Integrated Arctic Observation System

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CO	Confidential, restricted under conditions set out in Model Grant Agreement	
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EXECUTIVE SUMMARY

This report is presents examples of how INTAROS has contributed to several of EU's Arctic policy goals, in particular to promote science, research and innovation, contribute to safety and support people living and working in the Arctic. The report also links project results to the UN Sustainable Development Goals.

INTAROS has demonstrated how an integrated Arctic observation system is built on many observing sensors and platforms. For land-based observations, a number of in situ systems are installed and operated at research stations and temporary camps around the Arctic. For ocean-based observations, there is a difference between ice-free and ice-covered areas. In ice-free areas of the sub-Arctic regions, ships, floats, gliders, moorings, and various surface platforms are commonly used. However, several of the platforms, such as floats, gliders, and sail-buoys, have limited capability to operate in the presence of sea ice. In ice-covered areas it is required to use icebreakers for deployment and recovery of ice-based platforms and underwater moorings. These operations are much more complex and time demanding than using observing systems in open ocean.

The data value-chain ranges from raw data produced by sensors and instruments to higher-level information products. The in situ data is the basis for scientific analysis, as well as development and validation of models and remote sensing algorithms. Community-Based Monitoring (CBM) systems are complementary to scientific observing system, where data are collected by local communities to support their requirements for information about climate change, natural resources, and other topics.

Development of an integrated Arctic observation system requires that data management and data sharing within and between disciplines can function. This is a challenge due to the heterogeneity and complexity of observational data collected in various geoscience and bioscience disciplines. With development of new instruments and platforms, the amount of environmental data collected is expected to increase year by year. INTAROS has improved the data accessibility from a large number of distributed observing systems and to contributed to improve data management and data sharing systems.

The results from the project have been published in numerous deliverables, scientific publications and other dissemination channels (http://intaros.eu, http://intaros.nersc.no).

Key Messages for Policy Makers

Key Message #1: Arctic observation must continue and be extended without harming the environment.

Call for Action: Improve the support for integrated, multidisciplinary Arctic observation through funding for and policy allowing for long-term observing programmes and infrastructure with minimum impact on the vulnerable environment.

Key Message #2: Arctic observation must strive for excellent data sets.

Call for Action: Increase the efforts and support to provide scientific quality data sets that are needed for building knowledge about the Arctic environment.

Key Message #3: Collaboration is essential for developing and operating Arctic observing systems.

Call for Action: Greater support for cooperation and collaboration between data providers, data managers, across regional, national and international scales, to ensure interoperability and standardized methodologies for data gathering, transfer, treatment, storage and retrieval.

Key Message #4: Capacity building is important for engaging various Arctic communities in planning and implementation of observing systems, including management of the data.

Call for Action: Support capacity building in various communities to be engaged in developing sustainable observing systems. This should include local communities as well as relevant actors from public and the private sectors.

Key Message #5: Building sustained observations for creating new knowledge is important for sustainable development in the Arctic.

Call for Action: Create informed international policies and protocols to protect and exploit newly accessible areas of the Arctic and secure sustainable development in the region.

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1. Introduction

The overall goal for INTAROS stated in 2016 was to build an efficient integrated Arctic Observation System with focus on the in situ systems, which have large gaps in the Arctic. This was a huge undertaking with ambitions to improve atmospheric, terrestrial, and ocean-based observing systems in many Arctic regions. While polar orbiting satellites produce vast amounts of data from the Arctic every day, the in situ the observing systems on the ground and in the ice-covered ocean are highly under-developed and with low sustainability.

INTAROS launched shortly after the iconic Paris Agreement (2015) when political priorities firmly turned towards climate change. It was clear that the baseline information for assessing loss and damage, as well as measuring the success of mitigation, relied on the existence and availability of reliable, verified and validated environmental data. The Paris Agreement has direct implications for the Arctic, as CO_2 increases in the atmosphere cause disturbance in natural systems, and changes in the Arctic environment have impacts at lower latitudes. Therefore, it was and still is, critical to construct an integrated observing system to provide better understanding of the mechanisms underlying the climate crisis.

In April 2016, the European Commission (EC) and the European External Action Service (EEAS) published the new Joint Communication (JC) on an integrated EU policy for the Arctic where Research, Science and Innovation represented key components of the future EU policy actions. The EU's strategies for the Arctic emphasized the need to implement monitoring programmes to underpin sustainable development in the region. To build and sustain an integrated system of many discipline-specific observing systems requires agreement among the major players from Europe, North America and Asia who can contribute to this system. Many countries related to the Arctic have invested in infrastructure and logistical services to support various observing systems with a long-term perspective, which is an important condition for sustainable observing programmes.

The importance of the Arctic and its natural processes in moderating global climate was further highlighted by the release of the Arctic Monitoring and Assessment Programme (AMAP) Snow, water, ice and permafrost in the Arctic (SWIPA) report released in 2017. The report called for four priority policies for the Arctic: 1) limit future change, 2) adapt to near-term impacts, 3) support the advancement of understanding, and 4) raise public awareness. INTAROS was already underway and addressing these key priorities for the region.

