# SIOS contribution to ICARP IV process

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## Introduction

This report is the contribution of Svalbard Integrated Arctic Earth Observing System (SIOS) to the IV International Conference on Arctic Research Priorities (ICARP IV) process.

SIOS is an international consortium of research institutions with research interests and infrastructure in and around the Norwegian high Arctic archipelago of Svalbard. Within SIOS, researchers collaborate by sharing data and research infrastructure to build an efficient observing system that focuses on long-term monitoring of parameters that are important to understand the Arctic in the context of global environmental change. The vision of SIOS is to be the leading long-term observing system in the Arctic to serve Earth system science for society. SIOS has 28 member institutions from 10 different countries active in research in and around Svalbard.

SIOS publishes an annual report entitled “The State of Environmental Science in Svalbard” (SESS), which includes recommendations for future activities to close knowledge gaps in Svalbard. The SESS report is established as an authoritative source of information about the state of the environment in and around Svalbard and it is an important tool to convey knowledge to stakeholders and the public. The SESS report is the main driving force for the science-based development of the observing system and represents an opportunity for research groups to actively influence the prioritisation within SIOS.

The SESS report is a bottom-up process to develop SIOS. Each chapter in the SESS report includes recommendations on how to develop the observing system. Contributions to the SESS report are written by international and, preferably, multidisciplinary groups under the lead of researchers from SIOS member institutions. All chapters are peer-reviewed and subject to final approval by an editorial board. There have been more than 200 recommendations since the first SESS report in 2018, and these form the basis of the SIOS contribution to ICARPIV process.

The ICARP IV workshop was organised as part of the main annual event of SIOS, Polar Night Week (22$^{nd}$ to 26$^{th}$ January 2024). Polar Night Week is an arena for exchange of ideas, reflection and planning of future activities, and it creates a vibrant atmosphere in the middle of the beautiful polar night.

The workshop was organised in response to the seven Research Priority Areas identified by ICARP IV. In the workshop, we discussed six of these. We also organised a panel discussion with Polar Night Week’s keynote speakers. The contribution of SIOS to the ICARP IV process is based on the group discussion during the workshop, panel discussion, recommendations from the six SESS reports published so far and a synthesis report made from the first 4 SESS report recommendations. The recommendations were selected with respect to pan-Arctic relevance.

**The general recommendations are listed below:**

- Overall, it is stated that we need to be bold enough to ask questions like “What do we need to do to make sure the world still exists for future generations? How do we open this door for international frameworks and politicians to make sure we don’t end up in the worst-case scenarios in terms of climate change and warming?” Wider collaboration is required in the future to answer big science questions.

- To properly grasp the challenges we encounter with global environmental change, improved multidomain integration of science is required. This should ideally be based on long-term, continuous time series that enable the detection and identification of variations and changes as well as enabling a process understanding and providing data upon which predictions of future changes may be based. The continuation of long-term monitoring must coexist with the integration of new technology.

- Strong support should be given to collocate observations from several disciplines. These can be called focal sites of observational supersites. This concept makes it easier for researchers to establish multidisciplinary cooperation and new scientific initiatives. Furthermore, observational supersites decrease science's environmental impact with sharing of logistics, maintenance, data etc. With coordination also duplication in many respects is minimised. The Arctic receives a significant amount of interest and resources because of geopolitical strategies and natural resources. Arctic Supersites and Research Infrastructures, like SIOS, can influence politics by advancing existing data sharing and common use research infrastructures.

Recommendations to different identified research priority teams’ topics areas resulting from SESS report recommendations and workshop are listed below.

