrost.

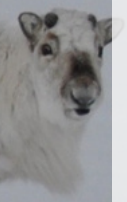


Photo by Andrea Spolaor

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-designing/co-producing Arctic research strategies and projects with northern and Indigenous communities.
- Monitoring contaminants and pollutants (including plastics, pathogen and air pollutants) in all parts of the Arctic environment and understanding their sources and impacts on Arctic societies.
- Improving understanding of the Arctic water cycle and its response to climate change.
- Understanding natural hazards, extreme weather, and wildfire dynamics and how these will evolve in response to climate change, and supporting the development of improved forecasting and early warning systems for northern communities.
- Investigating the intersection of environmental sustainability, maritime technology, and shipping safety and implications for Arctic marine emergency response preparedness.
- Investigating the nexus of climate change, resilience, and adaptation in the context of Arctic environmental change.
- Promoting health and wellness – community vitality, adaptation to climate and environmental change, and holistic human-environment approaches.
- Fostering diversity, gender equality, and inclusion in Arctic research.
- Bridging the intersection of humanities, social, and natural science topics.
- Understanding the Arctic by investigating the past, the present and the links between the different components of the Arctic system to improve prediction of future scenarios and increase Arctic resilience.
- Documenting coastal erosion and the impacts on carbon cycling, infrastructure, communities, and ecosystems; and improving risk assessments for both socio-economic systems and ecosystems.

Photo by

Major Ongoing and Upcoming Projects

Photo: Anne Hormes

International collaborative 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	This major international consortium project involves ten research organisations across seven 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.
Arctic Hubs	The project develops sustainable, solution-oriented tools for reconciling competing models of livelihood and land-use in Arctic hubs and their surroundings, whilst respecting the needs and cultures of local and indigenous populations.

(AC)³ - ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms	The project was established in 2016. It is a collaborative effort funded by the DFG (German Research Foundation) combining the expertise in Arctic research of three German universities (Leipzig, Köln, Bremen) and two non-university research institutions (Alfred Wegener Institute, Helmholtz-Centre for Polar and Marine Research, Leibniz Institute for Tropospheric Research). (AC)³ comprises modelling and data analysis efforts as well as observational elements. The project has assembled a wealth of ground-based, airborne, shipborne, and satellite data of physical, chemical, and meteorological properties of the Arctic atmosphere, cryosphere, and upper ocean that are available for the Arctic climate research community. Currently, (AC)³ is in its second four-year funding period and a proposal for a final project phase (2024-2027) is being evaluated.
ALPACA - Alaskan Layered Pollution And Chemical Analysis	This large international project 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.
The Arctic Five	A university alliance of five 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.
Arctic PASSION	The key motivation of this EU Horizon 2020 project 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, emphasising the inclusion of Indigenous and Local Knowledge and community-based monitoring, and streamline provision of data from observations to products for societal needs.
AASCO - Arena for gap analysis of the existing Arctic science co-operations (2020 – 2024)	A project funded by the Prince Albert II of Monaco Foundation that aims towards understanding the land-ocean-atmosphere feedback and interactions taking place in Arctic-boreal context and region under changing climate.
ACCC - Atmospheric and Climate Competence Center	This project addressing climate and air quality research in Arctic – boreal environments, is a Finnish Flagship, research and innovation project funded by the Academy of Finland.
ArcticWATCH	This European Research Council (ERC) Starting Grant project (2023-2027) aims at developing an early-warning system for future rapid Arctic sea ice loss at interannual time scales.
ARTofMELT - Atmospheric rivers and the onset of sea ice melt	The expedition (May-June 2023) with the Swedish icebreaker Oden targeted warm-and-moist air intrusions and the onset of sea ice melt.