Over the duration of INTAROS, several further key reports have been published, all calling for climate resilience, carbon neutrality, more science and better science towards a more secure and sustainable planet. The European Green Deal, released in 2020, set the target for climate neutrality by 2050, driven by heightened concern over climate change and its impacts on the environment, but also on the European economy, society, businesses, and more. Its main priority policy areas are clean energy, sustainable industry, building and renovation, farm-to-fork, pollution elimination, sustainable mobility, biodiversity, and sustainable finance.

In October 2021, the EC released a new strategy for the Arctic, towards "A stronger EU engagement for a peaceful, sustainable and prosperous Arctic." This strategy replaces the 2016 EC and EEAS JC and aims to raise the importance of the Arctic in Europe and internationally, to further climate action for the region and the planet. The Arctic strategy supports the fundamentals of the European Green Deal and its component climate-oriented packages, including peace, prosperity, safety, sustainability, cooperation, and inclusion, amongst others.

Alongside these main policies, other mechanisms have been put in motion, among those of the United Nations Sustainable Development Goals (UN SDGs)[1] published in 2015. The UN SDGs comprised a set of 17 global objectives towards creating a better future for all by 2030 (Fig. 1). While some of these goals were beyond the scope of INTAROS, the project could directly contribute to meeting Goals 13, 14, 15, 17, through research and its associated activities, and could further contribute to Goals 4, 5, 8, 9, 10, 11 and 12, through its engagement activities, educational activities and by spreading a general appreciation for the Arctic and its common heritage to humans everywhere.

Figure 1: The Sustainable Development Goals, adopted on 25 September 2015 as a part of the 2030 Agenda.

Another international initiative where INTAROS has contributed is the Polar Prediction Project (2013–2022) (PPP)[2], particularly its flagship programme, the Year of Polar Prediction (YOPP). The PPP was launched by the World Meteorological Organization's (WMO) World Weather Research Programme (WWRP) with the aim of promoting cooperative international research towards improving global weather and environmental predictions for the polar regions. PPP and YOPP, together with the other global observing programmes, have framed the landscape where INTAROS has contributed with observations and modelling efforts in the Arctic.

Finally, the Integrated European Polar Research Programme[3] (EPRP) highlighted the heterogeneity of the Arctic, particularly its geopolitical complexity, and called for greater integration and a bigger-picture

[1] https://sdgs.un.org/goals
[2] https://www.polarprediction.net/
[3] https://eu-polarnet.eu/the-integrated-european-polar-research-programme/

plan for the Arctic. INTAROS has worked to improve observing capability, knowledge, user requirements, and societal benefits of integrated Arctic observing.

Many efforts have been undertaken to build various components of an Arctic Observing System, addressing specific thematic areas or regions. The Arctic Council with its eight member countries has initiated and run environmental monitoring programmes for more than 20 years. Global programmes such GCOS[4] and GEOSS[5] provide a framework for implementing observing systems to serve a wide range of societal benefit areas. In USA the Interagency Arctic Research Policy Committee (IARPC[6]) provided a new Arctic research plan for 2022-2026, driven by four policy areas and five foundational activities.

In Europe the EU PolarNet[7] project has developed a number of strategy documents for Polar research (Fig. 2). These documents identified a growing need for coordination among European research infrastructures. The EU's strategies for the Arctic emphasize the need to implement monitoring programmes to underpin sustainable development in the region. To build and sustain an integrated system of discipline-specific observing systems requires agreement among the major players from Europe, North America and Asia. Many countries are investing in infrastructure and logistical services to support various observing programs. Several of these investments have a long-term perspective, which is an important condition for sustainable observing programmes. However, most of the in situ observations come from short term research projects, and it is a challenge to transfer these programs into more sustained funding schemes.

To meet these challenges, we need to improve the involvement of key sectors (e.g., local communities, shipping, tourism, fishing), to strengthen the role of Arctic observing systems in the sustainable development of the Arctic region. This will support the EU strategy for the Arctic and related maritime and environmental policies.

Figure 2. Some of the publications from EU-PolarNet on European Polar research strategies.

[4] GCOS documents: see https://gcos.wmo.int/en/publications-brochures-posters-and-presentations
[5] GEOSS documents: https://earthobservations.org/geoss.php
[6] https://www.iarpccollaborations.org/plan/index.html#download-plan
[7] https://eu-polarnet.eu/publications/

2. Contributions of INTAROS to Key Policy areas

2.1 Coordination of Arctic observing resources across scientific disciplines

An overarching goal of INTAROS was to ***improve and exploit existing observing systems and databases of atmosphere, ocean, cryosphere, geosphere, and terrestrial data*** as the backbone of an integrated Arctic Observing System (iAOS).

Arctic observing systems have been developed over many years, and it was essential for INTAROS build on existing observing systems. While satellite programmes such as Sentinel are well-developed in terms of operational delivery of observational data, the in situ observing system are very different. The in situ systems are usually funded by national programs and international agencies and do not necessarily provide sustained funding in the longer term. These systems are often focused on specific topics and do not integrate between scientific disciplines, which is needed for better understanding of the processes and changes in the Arctic region.

INTAROS conducted an assessment of existing Arctic in situ observing systems, identifying key gaps in the observing capacity and data coverage. A dedicated tool, ARCMAP was created where data providers inserted information about their observing platforms, sensors and data products. ARCMAP has been developed into a useful tool to visualize and explore the status of the observing systems after the end of INTAROS (Fig. 3).