**Topic Area 1: The Role of the Arctic in the Global System**

The Arctic includes the entire overlying atmosphere from the surface, through the troposphere and stratosphere and out into the mesosphere / lower thermosphere - ionosphere (M/LTI), which extends up to 1000 km altitude. To fully understand the effects of climate change, as well as the dynamics and interactions between these different layers (and the effect that space weather has on them), long time series datasets of the M/LTI region, not only above Svalbard, but in the polar cap, its boundary and cusp regions, are needed. The polar cusps are two funnel-shaped regions in the Earth’s magnetic field, where solar wind particles can directly enter the Earth’s atmosphere. Collisions between these particles and the atmosphere produce the aurora. Cusp aurora is the scientific term for the aurora in daytime. Svalbard’s unique

location and infrastructure means it is the only place where the cusp and the polar cap boundary can be studied using ground based observations. The polar atmosphere is strongly influenced by the solar wind (particles coming from the Sun) along with the solar magnetic field (the IMF or Interplanetary Magnetic Field). Research questions in this topic area are related to the physics of the coupling of the solar wind to Earth's magnetic field in the polar regions and the effects it has: how auroral particles are accelerated along magnetic field lines in the cusp and into the polar cap boundary region; how these energy inputs lead to heating, upwelling and outgassing of Earth's atmospheric gases into space, how atmospheric dynamics are driven by the IMF and how energy and momentum propagate down to the lower atmosphere and lower latitude regions. Space weather also has serious effects for man-made technologies such as GPS systems and satellite operability. For example, the recent solar storms in May 2024 caused NASA's ICESat-2 satellite to be knocked ~ 100 km off its nominal ground track and placed it into safe mode. This resulted in the loss of five weeks of data and significant usage of fuel to get it back to its correct orbit.

Ground based instruments, such as those at the Kjell Henriksen Observatory (https://kho.unis.no/), the SuperDARN radar network (http://vt.superdarn.org/) and the EISCAT Svalbard Radar (ESR) are able to give long term, continuous observations of the M/LTI region both over Svalbard (in the case of the KHO and ESR) and the entire polar region (in the case of the SuperDARN network). Sounding rockets (e.g., https://www.nasa.gov/soundingrockets/) are currently the only way to gain in-situ measurements of the processes within M/LTI region of the cusp and polar cap boundary region. This dynamic combination of in-situ and remote observing techniques for the cusp region is unique worldwide.

**Topic Area 2: Observing, Reconstructing, and Predicting Future Climate Dynamics and Ecosystem Responses**

To understand the changing water cycle in the Arctic, it is essential to monitor all parts of the cryosphere.This includes observing both small and large glaciers to determine peak riverine discharge, which necessitates linking meteorological data with detailed snow measurements, such as thickness and snow water equivalent. Additionally, more observations are needed on glacier thermal regimes and calving rates. In European Arctic it is also essential to study the impact of Atlantic waters entering fjords on glacier dynamics and nutrient cycles.

As glaciers recede, permafrost may emerge in freshly exposed glacier forefields. It is crucial to study landscape evolution in response to glacier change to understand the influence of the changing hydrological system on permafrost development.

Understanding water fluxes within the active layer and permafrost, including permafrost-groundwater interactions and sub-permafrost fluid migration, requires comprehensive observations of ground ice content, hydrological flows and aqueous geochemistry.

The physical, chemical, and biological interactions of snow with the atmosphere, soil, and sea ice are major observation gaps. Increased rain-on-snow events impact the entire system, highlighting the need for interdisciplinary studies.

As Svalbard is warming faster than the rest of the Arctic, it is an ideal location for detailed climate studies. The strong temperature gradients across Svalbard can be used to simulate broader Arctic environment and thus findings can be scaled to the broader Arctic and global contexts. In addition, the climatic gradient between warmer Svalbard and cooler Northern Greenland offers valuable insights for pan-Arctic studies.

While temperature and precipitation are vital parameters, studying events like temperature inversions provides deeper insights to atmospheric conditions. There is an urgent need for continuous observations of the vertical structure of the atmosphere. This calls for more sounding stations and sustained operation of existing stations.