CHARTER - Drivers and Feedbacks of Changes in Arctic Terrestrial Biodiversity	This EU Horizon 2020 project aims to advance state-of-the-art knowledge on Arctic biodiversity change and social-ecological systems.
CRiceS - Climate Relevant interactions and feedbacks: the key role of sea ice and Snow in the polar and global climate system	This EU Horizon 2020 project 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.
Decolonising Nordic Archives	This NOS-HS (Nordforsk) funded project examines the intersection of international law, history and archival theory and practice on State archives. It seeks to apply the international law of self-determination and decolonisation to decisions about access, custody and control of shared archives in the Nordic countries.
ECOTIP - Ecological tipping cascades in the Arctic Seas	This Horizon 2020 research project focuses on understanding and predicting changes in Arctic marine biodiversity and implications for two vitally important marine ecosystem services: fisheries production, which is the economic lifeblood of many Arctic communities, and carbon sequestration, which has important feedback to the global climate.
EISCAT 3D	This new international research infrastructure uses radar and incoherent scattering techniques. After completion in 2024, EISCAT 3D, operated by the EISCAT Scientific Association, will provide the research community with state-of-the-art high-resolution 3D data on the Arctic atmosphere and near-Earth space environment above the Fenno-Scandinavian Arctic.
EU Polar Cluster	Network of collaborative polar projects, which are funded by the European Commission, and four permanent members: the EPB, APECS, SIOS and EuroGOOS.
EU-PolarNet 2	The world's largest consortium of expertise and infrastructure for polar research.
European Space Agency (ESA) Polar Science Cluster	It joins several ESA-funded projects and activities and aims at promoting networking, collaborative research, and fostering international collaboration. This includes support for the Arctic Methane and Permafrost Challenge (AMPAC) which is a joint initiative of NASA and ESA.
FACE-IT	This EU Horizon 2020 funded project aims to enable adaptive co-management of social-ecological fjord systems in the Arctic in the face of rapid cryosphere and biodiversity changes.

GEOEO - North Greenland Earth-Ocean-Ecosystem Observatory	Expedition with the icebreaker Oden that focuses on the marine cryosphere's dynamic history and response to future climate change. This includes implications for marine and terrestrial ecosystems in North Greenland and the adjacent Arctic Ocean and the North Greenland Ice Sheet's contribution to global sea-level rise.
GreenFjord - Greenlandic Fjord ecosystems in a changing climate: Socio-cultural and environmental interactions	A Swiss Polar Institute funded flagship initiative running from 2022 to 2026. It focuses on the exchange and change of energy, nutrients, biological and biogeochemical tracers in two contrasting fjord systems in Southern Greenland, and the implications for local livelihoods.
InfraNorth - Building Arctic Futures: Transport Infrastructures and Sustainable Northern Communities	An ERC project at the University of Vienna that runs from 2021 to 2025. It explores how residents of the Arctic engage with transport infrastructures and their intended and unintended local consequences.
INTERACT - The International Network for Terrestrial Research and Monitoring in the Arctic	This network builds capacity and access to Arctic research stations.
ITEX - International Tundra Experiment	This project examines the impacts of warming on tundra ecosystems.
JUSTNORTH	This EU Horizon 2020 project investigates different dimensions of ethical systems and justice in the economic development in the Arctic.
LandSense	A project funded by the Federation Wallonie-Brussel (ARC) in Belgium about "Pushing the boundaries of Critical Zone research: Unravelling hydrological controls on carbon and nutrient fluxes by integrating proximal sensing, field measurements and smart modelling", with one application in Arctic, 2021-2026.
LIFTHAW - Nutrient lift upon permafrost thaw: sources and controlling processes	A project funded by Belgium's Science Policy (BELSPO, IMPULS) aiming at comprehensively assess the nutrient mobility response in permafrost regions undergoing thawing, 2023-2025.
MEDLEY - MixED Layer hEterogeneitY	A JPI Oceans & Climate project that aims (1) to evaluate the spatial heterogeneity of fluxes and processes controlling the ocean mixed layer and (2) to take into account this heterogeneity to improve the representation of the mixed layer transfer function in climate models, with focus on the northern North Atlantic and Arctic Oceans.

MOSAiC - Multidisciplinary drifting Observatory for the Study of Arctic Climate	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 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. International scientific conferences of the project were held in Potsdam (Germany) in 2022 and in Boulder (USA) in 2023 and are planned for 2024 in Potsdam (Germany).
The Nansen Legacy	This project 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 disposed 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.
NNA - Navigating the New Arctic	This US NSF-funded initiative, comprising over 100 individual and collaborative projects, tackles convergent scientific challenges in the rapidly changing Arctic that are needed to inform the economic, security and adaptation decisions. NNA is empowering new research partnerships from local to international scales and practising knowledge co-production where appropriate.
Northern EU Gateway	The project investigates in detail how subsea optical cables can connect Europe to Japan and North America through the polar region.
Nunataryuk	This EU Horizon 2020 funded project studies coastal catchments in permafrost areas, coastal erosion and impacts on carbon cycling, and science for socioeconomic adaptation.
Polar Connect	A Northern European initiative to obtain secure and resilient connectivity through the Arctic to Asia and North America for Research, Development, Innovation and Education.
PolarRES - Polar Regions in the Earth System	This EU Horizon 2020 project 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.
Polar to Global Online Interoperability and Data Sharing Workshop	This online workshop series 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.