Recommendations on making better use of existing observation systems and databases:

- Improve cooperation between data providers and data managers to facilitate for data sharing.
- Establish collaboration regarding Arctic observing resources at transnational and global level.
- Establish funding mechanisms for observation systems that are not dependent on short term research projects.

Contribution to UN SDGs: 13 Climate action; 14 Life below water; 15 Life on land; and 17 Partnerships for the goals.

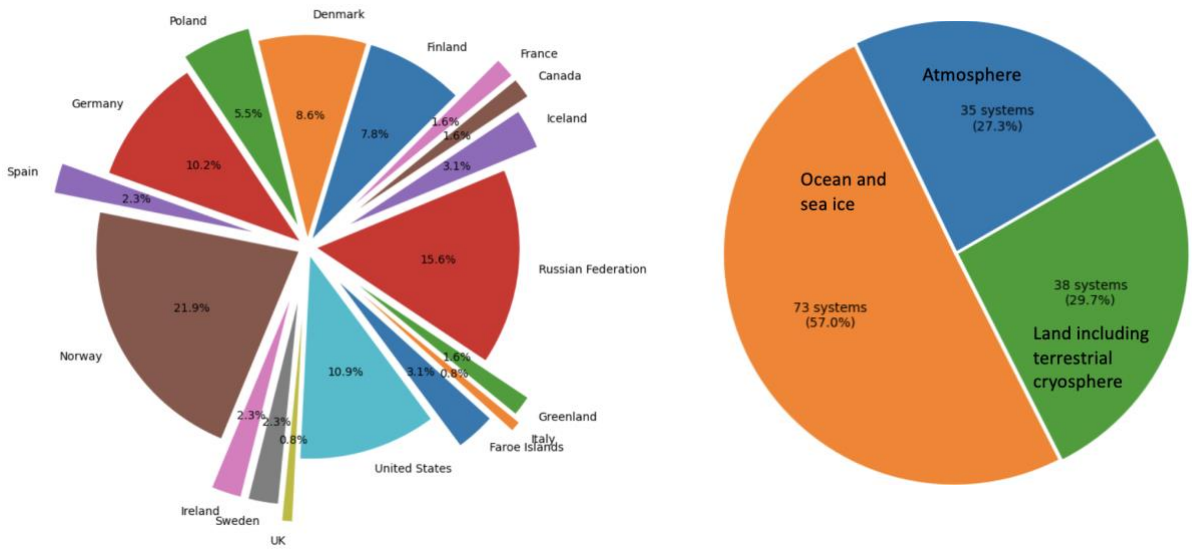

Figure 3. Statistics on Arctic observing systems registered in ARCMAP. Left: Distribution of systems by country; Right: distribution of systems by sphere (https://arcmap.nersc.no/).

2.2 Filling critical data gaps in the Arctic observing systems

INTAROS has contributed ***to filling gaps of the in situ observing system by use of robust technologies suitable for the Arctic.***

INTAROS identified a series of data gaps in the Arctic observing systems based on a survey and an assessment study. To fill some of these gaps a number of new in situ observations were collected, processed and uploaded to data repositories. New instruments or platforms were added to existing observing systems to extend time series of key variables or add new measurements of missing variables (Fig. 4). Requirements and technical recommendations for a future observing system were elaborated based on experience from numerous field campaigns in INTAROS and other projects. The majority of observing platforms, stations, and networks where INTAROS has contributed will be operated after the end of the project to be part of future observing systems.

Recommendations for filling gaps in Arctic observation:

- Build and maintain multipurpose supersites for terrestrial based observations.
- Implement ship-based observations for ocean and atmosphere data, e.g., Ferrybox systems.
- Improve power sources and broadband services to enable long-term operation and near real-time data transfer.
- Focus on implementing autonomous systems which can be deployed in remote areas and collect and transmit data without human intervention.

Contribution to UN SDGs: 13 Climate action; 14 Life below water; 15 Life on land; and 17 Partnerships for the goals.

