

Sustaining Arctic Observing Networks (SAON)  
Roadmap for Arctic Observing and Data Systems (ROADS)

S. Starkweather<sup>1</sup>, J-R. Larsen<sup>2</sup>, E. Krueemmel<sup>3</sup>, H. Eicken<sup>4</sup>, D. Arthurs<sup>5</sup>, N. Biebow<sup>6</sup>, T. Christensen<sup>7</sup>,  
R. Delgado<sup>8</sup>, A. Gambardella<sup>9</sup>, S. Kallhok<sup>10</sup>, M. Johannson<sup>11</sup>, H. Jóhannsson<sup>12</sup>, Y. Kodama<sup>13</sup>, S. Sandven<sup>14</sup>

1. Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, USA
2. Arctic Monitoring and Assessment Program (AMAP) Secretariat. Tromso, Norway
3. Inuit Circumpolar Council (ICC) – Canada. Ottawa, Canada
4. International Arctic Research Center (IARC), University of Alaska, Fairbanks, USA
5. Polar View
6. Alfred Wegner Institute (AWI), Bremerhaven, Germany
7. Aarhus University, Roskilde, Denmark
8. National Science Foundation (NSF), Alexandria, USA
9. European Commission, Brussels, Belgium
10. Indigenous and Northern Affairs Canada, Northern Contaminants Program, Gatineau, Canada
11. Lund University, Lund, Sweden
12. Arctic Portal, Akureyri, Iceland
13. National Institute of Polar Research (NIPR), Tokyo, Japan
14. Nansen Environmental and Remote Sensing Center (NERSC), Bergen, Norway

**Abstract**

Sustaining Arctic Observing Networks (SAON) set forth a bold vision in its 2018-2028 strategic plan to develop a Roadmap for Arctic Observing and Data Systems (ROADS). This plan marks a transition in SAON's focus from community-building and partnership development towards a more active vision for the systematic design and implementation of the Arctic Observing System. The lack of a consistent and holistic mechanisms to assess observing system priorities and link independently funded efforts across the Arctic can be viewed as a systematic short-coming that has hindered adaptation strategies and limited funding responses for an expanded and improved observing system. ROADS seeks to address this short-coming through generating a systems-level view of observing requirements and implementation strategies. ROADS is both a holistic concept, building from the systematic approach of the International Arctic Observing Assessment Framework, and one that can proceed step-wise so that the most imperative Arctic observing elements can be rapidly improved. ROADS is envisioned as a process that will proceed in close collaboration with the Arctic Observing Summit. SAON's Road Map Task Force (RMTF) developed these guidelines and principles for the community in order to mobilize maximal expertise towards the strategic expansion of the Arctic Observing System.

### I. Background

In recent decades, scientific and traditional observations of Arctic environmental and socio-economic systems have revealed a pace, magnitude, and extent of change that is unprecedented by many measures. These changes include rapid depletion of the cryosphere (*IPCC, 2019; AMAP, 2017*), shifts in ecological communities (*ICC-AK, 2015; CAFF, 2017; CAFF, 2019*) that threaten biodiversity while precipitating challenges to food security and resilience across northern communities (*ICC-AK 2015; Arctic Council, 2016*), and adaptation demands from increased human activity (*Arctic Council, 2016; ICC-CA, 2008; AMSA, 2009; ICC-CA, 2014*) that outpace the capabilities of management agencies. The impacts to both the natural and built environment that result from these changes include: increased coastal and riverine erosion, storm surges, more severe wildfires, damage to infrastructure and risks to fresh water supplies. Observed impacts from Arctic change are not confined to the region. Melting Arctic land ice impacts global sea level and ocean circulation (*IPCC, 2019*), while regional alterations to sea ice, ocean surface waters and the overlying atmosphere may influence the severity of weather in midlatitudes (*Overland et al., 2016*). Sustained observations of the region along with model projections provide critical insights to urgently needed adaptation strategies, yet Arctic observations are currently too limited both spatially and temporally and insufficiently coordinated to adequately inform them (*Lee et al., 2019*).