Q-Arctic	This European Research Council Synergy project (2021-2027) aims to establish a next generation coupled land-surface model that explicitly resolves highest resolution landscape features and disturbance processes in the Arctic. Model development will be synchronised with novel remote sensing methodologies linking landscape characteristics and change potential.
RESIST - Recent Arctic and Antarctic sea ice lows: same causes, same impacts?	This project funded by Belgium's Science Policy (BELSPO) aims at intercomparing the mechanisms at the source of recent negative sea ice anomalies both in the Arctic and Antarctic regions, as well as the impacts of these anomalies on the atmosphere and the land/permafrost systems.
SIOS - Svalbard Integrated Arctic Observing System	SIOS aims to realise an international observing system for long-term measurements in and around the archipelago of Svalbard addressing Earth System Science questions.
SIPN South - Sea Ice prediction Network South	This collaborative project coordinates seasonal predictions carried out in institutions worldwide.
Sustainable Arctic Cruise Communities: From Practice to Governance	This project funded by the Norwegian Research Council under the auspices of the Norwegian-Russian research fund, explores regional practices and management of cruise traffic and on-land management of Arctic cruise tourism in Norway, Iceland and Greenland. The project develops a toolkit of best practices for sustainable cruise tourism development.
SVALUR - Understanding Resilience and Long-Term Environmental Change in the High Arctic: Narrative-Based Analyses from Svalbard	This Belmont Forum funded consortium (2020-2023) aims at combining formal environmental monitoring with the knowledge and observations from people of all walks of life who know Svalbard well.
Synoptic Arctic Survey (SAS) and **Distributed Biological Observatory (DBO)**	These are projects coordinating Arctic marine observations for international and interdisciplinary benefit.
T-MOSAiC - Terrestrial Multidisciplinary Distributed Observatories for the Study of Arctic Connections	This project extends 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 the northern ecosystems, geosystems and human systems. A new renovated project is under discussion at some IASC Working Groups and should be implemented in the forthcoming years.

TRiNC - Truth and Reconciliation in the Nordic Countries	This project 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 with state representation.

Long-term monitoring projects

Long-term monitoring (i.e. annual to decadal time-series measurements) is crucial to building improved understanding of the circumpolar Arctic, and yet monitoring initiatives are still sparse in Arctic science, especially in the Russian Arctic, a situation that cannot be improved due to the current geopolitical situation. Examples of such monitoring include:

AMAP - The Arctic Monitoring and Assessment Programme	This Arctic Council Working Group is mandated to 1) monitor and assess the status of the Arctic region with respect to pollution and climate change issues, 2) document levels and trends, pathways and processes, and effects on ecosystems and humans, and propose actions to reduce associated threats for consideration by governments, and 3) produce sound science-based, policy-relevant assessments and public outreach products to inform policy and decision-making processes.
AVA - Arctic Vegetation Archive	This international effort consolidates and standardises vegetation plot data into a pan-arctic vegetation archive. This unique database provides baseline data for species distribution and plant biodiversity analysis.
CAFSN - Circumpolar Arctic Fox Sentinel Network	This network has been proposed in response to circumpolar rabies and lice outbreaks and was discussed at the Arctic Fox symposium on Svalbard in August 2022.
CAVM - Circum-Arctic Vegetation Map	This international effort maps the vegetation and associated characteristics of the Arctic using a common base map, as an important point of reference for comparisons across the Arctic.
CBMP - Circumpolar Biodiversity Monitoring Programme	Is a cornerstone programme of the CAFF working group of the Arctic Council. The CBMP is an international network of scientists, governments, Indigenous organisations, and conservation groups working to harmonise and integrate efforts to monitor the Arctic's living resources. Our goal is to facilitate more rapid detection, communication, and response to the significant biodiversity-related trends and pressures affecting the circumpolar world. The CBMP organises its efforts around the major ecosystems of the Arctic: marine, freshwater, terrestrial and coastal. The CBMP works to leverage monitoring activities of networks and nations and establish international linkages to global biodiversity initiatives. The CBMP has been endorsed by the Arctic Council and the UN Convention on Biological Diversity and is the official Arctic Biodiversity Observation Network of the Group on Earth Observations Biodiversity Observation Network (GEOBON).