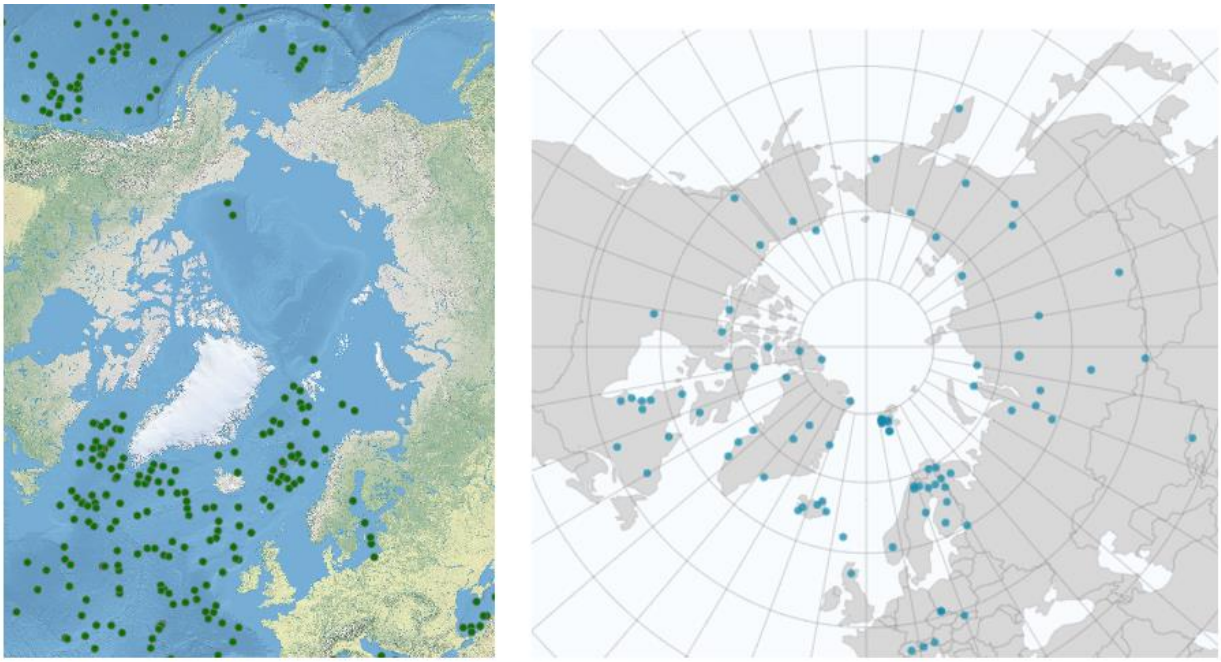

Figure 4. Network of in situ observations in the Arctic. Left: Argo floats with almost no coverage in the Arctic Ocean; Right: INTERACT network of 89 terrestrial field stations (https://eu-interact.org/).

2.3 Access to multidisciplinary data for climate and environment

INTAROS ***developed and implemented the iAOS portal for search, retrieve and analyze multidisciplinary data from distributed data repositories.***

Through the iAOS portal (Fig. 5) INTAROS has strengthen access to Arctic data, contributed to standardisation of metadata and data formats. The generic design of the portal makes it well suited for including future Arctic research and innovation projects. An important part of the portal is the INTAROS data catalogue containing metadata with links to data repositories on international, national or institutional level. The data catalogue is designed to register and store metadata for multidisciplinary scientific data. Some of the data repositories provide a DOI (Digital Object Identifier) for new data sets which enables citing and gives scientists credit for the data sets. By August 2022 155 data sets and 38 organisations are registered in the catalogue.

Recommendations for ensuring access to multidisciplinary data

- Facilitate for integration of national and international data repositories holding multidisciplinary Arctic data using the INTAROS iAOS portal and data catalogue.
- Improve protocols for discovery of data, and harmonization of metadata and data formats.
- Provide long-term storage in data repositories with standard interfaces to enable interoperability between the repositories.
- Develop indicators based on data from multidisciplinary data sets.

Contribution to UN SDGs: 12 Responsible consumption and production; 13 Climate action; 14 Life below water; 15 Life on land; and 16 Peace, justice and strong institutions.

Figure 5. Home page of the iAOS portal (https://portal-intaros.nersc.no/)

2.4 Added value of data through assimilation into models

INTAROS has demonstrated examples where ***observations were assimilated into models and thereby added value to the models***

Data from INTAROS were used in several scientific studies where observational data were combined with models through data assimilation. Long-term observations of key variables are essential to support model development and validation studies. There are several long timeseries of satellite retrievals of sea ice variables which are successfully used in assimilation. Examples of studies included: (1) Improving skill of climate model predictions of sea ice in the Arctic (Fig. 6), 2) Applying observations and models for environmental and fisheries management, 3) Studies of greenhouse gas exchange in the Arctic.

Recommendations on adding value to models through Arctic observation:

- Build time series of observations over longer time, typical a decade or more, to be useful in data assimilation. Especially, longer time series of in situ measurements are needed.
- Establish close dialogue between model developers and the data providers to ensure that there is mutual understanding of what data can be produced and how the models can use the data.

Contribution to UN SDGs: 9 Industry, innovation and infrastructure; 13 Climate action; 14 Life below water; 15 Life on land; and 16 Peace, justice and strong institutions.