There are several critical challenges to collecting and disseminating Arctic observations. The physical challenges of polar conditions (e.g. polar night, extreme cold, lack of infrastructure and access) increase observing system costs, constrain coverage and limit real-time data dissemination. The Arctic region is vast; it crosses many national boundaries and is home to Indigenous Peoples. International sharing of observational assets, products and services and partnership approaches, including ethical and equitable data sharing agreements with Arctic Indigenous Peoples, are thus imperative. Presently, a diverse range of independently sponsored activities are responsible for collecting and disseminating Arctic observations. Remarkably there is no comprehensive mechanism for linking and coordinating them. This can be viewed as a systematic failure of the present situation. For example, fragmented research and observing activities, particularly those that do not work in equitable partnership with Arctic Indigenous Peoples, put a strain on Indigenous communities and are unlikely to address the needs they have determined to support culturally-informed decision making. The collective challenges associated with deploying, sustaining and unifying pan-Arctic observations in response to rapid environmental and socioeconomic change motivated the initiation of Sustaining Arctic Observing Networks (SAON).

SAON is a joint initiative of the Arctic Council and the International Arctic Science Committee (IASC) that was created to strengthen multinational engagement in and coordination of pan-Arctic observing (Arctic Council, 2011). In recognition of the complex dimensions of Arctic observing activities, and the equally complex organizational patchwork of observing activities and infrastructures, SAON's intent as an open initiative is to unite Arctic and non-Arctic countries, Indigenous Peoples, academia, industry and other key stakeholders in support of a systematic network through structured facilitation. SAON partners have already invested a considerable amount in Arctic *in situ* and satellite observing and related data infrastructure in support of operational needs and academic research; regional governments,

Indigenous Peoples and local communities sustain their own networks as well. An important portion of these activities are independently initiated through grassroots efforts, supported by proposal writing and revolving grant awards. SAON's vision is to bring these parties into a connected, collaborative, and comprehensive long-term pan-Arctic Observing and Data System that serves societal needs. To achieve this vision, SAON facilitates and advocates for coordinated international pan-Arctic observations and mobilizes the support needed to sustain them. SAON's Strategic Plan (SAON, 2018) outlined the following guiding principles to achieve its vision:

- SAON values both research and operational needs for Arctic observations;
- The Observing System is implemented and sustained through open cooperation among all those committed to Arctic observations under a common SAON umbrella;
- The design and operation of the Observing System will be guided by a balance between bottom-up and top-down needs, priorities and perspectives;
- SAON will promote contributions of all types of observations including but not limited to *in situ*, remotely sensed, and community-based observations, and the infrastructure supporting them;
- The Observing System will use Indigenous and local knowledge guided by ethical use and honouring the proprietary rights of data contributors;
- SAON will promote ethically<sup>1</sup> free and open access to ethically-collected data;
- SAON will work with counterparts in the Antarctic, global, and national observation communities, where appropriate.

Several of these principles address critical ethical considerations for partnership with Arctic Indigenous Peoples and use of their Indigenous knowledge. In particular, processes for the direct engagement and involvement of Indigenous Knowledge holders in the planning, design, analysis and use of the information need to be in place, and sensitive data need to be protected. They also support rigor, as Indigenous Knowledge holders have noted that segmented science efforts can lead to false conclusions. Following these principles, SAON aims to mobilize the support for sustained observations on time scales from years to decades. **How does SAON propose to do this?**

### II. A Roadmap Approach – Recommendations of SAON's Roadmapping Task Force

In its recent strategic plan, SAON identified the need for a Roadmap for Arctic Observing and Data Systems (ROADS) to set a course towards systematically defining the needed Observing and Data System and to specify how the various partners and players are going to collectively work towards achieving that system. To initiate ROADS, the SAON Board empaneled a task force (Road Map Task Force<sup>2</sup>, RMTF) to set forth definitions and guidelines for the community of perspective contributors. What follows are

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<sup>1</sup> Ethically open refers to the principle that culturally sensitive data, e.g. Indigenous subsistence areas, should be treated differently than other scientific data.

