
# REPORT OF THE 4TH ARCTIC OBSERVING SUMMIT

## AOS 2018
## Davos, Switzerland
## 24-26 June 2018



## Citation

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# The Arctic Observing Summit

The Arctic Observing Summit (AOS) is an international, Arctic community-driven event established in 2013. The AOS aims to provide scientific and Indigenous and community knowledge-based guidance for the design, implementation, coordination and operation of a sustained, long-term international network of Arctic observing systems. From 2014 it has been held biennially in conjunction with Arctic Science Summit Week (ASSW), an annual event initiated by the International Arctic Science Committee (IASC) in 1999. Since the inaugural Summit, the AOS has been coordinated in collaboration by the International Study of Arctic Change (ISAC), IASC and the Sustaining Arctic Observing Networks (SAON) initiative. The AOS fosters communication and international collaboration and coordination of long-term observations aimed at improving understanding of and response to system-scale Arctic change. The AOS is an international forum for optimizing resource allocation, and minimizing gaps and duplication, through coordination of and exchange among researchers, agencies, Indigenous Peoples, non-governmental organizations, the private sector and others involved or interested in long-term observing activities.

# Need for the Arctic Observing System

The Arctic continues to experience dramatic environmental change, with no indication that rates of change are slowing down or that trends are reversing. For example, as of this reporting, Arctic sea ice has reached the sixth-lowest minimum since the start of the satellite record (Figure 1), following a near-record low winter maximum[i]. The 12 lowest sea ice minimums in the satellite record have occurred in the past 12 years, and there are increasingly unusual melt events including during the winter[ii]. Arctic change, whether in the sea ice regime or in other aspects of the Arctic system, has widespread influence with respect to the functioning of the planetary system as a whole. It also influences the actions and the decisions taken by individuals, communities, and nations with respect to adaptation, mitigation, security, development, and other aspects of human social, economic and cultural behavior. A sustained, pan-Arctic observing system will provide the tools and information needed for evidence-based decision making at all levels. The 2018 Arctic Observing Summit focused on assessing the costs and benefits of a sustained Arctic Observing System, and a plan for implementation and governance to ensure maximum societal benefit, including open sharing of data and information. The Summit Statement and Call to Action released at the close of the Summit is reproduced here.

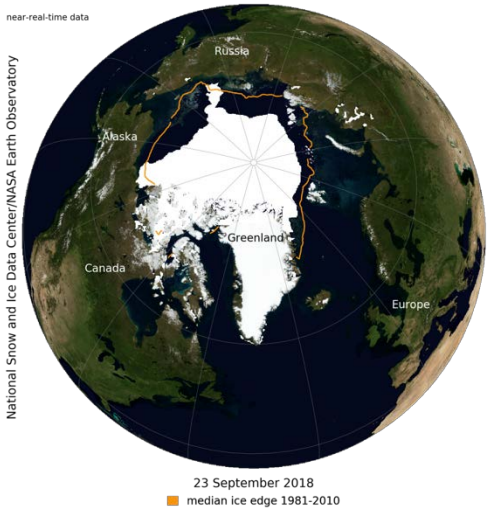


*Figure 1. Sea ice extent, 23 September 2018. https://nsidc.org/sites/nsidc.org/files/files/blue-marble-23-sept-2018-hr.png*

# 2018 SUMMIT STATEMENT AND CALL TO ACTION

We are living in the Anthropocene – a new era with human activities altering the planet in ways never experienced before. One of the fastest changing regions on the Earth is the Arctic where impacts of major transformations are felt both early and more strongly than elsewhere in the world. As an integral part of the Earth system, the Arctic is shaped by global processes, and in turn, Arctic processes influence living conditions of hundreds of millions of people at lower latitudes.

Through the efforts of governments, international organizations, Indigenous Peoples, academics, and many others, there is real progress in observing a rapidly changing Arctic. Numerous examples illustrate how insight from such observations enables, informs, and enhances decision-making at local to pan-Arctic scales. More, however, must be done, particularly with respect to the range, distribution and continuity of Arctic observing.

The Arctic has supported the lives of Arctic Indigenous Peoples for millennia and provides their economic security, as well as their cultural and spiritual well-being. Arctic Indigenous Peoples have acquired a dynamic knowledge system, allowing for a broader understanding across biological, physical, social, and spiritual domains. To fully benefit decision making at all scales, this knowledge and Indigenous societal priorities need to play a central role in the development of future Arctic Observing Systems. At the same time, developing capacities to allow Indigenous Peoples and Arctic communities to fully engage in observing efforts require urgent attention.

Based on examples where sustained observations have led to positive outcomes, we have confidence that expansion of observing activities will reduce vulnerability and build resilience of Arctic societies, environments and infrastructure. Not doing so increases the risk of greater impacts and associated costs. Importantly, optimization of existing observational capabilities, and addition of new components will require enhanced coordination at an international level.