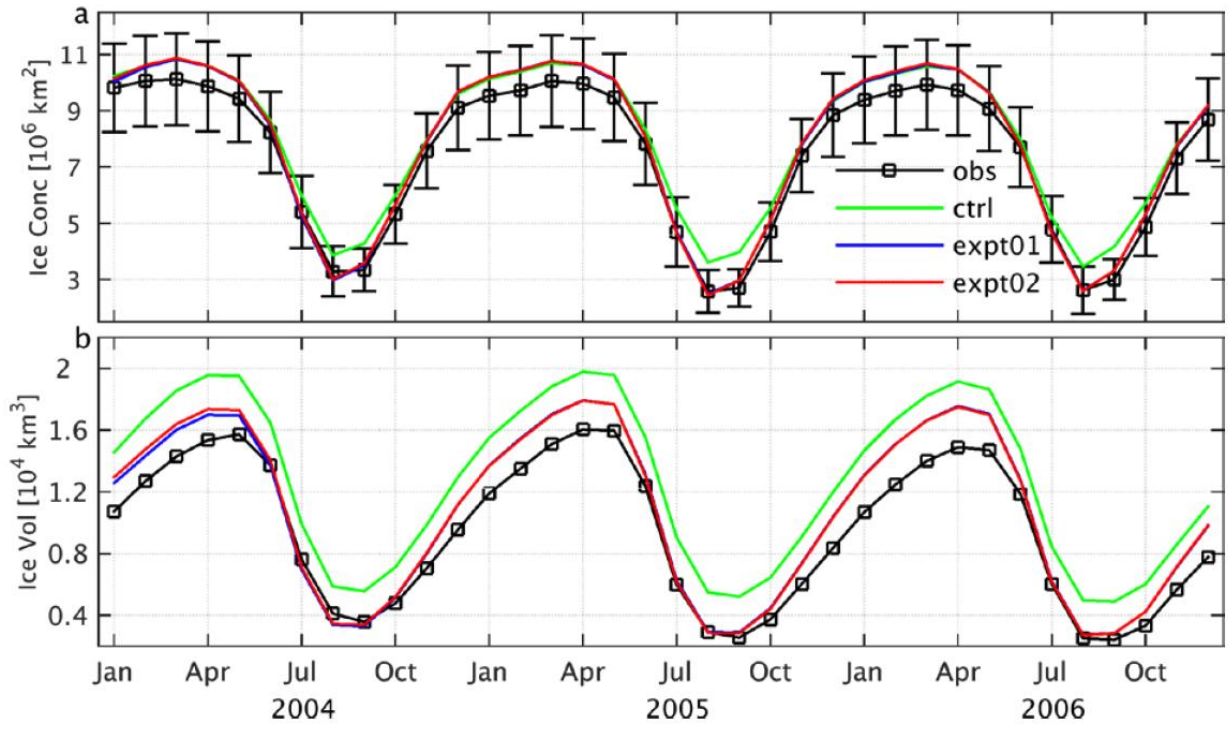

Figure 6. Total sea ice concentration and ice volume in the Arctic based on satellite observations (black), two assimilation experiments (blue and red) and a control run (green) by the ECCO model (Lyu et al., 2021, https://doi.org/10.1002/qj.4002).

2.5 Arctic knowledge-sharing tools for decision support

INTAROS ***demonstrated the benefit of sharing data and knowledge*** in several tailored applications. One of them is to strengthen community-based observing programs (CBM) for participatory research and capacity building in several Arctic regions.

INTAROS has established the Community Based Monitoring Library (Fig. 7), in collaboration with six monitoring programmes in North America, Russia and Greenland. The library enables community members and organizers of community-based monitoring and citizen science programs to exchange experience and gain advice on how to collect and use data to build more knowledge about the Arctic.

Recommendations on Arctic knowledge-sharing tools for decision support

- Increase the financial and political support for developing and maintaining shared knowledge systems, such as the CBM library in Fig. 7.
- Establish funding for citizen science and CBM programmes to inform local policy and decision-making.
- Create regular opportunities for co-development of CBM among communities and disciplines to increase trust and build personal connections.

Contribution to UN SDGs: 8 Decent work and economic growth; 9 Industry, innovation and infrastructure; 10 reduced inequalities; 11 Sustainable cities and communities; 13 Climate action; 14 Life below water; 15 Life on land; and 16 Peace, justice and strong institutions.

