IASC State of Arctic Science

Report 2024

IASC

1. Introduction

The **International Arctic Science Committee (IASC) State of Arctic Science Report 2024** presents a synthesis of current and upcoming Arctic research activities and priorities with a broad range of input and contributions touching upon all aspects of Arctic research. It is aimed at Arctic researchers, science agencies, managers, and users, including a wide range of decision-makers and policymakers, to help all Arctic science stakeholders and rights-holders stay up to date on Arctic research.

Published annually since 2020 by IASC, this report is updated by the members of several IASC committees:

- Five IASC Working Groups (Atmosphere, Cryosphere, Marine, Social and Human, Terrestrial)
- IASC Standing Committee on Indigenous Involvement (SCII) (beginning in 2024)
- IASC Council and Executive Committee
- Arctic Data Committee (ADC)
- Sustaining Arctic Observing Network (SAON)
- International Science Initiative in the Russian Arctic (ISIRA)

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 are included from the:

- ICARP IV International Steering Committee
- Seven ICARP IV Research Priority Teams

The content of the report is compiled by researchers and managers engaged with IASC and is thus not exhaustive. There are many other Non-Governmental Organisations (NGOs), Intergovernmental Institutions (IGOs), academic institutions, non-profits, Indigenous Peoples' organisations (IPOs), private and public companies, and others around the world working in the Arctic knowledge space that may not be participating in the preparation of this report.

IASC was founded in 1990 at a time of great geopolitical uncertainty, but also a time 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.

The geopolitical situation that has arisen as a result of Russia's actions in Ukraine continues to create immediate barriers and long-lasting uncertainties for research in the Arctic. The situation seriously affects international scientific collaborations and the ability of the international scientific community to carry out research and observations across vitally important and vast 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, and continue to be, 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, also remains affected by the geopolitical situation. After an initial suspension of activity in March 2022, Norway assumed the Arctic Council Chairship in May 2023 for the period of 2023 to 2025, with a focus on promoting stability and constructive cooperation in the Arctic and the four priorities: Oceans, Climate and Environment, Sustainable Economic Development, and People in the North. In addition, Arctic Youth and Arctic Indigenous Peoples are cross-cutting priorities of the Norwegian Chairship. In February 2024, the Arctic Council reached consensus on gradually resuming official Working Group meetings in a virtual format, enabling project-level work to further advance.

Photo Credit: Andreas Preußer

Despite the current challenges, the **Fourth International Conference on Arctic Research Planning (ICARP IV) Process (2022 - 2026)**, led by IASC in cooperation with more than 25 international organisations, continues to move forward engaging Arctic researchers, Indigenous scholars, policymakers, residents, and other interested parties from around the world. More than 200 individuals from 28 countries are currently involved in the seven ICARP IV Research Priority Teams. The process continues to seek community input while the teams begin to draft their initial outcomes. The summative event of the ICARP IV process will be the **ICARP IV Summit 2025** during the **Arctic Science Summit Week (ASSW) 2025** in Boulder, Colorado (USA) from 20–28 March 2025. The ICARP IV Summit theme of "Arctic Research Planning for the Next Decade" will provide a unique opportunity for participants to contribute toward the ICARP IV process.

The outcomes of the ICARP IV process will be crucial in shaping the **Fifth International Polar Year (IPY) in 2032–33**. This upcoming IPY will take place in an era of unprecedented need for large-scale coordinated research on polar and global changes. It offers a crucial opportunity to address and close significant knowledge gaps through targeted attention and globally coordinated action.

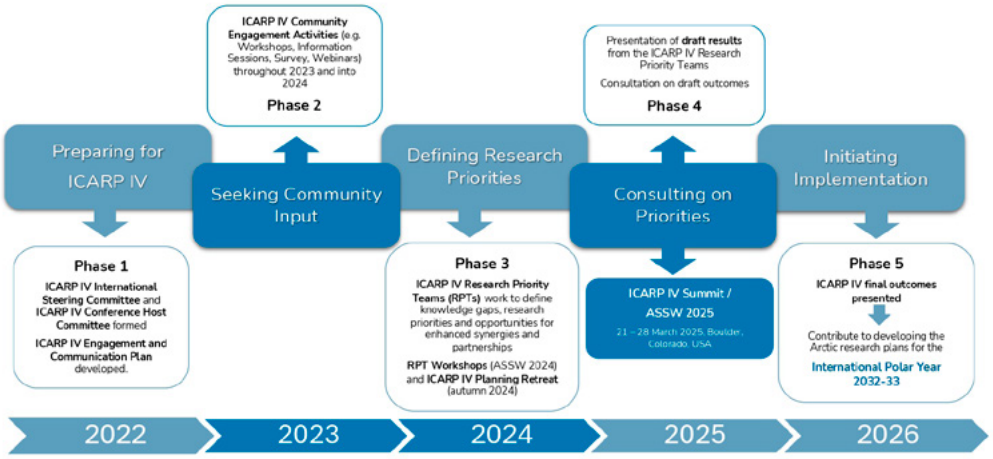
Arctic research relies on international collaboration, access, and continuous monitoring and data sharing among all regions of the Arctic to understand and to effectively respond to the climate crisis and other challenges. The principles of scientific freedom, research independence, and peaceful international cooperation are vital for all who are working together to understand and respond to the ongoing climate, environmental, resource and social changes, as well as wider societal challenges across the Arctic. These rapid changes are intricately linked to near- and long-term stewardship, security, and the human rights concerns of many Arctic nations, Indigenous Peoples, and the broader global community.

Those involved in Arctic research must continually be aware of the need to foster partnerships and to create space for 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 to identify and prioritise common areas of interest. This report also assists in monitoring the new realities and practical effects of physical and social environmental changes on Arctic research itself and scientific collaboration over the years.

2. The Fourth International Conference on Arctic Research Planning (ICARP IV) Process 2022 – 2026

2.1. ICARPs – 30 YEARS OF ARCTIC RESEARCH PLANNING

In preparation of 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, from 20 – 28 March 2025. IASC´s Founding Articles call upon IASC to periodically review the status of Arctic science. As a result, IASC has organised the International Conference on Arctic Research Planning (ICARP) every ten years since 1995. This provides a forum for the Arctic research community to come together to discuss and identify priorities for international and multidisciplinary science.



2.1.1 ICARP I – Hannover, New Hampshire, USA, 1995

ICARP I brought together about 300 scientists and representatives of the community of research funders, program managers, and other users of Arctic science information 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 and to address a set of priority topics identified by 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 it was a living document, ICARP I provided an opportunity to contribute new ideas to this Science Agenda. **Ten pairs of science and implementation plans** were created under the following themes:

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

Photo Credit: Mariasilvia Giamberini

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

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.

More information: ICARP website (https://icarp.iasc.info/past-icarps/icarp-i)

2.1.2. ICARP II – Copenhagen, Denmark, 2005

ICARP II was held from 10-12 November 2005 and brought together more than 450 scientists, policymakers, research managers, Indigenous scholars, 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 and based upon input from the science and Arctic community at large. ICARP II was structured around potential research needs under each theme, 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 between ICARP I and II, there was a paradigm shift amongst Arctic scientists from valuing separate and distinct understanding along disciplinary lines to seeking a more multidimensional perspective in research activities. This holistic perspective 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/objectives for the decade or two ahead.

The ICARP II process resulted in the development of **11 Science Plans and a Background Paper on Contaminants** and resulted in several international projects and programs, mostly within the framework of the **Fourth International Polar Year (2007-2008)**. The topics of the ICARP II 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
- Modelling 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 (https://icarp.iasc.info/past-icarps/icarp-ii)

Photo Credit: Mariasilvia Giamberini

2.1.3 ICARP III – Toyama, Japan, 2015

ICARP III was a more open process than the previous efforts, 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 policymakers as well as 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 in use at the time and complemented those with processes to identify gaps needing attention.

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

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

ICARP III was structured along scientific themes (Climate System and Transformations; Observing, Technology, Logistics, Services; Societies and Ecosystems; Outreach and Capacity Building) and included a series of events (workshops, sessions at research conferences etc.), culminating in a final conference at the Arctic Science Summit Week 2015 from 23 - 30 April 2015 in Toyama, Japan that brought together an international group of more than 700 scientists, students, policymakers, research managers, Indigenous scholars, and others interested in developing, prioritising and coordinating plans for future Arctic research.

The overarching research priorities of ICARP III were:

- 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 crosscutting, 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.

Final Report:

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

More information: ICARP Website (https://icarp.iasc.info/past-icarps/icarp-iii)

2.1.4. ICARP IV – Boulder, Colorado, USA, 2025

The ICARP IV process is ongoing from **2022 to 2026**. It considers the most urgent knowledge gaps and Arctic research priorities and needs for the next decade and explores avenues to address these research needs. These priorities and needs cut across disciplines and knowledge systems and require new thinking and collaboration. ICARP IV will provide opportunities to enhance synergies and formalisation of new alliances and collaborative partnerships.

Previous ICARPs focused the attention of Arctic researchers, policymakers, and funders on the value of strategic international science 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, and other political organisations currently concerned with Arctic issues.

The ICARP IV process is a community-wide undertaking engaging Arctic researchers, Indigenous Peoples, policymakers, residents of the North, educators, and other interested parties from around the world. It is well coordinated with other ongoing international activities (e.g. the UN Decade of Ocean Sciences for Sustainable Development). More than 25 international organisations are partners to the process and represented within the **ICARP IV International Steering Committee**.

IASC recognizes that Traditional Knowledge, Indigenous Knowledge, and academic scientific knowledge are equal and complementary systems that can, and should, inform the work of IASC and the ICARP IV process. In 2024, the ICARP IV International Steering Committee added an **Indigenous Co-Chair** and the **ICARP IV Indigenous Peoples' Coordination Group** was created as an informal body composed of Arctic Indigenous Peoples engaged in the ICARP IV Research Priority Teams (RPTs) and the ICARP IV International Steering Committee to advise the ICARP IV process and to further the recognition from ICARP III that Arctic Indigenous voices are necessary to move forward with a holistic perspective on Arctic research priorities. The majority of the ICARP IV Research Priority Teams have at least one Indigenous member and some have an Indigenous co-chair.

A key aim of ICARP IV is to operate in line with IASC's commitments to a more holistic perspective on Arctic interests. This means updating the structures and process for engagement as well as seeking additional ways to share research priorities and implementation plans with those creating and using Arctic scientific information. It also seeks to do so in a way that will advance the understanding of those interested in the Arctic beyond simply recognizing the value in cross-disciplinary approaches in science. This ICARP process acknowledges the limitations inherent to any reporting and attempts to be intentionally inclusive of perspectives that may contribute to closing knowledge gaps in previously compiled reports.

2.1.4.1. ICARP IV Engagement Phase in 2023 and 2024

The ICARP IV Engagement Phase held throughout 2023 and 2024 invites community input through a diverse set of activities worldwide. One of the main goals is that the process is inclusive and engages diverse perspectives to ensure that the scientific priorities for the next decade are firmly grounded on the advice and needs of Arctic scientists, science organisations, Indigenous Peoples, Arctic residents, stakeholders, and rights-holders.

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 their own research projects;
- Submitting documents that are relevant for the ICARP IV process;
- Participating in the ICARP IV Survey;
- Participating in the IASC-European Polar Board Webinar Series (later in 2024).