## Recommendations and Call to Action

1. Since the AOS-2016 (Fairbanks, Alaska, USA), analytical advances, in a series of efforts that emerged from the first Arctic Science Ministerial (ASM1), have provided quantitative and qualitative valuation methods to support informed decisions drawing on the societal benefits of sustained observing systems and accessible data. Case studies for selected Arctic challenges have shown positive return on investment, motivating our call for action to coordinate and extend sustained observations.

2. Compared to other, more populated parts of the globe, Arctic observations rely heavily on research projects, rather than operational infrastructures and initiatives. There is an urgent need to progressively shift key observing system components – including community-based observations – from short-term research funding to sustained, operational infrastructure support. The operational infrastructure of the Arctic Observing System must target key variables that capture the Arctic

system's main features. It has to be augmented by observing a broader set of variables required for addressing topical problems through research projects. Such a system also serves a critical function as information infrastructure in support of global services derived from the Arctic system.

3. A properly resourced, comprehensive effort is needed to identify strengths and gaps in the current set of systems, sensors, networks, and surveys used to observe the Arctic. A knowledge map connecting these observations to societal benefits can then guide new observations, data management needs, and development of products and services, leading to a much-needed roadmap for Arctic system observing. Support for an international and local team of experts to complete these tasks under the auspices of SAON will greatly increase the benefits derived from Arctic observing activities and is deemed critical for successful deployment and sustained operation of an Arctic Observing System.

4. Observing and data systems, at different spatial and temporal scales, have to emerge from co-design, co-production, and co-management processes with relevant stakeholders and rights-holders embracing free, ethical, and open data sharing, adhering to the "FAIR" data principles (Findable, Accessible, Interoperable, Reusable).

5. To build an Arctic Observing System that is comprehensive, coordinated, sustainable, and fills current observational gaps, all existing assets and activities, including Indigenous knowledge, must be leveraged to the greatest extent. Such a system needs to span the full range of spatial and temporal observation scales. This is achievable by combining multiple observational methods and technologies, including Indigenous knowledge, in situ observations, satellite remote sensing, community-based monitoring and citizen science, and by linking all relevant data systems.

This Statement builds on deliberations at the international biennial Arctic Observing Summit (AOS). AOS is a task of SAON under the auspices of the Arctic Council and IASC. At AOS-2018 (Davos, Switzerland), participants from 26 countries focused on the "Business Case for a Pan-Arctic Observing System." Demonstrating the value of Arctic observations, linked to relevant Societal Benefit Areas showed how long-term observing systems support decision-making from local to global scales.

# Background to AOS 2018

The 2018 AOS was the 4th Summit, following Vancouver, Canada in 2013, Helsinki, Finland in 2014, and Fairbanks, USA in 2016. Summits are structured thematically building iteratively on previous outcomes and recommendations. The AOS agenda is shaped by input from the Arctic community and is an iterative process during which previously prepared and distributed materials are refined through working sessions, plenary and panel discussions. The AOS is scheduled to enable the organization of side events to help advance planning, coordination and integration activities. AOS products are prepared for a diverse audience, including the general public, policy and decision makers, funding bodies, operational agencies, Indigenous organizations and the research community.

At the 2016 Summit, over 450 delegates from 30 countries, representing a broad spectrum of the scientific community, Indigenous People from Alaska, northern Canada, Greenland, Arctic Scandinavia and Arctic Russia, representatives of the private sector, governmental and non-governmental agencies, non-profit organizations, Arctic Council observers, Permanent Participants, and working group representatives came together to discuss and develop recommendations and a pathway toward the implementation of an internationally supported, Arctic Observing System that is considerate of and responsive to both local and global needs. Among these was the recommendation that the international Arctic Community:

**"***Propose to the highest levels of government, the business case for a comprehensive pan-Arctic Observing System."* (AOS Conference Statement 2016)

The recommendation also elaborated that:

"*This proposal should assess the costs and demonstrate the benefits for society at various levels, including an Implementation Plan that builds upon the present system and past planning, and that identifies needed resources including infrastructure, instrumentation, human capacity, the pathways to financing, and a strategy for sustained financing.*"

It is this recommendation, challenging the international Arctic community to present a "business case" for a comprehensive pan-Arctic Observing System that was the focus of AOS 2018. This includes evaluating societal benefits and costs, laying out financing options, and placing investments in observing activities and infrastructure into a broader context.

# Summit Themes 2018

The AOS 2018 focused on pressing issues in the implementation and support of sustained observations that can be addressed through a business-case lens (Figure 2). In addition to the report on outcomes and the 2018 Summit Statement presented here, background documents, presentations and materials from previous events can be found at the AOS website.