CRIOS - Cryosphere Integrated Observatory network on Svalbard	This project funded by the EEA funding scheme for basic research focuses on building an automatic measuring network on glaciers in Svalbard providing real-time weather, snow and ice data via the internet.
Distributed Biological Observatory (DBO)	Building on the success of the Pacific Distributed Biological Observatory (Pacific-DBO), new sibling coordinated marine observational networks are being established in the Davis Strait-Baffin Bay area, in the Atlantic Arctic region (Atlantic-DBO) and in the Eastern Arctic Ocean (Siberian-DBO). All these new initiatives have been kicked-off and will strengthen regional coverage as well as pan-Arctic collaboration and coherence.
GEM - Greenland Ecosystem Monitoring	This integrated monitoring and long-term research program on ecosystems and climate change effects and feedbacks in the Arctic has both a terrestrial and a marine component and takes place in selected locations in Greenland.
GLORIA - Global Observation Research Initiative in Alpine environments	Surveys and re-surveys monitoring mountain vegetation in the Arctic, e.g. in Zackenberg/Greenland and Iceland.
HiLDEN - High-Latitude Drone Ecology Network	This international effort collects and processes drone-based high-resolution imagery following a standardised protocol to answer ecological questions. The network currently covers 73 landscapes across the Arctic.
ICOS - Integrated Carbon Observation System	This project provides high-quality European climate and greenhouse gas data - some sites in Scandinavia and Greenland.
PROMICE - Programme for Monitoring of the Greenland Ice Sheet	This program operates and maintains more than 30 automatic weather stations on the Greenland ice sheet, delivering open-access data about the mass balance of the Greenland ice sheet in near real-time.
SITES - Swedish Infrastructure for Ecosystem Science	This is a national infrastructure for ecosystem research that facilitates long-term field-based ecosystem research.

Other Projects:

- Several programs at Arctic research stations are studying atmospheric, ecosystem, Critical Zone, marine and climate variables. See information on the Arctic stations and their programs on the **INTERACT** website
- Many monitoring projects in the Arctic harness polar orbiting, globally observing satellites, this includes airborne and field calibration efforts at several Arctic test sites.
- 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**

- The Russian research platform "**Severny Polyus**" (ice class M Arc5) set off from Murmansk in September 2022 for the two-year expedition "**North Pole-41**". Two months later, "Severny Polyus" was moored to an ice floe north of the New Siberian Islands and has been drifting in the eastern Arctic Ocean since that time. On board of the platform, which is 83 meters long, are 34 scientists and 14 crew members.
- Projects are monitoring migratory and native bird populations around the Arctic (e.g., Greenland, Svalbard, and Siberia) and around the world. Examples include: **CAFF's Arctic Migratory Birds Initiative**; **Arctic PRISM**; **International Breeding Conditions Survey on Arctic Birds**; **Global Flyway Network**.
- Passive acoustic monitoring has been established at multiple locations across the Arctic Ocean, to build up time series spatial and temporal patterns of biological (e.g. marine mammals) and anthropogenic (e.g. shipping, seismic surveys) sound sources and monitor underwater noise levels related to ongoing climate change and human use of the oceans.
- 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 and Novel Arctic Research

Photo by Andrew Tedstone

New technologies and capacities

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 is an emerging tool which gives insight into modern impacts of extreme weather events on terrestrial environments in the context of longer-term climate change, adding to existing proxy records such as lake sediments.
- There is increasing interest and technical development in the ability to collect and analyse environmental information from melt-affected ice cores.
- Development and advancement of autonomous vehicles and observing platforms, like autonomous (under-ice) ocean monitoring with passive and active acoustics, gliders, airborne drones, tethered balloons (helikites) and sail drones to collect enhanced information on the spatial and temporal variability of key physical, chemical, and biological processes occurring at high latitudes.
- The Arctic ice may serve as a proxy for the frozen moons of Jupiter and Saturn, e.g., Europa and Enceladus. Novel isotopic measurement methods for trace elements such as mercury, lead or/and osmium provide new insights for ice core climate studies as well as quantifying modern pollution and their sources and pathways.
- Bioprospecting and biotechnology approaches, including environmental DNA and nanopore sequencing, are being applied to the Arctic.