All input provided throughout the ICARP IV engagement process is collected by the IASC Secretariat and informs the work of the seven ICARP IV Research Priority Teams and the ICARP IV International Steering Committee. More information on the ICARP IV Engagement Process is available on the ICARP IV website.

Photo Credit: Igor Vasilevich

2.1.4.2. ICARP IV Research Priority Teams

In 2023, the ICARP IV International Steering Committee identified seven topic areas for **ICARP IV Research Priority Teams:**

- RPT 1: The Role of the Arctic in the Global System;
- RPT 2: Observing, Reconstructing, and Predicting Future Climate Dynamics and Ecosystem Responses;
- RPT 3: Understanding the dynamics and resilience of Arctic social-ecological systems to foster sustainable futures;
- RPT 4: Arctic Research Cooperation and Diplomacy;
- RPT 5: Co-Production of Knowledge and Indigenous-led Methodologies;
- RPT 6: Education and knowledge-sharing in and about the Arctic: Research and Practice;
- RPT 7: Technology, Infrastructure, Logistics, and Services.

The first three topic areas build on the outcomes of the ICARP III process, and the remaining teams address additional relevant topics areas. While ICARP IV organises its work around these topic areas, it is understood that holistic Arctic research priorities are likely to span individual RPT's areas of focus and that several topics areas (5 to 7) are cross-cutting. An eighth topic area not represented among these RPTs focuses on data (e.g. data interoperability and Indigenous data sovereignty) and will be addressed by the Arctic Data Committee (ADC), but not through a RPT.

The members of the seven RPTs were selected in 2023 through an open application process inviting nominations from ICARP IV partners and self-nominations from Arctic researchers of all career stages, as well as individuals and community leaders with knowledge, skills and experience relevant to Arctic research planning, particularly Indigenous Knowledge Holders. More than 200 individuals from 28 countries were selected to join the seven RPTs, each team led by several co-chairs. The RPTs started their work in early 2024 and were tasked with:

- Reviewing and summarising the wider community input provided for their topic areas through the ICARP IV engagement activities (see 2.1.4.1.);
- Defining knowledge gaps and research priorities for their topic areas;
- Identifying and suggesting opportunities to enhance synergies that might exist across existing research plans, or where there is potential for formalising new alliances and collaborative partnerships;
- Suggesting recommendations for implementation of the research priorities.

Each RPT held a two-day kick-off workshop during the Arctic Science Summit Week (ASSW) 2024 in Edinburgh, Scotland, UK (21 – 29 March 2024), with the first day being an open engagement workshop, open to all ASSW 2024 participants, and the second day being an internal meeting of the RPT members to plan their upcoming work.

An ICARP IV Planning Retreat will take place from 21 – 24 October 2024 in Akureyri, Iceland for the members of the ICARP IV International Steering Committee and the Co-Chairs of the ICARP IV Research Priority Teams to coordinate the drafting of research priorities, the outcome products of the ICARP IV process and to discuss the implementation of the ICARP IV results as part of the planning towards the Fifth International Polar Year 2032-33.

The preliminary results will be presented during the ICARP IV Summit / ASSW 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 contribute to the final outcomes of the ICARP IV process published in 2026. More information on the ICARP IV Research Priority Teams is available on the ICARP IV website: https://icarp.iasc.info/engagement/research-priority-teams

2.1.4.3 ICARP IV Summit 2025 / ASSW 2025

The I**CARP IV Summit 2025 during the Arctic Science Summit Week (ASSW) 2025 in Boulder, Colorado (USA)** from **20–28 March 2025** is the summative event of the ICARP IV process.

The theme of ASSW 2025 is "Arctic Research Planning for the Next Decade" providing a unique opportunity for participants to contribute toward planning the next decade of Arctic research. The ICARP IV Summit will engage Arctic researchers, Indigenous Peoples, policymakers, and other interested parties from around the world, serving as a crucial milestone for shaping the Fifth International Polar Year in 2032–33.

ASSW 2025 will be hosted as a hybrid event at the **University of Colorado Boulder**, located in the scenic foothills of the Rocky Mountains.

The preliminary ASSW 2025 Agenda:

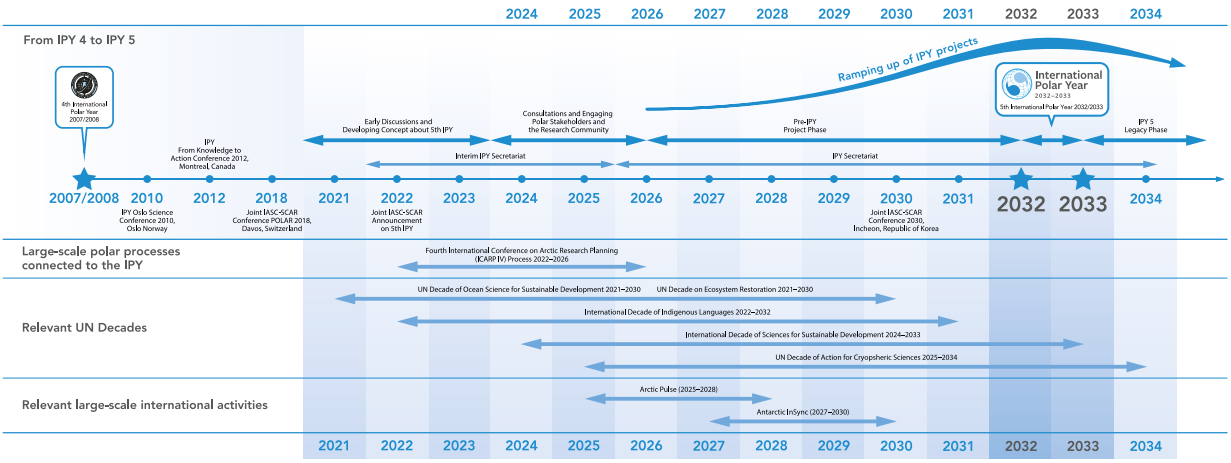
- 20–24 March 2025: ASSW 2025 Business and Community Meetings
- 25–28 March 2025: ICARP IV Summit

Registration and a preliminary program will be available in November 2024. More information on: www.assw.info

Photo Credit: Marie Bulinova

3. The 5th International Polar Year 2032-2033

The ICARP IV process aims to help define the Arctic research priorities and potentials for new alliances and collaborative partnerships for the **5th International Polar Year (IPY) in 2032-33**.



3.1. WHY AN INTERNATIONAL POLAR YEAR?

Extreme weather, increasing temperatures, sea level rise, and devastating events such as droughts, floods, and wildfires are becoming ever more prevalent and severe across the globe. At the same time, ongoing processes of ocean warming, sea-level rise, ocean acidification, and sea-ice change are negatively impacting ecosystems, economies, the rights, and livelihoods of Indigenous Peoples, and human wellbeing around the world. Many of these changes are taking shape faster than predicted. As the United Nations Intergovernmental Panel on Climate Change's (IPCC) 6th Assessment Report points out, several of the more serious global consequences are linked to unprecedented changes in the Arctic and Antarctic ('polar regions'). The urgency of understanding the consequences of such rapid changes in the polar regions for global climate, biodiversity, and human societies has never been greater. The transformations in the polar regions (particularly the Arctic), also highlight a need to articulate and elevate the critical status, rights and roles of Indigenous Peoples and their knowledge systems with respect to understanding, addressing and adapting to these changes. Global transdisciplinary coordination focused on the polar regions is therefore essential to achieving the major knowledge breakthroughs that are required to inform and develop effective international, regional, national, and local strategies to mitigate and adapt to the recent unprecedented levels of global change.

In this context, there is an urgent need to organise a **5th International Polar Year (IPY) ("IPY-5")** in **2032-33**.

3.2. IPY-5: A CRUCIAL NEW PHASE IN ORGANISING REGULAR IPYs

The **5th IPY (2032-33)** will build on four groundbreaking IPYs convened between 1881 and 2009 (IPY-1: 1882-1883; IPY 2: 1932-1933; IPY 3 / IGY: 1957-1958; IPY 4: 2007-2008). Together with millennia of Indigenous Peoples' knowledge production, the IPYs form a long chain of coordinated polar research and credible scientific evidence on socio-ecological changes in the polar regions. This record of biophysical and social changes and our understanding of their impacts to the polar systems themselves (particularly for Indigenous communities, residents and human visitors), offers a unique opportunity to more deeply understand global processes, make informed decisions and act accordingly.

Encompassing planning, project, and legacy phases implemented over a span of ten years, **IPY-5** is an opportunity for many countries, institutions, and networks to coordinate their research, observations, protocols, and expeditions in the polar regions. It provides the necessary opportunities for global and transdisciplinary coordinated research action among polar researchers, knowledge holders, rights holders, educators, and other stakeholders

to produce urgently needed actionable information that will support evidence- and human rights- based solutions to local and global challenges. Meaningful impact is supported by an inclusive and coordinated approach across different scientific disciplines, programmes, and knowledge systems including through co-production and co-creation of knowledge as well as education and community/citizen science approaches. IPY-5 also supports progress towards achieving implementation of international treaties, agreements, and other large-scale international processes including the UN Declaration on the Rights of Indigenous Peoples, the UN Sustainable Development Goals (SDGs), the 2023 Helsinki Declaration on Climate Change and Antarctica adopted by the Antarctic Treaty Consultative Meeting, and the 4th International Conference on Arctic Research Planning Process (ICARP IV), as well as several relevant UN Decades.

IPY-5 will leverage these, and other initiatives, which together highlight the need for greater international coordination to provide the credible scientific evidence needed for effective decision-making on urgent local to global issues.

IPY-5 will:

- Provide a unique and essential opportunity for strengthened international cooperation and partnership to advance polar research and knowledge production.
- Allow researchers and knowledge holders to build on the outcomes of previous IPYs, including by: expanding integrated and coordinated observations of accelerating changes; supporting modelling efforts; deepening understanding through transdisciplinary syntheses studies; and expanding the long-term monitoring of current conditions required to understand deeply integrated Earth systems and inform predictions of future impacts of climate and environmental changes.
- Build specifically on the methodological, technological, educational, and epistemological advancements of the 4th IPY, including major shifts toward working across knowledge systems and transdisciplinary research with specific emphasis on equitable and ethical engagement with Indigenous Peoples and their knowledge systems.
- Support, connect and extend networks of Indigenous Peoples, academics, local leaders, and early career and community researchers to understand the human and environmental links, impacts and feedbacks with the polar regions and beyond.
- Provide a comprehensive assessment of the operation and evolution of polar ecosystems enabling a more holistic understanding of the Earth's interconnected living systems and their trajectories in a changing climate.
- Document, understand, and amplify experiences and knowledge held by Indigenous Peoples and the societies in the Arctic in the context of rapidly changing interconnected natural and human systems.
- Produce education and outreach opportunities to engage the wider community with open and accessible communication strategies, platforms and co-developed content, including by identifying new ways to communicate research and engage communities worldwide to seek solutions and act.
- Support education, recruitment, and capacity-building for the new generation of experts needed to continue Arctic and Antarctic changes as well as their global implications.
- Inform and support local to global evidence-based mitigation and adaptation solutions and progress towards a chieving the UN Sustainable Development Goals, including by supporting enhanced science- and knowledge policy interfacing.

3.3. CURRENT PLANNING STATUS

Since 2021, a 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 has been engaging in planning discussions for a 5th IPY. In December 2022, a joint statement from the partners confirmed that preparatory work had started. Over the following year a growing number of international, Arctic and Antarctic partners joined these discussions and continued to build momentum. In October 2023, an initial concept note and timeline for planning IPY-5 was published, and an updated version released in October 2024.