<table>
<tr><th colspan="3">AOS 2018 Themes and Sub-themes</th></tr>
<tr><th>Need for the Observing System</th><th>Implementation and Optimization</th><th>Leveraging Observing Systems and Networks</th></tr>
<tr><td>Societal Benefits: Long Term Perspective<br>Strategies and examples for observations guided by assessment and prioritization frameworks that link to Societal benefit areas.</td><td>Funding and Support Models<br>Public-private partnerships, international funding models, entrepreneurship, in-kind support.</td><td>Success Stories<br>Lessons learned from relevant observing efforts.</td></tr>
<tr><td rowspan="3">Societal Benefits - Short/Medium Term Perspective<br>Strategies and examples for observations driven by local information needs, responses and adaptations to rapid Arctic change, operational needs, resource co-management, emergency preparedness and response.</td><td>Optimizations of Existing Platforms and Technologies<br>Model- and outcomes-based optimization approaches.</td><td rowspan="3">Use of Data and Information for Observing Systems<br>Community-based monitoring to guide bottom-up management;<br>Data management in support of public and private interests;<br>Entrepreneurship and sustained observations – economic development and diversification associated with Arctic observing systems;<br>Observing systems as social enterprises.</td></tr>
<tr><td>Adoption of New Technologies<br>Increasing efficiency, reach and impact of observations.</td></tr>
<tr><td>Data<br>The role of data management in observing system implementation.</td></tr>
</table>

*Figure 2. AOS 2018 – themes and sub-themes defined prior to the Summit. Themes and subthemes developed further during the Summit itself.*

Prior to the Summit contributions in the form of short statements on these thematic areas and sub-themes were solicited in a call for input. Thirty-nine were received and are posted on the AOS website[iii]. Thematic working groups evaluated and synthesized these statements, and other relevant information to report on the state of Arctic observing under each theme, to identify linkages among themes, gaps, need and priorities and to generate discussion around solutions, implementation, community engagement and international cooperation. There were six working groups. Summaries of outcomes recommendations, and pathways forward from each follow below.

## Working Group 1: Societal Benefits

Over the past two years, following from AOS 2016, positive developments in methods and analytical approaches have increased the societal benefit of observing systems. Quantitative and qualitative valuation methods continue to support informed decision-making and movement toward achieving United Nations Sustainable Development Goals (SDGs). Working Group 1 (WG1) considered strategies and examples for observations guided by assessment, prioritization frameworks that link to Societal Benefit Areas (such as Value-Tree Analysis and intervention logic), Sendai framework and SDGs. Group discussions focused on strategies and examples for observations that are driven by local information needs, responses and local adaptations to rapid Arctic change, operational needs, resource co-management, emergency preparedness and response. For example, satellite imagery provided by Polar View and SmartICE can aid users to identify smooth, rough, and mobile ice and plot waypoints to develop safe travel routes (Figure 3).