- New, modern research stations in areas of northern Canada, such as the **Canadian High Arctic Research Station** are providing logistical and laboratory support and represent significant capacity investment in Arctic communities. These stations are supported by smaller observatories such as at Trail Valley Creek in the Inuvialuit Settlement of the western Canadian 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 - Towards an Arctic Critical Zone Observation Network project**

Remote Sensing technology and techniques

Remote sensing (satellite, ground-based and airborne) technology and techniques have been highlighted:

- Historical archive data is being combined with current data to understand past changes.
- Climate normals of downwelling shortwave radiation at the surface and cloud properties are being prepared using satellite-based climate data records by the Swedish Meteorological and Hydrological Institute according to the recommendations of WMO for the new 30-year normal period 1991-2020. These normals will be useful for the assessment of the state of the climate and climate change studies.
- A sea-ice lead climatology for the period 2002-2021 has been established and published on PANGAEA by the University of Trier (Germany). The data are available with 1km on a daily basis and are useful for the understanding of air/sea-ice/ocean interactions.
- 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 various properties and processes, including vegetation composition and biomass, atmospheric composition, atmospheric dynamics, and snow and ice properties across large domains.
- Ground-based remote sensing of atmospheric properties allows for a long-term, continuous and high-resolution (space and time) monitoring of the atmospheric boundary layer.

New methodologies and techniques

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

- Development of a highly accurate digital model of the Earth (**Destination Earth**). It will help to 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, vegetation, 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.
- Making publications and associated data in journals and data repositories freely available for scientists and society alike through an open-access framework.
- Sharing results with Indigenous and other local communities in an accessible format (including translations into the language spoken by the knowledge holders and 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.
- 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.
- Convergent research: deeply interdisciplinary work focusing on addressing grand challenges and broad questions yields profound discoveries.
- Establishment of new technologies and applications in the Arctic, like unmanned aerial or underwater platforms.

New and novel research themes

New and novel research themes include:

- **OneHealth**, a cross-cutting, interdisciplinary concept and practical approach 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**
- Plastics in aquatic, terrestrial, and cryospheric environments and in wildlife.
- 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, and conversely, investigations of the effects of meltwater runoff and iceberg melt on ocean stratification, mixing, and nutrient fluxes.
- The impacts of increased liquid precipitation on the ground carbon budget, ice and snow processes, ice sheet mass balance, ecosystems, and the food security 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.

- 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.
- Increasing boreal and tundra heat waves and wildfire frequency.
- The effects of permafrost thaw and rising temperatures on the changes of the Arctic Critical Zone and corresponding impacts on natural resources, as well as on societies and people and among others their health, economy, livelihoods, cultures, and infrastructure.
- Intersectionality: focus on different/multiple experiences of marginalisation to help elicit social inequalities in the Arctic.
- Considerations on how to critically apply justice and equity theories into policies and actionable frameworks for sustainable development 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 and increased geopolitical/economic interest in the Arctic.
- Diverse other social science topics, including sustainable tourism and small-scale business development, mobility, connectivity, human rights, globalisation, science diplomacy, green transition climate change adaptation and mitigation in Arctic communities as well as climate change effects on health in the Arctic.

Emerging Arctic Research Issues

Photo by Pauline Snoeijs Leijonmalm

Many of the areas of emerging Arctic research are nuanced, and the discussion below expands upon the broadly stated priorities listed under "Current Arctic research priorities". In addition to advancing research visions to tackle these issues, an international strategy for transdisciplinary pan-Arctic research is needed urgently.

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.
- A better understanding of Arctic amplification is also emerging, both in the present Arctic and during warming periods in the geological past, as well as societal impacts of rapid warming.
- 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 at short and longer time scales. Understanding how these interactions will respond to a warming Arctic is a priority, especially at the scales of interest to Arctic communities.
- 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 coastal zones.
- Understanding the 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, ecosystem functioning, ecosystem conservation and environmental change through space and time.
- Studying other processes like:
    - Cryospheric controls on tundra and marine nutrient cycling.
    - Fjord and ocean productivity.
    - Shifts in primary production in response to sea-ice and climate change.
    - The Arctic marine carbon cycle and impacts of ocean acidification.
    - Permafrost thaw processes in light of changing snow depths and vegetation regimes.
    - Impacts of rapid permafrost thaw on surface water systems, contaminants, and greenhouse gas fluxes.
    - Subsea permafrost degradation.
    - 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.
    - Improved understanding of ice sheet hydrology, meltwater refreezing, and subglacial drainage processes, including subglacial permafrost regimes.
    - Sources, dispersion, and impact of high latitude dust.
    - Establish linkages between the different Arctic systems (e.g. glacial, terrestrial, freshwater and ocean) under the current Global Change.