In 2024, a more detailed planning structure has been set up which includes:

- **IPY Planning Group** comprised of representatives of international organisations that meets twice a year and:
  - provides input, advice and overall direction for the IPY planning process and the IPY Executive Committee.
  - prepares, presents and assists on taking forward specific issues to the IPY Executive Committee.

Photo Credit: Mariasilvia Giamberini

- **IPY Executive Committee** composed of representatives of the International Arctic Science Committee (IASC), the Scientific Committee on Antarctic Research (SCAR), the International Science Council (ISC) and the World Meteorological Organization (WMO), plus others as needed. This committee moves planning efforts forward between IPY Planning Group Meetings and takes overall responsibility for the direction and development of the IPY.
- **Task Groups** are set up by the IPY Planning Group to work on specific aspects of the planning process in more detail. The task groups report back periodically to the IPY Planning Group.
- **Interim IPY Secretariat** provided by the Secretariats of IASC and SCAR with additional contributions from the ISC and WMO. A call for a host and funding for a dedicated IPY Secretariat will be issued in 2025.

The interim IPY Secretariat can be contacted at: ipy-secretariat@iasc.info

3.4. HOW TO GET INVOLVED IN THE IPY PLANNING?

Interested stakeholders can get involved in the IPY process over the coming months in various ways, including by:

- Participating in the 5th IPY Planning Group* and Task Groups;
- Contributing to upcoming town hall meetings / fora held among others at upcoming polar conferences or online; and
- Sharing ideas and suggestions of how to contribute to the planning, delivery and legacy of the International Polar Year.

*An open-ended call for international and regional organisations to join the IPY Planning Group was issued in July 2024. This call was directed specifically at regional or international organisations / unions / associations (scientific, Indigenous educational etc.) that

- work on / in the polar regions, including organisations working to deliver/enable science in the polar regions (e.g., logistics), and
- are committed to contributing directly and long-term to the planning and delivery of the IPY 2032-33.

More information on opportunities to participate in the IPY planning process will be shared on the **IPY-5 website** starting mid-October 2024.

Photo Credit: Annina Maier

4. Current Arctic Research Priorities

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. The pillars span topics with strong overlapping themes that were identified by both Arctic and non-Arctic nations as research priorities. Addressing ongoing natural changes and social impacts in the Arctic, these inherently interdisciplinary research areas presented below update the ICARP III pillars to 2024.

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

4.1. ICARP III PILLAR 1:
The Role of the Arctic in the Global System

- Improving our understanding of connections between Arctic changes and lower-latitude weather, climate and extreme events, climate variability, and environmental processes.
- Improving our understanding of Arctic amplification, including the causes/contributions from natural and forced variability, and Arctic (and polar) climate feedbacks.
- Developing new approaches to monitor and model the changes in energy, water, carbon and nutrient budgets in the Arctic region, in particular, coupling between the atmosphere, land, cryosphere, and ocean.
- Understanding the consequences of ongoing climate change in the atmosphere, cryosphere, terrestrial and marine environment, and their impacts on ecosystems and Arctic socio-ecological systems (including biodiversity, biosecurity, food webs, multispecies social systems, biogeochemical cycles).
- Evaluating the contributions of Arctic ice sheets and glaciers to regional and global sea level change and the impacts of glacier melt and permafrost thaw on coastal / ocean biogeochemistry, mixing, and circulation.
- Studying past environmental changes through climate, geological and environmental archives such as ice cores, marine and lake sediment records, permafrost deposits, shrub and tree rings and investigating their interrelation with transformations of socio-cultural systems.
- Transboundary pollution through aerosols and oceanic currents.
- Identifying and tracking the 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.

4.2. ICARP III PILLAR 2:
Observing and Predicting Future Climate Dynamics and Ecosystem Responses

- Observing, understanding, and forecasting Arctic (environmental) change by integrating improved coupled and uncoupled climate models and Earth system models with Traditional Ecological Knowledge of the Indigenous Communities.
- Maintaining and developing long-term data sets, including paleoclimatological, paleolimnological / ecological and paleoceanographic approaches to contextualise current Arctic change and validate Arctic predictive models.
- Monitoring long-distance pollution transport to the Arctic (greenhouse gases, aerosols, trace gases, inorganic and persistent organic pollutants, microplastics, pharmaceuticals, radionuclides, emerging contaminants) to improve our understanding of aerosol-cloud interactions, climate feedbacks, and Arctic amplification, and to develop models to understand how long-range transport may respond to emission, deposition, and climate changes.
- Investigating interactions and coupling processes at climate-domain interfaces to improve our understanding of Arctic amplification, Arctic-related feedbacks, permafrost thaw and the subsequent

emissions of greenhouse gases (CO2, CH4, N2O) and release of modern and ancient organic matter into streams, lakes, rivers, fjords and the nearshore ocean systems. Quantifying the interactions between different components of the climate system (atmosphere, ocean, cryosphere, land surface, hydrological systems, surface groundwater interactions, SGDs, ecosystems) is essential to improving the representation of these coupled processes in local, regional and pan-Arctic climate models.

- 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), and developing models to understand how this energy transport may respond to cli mate changes. Critical today is the need to quantifying the expanded injection of water vapour from the ice-free Arctic Ocean into the atmosphere and its spatial and temporal variation, as well as the transport of this new water source within and out of the Arctic Basin into the Low and Sub-Arctic regions and landscapes that are occupied by citizens of the north.
- Developing new ground-based observing systems and capabilities for surface and vertical profiles in the atmosphere and ocean, improving spaceborne Earth Observation programs, and in coordination with ship and icebreaker based platforms with simultaneous, like-type measurement packages and modelling communities and providing opportunities for collaboration to generate large-scale, standardised in-situ validation datasets including developing AI-based methods for filling data gaps in Arctic regions.
- Monitoring future developments in the Central Arctic Ocean, including changes to sea ice cover, and feedback dynamics with commercial fishing potential and transportation routes, and the exploitation of natural resources.
- Monitoring life in (extreme) Arctic environments (disappearing ecosystems, resurrected ecosystems, adaptation strategies of Arctic and migratory populations, and invasive species), and modelling changes in biodiversity, biochemistry, biogeochemistry, and ecosystem functioning from microhabitats to pan-Arctic scale, including improved understanding and attribution of the drivers of biodiversity and ecosystem change. A particular focus should be given to monitoring and modelling the shift of species towards Northern latitudes and the consequences for the food web and carbon storage capabilities.
- Investigate how Arctic terrestrial ectotherms cope with high and increasing temperatures. Establish warming tolerance and thermal safety margins of key organisms. Establish direct and indirect effects of climate change in terrestrial ecosystems.
- Improve automated observation systems for terrestrial invertebrates to improve modelling of effects of climate change on terrestrial ectotherms. Includes continuous measurements of key climate and (vegeta tion and soil) biogeochemical parameters.
- 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 gases and persistent organic pollutants fluxes from thawing permafrost.
- Improve observations for tidewater glaciers in the Arctic to enhance the simulation of land ice-ocean interactions in earth system models or improve existing parameterizations in glacier and ice sheet models. This includes (i) improving the temporal resolution and geographic/temporal coverage of velocity obser vations in many parts of Arctic Russia, northern Canada, and northernmost Greenland, (ii) improving fjords' bathymetry coverage and (iii) ice thickness observations at the calving front.

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

- Bridging the intersection of Indigenous Knowledge with humanities, social and natural science topics, by better integrating Indigenous and local knowledge including Traditional Ecological Knowledge in ontologically informed research efforts and co-creating / co-producing Arctic research strategies and projects with northern and Indigenous communities.
- Investigating the nexus of climate change, resilience, and adaptation in the context of Arctic environmental and socio-cultural change.
- Improving understanding of the Arctic water cycle, its response to climate change and how these changes affect the communities of the North.

Photo Credit: Guangqing Chi

- Understanding natural hazards, extreme weather, land subsidence 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.
- Documenting coastal erosion, sea level rise and habitat loss and the impacts on ecosystems, carbon cycling, infrastructure, Indigenous and local communities as well as for other living beings; and improving risk assessments for both socio-economic systems and ecosystems.
- Monitoring contaminants and pollutants (including plastics, pathogen and air pollutants, emerging contaminants, light, and sound pollution) in all parts of the Arctic environment and understanding their sources and impacts on Arctic societies, human and other living beings (e.g. health).
- Promoting a One Health approach (health and wellbeing) – recognizing the interconnection between people, animals, plants, and their shared environment (community vitality, adaptation to climate and environmental change, and holistic human-environment approaches).
- Investigating the intersection of environmental sustainability, maritime technology, and shipping safety and implications for Arctic marine emergency response preparedness.
- Fostering diversity, equity, and inclusion in Arctic research.
- 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.
- Analysing future sustainable energy management: availability on site, local (increasing) demand (in all the sectors: residential, transport, industry), possible export (energy and/or energy vectors such as e-fuels and e-chemicals) and how to deal with local sources (including materials); all this ensuring sustainability (economic, environmental, social, cultural) and avoiding energy/materials colonialism

5. Major Ongoing and Upcoming Projects and Events

5.1. INTERNATIONAL COLLABORATIVE PROJECTS

International coordination is key for building public engagement, knowledge-sharing, and impactful initiatives. Examples of collaborative initiatives and projects currently ongoing or upcoming in the Arctic research community include, but are not limited to:

Project Name	Duration	Coordinator	Funded By	Description
ACRoBEAR - Arctic Community Resilience to Boreal Environmental change: Assessing Risks from Fire and Disease	2020 – 2024		Belmont Forum	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
ArcticHubs (Global drivers, local consequences: Tools for global change adaptation and sustainable development of industrial and cultural Arctic "hubs")	2020 - 2024	Natural Resources Institute Finland, Finland	EU Horizon 2020	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	2016 – 2027; started its third four-year funding period (2024-2027)		DFG (German Research Foundation)	The project is a collaborative effort 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.
ACTRIS ERIC - Aerosols, Clouds and Trace Gases Research Infrastructure	2023 – onwards	Finnish Meteorological Institute	ACTRIS-ERIC is an International organisation funded by 22 member countries.	ACTRIS is the pan-European research infrastructure producing data on short-lived atmospheric constituents and on the processes leading to the variability of these constituents in natural and controlled atmospheres. Several sites are located in Arctic locations (Ny-Alesund, Pallas, Villum) for long-term observation of aerosols, clouds and trace gases (www.actris.eu).
ALPACA - Alaskan Layered Pollution And Chemical Analysis	2017 – 2024			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. Results from the field study are still being published in peer-reviewed journals.
ArCS II	MEXT (Ministry of Education, Culture, Sports, Science and Technology) (Japan)		MEXT (Ministry of Education, Culture, Sports, Science and Technology) (Japan)	The Arctic Challenge for Sustainability II (ArCS II) is a national flagship project for Arctic research. Aiming to foster the realisation of a sustainable society, the ArCS II project will promote advanced research to understand the current status and process of environmental changes in the Arctic and to improve meteorological and climate prediction in order to assess the impact of rapid environmental changes in the Arctic on human society, including Japan, as well as to implement the results of this research into society.
The Arctic Five	since 2021			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.