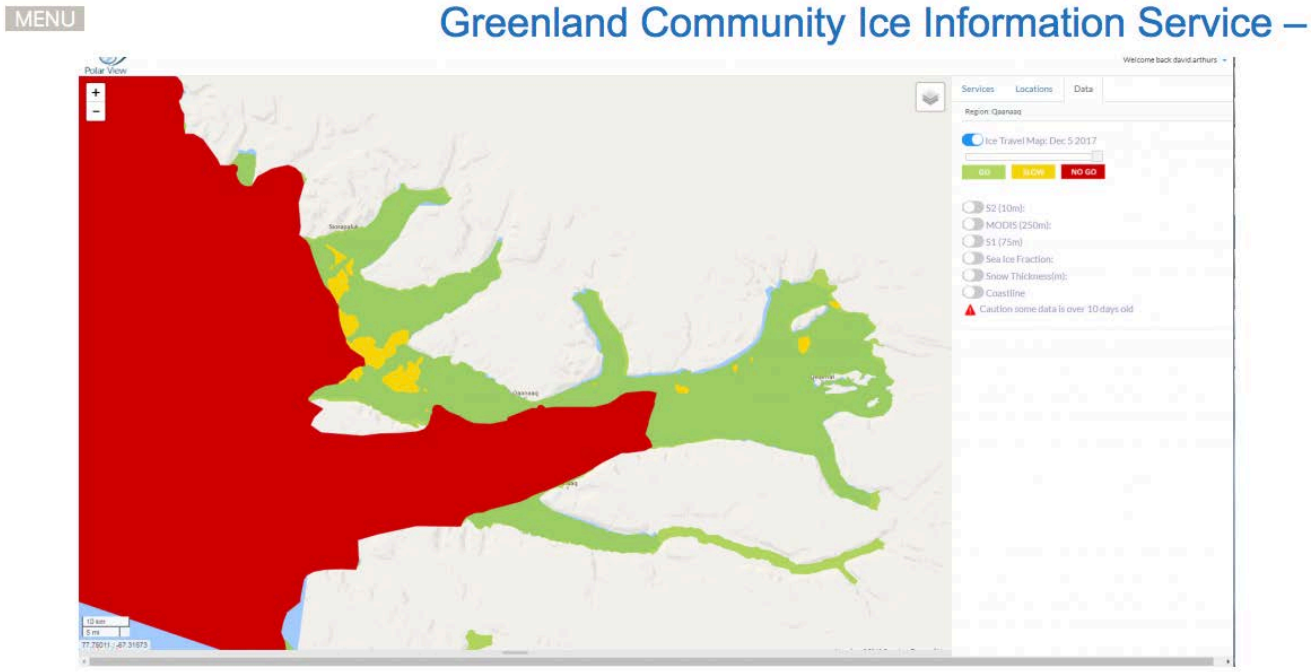


*Figure 3. The community ice information service uses near-real-time Sentinel 1 satellite imagery to monitor the ice conditions for communities, offering 'go', 'slow go' or 'no go' recommendations using a green, yellow, and red colour code. Also included is a selection of satellite images (Sentinel 1 and 2, and Modis), locations of interest, a community base map containing local knowledge, information from the Copernicus marine service. http://floeedge.polarview.org*

Integration of technologies, as in the above example, shows promise for extending the use of observation data to address a broad range of Arctic needs but there is more work to be done, particularly with respect to the design of the observing system, production of end-user products and flow of data and information. The UN SDGs offer an important framework for both guiding a sustainable development process, and in relation to observations, provide user-oriented guidelines to improve existing and developing observation and monitoring systems in/for the Arctic. However, to be relevant to specific contexts, the goals and their targets have to be adjusted to Arctic needs and scaled down from their global to a regional and local context. It is also essential to co-produce indicators with scientific experts and stake- and rights holders respectively and to validate their appropriateness with local communities in the Arctic.

## WG1 Recommendations

Technologies, connectivity, and access to data need to be improved for continued societal benefit, which in itself must be defined at the appropriate level (community, region, planetary). Methods and technologies should be linked to the benefit area(s) and adapted to the relevant spatial and temporal scales, and to the needs of stakeholders and rightsholders through co-design and co-production. Ways forward include:

1. Develop a roadmap for determining methods and metrics to measure societal benefits of the existing and proposed observing system across scales - predesigned benefit areas (i.e., UN SEBs) may not be useful at the local level;

2. Standardize and define terminology to improve access to and understanding of observing system data;

3. Include northern communities in a substantive way in consultation and decision-making around implementation of observing system infrastructure.

## Working Group 2: Implementing and Optimizing the Observing System

Clearly defined specifications and requirements are prerequisite to observing system implementation and to ensure that key information needs are served. WG2 situated itself at the interface between the drivers of specific observing requirements and different elements critical to successful implementation of an observing system, also serving as a link for other working groups (Figure 4).

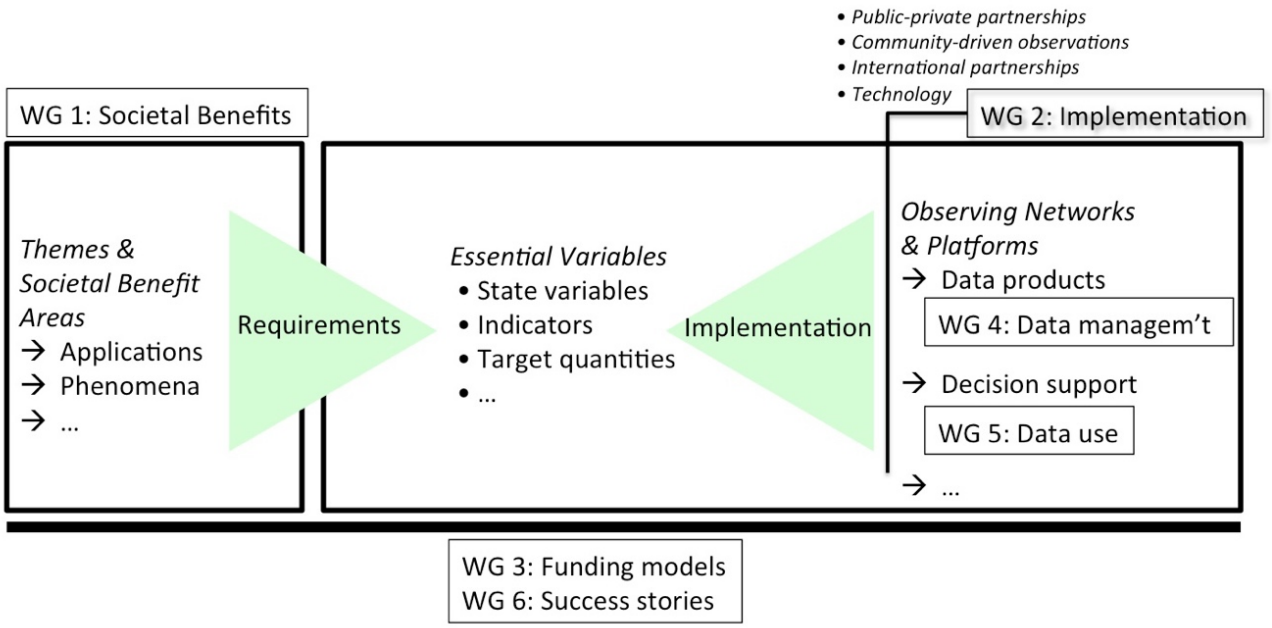


*Figure 4. AOS 2018 Working Groups in the context of requirements, essential variables, networks and platforms.*