Observation, 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. Community partnerships and co-developed monitoring programs will be increasingly needed to address northern capacity, Indigenous self-determination, and the sustainability of monitoring systems.
- 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 resources use, exploitation, and development: past, present, future; and human health and well-being.
- Focus on resilience and adaptation of Arctic communities to climate change.
- Ethical and equitable research approaches, including within data and metadata management (e.g., recognition of CARE Data Principles and Indigenous knowledge sovereignty).

- 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.
- Supporting the emerging and next generation of early-career Arctic and polar researchers.
- 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.
- Tourism and the environmental effects of tourism in the Arctic and beyond.
- Green transition and societal effects of green transition on Indigenous communities in the Arctic.
- Focus on environmental & climate justice in changing geopolitics.

- 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 are transported from Subarctic to Arctic regions.
  - Expanded research on the understanding of the dynamics or priority pollutants (e.g., metals, organics, etc) and their transformations in the environment as a consequence of permafrost thaw, icy environments or Arctic Ocean properties.
  - Expanded research into the consequences for Arctic human and wildlife health (e.g., pathogens & climate change).

Current Gaps in Research, Observation and Data

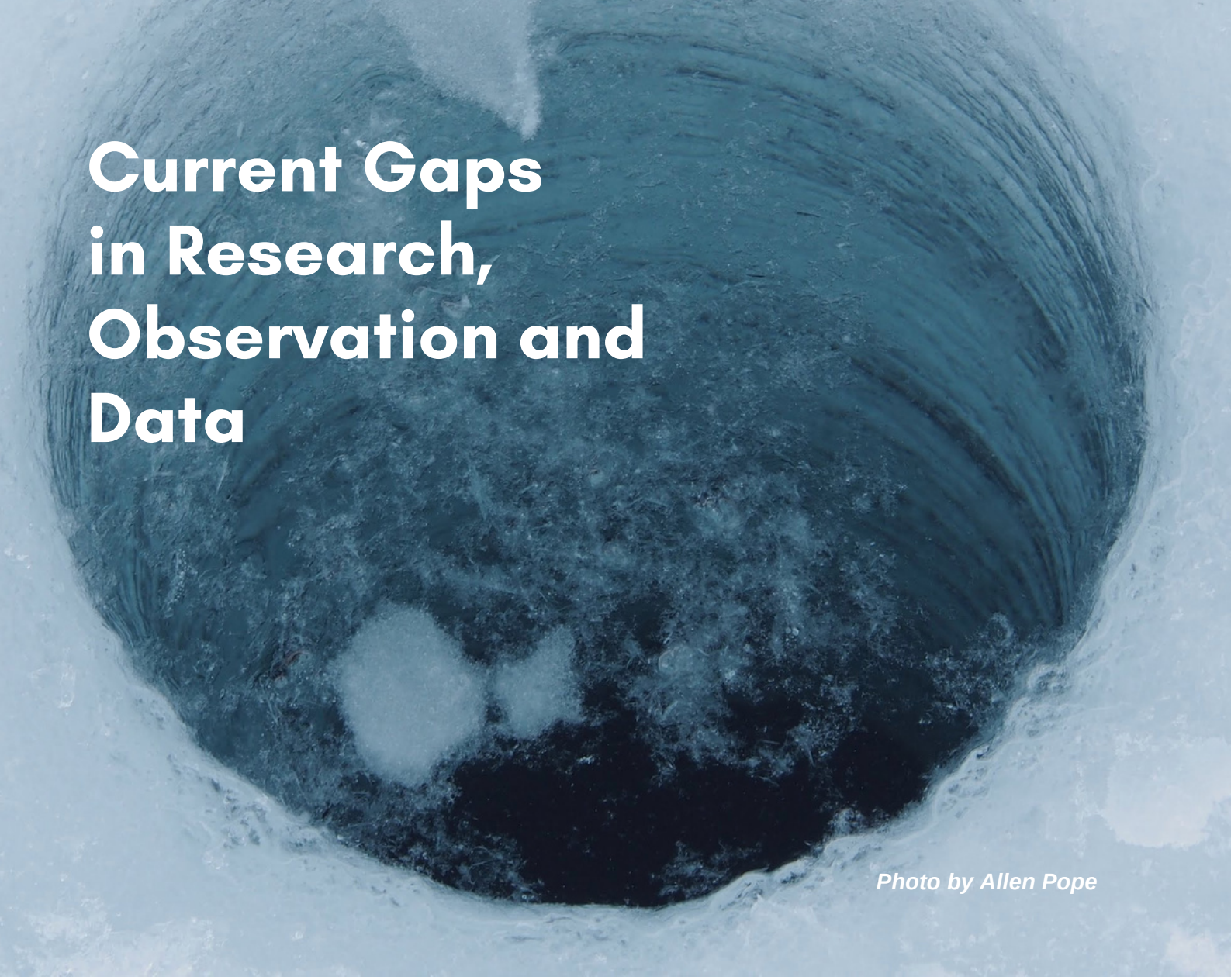


Photo by Allen Pope

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. The **Sustaining Arctic Observing Network (SAON)**'s **Roadmap for Arctic Observing and Data Systems (ROADS)** proposes to develop broadly beneficial implementation strategies that are organised 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.

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.

- Spatial 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 exacerbates 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 the **Multidisciplinary drifting Observatory for the Study of Arctic Climate (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.
- The deep time record (thousands to millions of years in the past) is an often disparate and incomplete record but is key to understanding and quantifying driving forces, rate of change and interactions in the coupled climate system, and the impact of climate change on Arctic ecosystems.
- 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.
- Improved understanding of the spatiotemporal effects of Arctic climate change, pollution, invasive species, resources exploitation in the Arctic socio-ecological system.

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.

- Promote research fellowships for arctic Indigenous people and residents, including grants to assist arctic science meetings.
- Equitable collaborations with Indigenous, traditional, and local knowledge holders is integral to co-produced knowledge generation.