Project Name	Duration	Coordinator	Funded By	Description
Arctic Great Rivers Observatory (ArcticGRO)	Since 2003		U.S. National Science Foundation	Since 2003, ArcticGRO has provided essential data about the biogeochemistry and discharge of the largest Arctic rivers. These rivers transport huge quantities of water and constituents from the continents to the Arctic Ocean, and changes in Arctic river discharge and chemistry reflect changes occurring on land and lead to changes in the chemistry, biology, and circulation of the receiving coastal and ocean waters. Thus, understanding a rapidly changing Arctic requires an understanding of the Arctic's rivers, which is exactly what ArcticGRO aims to provide.
Arctic PASSION Pan-Arctic observing System of Systems: Implementing Observations for societal Needs	2021 – 2025	Alfred Wegener Institute (Germany)	EU Horizon 2020	The key motivation of this project is the co-creation and implementation of 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.
ArcticPulse	2024-2030	Various	Various (including Davie Shipbuilding)	Major Arctic science mission in Canada - coordination and endorsement of projects (focused in 2027). Laying the groundwork for IPY.
AASCO - Arena for gap analysis of the existing Arctic science co-operations	2020 – 2024		Prince Albert II of Monaco Foundation	A project 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	2020 – 2028	University of Helsinki, Finnish Meteorological Institute, University of Eastern Finland, Tampere University, Finland	Research Council of Finland	This research and innovation project addresses climate and air quality research in Arctic - boreal environments.
Arctic Archives	since 2023			A new subgroup on Arctic Archives was launched under the U Arctic Thematic Network on Arctic Law. The group investigates the intersection of Indigenous knowledge, law and customs, international law, history, and archival theory on shared, displaced and disputed archival heritage in the Arctic.
ArcticWATCH Early warning of future rapid Arctic sea-ice loss:	2023 – 2027	Université Catholique de Louvain (Belgium)	EU Horizon Europe	This project 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:	2023 – 2024			The expedition (May-June 2023) with the Swedish icebreaker Oden targeted warm-and-moist air intrusions and the onset of sea ice melt. Measurements were successfully obtained and the ARTofMELT community held its first science meeting in April 2024.
Beaufort Gyre Exploration Project (formally Beaufort Gyre Observing System)	Since 2003		U.S. National Science Foundation/Woods Hole Oceanographic Institution	Since 2003, during a time of unprecedented change, the Beaufort Gyre Exploration Project has provided continuous monitoring of conditions in the region and established a strong foundation that is vital for understanding the current state and future trajectories of the Arctic Ocean environment.
CALM: Circumpolar Active Layer Monitoring Network	Since 1991		U.S. National Science Foundation	The primary goal of the Circumpolar Active Layer Monitoring (CALM) program is to observe the response of the active layer and near-surface permafrost to climate change over long (multi-decadal) time scales. The CALM observational network, established in the 1990s, observes the long-term response of the active layer and near-surface permafrost to changes and variations in climate at more than 200 sites in both hemispheres..
CASP-ICE – Cryospheric Algal Sampling Protocols – International Collaboration and Exchange	2023 – 2025	University of Bristol (UK)	UK Natural Environment Research Council (UKRI)	This initiative unites the global expertise on snow and glacier algal research to capture the state-of-the-art, define standardized protocols and establish the first global monitoring network of snow and glacier algal blooms across snowpack, mountain glacier and ice sheet systems.

Project Name	Duration	Coordinator	Funded By	Description
CATCH - the Cryosphere and Atmospheric Chemistry	since 2017		SOLAS, IGAC	The CATCH mission is to facilitate atmospheric chemistry research within the international community, with a focus on natural processes specific to cold regions, including the Arctic. CATCH is working with international initiatives in 2024 to engage in IPY planning and prioritisation. CATCH is also planning a Faraday discussion (meeting) on atmospheric chemistry in cold regions in February 2025 in London.
CHARTER - Drivers and Feedbacks of Changes in Arctic Terrestrial Biodiversity	2020 – 2025	University of Lapland (Finland)	EU Horizon 2020	This project aims to advance state-of-the-art knowledge on Arctic biodiversity change and social-ecological systems.
CINUK - Canada - Inuit Nunangat - United Kingdom research programme	2022 - 2025	Fonds du recherche du Québec*; Inuit Tapiriit Kanatami; National Research Council of Canada*; Parks Canada; Polar Knowledge Canada*; United Kingdom Research and Innovation*; (*also a research funder		Projects within CINUK address key themes connected to climate-driven changes to the terrestrial, coastal and nearshore marine environments in Inuit Nunangat, as well as impacts on Inuit and community health and well-being.
CleanCloud - Clouds and climate transitioning to post-fossil aerosol regime	2024-2028	Forth (Greece) and AU-ENVS (Denmark)	EU Horizon 2020	The overall objective of CleanCloud is to enhance our knowledge on ACI-related aerosol and cloud properties and processes, their regional and temporal differences, how they will evolve in the transition to the post-fossil regime, and in this way improve their representation in climate models, quantifying their impacts on weather and climate, and thus societies.
CRiceS - Climate Relevant interactions and feedbacks: the key role of sea ice and Snow in the polar and global climate system	2021 – 2025	Finnish Meteorological Institute (Finland);	EU Horizon 2020	This 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.
ECOTIP - Arctic biodiversity change and its consequences: Assessing, monitoring and predicting the effects of ecosystem tipping cascades on marine ecosystem services and dependent human systems	2020 – 2024	Technical University, Denmark	EU Horizon 2020	This 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 Co-ordinating and Co-designing the European Polar Research Area	2020 – 2024	Alfred Wegener Institute, Germany	EU Horizon 2020	The world's largest consortium of expertise and infrastructure for polar research. The project will establish a coordination platform creating a network and developing instruments of coordination and co-design of strategies of European polar research actions.

Project Name	Duration	Coordinator	Funded By	Description
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 The future of Arctic coastal ecosystems - Identifying transitions in fjord systems and adjacent coastal areas	2020 - 2024	University of Bremen (Germany)	EU Horizon 2020	This 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	2024			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.
GIOS – Greenland Integrated Observing System	2021 – 2025	Aarhus University, Denmark		The purpose of the Greenland Integrated Observing System (GIOS) is to resolve and understand the mechanisms behind climate and environmental change in Greenland and beyond. GIOS is a new coordinated network of sustainable long-term research infrastructures in and around Greenland observing the changing air, ice, land, and ocean conditions.
GreenFjord - Greenlandic Fjord ecosystems in a changing climate: Sociocultural and environmental Interactions	2022 – 2026		Swiss Polar Institute	The flagship initiative 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.
i2B – Into the Blue Resolving past Arctic greenhouse climate	2023 – 2029		European Research Council Synergy Grant	The project aims at answering the questions What are the global impacts of an ice-free Arctic? How will the Arctic develop with increasing climate warming? What does an ice-free Arctic mean for our environment and our society?
IABP: International Arctic Buoy Programme	Since 1991		Multiple international agencies	The International Arctic Buoy Programme (IABP) is a joint effort between multiple international agencies to deploy and maintain Arctic buoys in the Pacific Arctic region for the purpose of collecting oceanic and meteorological data.
JPA - Comparative understanding of Arctic-Mid-latitude Weather Connections occurring over the United States and Korea in recent decades.		joint project between US NOAA and the Korean Ministry of Oceans and Fisheries.		The weather of both the east coasts of Asia and North America has similar upstream jet stream/stationary blocking regions. Understanding the mechanisms can greatly benefit by a comparative approach connecting Korean and the US scientists in data and modelling analyses. Our intention is to sort out the influence of the Arctic and separate large-scale wind patterns on weather in the eastern regions of Asia and North America, by joint investigation of historical severe weather cases.
HarSval - A bilateral initiative for harmonisation of the Svalbard cooperation 'Scientific collaboration between Poland and Norway in Svalbard for a sustainable future	2024-2025	University of Silesia	Norway Grants	The following activities aiming at strengthening bilateral relations between Norway and Poland, networking, exchange, sharing and transfer of knowledge, technology, experience and best practice between entities in Poland and Norway (25 partner institutions, representing natural and social sciences)
HiAOOS - High Arctic Ocean Observing System	2023 - 2027	NERSC Nansen Environmental and Remote Sensing Centre (Norway)	EU Horizon Europe	This project, in collaboration with the NSF-funded HiATTS project, will deploy new multi-purpose moorings in the deep Nansen and Amundsen basins in 2024. The moorings will be equipped with long-range acoustic sources and receivers, enabling both tomography and under-water navigation, as well as a suite of other oceanographic sensors. The project will also test new technologies for data transfer on moorings north and produce improved methods for data flow and provision of useful end products.

Project Name	Duration	Coordinator	Funded By	Description
HiLAT - High-Latitude Application and Testing of Earth System Models (HiLAT			U.S. Department of Energy (DOE)	The project answers Arctic and Antarctic climate change questions targeted application of global modelling and analysis capabilities to evolving polar processes and their impacts. In the current phase of the project, HiLAT is teaming up with the Regional Arctic System Model (RASM) project to study feedbacks that contribute to Arctic Amplification, improve our ability to project future Arctic changes by developing a unifying framework to understand and quantify the complex Earth system feedbacks that modulate Arctic warming, and to improve the model representation of such feedbacks, especially in E3SM-Arctic (DOE E3SM model with refined meshes in the Arctic) and RASM.
ILLUQ - Permafrost - Pollution - Health	2024 – 2027	Alfred Wegener Institute (Germany)	EU Horizon Europe	The project aims to provide the first holistic look at permafrost thaw, pollution, and human and environmental well-being in the Arctic. Moreover, it will deliver information on the risks from contaminant release, infrastructure failure and ecosystem changes to stakeholders.
International Association of Cryospheric Sciences (IACS) Working Group on the delineation of glaciers, ice sheets, and ice sheet basins				This group aims to deliver a complete delineation of glaciers, ice sheets, and ice sheet basins for both Greenland and Antarctica.
InfraNorth - Building Arctic Futures: Transport Infrastructures and Sustainable Northern Communities:	2021 – 2025	University of Vienna (Austria)	Horizon 2020 (ERC-ADG - Advanced Grant)	This project 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	2020 - 2024	Lund University (Sweden)	Horizon 2020 INFRAIA-01 -2018-2019	This project is building capacity for terrestrial research and monitoring all over the Arctic, boreal and northern alpine regions and is offering access to numerous research stations through its Transnational Access Program.
ITEX - International Tundra Experiment				This project involves researchers from more than 11 countries and examines the impacts of warming on tundra ecosystems.
LandSense	2021 – 2026		Federation Wallonie-Brussel (ARC) (Belgium)	This project is 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.
LIFTHAW - Nutrient lift upon permafrost thaw: sources and controlling processes:	2023 – 2025		Belgium’s Science Policy (BELSPO, IMPULS)	A project funded by Belgium’s Science Policy (BELSPO, IMPULS) aiming at comprehensively assess the nutrient mobility response in permafrost regions undergoing thawing
LIQUIDICE - LinkIng and QUantifying the Impacts of climate change on inlanD ICE, snow cover, and permafrost on water resources and society in vulnerable regions	2025 - 2029	Institute of Geophysics Polish Academy of Sciences	EU Horizon Europe	The LIQUIDICE project aims to better understand the impact of climate change on snow, ice, and permafrost. By combining observations and modelling, the project will assess changes in Greenland’s ice sheet and vulnerable regions like the Alps, Norway, HMA, and Svalbard. This will involve collecting new data from satellites and ground stations to improve climate models and inform water resource and socio-economic strategies.
MEDLEY - MixED Layer hEterogeneitY	2020 – 2024		Joint programming initiatives – JPI ocean and JPI Climate (France)	A 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.