Structured, thematically focused approaches can lead to a coherent overarching observing framework. Four case studies were conducted to explore how such approaches can be put into practice (loosely following a Global Ocean Observing System framework that includes requirements, essential variables, observations, improving readiness and system evaluation[iv]). Case studies focused on Benthic Invertebrate Abundance and Distribution, Sea Ice Forecasting, Thermal State of Permafrost, and the Integrated Arctic Observing System (INTAROS) Observing Assessment Framework.

WG2 aims to facilitate and support work at the thematic, community-of-practice level, in particular as relevant to the Sustaining Arctic Observing Networks (SAON; arcticobserving.org) initiative and the SAON Committee on Observations and Networks (CON). At the Summit WG2 explored the potential role of public-private partnerships and the private sector, which will play an important role in sustained Arctic observing systems.

## WG 2 Recommendations

1. Develop a comprehensive, international inventory that describes the current set of systems, sensors, networks, and surveys that are used to observe the Arctic today, as well as a knowledge map that connects these observation inputs to societal benefits. Use the knowledge map to assess and prioritize new observations, data management needs, and the development of products and services.

2. The inventory effort requires an international team of experts – working under SAON - to complete specific tasks, in particular to generate an Arctic Observing Roadmap that builds on existing inventories and assessments, and identifies gaps. Such a team of experts likely will include a half dozen full-time equivalents engaged over the course of two to three years as part an optimization and implementation task force.

Effective integration of private sector activities and contributions requires consolidation of the scientific and operational communities around data needs and priorities. Business models require a market. Consistent operating procedures, data requirements, and platform demands among operational, research sub-communities, and others will reduce costs for everyone, potentially making the private sector a viable route to system sustainability. There is great potential for collaboration between scientists and mission-as-service providers on value-added products, leveraging one design solution or mission for other scientific questions.

## Working Group 3. Funding and Support Models

Sustained funding is the key to successful long-term observing and monitoring activities. This is evidenced by such initiatives as Canada's Northern Contaminants Program (NCP), which, over a 25-year period has worked in partnership with Northerners, federal and regional governments and scientists, to develop a long-term monitoring program that contributes data on persistent organic pollutants and other contaminants to inform action and policy pertaining to human exposure through consumption of traditionally harvested foods at local to international scales[v]. NCP data is embedded in many Arctic Monitoring and Assessment (AMAP) reports and has been used successfully to contribute to the development of policy which as reduced levels of some contaminants (for example through the Stockholm Convention on Persistent Organic Pollutants[vi]).

Traditionally it is been difficult to secure long-term support for monitoring through typical science or research forums. However, to address the planetary-scale problems we face today, and in the future, the data derived from long-term observing is critical. Individual monitoring or observing sites are not necessarily informative at the system level, but when linked together into a network we can improve our understanding of current change and emerging system properties which is key to adaptation and mitigation. A roadmap for an international Arctic observing infrastructure is critical, and there are examples upon which the Arctic Community can build, including the roadmap of the European Strategy Forum on Research Infrastructure[vii].

Such a roadmap must distinguish among long-term observations of key variables and topical observations with accommodation for collecting data by enhancing the density of observations and /or the number of variables observed as needed to improve understanding of specific processes or improve models. It must identify a pathway for provide long-term support of observing infrastructure that includes a role for the private sector in support and use of the observing system.

## WG 3 Recommendations

1. SAON should be established as the Coordination Body for the support of the Arctic Observing System (Figure 5). Responsibilities would include facilitating coordination among nations, agencies, the private sector, the research community and Indigenous communities and organizations for the development of a funding and support roadmap for the Observing System.

2. The Observing System is already supported to some extent by existing assets. These need to be leveraged to the fullest extent and the roadmap for long-term support should be enacted in partnership across agencies, nations, institutions, and with the private sector.

3. SAON should coordinate assessments of the Observing Systems, coordinate entities to identify observing priorities and key variables for operational infrastructure and coordinate with the research community to ensure that topical observations augment and support the system where appropriate.