<sup>2</sup> <https://www.arcticobserving.org/governance/road-map-task-force-rmtf>

## SAON – ROADS

the recommendations of RMTF, starting with the following principles and assumptions to guide the ROADS process:

- Indigenous Peoples' equitable partnership and funding for their active participation is critical to ROADS from its inception through its implementation;
- The ROADS process should complement and integrate, without duplication, the current planning approaches used by existing networks (regional to global), activities and projects;
- ROADS should support step-wise development through a flexible, federated and evolving structure that allows grassroots identification of themes, infrastructures and regional foci.

The RMTF asserts that the purpose of ROADS is to stimulate multinational resource mobilization around specific plans with clear societal value propositions; to serve as a tool for the joint utilization of Indigenous Knowledge, local expertise and scientific observations; and to ensure maximal benefits are delivered from the Observing and Data System to its intended users. For ROADS to be effective in advancing *sustained resources* for Arctic observations, its plans must be *relevant* to local communities, national funding organizations, industry, operational and scientific agencies, global networks and national political decision bodies. Therefore, this document is targeted towards policy-makers at all levels, Arctic Indigenous Peoples organizations, Arctic and non-Arctic states, academia, civil society and the private sector, as well as other multilateral/international groups and organizations.

### **A. A Network that Serves Societal Needs**

A well-defined assessment process is required to establish a communal view of societal value, impact and the intended user base of Arctic observations. A key tool for such assessment is *The International Arctic Observing Assessment Framework* (IAOAF, IDA 2017), a *Value Tree* assessment approach jointly created by SAON and the Science and Technology Policy Institute following the 2016 Arctic Science Ministerial. The IAOAF identified 12 Arctic-specific *Societal Benefit Areas* (SBAs) including *Food Security, Disaster Preparedness, Human Health, and Fundamental Understanding of Arctic Systems*; these SBAs were further specified into sub-areas and ultimately more than 160 *Key Objectives* for ROADS to address. ROADS will ultimately translate these *Key Objectives* into requirement for the observing and data system and estimate the resources that will be needed to accomplish them. The IAOAF has already been applied to the EU's *Impact Assessment on Long-Term Investment on Arctic Observations* (IMOBAR, 2018) project to demonstrate the economic value of Arctic observations in application areas like ship routing. IAOAF was also applied to a Finnish-led effort, *Value Tree for Physical Atmosphere and Ocean Observations in the Arctic* (FMI, 2019); further work on the IAOAF is being conducted in the US and Japan. SAON supports these applications of IAOAF and solicits additional input from the 2020 Arctic Observing Summit (AOS) working groups to build upon and endorse comprehensive *Value Tree* methodologies for holistically assessing the impact of observing efforts. Systematic assessment in the ROADS process, along with on-going input from Indigenous, scientific and other subject matter experts, will assure that observing system requirements are consistent with a network that broadly serves societal needs and provide the on-going rationale for sustained investments in Arctic observing. The conceptual structure for ROADS is the subject of the next section.

## B. Essential Arctic Variables Structure

The RMTF reviewed planning approaches employed by a variety of global and regional observing networks<sup>3</sup>. The essential variable strategy clearly emerged as a best practice for supporting network development. The approach is conceptually holistic, yet can proceed step-wise as each variable's implementation strategy achieves readiness, and ROADS will be organized around Essential Arctic Variables (EAVs). These are conceptually broad observable phenomena (e.g. "sea ice") identified for their criticality to supporting Arctic societal benefit, as defined through IAOAF assessment. A useful EAV will cut across multiple SBAs and fulfil at least a portion of the observing requirements of many *Key Objectives*.