- It is important to improve collaboration of research groups studying Arctic landscape system transformation related to climate change; coordinated, evolutionary and ecological biodiversity, 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 do standard disciplinary projects. This is especially 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 open and easily accessible, with the implementation of web portals and archives (e.g., within international networks such as the International **Network for Terrestrial Research and Monitoring in the Arctic - INTERACT**, permanent data archives such as PANGAEA, and research infrastructure such as the **Svalbard Integrated Arctic Earth Observing System - 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 and Infrastructure

- International scientific cooperation is underway in many research areas and there are numerous examples of joint and multilateral programs, but there is a need for infrastructure support (e.g., innovative technologies, new terrestrial observatories, new icebreaking platforms, etc.).

- There is a lack of underpinning funding, funding stability, and prioritisation of sustained baseline monitoring.
- Arctic scientists should further build cross-disciplinary, interdisciplinary, and convergent research practices within the scientific community and other stakeholders.
- There exists a need to explore a gap in Arctic research – **'sex, gender and intersectional analysis of the research content'.**
- 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 prioritise Arctic research, the current levels of monitoring and research are clearly insufficient to meet these challenges.
- Increased connectivity in the Arctic transforms both what Arctic scientists are able to achieve, 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.
- Future key questions include: 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 contextualised 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 Gregory Tran

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 rights holders' organisations. Arctic research does, and should continue to, involve extensive international collaboration; barriers, including geopolitical boundaries, high cost-distances, and socioeconomic disparities need to be overcome.

As already remarked in the introduction to this 2023 State of Arctic Science Report, whilst the challenges for Arctic research due to the Covid-19 pandemic in the last three years have now largely eased, the geopolitical situation that has arisen as a result of Russia's actions in Ukraine continues to create further short-term and also long-lasting uncertainties for research in the Arctic. The situation is seriously affecting international scientific collaborations and the ability of the international scientific community to carry out research and observations across vitally important areas of the Arctic.

The impacts on scientific collaboration, data exchange and publications, conferences and events, travel and fieldwork, maintenance of experiments and long-term monitoring stations, exchange programs and secondments, funding decisions and international research expeditions are profound. The consequences are felt by national and international researchers of all career stages, however some of the greatest impacts are experienced by the Indigenous Peoples of the Arctic, many of whose lands, waterways, relations, hunting and gathering grounds, and communities span national boundaries.

The work of the Arctic Council, to which IASC is an observer, restarted with limited collaboration in June 2022, when seven Arctic nation states resumed limited continuation of projects and cooperation without Russian participation, based on the work plan that all eight Arctic nation states had approved in 2021, while the Russian Federation continued to implement its chairmanship program domestically.