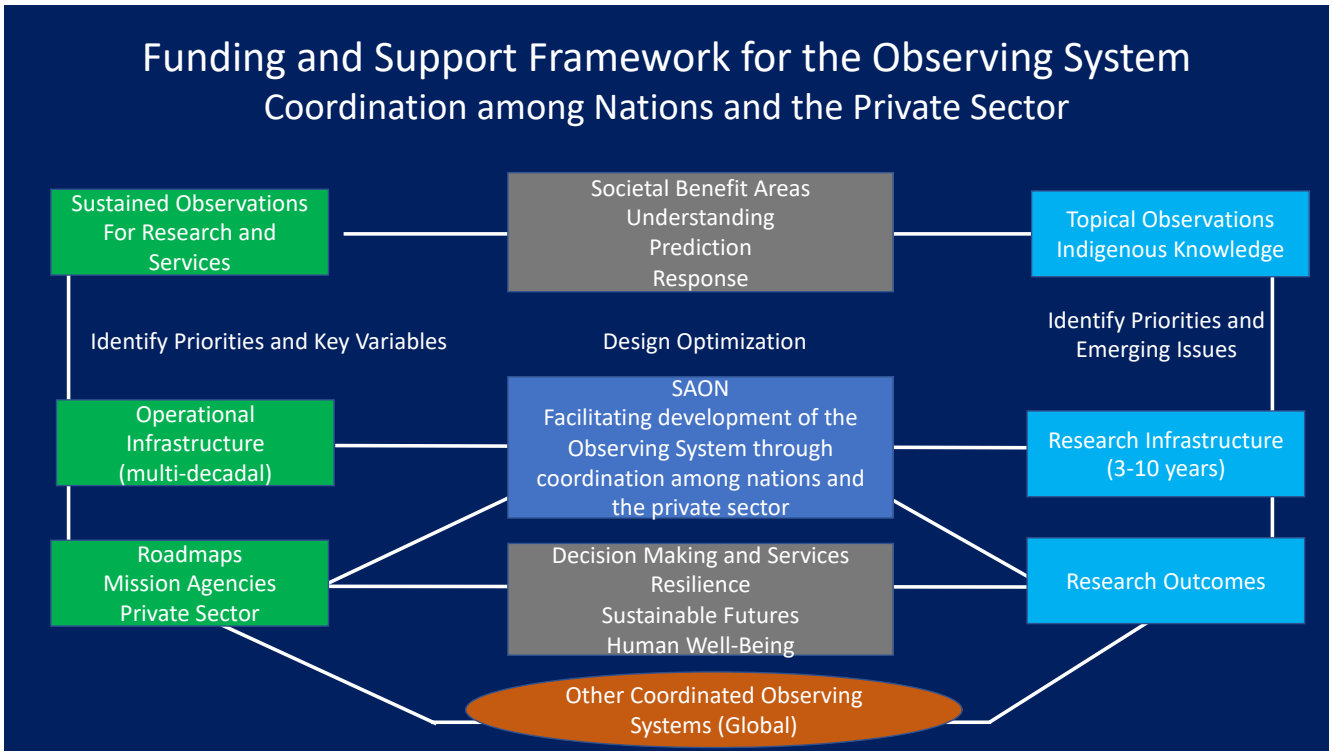


*Figure 5. A proposed support framework for the Arctic Observing System with SAON acting as a coordinating entity to ensure communication and collaboration. Societal Benefit Areas influence priorities, infrastructure needs, and outcomes (products, services) which are enhanced through science and Indigenous Knowledge.*

## Working Group 4. Data Management and Observing System Implementation

Data are an integral element in the observing system value chain. Without a system that makes well documented data accessible, many kinds of observations are ephemeral and their value is limited. As such, the overarching observing framework must emphasize data management throughout the entire process from initial collection to use including science, policy development, and decision making (Figure 6). An integrated Arctic data system that is part of the global data system is critical for developing our understanding of a rapidly changing Arctic, mitigating risk, reducing costs, supporting disaster response, informing resource development, and supporting Indigenous needs among many others.