EAVs shall be specified by their observing system (e.g. spatial resolution, frequency, latency, uncertainty) and data management requirements, which should transcend specific observing strategies (i.e. technology neutral), programs or regions. They shall be implemented through specific recommendations based on Arctic-viable technology and practices. A holistic and collaborative Observing and Data System organized around EAVs is achieved through employing consistent strategies in assessing, linking and developing requirements for sampling. The EAV approach allows for progress on implementation, under an expectation of continuous innovation in the underlying technologies. Importantly, EAVs provide a structured interface for coordination and collaboration in support of societal benefit as well as a data management framework for integrating independently sponsored observations into interoperable data streams.

In keeping with the ROADS principle of complementing current efforts in a non-duplicative approach, a rational starting point for identifying priority EAVs begins with a recognition of the considerable work that has already been done, as reflected in existing catalogs of essential variables associated with global networks (e.g. Essential Ocean Variables, Essential Climate Variables, Essential Biodiversity Variables), regional programs (e.g. Arctic Monitoring and Assessment Programme (AMAP) and Circumpolar Biodiversity Monitoring Programme, (CBMP)) and with reference to gaps analyses like the European Space Agency's Polar View assessment (*Polar View, 2016*). ROADS EAVs should extend the requirements (e.g. adding requirements for fast ice observations to global variables for sea ice) and implementation strategies of the global networks, where necessary, to account for Arctic conditions (e.g. polar night) and opportunities (e.g. community observers). A global variable should only be adopted by an EAV if the global definition is inadequately serving Arctic needs. The ROADS process for each EAV should fully specify the observing and data systems requirements from acquisition through high impact information dissemination. It is recognized that new EAVs - unique to the Arctic – could also be identified through IAOAF assessment. Both the adoption of existing and creation of unique EAVs should be based upon practices of co-design (e.g. *CTKW, 2014*).

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<sup>3</sup> Including the GOOS Framework for Ocean Observing; Circumpolar Biodiversity Monitoring Program (and GEOBON); Arctic Monitoring Assessment Program (and GCOS); GEO Global Water Sustainability (GEOGLOWS); WMO Integrated Global Observing System (WIGOS)

## SAON – ROADS

Many global networks have defined procedures, templates<sup>4</sup> and principles for essential variable maintenance. It is envisioned that the ROADS process will evolve step-wise through a series of funded pilot efforts; lessons from these efforts will lead towards a unified model for structuring documentation about ROADS EAVs. The mechanism for mobilizing the funding and expertise for identifying, defining and implementing EAVs is the subject of the following section.

### C. Governed via a System of Expert Panels, Advised by SAON

SAON's goal for its Roadmap was presented to and supported by the Second Arctic Science Ministerial (ASM2, 2018); continuing multinational coordination through SAON was endorsed in their Joint Statement with an emphasis on: "moving from the design to the deployment phase of an integrated Arctic observing system". ROADS is a critical tool in making this move from design to deployment as it will systematically identify and integrate requirements for observing and data systems along with implementation strategies that are based on mature approaches, linking new deployments to existing infrastructures for maximal efficiency. ASM2, along with recommendations from efforts like EU-PolarNet<sup>5</sup>, mobilized new resources to benefit SAON and related observing and data system imperatives under funding calls like the U.S. National Science Foundation's Navigating the New Arctic and the EU Horizon2020 call LC-CLA-20-2020 to establish an Arctic Global Earth Observation System of Systems (ArcticGEOSS)<sup>6</sup>. To achieve a comprehensive ROADS in a timely fashion, SAON, in addition to direct fund raising via national contributions, is partnering with research consortia through these types of funding opportunities to support its expanding facilitation role. It is also calling on new and existing networks and partners for in-kind organizational support and expertise through a system of thematically-driven Expert Panels.