The chairship program for the next two years will focus on the four priority topics of the oceans, climate and environment, sustainable economic development, and people in the North; and the two cross-cutting priorities of Arctic youth and Arctic Indigenous Peoples. In the first few months, the focus was on finding ways forward to allow the Working Groups to resume their work. In late August 2023, a consensus was reached by the Arctic States, in consultation with the Permanent Participants, on guidelines to resume the work of the Arctic Council at the Working Group level using written procedures. It is expected that work in the Council will further resume, albeit on a limited scale, when more details about the Norwegian Chairship activities are published.

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.

Focus on Transitions in Arctic Natural and Human Systems

- 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.
- Institutionalised 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 maximise joint benefits and avoid duplicated efforts.
- **Sustaining Arctic Observing Network (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 being supported through the Canada-Inuit Nunangat-United Kingdom (CINUK) Arctic Research Program (see below) to carry out interdisciplinary research across the Canadian Arctic and Inuit Nunangat.
- The Multidisciplinary drifting **Observatory for the Study of Arctic Climate (MOSAiC)** project 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. **International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT)** and the recently completed **Arctic Research Icebreaker Consortium (ARICE)** connect researchers around the Arctic. The **Svalbard Integrated Arctic Earth Observing System (SIOS)** promotes integration along the Svalbard Archipelago. The Pacific Arctic Group 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 organisations and research infrastructure bodies like the **International Arctic Science Committee (IASC)**, polar clusters (e.g. **EU Polar Cluster**), polar boards (e.g. **European Polar Board**), the **Forum of Arctic Research Operators (FARO)** and others 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. Researchers and Indigenous and/or Local actors co-create 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)
- Active involvement and support of early career networks and initiatives such as the Association of Polar Early Career Scientists (APECS)

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.
- 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.
- 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.
- 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. A long-term cooperation between Germany and Russia funded by BMBF (until February 2022) had supported interdisciplinary research in the Eurasian Arctic with numerous early career scientists from both countries.
- 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.
- 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.
- Increased uncertainty for early-career scientists in gaining permanent positions and therefore access to long-term funding and involvement in large-scale and/or long-term initiatives.

Engagement and Participation of Indigenous Communities

- Funding for the engagement and participation (e.g. through higher education research scholarships) of Indigenous Peoples 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 that are actively promoted to under-represented communities. It is important to provide support in a way that trained researchers of all communities may have access to more stable research possibilities (permanent positions, stable funding, etc.).

Access

- Access to data and objects, including acquisition, collection, transportation and repatriation of data, information, historical materials, archaeological artefacts, 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 rights holders must be sought to conduct culturally appropriate research on 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.
- The important roles of research infrastructure, networks, and field stations have been discussed earlier in this report.

- .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**.

Legal Framework

- Arctic researchers welcome efforts by the **International Arctic Science Committee (IASC)**, **International Arctic Social Sciences Association (IASSA)**, and the **University of the Arctic (UArctic)** to promote the **Arctic Council´s Agreement on Enhancing International Arctic Scientific Cooperation** ("Arctic Science Cooperation Agreement") signed in 2017. 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 organisations 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. **Inuit Tapiriit Kanatami National Inuit Strategy on Research**).
- The marine research community emphasises 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).

Conclusion

More than ever before, we (Arctic, non-Arctic and Indigenous and Northern residents) need to continue to advance our observations and holistic, system-scale understanding of the Arctic. With a bigger capacity to address issues than any single discipline or country can manage individually, IASC leads by bringing together science disciplines and international collaborations, prioritising science over nationality.

The **IASC State of Arctic Science 2023** 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, uplift, and respond to 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.

- 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 **IASC State of Arctic Science 2023** aims to capture key elements and reflect the status of the scientific endeavour at high northern latitudes. Building on the foundation of ICARP III, IASC has compiled this report out of the broad, bottom-up contributions from the IASC scientific community. While this report is static, Arctic research is vibrant and evolving. Therefore, IASC updates this report on an annual basis.

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 2023 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 2023 and the IASC State of Arctic Science Report series are available on the IASC website (iasc.info).

Photo: Teugsu Shin

IASC 2023 State of Arctic Science Report (SAS)
Online version available on the IASC website
https://iasc.info/about/publications-documents/state-of-arctic-science

IASC Secretariat
Borgir, Norðurslóð
600 Akureyri - Iceland
info@iasc.info I +354 515 5824