Project Name	Duration	Coordinator	Funded By	Description
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 on the project were held in Potsdam (Germany) in 2022, Boulder (USA) in 2023, and Potsdam (Germany) in 2024.
NABOS: Nansen and Amundsen Basins Observational System	Since 2002		IARC, multiple international partners	Established in 2002, NABOS employs a diverse range of observational methods to understand Arctic climate change. NABOS researchers collaborate with scientists from several different countries, collecting vital information to document and understand climatic changes in the Arctic Ocean.
The Nansen Legacy	2017 – 2024			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			US National Science Foundation	This 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.
ObsSea4Clim Ocean Observations and Indicators for Climate and Assessments	2024 – 2028	Danish Meteorological Institute (Denmark)	EU Horizon Europe	The overarching goal of ObsSea4Clim is to deliver an improved framework for nations' contributions to European and Arctic ocean observations of Essential Ocean Variables (EOV)/Essential Climate Variables (ECV) in support of regional and global climate assessments, projections and actionable indicators for sustainable development.
Permafrost Pathways	2022 - 2028	Woodwell Climate Research Center (United States)	TED Audacious Project	Permafrost Pathways is coordinating a comprehensive monitoring network to improve tracking and modelling of Arctic permafrost and carbon fluxes, and fostering partnerships with local leaders and national policymakers to harness these data to support Arctic community adaptation and drive international climate mitigation policy change.
POLARIN Polar Research Infrastructure Network	2024 – 2029	Alfred Wegener Institute (Germany)	EU Horizon Europe	A network of 50 partner institutes that provide access to polar research infrastructures.
Polar Connect North Pole Fiber Polar Connect Step 1	2022-2030+ 2024-2026 2025-2027	Swedish Research Council (VR)	CEF Digital 22-EU-DIG-NPF 23-EU-DIG-PC1	Polar Connect is a strategic initiative to obtain secure and resilient connectivity through the Arctic between Europe, EastAsia and North America for Research, Development, Innovation and Education. The cable is foreseen to be a SMART cable equipped with seismic, pressure and temperature sensors recording conditions every ~100 km along the route. In addition, fibre sensing technologies, such as Distributed Acoustic Sensing or State of Polarisation, will be implemented to detect strain changes and vibrations all along the cable.
PolarRES - Polar Regions in the Earth System	2021 – 2025	NORCE Norwegian Research Centre	EU Horizon 2020	This 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.

Project Name	Duration	Coordinator	Funded By	Description
Polar Data Search	2021- ongoing	Polar Data Discovery Enhancement Research (POLDER) Working group		The portal was created to aid researchers, stakeholders, and rights holders who are looking for polar meta(data). The Polar Data Search (Formerly POLDER Polar Federated Search) is an amalgamation of 23 (and growing) multidisciplinary repositories that host some form of polar data, which are then indexed into a single search interface. Research datasets that are available through the Polar Data Search encompass many different types of observations including but are not limited to weather station records, human written stories, organism counts, and instrument cruises.
P2G - 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.
Registry of Polar Observing Networks (RoPON)	2024-ongoing	Polar Observing Assets Working Group	NSF	Systems and related organizations that coordinate or track observing activities & infrastructure in the polar regions. RoPON was created as a collaborative effort by the Polar Observing Assets Working Group and is maintained by an international organization, Sustaining Arctic Observing Networks (SAON).
Qanittaq: clean Arctic shipping initiative	2024-2031	Memorial University, Inuit Circumpolar Council Canada, University of Ottawa	Government of Canada - Canada First Research Excellence Fund	Generating knowledge to support safe and sustainable Arctic shipping
Q-Arctic Quantify disturbance impacts on feedbacks between Arctic permafrost and global climate	2021 – 2027	joint coordination by MPI-MET Hamburg (Germany), MPI-BGC Jena (germany) and b.geos (Austria)	EU Horizon 2020	The project 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.
QuIESCENT Arctic: The QuIESCENT (Quantifying the Indirect Effect: from Sources to Climate Effects of Natural and Transported aerosol in the Arctic)				initiative aims to improve understanding of the roles that aerosols play in regulating cloud and precipitation properties in the Arctic. The team holds biennial meetings, with the next meeting planned for October 2024, in Lausanne, Switzerland.
RESIST - Recent Arctic and Antarctic sea ice lows: same causes, same impacts?	2023 – 2026		Belgium's Science Policy (BELSPO)	This project 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.
SciDINE - Science diplomacy in Northern Europe	2022-2026	Maria Curie-Sklodowska University, Lublin, Poland	National Science Centre (Poland)	The project is a multi-case exploratory study of science diplomacy in Northern Europe concentrated on two types of entities: 1) the states (Denmark, Estonia, Finland, Germany, Iceland, Latvia, Lithuania, Norway, Poland, Sweden); and 2) intergovernmental organisations that shape two interrelated regional governance systems: the Arctic Council, the Nordic Council, the Nordic Council of Ministers, the Baltic Marine Environment Protection Commission - Helsinki Commission, the Council of Baltic Sea States.

Project Name	Duration	Coordinator	Funded By	Description
Science & Society: bilateral initiative in social sciences, arts and humanities Activity 6 Enhancing Science-Policy Interface and Knowledge Transfer: a Polish-Norwegian collaborative seminar and research initiative	2024-2025	Jagiellonian University Activity 6: Maria Curie-Sklodowska University	Norway Grants	Science & Society: bilateral initiative in social sciences, arts and humanities aims at tightening cooperation between scientists and the non-academic sector, allowing knowledge to be transferred and used in decision-making processes and strengthening the capacity for civic engagement.
SEA-Quester	2024-2028	Technical University of Denmark, DTU-Aqua (Denmark, Lead)	EU Horizon Europe	SEA-Quester is investigating marine carbon cycling in novel ecosystems in the polar seas that are emerging due to climate change.
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	2020 – 2024		Norwegian Research Council	This project is 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.
Synoptic Arctic Survey (SAS) and Distributed Biological Observatory (DBO)	SAS (2020-2022), DBO (2010-)			These are projects coordinating Arctic marine observations for international and interdisciplinary benefit.
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.

5.2. 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 projects 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.
- AREX - Long-term observational program and annual cruises carried out in the Nordic Seas and the European Arctic since 1987 by the Institute of Oceanology Polish Academy of Sciences (Poland; r/v Oceania).
- **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 characteris tics 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 Biodiversity, including Arctic's living resources. The CBMP 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 programme produces regular assessments on status and trends of focal ecosystem components in the Arctic and also evaluates ongoing monitoring activities and recommended methods to use. 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, Svalbard and Greenland.
- **IABP - International Arctic Buoy Programme:** The participants of the IABP work together to maintain a network of drifting buoys in the Arctic Ocean to provide meteorological and oceanographic data for real-time operational requirements and research purposes including support to the World Climate Research Programme and the World Weather Watch Programme. Coordinated buoy deployments have been ongoing since 1979.
- **PROMICE/GC-Net - 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. The data now feeds into the World Meteorological Organisation data streamline.
- **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.
- **SITES - Swedish Infrastructure for Ecosystem Science:** This is a national infrastructure for ecosystem research that facilitates long-term field-based ecosystem research.
- **US Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) North Slope of Alaska (NSA) Facility:** The DOE has been collecting measurements of atmospheric properties in northern Alaska for nearly 30 years. The NSA site, located in Utqiagvik, Alaska, represents one of the longest and most comprehensive continuous time series of data available to the general public for analysis.

Several programs at Arctic research stations are studying atmospheric, ecosystem, Critical Zone, marine and climate variables. More information on the Arctic stations and their programs can be found 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. Two EU/ESA Copernicus polar missions are currently under development: CRISTAL (altimeter) and CIMR (microwave radiometer) and will be launched by the end of this

decade. For both algorithm development and field studies are ongoing. 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).

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 the platform, which is 83 meters long, are 34 scientists and 14 crew Members.

Several 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 and the Circumpolar Biodiversity Monitoring Programme; 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.

5.3. MAJOR UPCOMING ARCTIC RESEARCH CONFERENCES

5.3.1. Upcoming Arctic Science Summit Weeks (ASSWs)

The **Arctic Science Summit Week (ASSW)** is organised annually by the **International Arctic Science Committee (IASC)** to provide opportunities for coordination, cooperation and collaboration between the various scientific organisations involved in Arctic research. It was initiated by the IASC in 1999 and has evolved into one of the most important annual venue for meetings or Arctic organisations, scientific collaborations and more. The entire Arctic (science) community is encouraged to use ASSW as a venue for bringing together their organisations, collaborations, and teams for annual meetings, workshops and other events.

The dates and venues for the upcoming ASSWs are:

- ASSW 2025 in Boulder, Colorado, United States from 20 - 28 March 2025
- ASSW 2026 in Aarhus, Denmark from 27 March - 2 April 2026
- ASSW 2027 in Hakodate, Hokkaido, Japan, spring 2027

5.3.2. Other Major Upcoming Arctic Research Conferences in 2024 and 2025

While not all upcoming Arctic research conferences, workshops and meetings can be listed here, a selection of the largest upcoming conferences from November 2024 to October 2025 are listed below:

- 5th International Arctic Change Conference in Ottawa, Canada from 9 – 12 December 2024
- Arctic Frontiers 2025 in Tromsø, Norway from 27 – 30 January 2025
- Arctic Encounter Symposium 2025 in Anchorage, Alaska 2-4 April 2025
- Arctic Circle Assembly 2025 in Reykjavik, Iceland from 16 – 18 October 2025

Photo Credit: Mariasilvia Giamberini

6. Emerging Arctic Research Issues

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 strategies to tackle these issues, an international plan for transdisciplinary pan-Arctic research is urgently needed.

6.1. NEW METHODOLOGIES, TECHNOLOGIES AND CAPACITIES IN ARCTIC RESEARCH

Newly recognized approaches, methodologies, technologies, and capacities are enabling transformative science, knowledge mobilisation and dissemination within Arctic research and facilitate more interdisciplinary efforts.

6.1.1. Indigenous-led work and knowledge co-production

Indigenous-led work and knowledge co-production are integral components of Arctic research. It is important to develop an understanding of meaningful co-production of knowledge and meaningful involvement of Indigenous Knowledges to enhance academic science. Recognizing Indigenous ownership of Knowledge and Indigenous data sovereignty, the need for compensation of knowledge holders, the need to share results with Indigenous communities in an accessible, community-friendly format (including translations into the languages spoken by the knowledge holders and community) and on the terms of the community will enable new ways of knowing across knowledge systems in Arctic research. There is a need to emphasize the role of Indigenous scholars in leading and developing projects to build knowledge that is relevant to the resilience of Indigenous communities. For policymakers and decision-makers to be able to analyse and understand Arctic research priorities, Indigenous science within Indigenous Knowledge Systems as well as co-production of knowledge based on academic science are equally valid approaches.

Scientists of all backgrounds have a responsibility to ethically work with Indigenous and local knowledge holders at all stages of Arctic research. Collaboration between scientists and Indigenous and local knowledge holders and communities is a powerful means of addressing environmental and socio-cultural challenges and providing opportunities for transdisciplinary and post-disciplinary thinking and knowing. Learning and using Indigenous methodologies, applicable in all fields, acting on co-created scientific materials (data) to co-produce and co-design sustainable and viable pathways and solutions is an imperative for identifying a road map for a green transition for Arctic communities and addressing other priorities. Ensuring fair compensation for local knowledge holders and supporting the maintenance of field equipment and monitoring activities with training and other support is an important way for researchers to contribute towards community capacity building.