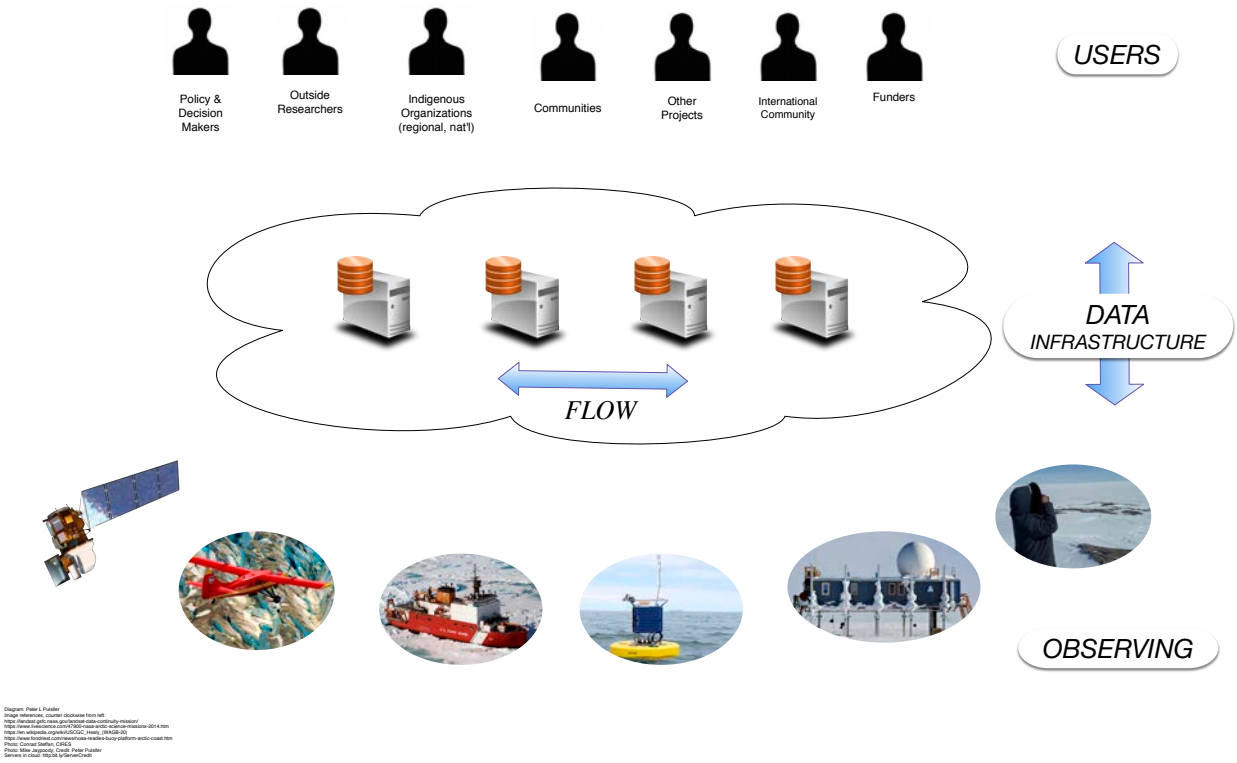


*Figure 6. Arctic observing is being carried out using many methods ranging from space-borne remote sensing to community-based monitoring. These observations are increasingly stored in digital format on computers and the broader information "cloud". This observing and data system must server many different users and applications. An effective and efficient system requires that observations in the form of data can flow through different parts of the system. Achieving these flows requires high level, international cooperation, establishment of policy (e.g. ethically open data), and the use of an appropriate level of standardization. To ensure sustainability, we must consider the data system as a form of infrastructure.*

A fully developed Arctic Data System will use open data policy and standards to network people to people and machines to machines, allowing users to find, access, integrate and reuse data. Using a structured approach, user-driven design, and coordinated international collaboration, the arctic data community will develop a detailed design (architecture) that will enhance and better connect existing data resources to build a system supporting knowledge integration and analysis appropriate for a wide range of different users. This includes improving the mechanisms and resources needed to ensure that indigenous perspectives and knowledge are ethically and appropriately utilized. A comprehensive Arctic Data System to support the Arctic Observing System must leverage existing resources and infrastructures and requires long-term investment for maintenance to allow consideration and inclusion of new developments including innovations from the private sectors and advances in machine learning.

## WG 4 Recommendations

1. Develop a detailed architecture for an international, interconnected arctic data system, that leverages substantial existing resources and infrastructure and contributes to and integrates with the broader global data system

2. Convene a series of international working design and development meetings that build on recent, successful data management workshops.

3. Focus working design and development meetings on:

i) Clear identification and documentation of all actors and stakeholders;

ii) Analysis of user needs;

iii) Enabling the ability to search across data catalogues;

iv) Identifying standards and protocols to improve data access;

v) Enhancing the ability for system--system integration (interoperability);

vi) Enabling data reuse for multiple audiences;

vii) Ethical utilization of Indigenous Knowledge and community-based monitoring;

viii) Inclusion of advanced, networked analytical capabilities.

## Working Group 5. Use of Data and Information from the Observing System

In considering the use of data and information from the observing system it is particularly important to establish how value is derived through the development of data products that assist in addressing societal needs, including those of northern communities, and the public and private sectors. Barriers to use of data need to be identified and overcome with data priorities identified based on collaboration with the entire spectrum of end users to meet multiple needs. Data needs to be presented in a format that is usable for improved and rapid decision making, yet there are many challenges including a lack of suitable standard workflows for data analysis and use, limited human capacity for transforming raw data into decision-support tools, and the uneven distribution of funding wherein emphasis is placed on data collection with limited support for data mobilization.

Boundaries that prohibit sharing data, data products and observations need to be eliminated as the value of data sharing cannot be underestimated. It is a means of filling knowledge gaps and of supporting mitigation and adaptation in a rapidly changing world. Similarly, the tremendous value of community-based monitoring (CBM) has yet to be fully realized, although these programs can function quite effectively to support environmental planning, co-management of resources (Figure 7), individual and community decision making, and as social enterprise. However, the data and information from these efforts are not always accessible for broad use. Best practices for CBM are established and a roadmap that includes CBM as a key element in the observing system will support improved sharing of CBM information.