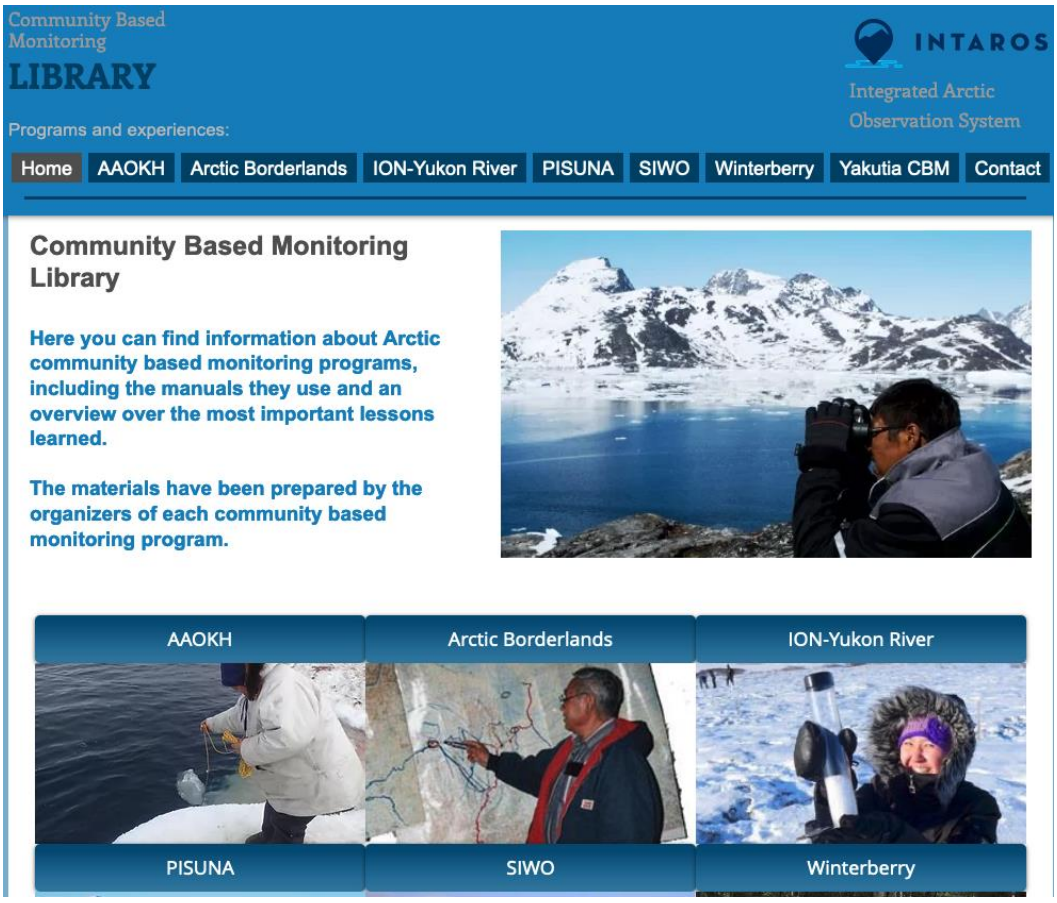

Figure 7. Screenshot of the Community-based Monitoring Library (https://mkp28.wixsite.com/cbm-best-practice)

2.6 Capacity building through skill development and education

INTAROS aimed to ***develop professional skills in using the iAOS platform and new data products in Arctic science education to young people at various stages of education***.

INTAROS produced a range of learning experiences for communities, young researchers, schools and the general public. INTAROS has provided training and education of the next generation of Arctic scientists through short courses, lectures, and summer schools, as well as channels for autonomous online learning (Fig. 8).

Two learning modules were developed specifically for high school students and the general public, and teaching toolkits were provided to help teachers prepare and give the lessons autonomously.

Recommendations for improving capacity building and education in and about the Arctic:

- Support for interdisciplinary projects with training in Arctic field work and data collection.
- Provide training and education across multi-disciplinarity fields as a key to understanding complex arctic systems.
- Investment in a long-term Arctic education digital resources hub.

Contribution to UN SDGs: 4 Quality education; 5 Gender equality; 8 Decent work and economic growth; 9 Industry, innovation and infrastructure; 10 reduced inequalities; 11 Sustainable cities and communities; 13 Climate action; 14 Life below water; 15 Life on land; and 16 Peace, justice and strong institutions

Figure 8. Activities in the Arctic Science Study programme in Greenland in 2021 (https://gcrc.gl/education/assp/).

2.7 International cooperation

INTAROS has ***extended collaboration between projects and programmes developing Arctic observing systems across EU member states, non-EU countries and transnational organizations.***

INTAROS has developed collaboration with a number of programmes and projects which include European infrastructures such as Euro-Argo, EPOS, Copernicus and other global programmes under WMO and IOC as well as institutions in USA, Canada, Russia, China, Japan and South Korea. There has been particular focus on collaboration in field work where icebreakers, research vessels, tourist expedition and other ships of opportunity as well as terrestrial stations have contributed to data collection in different Arctic regions. Collaboration efforts have also focused on challenges regarding processing, dissemination and management of in situ data produced by research institutions (Fig. 9).

Recommendations on international cooperation:

- Access to Arctic areas where observations are needed. This means that infrastructure, transport and logistical services must exist to deploy and operate the observing systems in remote areas.
- The full data delivery chain, including observing system, processing, dissemination, and management of the data must be established to ensure that data are available for the users.
- Interoperability between different data systems must be improved to establish an integrated Arctic Observation System.
- Collaboration between countries and institutions should be improved to make best possible use of resources, personnel, and secure continuity of the systems.
- Funding mechanisms to support both development and operation of the observing systems.

Contribution to UN SDGs: 9 Industry, innovation and infrastructure; 10 Reduced inequalities; 13 Climate action; 14 Life below water; 15 Life on land; and 16 Peace, justice and strong institutions.