6.1.2. Methodologies and Technologies

New sustainable research and monitoring methodologies and technologies are being developed with the aim of reducing carbon footprint, such as avoiding the use of plastics and other hazardous substances (e.g. PTFEs) or eliminating the use of chemicals.

Increased connectivity in the Arctic benefits Arctic scientists visiting for fieldwork, as well as easing the lives of Arctic residents, and supports the use of remote-sensing and long-term monitoring equipment at unmanned locations.

Trans-Arctic telecommunication cables can be leveraged to observe the seabed and the water column along their path. There are at present three major projects for the Arctic: Far North Fiber, Polar Connect and Tusass Connect Vision. Three different environmental sensing technologies can be implemented within the same cable.

- The first technology consists in installing long-lived sensors along the cable every 100 km or so. The possible sensors include temperature, pressure and accelerometers and their data will be sent in real-time back to shore offering the possibility to support geohazard alerts. This is the concept of a SMART cable, now recognized as an emerging network of GOOS, the Global Ocean Observing System.
- The second technology uses recent developments in distributed acoustic sensing (DAS), a method that can precisely pinpoint changes in the strain of an optical fibre by illuminating it with short laser pulses and "interrogating" the reflected signal to measure changes over time. The technology allows acoustic/seismic sensing in real-time along thousands of kilometres of cable.

- The third associated technology adds branching units and spur cables along the main route of a telecom cable that feed power and communication capabilities to instrument platforms that support continuous, high-resolution observations at the service of many ocean disciplines. This method has been demonstrated for almost 20 years with the Ocean Networks Canada's VENUS and NEPTUNE observatories, and with the US Ocean Observatory Initiative's Regional Cabled Array in the Pacific Ocean. The same method could be applied to an Arctic crossing cable.

Bioprospecting and biotechnology approaches (including environmental DNA and nanopore sequencing), and **modern metagenomic and proteomic approaches** to build better ecosystem and biodiversity understanding (encompassing the atmosphere, ocean, land, and inland waters) and exploring their change over time through ancient sedimentary DNA methodologies are being applied in the Arctic.

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 also increasing interest and technical development in the ability to collect and analyse environmental information from **melt-affected ice cores**.

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.

Historical archive data is being combined with current data to understand past changes. For example, 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.

Artificial Intelligence is gaining importance also for multiple areas including climate forecast applications, providing much faster model simulations using emulators and new opportunities for representation of small-scale (typically sub-grid) phenomena. **Machine learning and artificial intelligence** are also important for identifying insights, processes and feedback loops in big data sources associated with satellite observations and model simulations. These advancements come with increased need for ethical data acquisition, use, and management techniques, especially in regard to respecting Arctic Indigenous data sovereignty, free, prior, informed consent, and self-determination.

Development of a highly accurate digital model of the Earth (Destination Earth) will help to monitor, model, and predict natural and human activity, and develop and test scenarios for more sustainable development.

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.

Cross scale monitoring and modelling of summer and winter CO2 and CH4 fluxes from tundra and water bodies, using different measurement techniques at different scales (flux chambers, eddy covariance, UAV and satellite borne sensors).

Developing a network of **pan-Arctic (including remote regions) marine and terrestrial paleoecological archives** will allow us to track and study biogeochemical and biodiversity changes over time and space.

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 Arctic coastal environments and their relevance for the resilience of Arctic maritime transportation, offshore energy production, and fisheries; to improve prediction products; to understand the value of additional Arctic data on the quality of Arctic forecasts and develop novel observations to meaningfully constrain climate models.

Chemical analytical capabilities to gain detailed molecular understanding of natural and anthropogenic organic carbon sources from different matrices (e.g. aerosols, ice, sediments, soil) allows tracking the origin of mobilised organic carbon, estimating the potential for organic carbon decomposition, and thereby better quantifying the associated carbon emissions.

Redesign the local energy management (production/storage/distribution/end use) according to criteria of decarbonization, exploitation of local sustainable resources, implementation of advanced technologies (electrochemical and thermocatalytic processes and technologies, energy storage devices, smart grids) for local energy enrichment, export of sustainable energy and energy commodities (such as e-fuels, e-chemicals) to EU, North American and Asian markets, and management of local energy raw materials; all this in a perspective of local sustainability (economic, environmental, but especially social and cultural) and avoiding energy colonialism.

6.1.3. Research Stations

New, modern research stations such as in areas of northern Canada (e.g. 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 Alaska, the U.S. National Science Foundation-funded Toolik Field Station celebrates its 50th year of research including the COVID-borne innovation of remote access that provides year-round trained technicians to assist projects that cannot travel to the station. **The Aalto Ice Tank in Finland** 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. In Greenland, a network of mobile stations of containers are deployed under development using energy from solar panels and windmills within the Greenlandic Integrated Observing System (GIOS – Greenland Integrated Observing System). A new interdisciplinary research station is established in Northeast Greenland, Villum Research Station, Villum Research Station, Station Nord. The station provides long term monitoring data and hosts short term research research campaigns e.g. latest the CleanCloud campaigns. The U.S. National Science Foundation's Summit Station is the only high altitude, high latitude, inland, year-round observing station in the Arctic, and is undergoing a modernization and recapitalization effort, scheduled to be completed during IPY (2032-2033).

6.1.4. Remote Sensing (satellite, ground-based and airborne) technology and techniques

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 vegetation phenology and lake surface elevations across the Arctic, greenhouse gas concentrations among others (e.g. a novel lidar mission which will allow winter retrievals will be launched in 2029 (MERLIN)). Remote sensing of land- and sea-ice properties were widely noted.

The **long time-series of freely available satellite remote sensing data** allows the capability of monitoring and modelling an array of processes happening in the Arctic at unprecedented time and space resolution. The provision of very high-resolution data from targeted missions also enhances this capability.

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. 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.

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 is increasing.

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.

6.2. EXAMPLES OF NEW ARCTIC RESEARCH THEMES

6.2.1. Coupled Arctic Systems

Coupled Arctic systems include biogeochemical cycles and natural emissions; coupling between the Arctic and the large-scale global climate system; terrestrial water fluxes; terrestrial-atmosphere carbon fluxes; heat 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. Integrated cross-field understandings and implications of Arctic change will be enhanced by understanding past and current transformations through deep-past perspectives on human-environment interactions based on palaeoecological and archaeological evidence as well as Indigenous Knowledge.

It is important to gain a better understanding of Arctic amplification, both in the present Arctic and during warming periods in the geological past, as well as societal and socio-cultural impacts of rapid climate change through short-term events and over the long run. Examples of new Arctic research themes include:

- Improved understanding of the impacts of increased extreme events, such as droughts, floods, heatwaves, storms, wildfires, or fast changing weather (moist intrusions, sea ice disruption, rapid temperature changes, rain on snow events);
- 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 living marine resources in the Central Arctic Ocean;
- Increasing monitoring and mapping of biodiversity of all levels through integrated ecosystem assessments examining linkages between biodiversity, biogeochemistry and ecosystem functioning, ecosystem conservation and environmental change through space and time (including the use of long-term monitoring and paleoecological data).
- Studying other processes, such as 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; destabilisation of mountain slopes due to permafrost thawing and retreating of glaciers; 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; sources, transformations, sinks and effects of air pollutants; response of marine cloud to sea-ice melt and retreat; estab lish linkages between the different Arctic systems (e.g. glacial, terrestrial, freshwater and ocean) under the current Global Change; Arctic greening and browning.

6.2.2. New Societally Relevant Arctic Research Themes

There are many societally relevant issues emerging in Arctic research. Interdisciplinary and transdisciplinary approaches are needed to identify and address them and to understand human-environment relations in the Arctic, including Indigenous Knowledge, agendas and perspectives. The IASC Social & Human Working Group has a work plan that identifies for example scientific foci related to socially-relevant Arctic research as being:

- Thriving communities: Cultural wellbeing, mental wellness, Indigenous languages, land-based observations and healing;
- Land use for sustainable livelihoods: Resource development in a changing environment, land use by Indigenous Peoples;
- Demographics: COVID impacts in Arctic communities, monitoring infectious diseases, Arctic migration.

Other important societally relevant Arctic research themes identified by the contributors to this report are:

Climate Change, Sustainability, Resilience & Adaptation:

- Focus on resilience and adaptation of Arctic communities to climate change, with a sub-focus on food sovereignty and security, social and environmental determinants of health, changing landscapes, impacts to community wellness, and community adaptation;

Photo Credit: Mariasilvia Giamberini

- Green transition and societal effects of green transition on Indigenous communities in the Arctic; 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, equality and diversity in Arctic research.

Deep histories:

- Integrated archaeological and paleoenvironmental research on past transformations of human-environmental systems in the Arctic including topics such as land use, resilience and niche construction, regional and trans-regional relations, socio-economic solutions and cultural change; Arctic economic and technological futures; The role of extractive industries in society, and resource extraction and sustainability. Arctic infrastructure including connectivity, and their impact on wellbeing, liveability, viability and sustainability of Arctic communities; Tourism and its environmental and societal effects in the Arctic and beyond. The rapid development of cruise tourism in the Arctic requires integrated research on environmental, societal and economical aspects for sustainable development.

Health:

- One Health, Planetary Health, Indigenous frameworks and Indigenous Knowledges. One Health is 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; Healing processes, strategies for achieving spiritual strength, decolonization, reconciliation, and restorative justice, especially for Indigenous Peoples; Comparative health and social policies – sharing best practices and evidence informed policy.

Geopolitics & Governance:

- Geopolitics, circumpolar governance, Arctic legal governance, and science diplomacy in the Arctic (in detail addressed in chapter 8); Arctic Socioeconomic Amplification: feedback, amplification, and loop effects between empowerment of Arctic communities and increased geopolitical/economic interest in the Arctic; Focus on environmental and climate justice in changing geopolitics.

Pollution:

- Pollution 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 a source of Arctic pollution are also identified, as well as issues around the impacts and processing of mercury pollution 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. In addition, litter in the Arctic, plastics and emerging contaminants in aquatic, terrestrial, and cryospheric environments and in wildlife, and evaluation of the impact of plastics, emerging pollutants (such as UV filters in personal care products and pharmaceutical products), and pathogens require more research. There are also ongoing projects focusing on air quality in the Arctic. Expanded research is among others needed 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; as well as on the consequences for Arctic human and wildlife health (e.g., pathogens and climate change).

Methodologies and Ethics:

- Responsible research practice: Ethics for Indigenous and community-based research and methods that support the co-production of knowledge; Decolonial research methods; Ethical and equitable research approaches, including within data and metadata management (e.g., recognition of CARE Data Principles and Indigenous knowledge sovereignty); 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.

Capacity Building and Sharing:

- Supporting the emerging and next generation of early-career Arctic and polar researchers. Enhancing the capacity building of the next generation of Arctic researchers among the Arctic Peoples; 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 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); Innovation in knowledge sharing and dissemination: Partnerships and impact with decision-makers (i.e. EU); Use social media to share WG information and project highlights; Virtual collaboration among interest groups; Align with In ternational Declarations (i.e. UNFCC, IPCC Assessments), United Nations Declaration on the Rights of Indige nous Peoples (UNDRIP); Making publications and associated data in journals and data repositories freely available for scientists and society alike through an open-access framework.