Research into the discharge of microorganisms from thawing permafrost is necessary to understand the impact on downstream environments, such as fjord ecosystems. This requires prioritisation of monitoring microbial communities in permafrost vulnerable to thaw, as well as measuring parameters such as hydrological flow and sediment or substrate composition (for example)

**Topic Area 3: Understanding the Vulnerability and Resilience of Arctic Environments and Societies and Supporting Sustainable Development**

In the SIOS community, there is a recognition of the importance of coastal studies, particularly in the interdisciplinary exploration of coastal erosion. Understanding the stability of coastal areas is crucial for both human societies and the environment, demanding collaborative efforts across disciplines. Coastal regions are dynamic interfaces where the atmosphere, marine, terrestrial, and cryosphere environments converge and interact. This interdisciplinary approach is essential for comprehensively addressing the complexities of coastal dynamics and developing sustainable management strategies.

It is crucial that the monitoring of pollutants is prioritised. For instance, benthic animals have high concentrations of antibiotic residues, which also affect humans. Moreover, the surveillance of the airborne bacterial population is an important area requiring further investigation.

**Topic Area 4: Scientific cooperation and diplomacy**

It is vital that research in the Arctic becomes more interdisciplinary. Interdisciplinarity requires a common language and vocabulary, not only between scientists from various fields, but also between scientists, policymakers, and funding organisations. There is a gap between data and knowledge creation and the communication of this knowledge to

the public, thus it is important to integrate rather than confine discussions within our scientific bubbles.

Understanding experts from other professions can be a more effective strategy to foster interdisciplinarity than just managing economics and administration. Environmental pollution and climate change do not feel boundaries. These challenges require global answers, and it is our duty as scientists to take a stand and promote global cooperation. Stronger cooperation and coordination amongst national funding agencies are necessary for achieving this goal.

**Topic Area 6: Preparing present and future generations through Education, Outreach, Communication, Capacity Building, and Networking**

The significance of a common language was discussed in Topic Area 5. Communication and exchange should be encouraged at many different levels, including scientists in various fields, policy makers, local and indigenous people, and other stakeholders. There needs to be more exchanges and communication with society on all fronts. In the modern age, social media is evolving rapidly. Social media and related algorithms have tendency to produce "echo chambers." To effectively convey our message, we must be innovative.

The SIOS community strongly believes that early career scientists should be encouraged and encouraged to participate in the ICARP IV process. Those early career scientists who participate are an asset to the process and must be treated as equals. Today’s early career researchers will comprise most of the participants in the Fifth International Polar Year (2032).

**Topic Area 7: Technology, Infrastructure, Logistics, and Services**

Scientists need to consider sustainability and the environmental impact of their work. There are multiple ways to address these considerations. Uncrewed observation platforms (for instance, drones and floats) have a lower environmental impact than icebreakers. Automated sampling and observations should be utilised whenever possible. Developing interdisciplinary supersites for observations, sharing research infrastructures[*], coordinating fieldwork activities to avoid duplicate efforts onshore and offshore and remote access[**] to research infrastructures can also significantly reduce the environmental footprint. Interdisciplinary supersites are also natural meeting places of different disciplines which is a fertile ground for new inter- and multidisciplinary scientific initiatives.

Improving the reuse of existing data, including its continuation, relies on timely data publication according to the FAIR guiding principles and the use of open tools that support this publication and reuse. It is crucial to actively develop and implement data management standards throughout the entire value chain of science, not just in the final stages before publication. Harmonizing observation protocols allows for easy comparison of different datasets.

The development and utilization of new and emerging technologies, along with AI and the digital twin concept—numerical simulation models linked with harmonized data in both observation protocols and documentation—can help identify interconnections between processes and knowledge gaps. Making observations available in real time where possible will further support sustainable scientific practices and support operational services.

*Research Infrastructures are facilities that provide resources and services for research communities to conduct research and foster innovation. They can be used beyond research e.g. for education or public services and they may be single-sited, distributed, or virtual. They include major scientific equipment or sets of instruments collections, archives, scientific data computing systems and communication networks, and any other research and innovation infrastructure of a unique nature which is open to external users.

**Remote access to research infrastructures means that sampling and observations can be conducted by scientists or other qualified personnel already on location.