An Expert Panel approach is in keeping with SAON's and ROADS' guiding principles; ROADS development will proceed at the interface between funded coordination, advising and facilitation from SAON (top-down) and a growing collection of community-led (bottom-up) Expert Panels with authoritative remits in their respective subject areas. This document provides broad guidelines for how SAON envisions ROADS to be collectively developed by these Expert Panels, with additional detail to be developed through the Arctic Observing Summit (AOS) 2020 Working Groups. **Who will lead and participate in these Expert Panels?** Leadership from existing SAON and Arctic Council partner networks (e.g. AMAP and CBMP), Indigenous networks and working groups (e.g. Indigenous Knowledge Social Network, SIKU and the AOS Indigenous Working Group), infrastructures (e.g. Svalbard Integrated Observing System, SIOS) and new projects that initiate as a result of funding calls will be critical to achieving a successful ROADS, as will global networks (e.g. Global Cryosphere Watch, GCW) and regional activities (e.g. Alaska Ocean Observing System, AOOS). Expert Panels may convene around a subject of interest; their scope should be broad enough to cover at least one "Essential Arctic Variable" (EAV, see Section C), preferably a related set of EAVs. Participation in the panels must be as broadly inclusive and relevant as the IAOAF

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<sup>4</sup> For example, specifications for: [GCOS ECV](#), [GOOS EO](#), [GEOBON EB](#).

<sup>5</sup> <https://www.eu-polarnet.eu/>

<sup>6</sup> H2020 LC-CLA-20-2020: [https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-climate\\_en.pdf](https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-climate_en.pdf)

## SAON – ROADS

framework itself, drawing subject matter experts from academia, Indigenous organizations, northern communities, operational agencies, partner organizations, industry and government; SAON will play a critical advisory role in assuring inclusive expertise on each panel. Here, it should be underscored that Arctic Indigenous Peoples need to be recognized as rights holders in the Arctic, and research in their homeland needs to be conducted in partnership with them. Governance of and progress under ROADS shall be shaped by and benefit greatly from this critical consideration. ROADS shall proceed in accordance with guidelines on ethical research (e.g. *NISR, 2018; IARPC, 2018*) provided by Arctic Indigenous Peoples in the various locations.

**How will participation in ROADS benefit these efforts?** While many Arctic observing networks have their own processes for identifying observing system priorities, there is currently no meta-structure to tie these efforts together into a systematic, pan-Arctic view. The community-led Arctic Observing Summit (AOS, 2015) and the Arctic Science Ministers have both upheld the need for such structure as well as SAON’s role in shepherding it forward. Partnership with SAON continues to be a critical success factor for grant proposals; it is a requirement for EU Horizon2020 call LC-CLA-20-2020<sup>6</sup> and was voluntarily pursued by the US proposal: *Research Networking Activities in Support of Sustained Coordinated Observations of Arctic Change*. Both the H2020 and US effort are aligning to support the ROADS process with pilot efforts; each proposal will include direct or indirect support for the SAON Secretariat to execute its advising and coordination role, as well as funding for partnership with Indigenous Peoples.

To facilitate ROADS, SAON will establish a ROADS Advisory Panel to support alignment between and across Expert Panels at each phase of their progress. It is envisioned that this board will be comprised by representatives of SAON’s Board<sup>7</sup>, SAON Committees<sup>8</sup>, and partners<sup>9</sup>. Given the principles for ROADS, Indigenous participation in the Advisory Panel is essential. The ROADS Advisory Panel will provide a neutral standing body to assure that each EAV is identified, defined and follows an implementation strategy that is consistent with ROADS principles. In addition to assuring an inclusive process, the Advisory Panel will have the ability to foster integration with other panels; mobilize international participation and collaboration with global networks; and work to cultivate consensus approaches across panels. The ROADS Advisory Panel can also work with relevant funding agencies and organizations to advance support for Expert Panel efforts. The Advisory Panel will interact with Expert Panels following a multi-phase process described next.