6.2.3. Other new Arctic Research themes

- Research focusing on sea ice, particularly the shift from multi-year to first-year ice – and more generally, research on other transitioning systems.
- Role of subglacial discharge (SGD) and surface melt from glaciers in the coastal blue carbon and C sequestration and marine biogeochemistry.
- Investigations of the role ocean circulation plays in ice sheet mass loss in Greenland and its consequences or sea level rise, and conversely, investigations of the effects of meltwater runoff and iceberg melt on ocean stratification, mixing, and nutrient fluxes.
- The observed acceleration of global climate warming in recent years and its relationship with soil drying, deglaciation, increased atmospheric transparency and changes in surface albedo.
- The growing influence of both Atlantic and Pacific inflows into the Arctic Ocean.
- 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 effects of permafrost thaw and rising temperatures on the changes of the Arctic Critical Zone and corresponding impacts on carbon cycle and GHG emission, on natural resources, as well as on societies, people, and other living beings and among others their health, economy, livelihoods, cultures, and infrastructure.
- Increasing boreal and tundra heat waves and wildfire frequency.

7. CURRENT GAPS IN RESEARCH, OBSERVATION, CYBERINFRASTRUCTURE, AND DATA

There is a need for more expansive, dynamic, and robust data ecosystems to meet the research and societal needs related to Arctic research. Existing needs include:

- Data and system-level interoperability;
- Applied Indigenous data sovereignty;
- Advancements in data provenance techniques to meet the need of increased data aggregation and prevalence of secondary and tertiary data products. Advancements may stem from technologies such as blockchain and distributed ledgers:
- Innovations in the areas of data licensing and sharing / re-use agreements particularly with regards to respecting Indigenous data sovereignty, and for data aggregation activities that may require stacking licensing or re-licensing;
- Research cyberinfrastructure that sufficiently enforces complex licensing and access regimes, including but not limited to complex access needs related to Indigenous data sovereignty;
- Expanded capacity to protect data gathered, created, and transmitted by edge devices, deployed sensors, “Internet of Things” and other networked devices;
- Improved processes for handling difficult-to-access or otherwise protected data assets, including where appropriate increased awareness of data diodes and other uni-directional technologies;
- Formation of data trusts and other advanced governance institutions;
- Persistent identifiers for observing platforms, institutes, and research programs;
- Metadata, ontologies, controlled vocabularies and other techniques that can support federated search and other distributed, networked, interoperable, and/or mesh infrastructure.

To meet these needs, there is a current gap and lack of resources dedicated towards the technical training and capacity building necessary for proper data handling and system design within the robust Arctic data ecosystems whose attributes are described above, especially to prepare for increasing prevalence of AI systems and their expected impact on data governance and ethical norms.

To be prepared, Arctic research and communities require advancements in the systems, techniques, and protocols they have at their disposal to protecting against large-scale AI system extractive and non-consensual access to and training on Arctic data, including but not limited to the misuse of Indigenous data, information, and Knowledge governed by sovereign and other inherent rights. Further resourcing to Indigenous-led groups capable of innovating and advancing such activities is advised. Additional consideration must be given to the significant energy, water, and mineral resources required to sustain AI systems, particularly with regards to computation processing of large-scale datasets, and how those systems impact Arctic environmental and social needs.

There is also 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 findable, available and reusable internationally. There is a need to design, coordinate or refine monitoring programs in support of societal benefit, including fundamental understanding of the Arctic system. In 2022, U.S. Arctic Observing Network issued a report to U.S. Congress “On the Need to Establish and Maintain a Sustained Arctic Observing Network”. 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.

Photo Credit: Lionel Favre

7.1. SPATIAL AND TEMPORAL COVERAGE

While field stations facilitate research, the current organisation of research infrastructures often limit Arctic science due to insufficient collaboration and coordination between sites. Cross-site comparisons are essential to assess the generalizability of individual results. 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.).

Long-term observations and perspectives including the geological and archaeological deep past, research continuity, and comparative analyses in all disciplines are needed.

Adequate spatial coverage in ground-based network measurements is scarce. Data coverage and availability of data from the Russian Arctic, including Siberia, are particularly lacking. The current geopolitical situation exacerbates this further.

Research gaps also include the Central Arctic Ocean, 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 which 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.

The marine Arctic infrastructures that ensure continuous data collection even during the winter months continue to pose technological and logistical challenges that must be addressed in a multidisciplinary and cross-border manner to ensure cooperation in data exchange, but above all in logistical support (e.g. use of research vessels for annual maintenance).

A pan-arctic effort to enhance the spatial and temporal coverage and the coordination of Active Layer Thickness, vegetation cover and greenhouse gas fluxes measuring and modelling from terrestrial ecosystems in a whole framework is needed to improve the contribution of Arctic vegetation-climate feedback to Earth System Models.

Subarctic terrestrial regions in Canada are not well studied, despite meeting the definition of North (permafrost and discontinuous permafrost). Recent literature also revealed that Winter CO2 fluxes from the snowpack are not negligible; yet, winter measurements are scarce around the Arctic. A pan-arctic effort to improve the quantification of winter CO2 fluxes is also needed.
There is also a longer-term need to develop year-round sampling capabilities and sampling of the land-sea interface. Ensuring high-quality climate and water data collection during the winter at remote, unmanned stations, is urgently needed. Integrating local observations from remote communities and utilising shared methodologies and accessible data should also be encouraged.

The deep time record on archaeological and geological scales (thousands to millions of years) comprises disparate proxies and is often incomplete, but it is key to understanding and quantifying the key drivers and past rates of change, and the long-term impact of climate change on Arctic ecosystems. Such data are critical for evaluation of earth-system and process models and hence our understanding of interactions in the coupled climate system. Widespread and regular atmospheric vertical profile information is severely lacking, in particular important for model validation and process understanding (e.g. altitude of temperature inversion, profiles of aerosols).

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. Active, illumination independent sensors only inconsistently cover the terrestrial Arctic. There is also a lack of cloud and lower atmosphere measurements (e.g., energy budget, aerosols) outside the summer 'fieldwork' season.

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.

Improved understanding of the spatiotemporal patterns of Arctic climate change, including meteorological observations, paleoclimate data, remotely sensed and reanalysis products and climate models, is needed to quantify regional patterns (and drivers), as well as the impact of Arctic changes on global climate.

Socio-cultural, political, governance, education, and other human sciences are unequally (and inequitably) researched across the Arctic. Some Indigenous and northern communities bear a disproportionate burden of being asked to serve as subjects, participants, and/or co-producers of knowledge while others are hardly reached by the Arctic science community. There are significant gaps in existing research which prevent in-depth and cross-region analysis of impacts from any given physical aspect of a changing climate. Actionable science is rarely possible without an understanding of human sciences for a given community, region, country, or people.

7.2. INTERDISCIPLINARY AND TRANSDISCIPLINARY 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. There is also a need for multi-component (land, ice, ocean, atmosphere) integrated observations and models of coupled coastal zone dynamics and processes.

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, also related to the assessment of carbon stock changes in terrestrial ecosystems).

There is a need for Indigenization and decolonization of approaches and methodologies in Arctic research. It is important to include Indigenous Knowledge in co-designing, co-planning, co-conducting and co-disseminating Arctic research. Equitable collaborations with Indigenous Peoples, communities, and traditional and local knowledge holders are integral to co-produced knowledge generation. Indigenous-led research is key to contributing to an Arctic science that is in accordance with decolonizing and post-colonial agendas.

7.3. INTERNATIONAL DATA SHARING

The ownership, control, access to and possession of data must be tackled in equity-based exchanges between Indigenous rights-holders, the wider public good, and scientists. There is a need to make polar science more accessible by ensuring access to documents and data, developing databases and ISO-compliant metadata 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, computing platforms and internet services.

Data sharing and in-situ data access are still not universally available across the Arctic. For example, 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). The engagement of institutions like NSERC, NSF and NIH or other international partners remains substandard and below the expectations from the Fourth International Polar Year (2007-2008).

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, e.g. GBIF.org. OBIS) but insufficient will, funding and personnel relative to the scope of the task are available to be able to support implementation and follow-through. Special attention is therefore needed for improving the international efforts to make Arctic data and metadata ISO and FAIR (Findable, Accessible, Interoperable and Reusable), 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 Zenodo, Data Basin, public libraries and research infrastructure such as the Svalbard Integrated Arctic Earth Observing System - SIOS and the NSF funded Arctic Data Centre to facilitate data access. Attention must also be paid to Indigenous Data Sovereignty and use of CARE (Collective Benefit, Authority to Control, Responsibility, Ethics) data principles in cooperative science efforts.

While coordination has partly improved in the data management community in recent years, there is a need for connecting the research community to those efforts and related activities.

7.4. RESEARCH APPROACHES AND INFRASTRUCTURE

- There is a need for increased support for Indigenous-led (co-produced and otherwise) research.
- There is a lack of underpinning funding to ensure stability, and prioritisation of sustained baseline monitoring, including data and metadata.
- 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, logistic, long-term personnel stay at the observatories, etc.).
- 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.
- Arctic scientists should build further cross-disciplinary, interdisciplinary, transdisciplinary, and convergent research practices within the scientific community and include other stakeholders and rights holders.
- There are further needs for increased emphasis on co-producing research with Indigenous Peoples, communities, and Traditional and local knowledge holders; for recognizing and validating the priorities of Northern residents and communities that can be answered through research; and for more engagement by scientists in supporting Arctic communities undertaking vulnerability assessments. These will require a commensurate emphasis on research ethics and Indigenous data sovereignty, and also on capacity sharing from and within the science community.
- Often, there is limited Northern infrastructure and capacity; many research projects still require equipment, labs, personnel, and training from lower latitude institutions. This non-local and often long-distance focus of control creates a discontinuity in many projects, limiting the effectiveness towards long-term sustained observations. Longer stays and integration in Northern communities and deeper relationships and shared responsibilities with local partners should be considered to reduce the limitations inherent to projects in the North reliant on infrastructure in lower latitudes.
- Supporting new and more diverse Arctic research teams and participating in establishing new Arctic observing networks.

7.5. FOCUS ON DRIVERS AND TRANSITIONS IN ARCTIC SYSTEMS

It is an enormous challenge just to document Arctic environmental 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 funding are insufficient to meet these challenges.

Long-term ecosystem monitoring with meaningful data and metadata is important for scientists to understand and communicate the roles and functions of living and other natural resources to support decision-makers in the development of sound policy towards sustainable development and resilience in the Arctic.

Future questions on transition research include: 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 back to sustainability look like in and for Arctic communities? What impacts do new influences or technologies (e.g., expanded tourism, renewable energies, multimedia, digital communication, improved infrastructure) have in the Arctic?