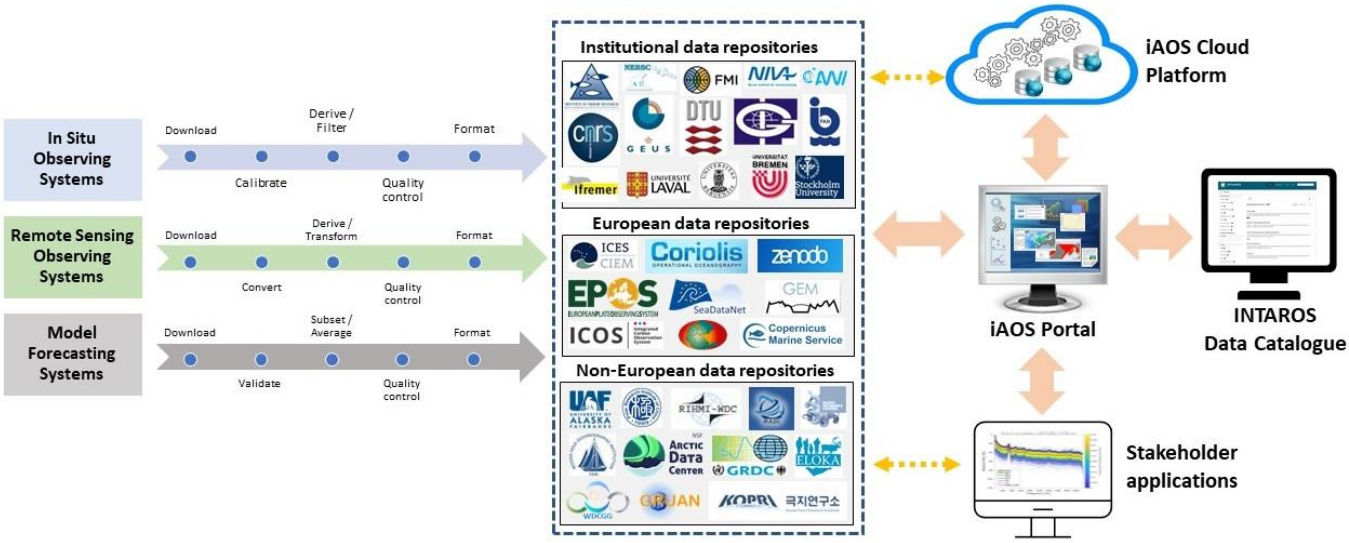

Figure 9. Data value chains for integrating INTAROS data sets into various applications (https://portal-intaros.nersc.no/) .

2.8 Arctic Blue Economy

INTAROS found ***examples of how observing systems can support the development and sustainability of the Arctic Blue Economy through three business cases: shipping in the Arctic Ocean, cruise tourism industry around Svalbard and east Greenland, and fisheries in the Barents Sea***.

Ship traffic in the Arctic has been increasing in the last decade according to PAME's Arctic Ship traffic Data System[8]. This trend is expected to continue since the Arctic shipping routes have the potential to be more economical. The reason is that the sea ice cover is reduced, implying longer navigation season, shorter sailing distances, and less fuel consumption combined with improved ship technology.

Further analysis was made of the recreational cruise ship activity in the Arctic, particularly focusing on non-icebreaker activity. Svalbard and Greenland were among the most popular destinations and Arctic activity in this sector has seen a general increase over the past 10-15 years. The main concern for this industry is one of safety, since search and rescue capacity in the Arctic is underdeveloped.

The Barents Sea is a major fishery area in the Arctic (Fig. 10) and recent studies showed that fishery resources are heavily affected by the changes in water temperature, sea ice and the marine ecosystems. Management of the fisheries requires extensive observations and modelling efforts to establish knowledge about the environment and how it is affected by the climate change.

Recommendations for developing the Arctic Blue Economy:

- Develop the ocean observation systems to support the key industries involved in developing the Arctic Blue Economy, in particular fisheries, tourism and shipping.
- Extend satellite-based vessel tracking and communication systems in the Arctic
- Improve search and rescue infrastructure to support the companies working in the Arctic
- Improve education and training for the operators who working in the companies.

Contribution to UN SDGs: 8 Decent work and economic growth; 9 Industry, innovation, and infrastructure; 10 Reduced inequalities; 11 Sustainable cities and communities; 13 Climate action; 14 Life below water; 15 Life on land; and 16 Peace, justice and strong institutions.

Figure 10. Stern trawler Nordtind, designed for fisheries in the winter season (http://www.havfisk.no)

[8] www.astd.is

3. Future Policy Support

A main outcome of INTAROS was ***the Roadmap for future implementation of a Sustainable Arctic Observing System,*** describing a way forward for Arctic observation, taking into account the existing infrastructure, collaborations and international policy and regulations.

The polar regions represent parts of the world that are still not easily accessible and still relatively untouched by direct anthropogenic intervention. On the other hand, the regions are heavily affected by climate change leading to warming and reduction of ice, snow and permafrost. This has severe impact on people living and working in the Arctic, in particular the lives of indigenous people and other local communities.

To preserve what remains of the natural status of the Arctic, while at the same time providing for progress and social impartiality for the people of the northernmost latitudes, the first key factor is **sustainability** of the observing systems. It means that the systems should be developed and operated over long time and support sustainable use of Arctic resources, and have minimum impact on the environment.

The second key factor is **Innovation** – the technology and methodology launched to study the Arctic should benefit from cutting-edge, state-of-the-art technology and social innovation. Technologies need to be robust and adapted for Arctic conditions to minimize the risk for accidents in a vulnerable environment. From a social perspective, it is essential to build on native knowledge and indigenous understanding of the environment and its resources, natural cycles and how they have changed in recent decades. Through modern, state-of-the-art social interventions, this knowledge can be leveraged to provide an industry standard for citizen science and community-based monitoring.

A third key component for a future integrated Arctic observing system is **Economy.** There are currently many initiatives focused on the Arctic, particularly due to changing climate and its impact on environment and human activities. With rising global temperatures causing progressive ice recession, the Arctic is opening up in ways we have not seen before. As a result, previously inaccessible resources are becoming accessible, both living and non-living. The Arctic is developing into a transit passage for global shipping, allowing humans to enter into the deepest, previously remote areas of the northernmost latitudes. This opens up for exploitation of the rich resources in the Arctic. A successful future Arctic observing system should harness the value of these existing assets for a more efficient and comprehensive monitoring system.