*Figure 7. Opening Doors to Native Knowledge (Piniakkanik Sumiiffiinni Nalunaarsuineq, abbreviated PISUNA): a Greenland Government project using locally based monitoring of living resources as a tool for improving Arctic resource management (Polar Geogr.37:69; http://www.pisuna.org; https://eloka-arctic.org/pisuna-net/).*

## WG 5 Recommendations

1. To bring data to the broadest possible audience open data policies need to be widely adopted and directed towards both public and private sectors. Information sharing must cross-cut nations, sectors and support research, operational organizations, the public and private sectors and Indigenous communities and groups. Funders can support this by requiring open access and supporting data mobilization efforts.

2. SAON, in partnership with rights and stakeholders should develop a strategic and business plan for the Arctic Observing System. It should focus on addressing societal benefits areas and include a pathway for bringing data to the public, as well as protecting sensitive information including from CBM.

3. Direct resources for fostering training in data collection, analysis, management and mobilization.

## Working Group 6. Observing Technologies in Support of Public Interests

Innovative observing technologies and sustained observing support basic science but also, importantly support and empower Arctic Indigenous Peoples, and communities and governments worldwide to respond to the impacts of a changing Arctic and a changing world. Success is dependent upon several guiding principles: a collaborative approach, common objectives, and often, co-design that is inclusive of Indigenous Knowledge. The latter is particularly necessary for the successful development of community-based observing and observing in support of social enterprise. Such an approach energizes communities and provides resources to complement local research agendas and advances locally-driven enterprise for local benefit.

Observing technologies are successfully employed at multiple scales to address global issues with significant societal impacts. Elements of the Arctic Observing System are already directed towards the collection of observations that address specific societal issues with benefits far outweighing costs. For example, contaminant monitoring led to international awareness and the formation of an international consortium with an action plan to reduce contaminant levels through the Stockholm Convention. Sustained observations enhance our decision-making ability and allow us to tackle the challenges associated with global climate change in a fully informed manner. Simultaneously, sustained observations and innovative technologies also provide the information needed for daily life. Transportation is a case in point, wherein satellite data, sensor data, and human observation combined provide necessary information on sea ice, weather and ocean conditions to enable safe navigation, expedite search and rescue when needed, and minimize risk to people, wildlife and infrastructure. Such observational data is useful across many scales of human decision making and many sectors, with tangible social, economic and environmental benefits.

A sustained Arctic Observing System needs to be insulated from external political influences and pressures such that it is able function over the long-term and be iteratively developed to respond to changing conditions, priorities and needs. Multiple case studies on the successful use of observing technologies have shown that sustained observations of environmental change enable improved predictability and enhanced adaptation while building socio-economic capacity at the community level.

## WG 6 Recommendations

1. The Arctic and the global communities should provide broad multilateral support for the Arctic Observing System, shaped by a shared vision, inclusive governance and commitment to sustained implementation.

2. Investments in improved observing technologies at the local and regional levels should be prioritized and encouraged. This is imperative to ensure continued sustainability of actions geared towards mitigating the effects of climate variability.

## The Way Forward

This report summarizes the main recommendations from the AOS 2018. Action on a number of the above recommendations is underway and further actions will be forthcoming.

The IPCC Special Report on Global Warming of 1.5C[viii] makes it clear that it is ever more urgent to expand and enhance Arctic observation and to quickly mobilize the data from the observation system to inform climate action in the Arctic and beyond. Indeed, the Joint Statement of Ministers from the Second Arctic Science Ministerial declared that, "We therefore intend to cooperate through the following actions … taking stock of progress made in the analysis of societal benefits of Arctic observations, continue and expand the cooperation in this area by progressively moving from the design to the deployment phase of an integrated Arctic observing system which also supports and includes community-based observatories, in cooperation with the Sustaining Arctic Observing Networks (SAON) initiative".

The Arctic is changing faster than we can currently observe. The time to act is now. Not doing so increases the risk of greater negative impacts, higher associated costs, and an uncertain future for our entire planet.

[1] https://nsidc.org/news/newsroom/arctic-sea-ice-2018-minimum-extent

[1] https://climate.nasa.gov/news/2690/unusually-warm-winter-breaks-up-sea-ice-in-the-arctic/

[1] http://www.arcticobservingsummit.org/aos-2018-statements

[1] http://www.goosocean.org/index.php?option=com_content&view=article&id=125&Itemid=113

[1] http://www.science.gc.ca/eic/site/063.nsf/eng/h_7A463DBA.html

[1] https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-15&chapter=27&clang=_en

[1] http://www.esfri.eu/about

[1] http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf )

*Photo: M. Ayre, Barrow, Alaska, 2018*