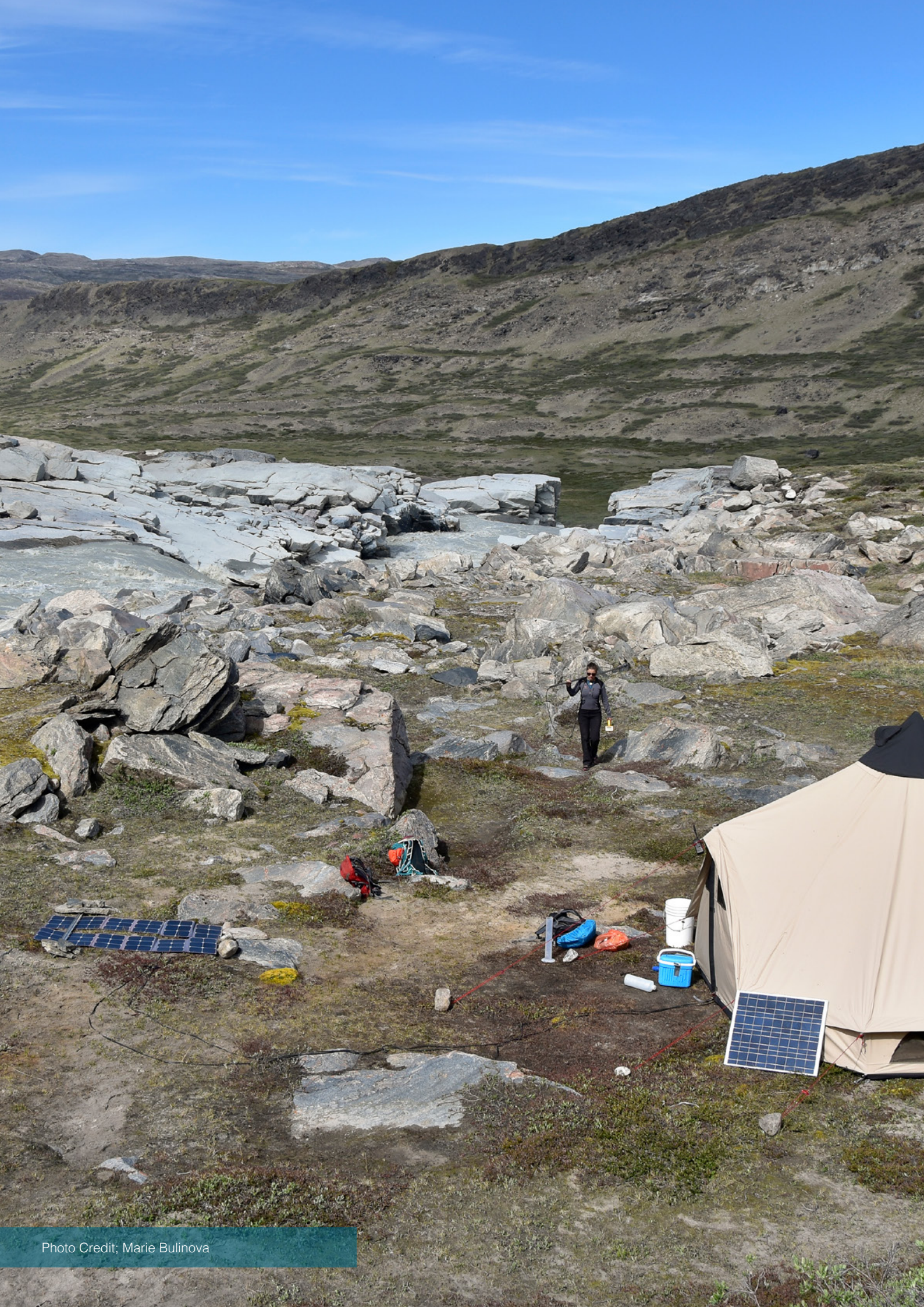


Photo Credit; Marie Bulinova

8. EMERGING ISSUES CONCERNING INTERNATIONAL SCIENCE COOPERATION

International cooperation is key to studying Arctic systems, many of which know no political 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 upon in the introduction to this IASC State of Arctic Science Report 2024, the geopolitical situation that has arisen as a result of Russia's actions in Ukraine continues to create immediate barriers and long-lasting uncertainties for research in the Arctic. The situation seriously affects international scientific collaborations and the ability of the international scientific community to carry out research and observations across vitally important and vast 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 and continue to be 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, also remains affected by the geopolitical situation. After an initial suspension of activity in March 2022, Norway assumed the Arctic Council Chairship in May 2023 for the period of 2023 to 2025, with a focus on promoting stability and constructive cooperation in the Arctic and the four priorities: Oceans, Climate and Environment, Sustainable Economic Development, and People in the North. In addition, Arctic Youth and Arctic Indigenous Peoples are cross-cutting priorities of the Norwegian Chairship. In February 2024, the Arctic Council reached consensus on gradually resuming official Working Group meetings in a virtual format, enabling project-level work to further advance.

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. International research cooperation in the Arctic in the time of geopolitical tensions is influenced by the state-centric approach and security issues. New challenges for international scientific initiatives in the Arctic occur: changing conditions in data collecting and public open access sharing and metadata; the role of technological shift (satellite technologies, AI) and its consequences for science and politics (e.g. security of large data sets, data of dual use, digital divide as a consequence of private actors activity in sectors such as satellite technologies in remote sensing, AI and machine learning; legal issues of data ownership and liability; ethical concerns related to large data sets and access/use of sensitive data such as navigational data/environmental data/personal data etc.). On the other hand, technological shifts bring benefits such as the possibility to collect data without physical access to locations such as the Russian part of the Arctic. All these changes require adaptation in the modes of international research cooperation.

8.1. FOCUS ON TRANSITIONS IN ARCTIC 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 is 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. 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.
- Support for connections between Arctic institutions, non-Arctic institutions that operate field stations in Arctic locations, and institutions from other 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 to carry out interdisciplinary research across the Canadian Arctic and Inuit Nunangat.
- The Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) project was an important success story in developing a major multidisciplinary 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.
- 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.
- There is growing cooperation in international research initiatives via the EU Horizon Europe projects within the EU Polar Cluster. The International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT), now making its last steps before being replaced by the POLARIN project, and the recently completed Arctic Research Icebreaker Consortium (ARICE) connected 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.
- Arctic inhabitants are not only facing rapid socio-ecological change but are relevant partners in international science activities. Researchers and local Indigenous Knowledge Holders or scholars can co-create understanding and other scientific outputs about changing Arctic systems. Such collaborations in all scientific disciplines need to be actively improved.
- Cooperation with and involvement in programs that do not necessarily focus on the Arctic, but where Arctic researchers can benefit from exposure to new methodologies and technologies (e.g., uncrewed aircraft systems) should be encouraged.
- Active involvement of scientists from all fields and support for early career networks and initiatives, such as the Association of Polar Early Career Scientists (APECS), should be encouraged to sustain the human capital within the Arctic research community.

8.2. FUNDING

8.2.1. 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. Another current example is the Nordic joint call for science proposals on ‘Sustainable Development of the Arctic’ through Nordforsk.

Photo Credit: Alexander Fogal

- 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, the UK-NERC Changing Arctic Ocean Program with bilateral funding and projects between the UK and Germany, the NERC-U.S. NSF Lead Agency agreement established in 2015) have been highly successful in stimulating research and collaboration.

There has been a shift in research project solicitations and funding streams towards more multi- and interdisciplinary and transdisciplinary scholarship. Funding remains tight for the maintenance and 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 is an ongoing issue. Without addressing this gap, advancing social sciences, health research, and humanities scholarship in the Arctic will be, at the very least, challenging. Creating useful products, such as actionable science or data that is useful for decision-makers, is difficult if not impossible without significant understanding of the human sciences within and across relevant Arctic regions.

Likewise, the shortage of funding for sustaining and maintaining data and metadata management, governance, preservation, and technical training to support cross-boundary, cross-disciplinary, and Indigenous data sovereignty considerations remains a hindrance to achieving the robust and resilient data ecosystem required for equitable and holistic Arctic research, and the societal benefits that stem from it.

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. Funding and programs that support the development of relationships across and within scientific disciplines, between scientific institutions and communities in the North, and amongst non-Arctic and Arctic Indigenous Peoples are imperative for the development of relevant future research.

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 is a growing concern.

Photo Credit: Igor Vasilevich

8.2.2. Engagement and Participation of Indigenous Communities

Funding for the engagement of Indigenous Peoples in research planning and implementation is critical for ethical science practices and to the generation of more equitable outcomes, yet identifying funding mechanisms for this support continues to be an issue. Support for participation in Arctic research by Indigenous scholars (e.g. through higher education research scholarships for Arctic Indigenous students) is another potential pathway to make science practices more equitable and to include local perspectives in research analysis.

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. This must include support for Indigenous-led research and the adjustment of funding requirements to enable ethical and equitable knowledge co-production. Research that is multi-, inter-, or transdisciplinary needs more time and adjusted funding schemes to mature than do disciplinary projects. This is especially true for projects that include participation by Indigenous Peoples, Arctic communities, or utilise Indigenous methodologies.

There is also a need to promote research fellowships for Arctic Indigenous scholars at both the undergraduate and post-graduate levels, including grants to assist the attendance of Arctic science meetings.

8.2.3. Diversity, Equity, and Inclusion

Recruiting and retaining a more diverse and inclusive 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 for individuals from underrepresented communities. It is important to provide support in a way that trained researchers of all backgrounds may have access to more stable research possibilities (permanent positions, stable funding, etc.).

8.3. ACCESS

Access to data and objects, including acquisition, collection, transportation and repatriation of data, information, historical materials, and archaeological artefacts 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. Cooperation with Indigenous and other local partner communities, and frequently longer-term presence for co-learning and sharing of expertise, are necessary for most social science research; this remains difficult in many current funding structures.

Open and timely data sharing is still missing but growing and critical. Yet, data management remains challenging and not so well supported. It is important to ensure common data policies and practices across nations, as well as to provide funding and resources to enable broad access to data.

Providing sustainable platforms and protocols for scientific cooperation, including data and metadata sharing, facilitates research across the Arctic. This includes adhering to ethical and cultural protocols of data collection, inclusion of Indigenous Peoples in research planning, implementation, interpretation and dissemination, following, inter alia, research protocols developed by Indigenous Peoples' organisations, such as the ICC Circumpolar Inuit Protocols for Equitable and Ethical Engagement.

The important roles of research infrastructure, networks, and field stations have been discussed earlier in this report.

8.4. 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 apply-

ing 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 inter- and transdisciplinary experiences, expertise, and funding. The Arctic research community places high hopes in the implementation of the Arctic Science Cooperation Agreement. It 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).

It would be good to have regulations on waste treatment and leaving material behind in the Arctic, like it is regulated in the Antarctic Treaty. At least research should commit to environmentally friendly research and avoid e.g. unnecessary plastic leftovers in the Arctic.

9. 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 2024 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, transdisciplinary, collaborative, and indeed convergent, in order to meet both Arctic and global challenges.
- Indigenous-led work and knowledge co-production are integral parts of Arctic research.
- 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.
- Workshops/Training that make researchers from different countries and universities and institutes use common mode of measurements, analysis, data storage format and use common models etc., to get a common output needed to understand the Arctic environment in the past and in future.
- 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 2024 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.

Photo Credit: Igor Vasilevich

10. Arctic Land 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 traditional homelands of many Indigenous Peoples. Wherever you may be reading this report, IASC honours and recognises the place-based knowledges of Arctic Indigenous Peoples, and the ancestral and contemporary stewardship of their homelands. IASC encourages the Arctic science community to do the same. We are all responsible for learning, listening, reading, respecting, and continuously improving our understanding of Indigenous Peoples and cultures we engage with. 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 knowledges and scientific systems (including Indigenous, traditional and local knowledges), are equal and complementary, and should inform the work of IASC.

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Marie Bulinova, Mariasilvia Giamberini, and Lionel Favre.
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IASC State of Arctic Science

Report 2024

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