To foster sustainability, innovations and economy in the Arctic it is essential to build **Cooperation and and Collaboration** on international, national, and regional level. Here, the Arctic Council (AC) and its working groups have been playing an important role since they started collaboration in 1991 and AC was formally established in 1996. AC has established agreements between states, regions, and stakeholders and supported monitoring programmes and other collaboration between the member states. It is expected that AC will continue its central role in deciding what should be done in the Arctic because of the member countries' territorial ownership in the region. However, many countries outside of the AC are active in the Arctic, which is demonstrated by the Arctic Science Ministerial which started in 2016. In 2021 25 countries and a number of organisations have signed the Joint Statement of Ministers, stating that they will *"further enhance international cooperation in science, research and knowledge production to advance understanding of the Arctic region, and support to the role of science in policy and decision-making in the Arctic"* (https://asm3.org/) .

EU's Arctic policy, formulated in the Joint Communication from 2016, has focus the (1) responding to climate change and safeguarding the Arctic environment, (2) promoting sustainable development in the region, and (3) strengthening international collaboration. In the public consultation process completed in 2021, the conclusion was that the EU policy should continue long the same three priorities. An updated policy document was published in October 2021 with title *"A Stronger EU Engagement for a Peaceful, Sustainable and Prosperous Arctic"* (JOIN(2021) 27 Final).

From 2022, after Russia started the war in Ukarine, the geopolitical tension in the Arctic has increased. This will have impact on the Arctic since Russia is the largest Arctic country. In the coming years it is envisaged that national interests will be a major driver in developing Arctic observing systems.

4. Conclusions and Key Messages for Policy Makers

Conversation on the political level and at the science-policy interface has started to turn towards the actions needed to deal with climate change rather than the knowledge needed to understand it. This is a very positive step in the right direction, but one action cannot replace the other. It is not uncommon to hear statements that claim we have enough scientific knowledge, and now it is time to act. Yes, it is time for action, but the science must go on.

The Arctic is changing rapidly and unpredictably, and we can only begin to understand the extent and impact of these changes with long-term monitoring. This requires development and operation of observing systems designed for a wide range of climate and environmental variables. Arctic observation efforts should be enhanced not only because of their critical implications for understanding climate change, but also given the momentum of Arctic advocacy and cooperation.

The key messages for policy makers from the INTAROS project are as follows:

Key Message #1: Arctic observation must continue and be extended without harming the environment.

Arctic observation is critical to understanding the earth system, particularly in the face of climate change. Although the time for climate action is here, Arctic observation, science and research has to continue in parallel to better guide and evaluate the actions taken.

Call for Action: Improve the support for integrated, multidisciplinary Arctic observation through funding for and policy allowing for long-term observing programmes and infrastructure with minimum impact on the vulnerable environment.

Key Message #2: Arctic observation must strive for excellent data sets.

Arctic observations need to encompass a wide range of in situ measurements which include validation data for satellite remote sensing. The observations must be developed and operated according to scientific requirements. This means that state-of-the-art technologies must be used and be complemented by new, innovative solutions. Scientific procedure must be used to ensure that the quality of the data is well documented.

Call for Action: Increase the efforts and support to provide scientific quality data sets that are needed for building knowledge about the Arctic environment. This involves developing strategic observation

systems to serve different user groups, leveraging new and innovative technologies, and autonomous data collection systems.

Key Message #3: Collaboration is essential for developing and operating Arctic observing systems.

Arctic science has already benefitted from investment in research and observing technologies, but there is still a lot of scope for better and more efficient use of the existing resources. To better exploit previous efforts and to improve sharing of knowledge for mutual benefits, there is a need for greater integration of existing resources and infrastructure, including data integration, which requires better collaboration between the institutions, projects and programmes involved in Arctic observing. The collaboration requires long-term financial and political support for the observing systems in all earth system disciplines.

Call for Action: Greater support for cooperation and collaboration between data providers, data managers, across regional, national and international scales, to ensure interoperability and standardized methodologies for data gathering, transfer, treatment, storage and retrieval.

Key Message #4: Capacity building is important for engaging various Arctic communities in planning and implementation of observing systems, including management of the data.

Continuity and longevity in Arctic observing requires ownership and responsibilities for the systems. In the Arctic, many actors are involved in developing various observing systems, including indigenous groups and other local communities. Capacity-building is needed to engage people in planning, development and operation of the observing systems..

Call for Action: Support capacity building in various communities to be engaged in developing sustainable observing systems. This should include local communities as well as relevant actors from public and the private sectors.

Key Message #5: Building long-term observation for creating new knowledge is important for sustainable development in the Arctic.

With climate change comes many challenges, but also many opportunities. With the retreat of Arctic sea ice, areas of the ocean are opening up like never before. These changes offer new opportunities for Arctic sea routes, fisheries, and exploration and exploitation of the seabed. With these opportunities comes the responsibility to avoid the mistakes of the past and from other parts of the ocean, in this virtually pristine and untouched environment.

Call for Action: Create informed international policies and protocols to protect and exploit newly accessible areas of the Arctic and secure sustainable development in the region.

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INTAROS

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