### D. A Facilitated Process from EAVs to Implementation

The RMTF outlined a multi-phase process for the initiation and progression of Expert Panel work under ROADS, and the interactive facilitation of the ROADS Advisory panel, which will review each step of the process. It is as follows:

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<sup>7</sup> <https://www.arcticobserving.org/governance/board/board-members>

<sup>8</sup> <https://www.arcticobserving.org/committees>

<sup>9</sup> <https://www.arcticobserving.org/partners>

1. Initiate – Each proposing Expert Panel is invited to write a brief proposal to the ROADS Advisory Panel outlining a proposed scope of EAV development activities and participants. SAON will have the opportunity to assure panel alignment with ROADS principles, like the equitable inclusion of Indigenous experts and will furnish a support letter to acknowledge that alignment. While it is not necessary for Expert Panels to have funding, SAON will encourage and support panels in seeking resources for community meetings (virtual or in person).
2. Phase I – Convene relevant participants (as identified at the proposal stage) in one or more community meetings to identify critical EAVs for the Expert Panel’s scope of interest. Criticality should be systematically assessed using IAOAF principally, through *Value Tree Analyses*, as well as using ethical guidelines – i.e. partnership with Arctic Indigenous Peoples. It could occur that more than one Expert Panel is working on different aspects of the same EAVs for different outcomes. The SAON Advisory Panel will facilitate cooperation in these instances.
3. Phase II – Convene relevant participants (as identified at the proposal stage) in one or more community meetings to specify the requirements for each relevant EAV for the scope. Requirements should be comprehensive of data collection, data management (in keeping with the IASC *Statement of Principles and Practices for Arctic Data Management*), analysis, system management, and dissemination. Systematic approaches to requirements development, such as Observing System Experiments, are highly encouraged where viable.
4. Phase III – Convene relevant participants, in collaboration with relevant funding agencies and partner organizations, to outline strategies for implementation and engage commitments for sustainment. This process should describe which infrastructures (physical and cyber) are essential for current implementation. These include satellite earth observation programs, terrestrial stations, vessels, aircraft and various autonomous platforms providing observing systems. Implementation should also describe how these infrastructures will be integrated into value-added services and products and the strategy for their dissemination, such as via an ArcticGEOSS. This phase of work should also identify technology development needs in order to improve readiness of future generations of the observing system.

### **E. Evaluation System**

Given the complexity and progressive nature of the proposed ROADS process, it will be critical to evaluate both the process and its elements on a revolving basis. The RMTF recommends that the ROADS process be evaluated following the first two years of pilot efforts, potentially in collaboration with AOS 2022. Partnerships with AOS Working Groups will provide an effective means for continuous input and refinement of the ROADS process, such is being implemented at AOS 2020. The US proposal: *Research Networking Activities in Support of Sustained Coordinated Observations of Arctic Change*, includes funding for evaluation of their success within the ROADS process. Their experiences and those of the H2020 consortium will prove extremely valuable to refining ROADS for on-going success.

The RMTF recommends that the collection of approved EAVs and their underlying descriptions be evaluated every five years as the requirements and strategies for observing will be subject to change. The pace of Arctic change suggests as much, but also the recognition that our scientific and societal needs of an observing system will change over time.

### **F. Milestones in the ROADS process**

The SAON Strategy covers a ten-year timeline from 2018 to 2028, but progress on ROADS is expected to advance more swiftly. ROADS will not measure its success by the number of Essential Arctic Variables defined, but rather by the extent to which the Key Objectives under the IAOAF have been translated through EAVs into a system of observing requirements and resource-estimated implementation plans. That is to say the quality of the EAVs descriptions and their effectiveness at supporting societal benefit. That said, a successful ROADS process could generate 20 or more EAVs by 2028. The Arctic Observing Summit will serve as an important venue for initiating ROADS and charting its progress. Collaboration with Arctic Observing Summit Working Groups and funded proposals working on ROADS will be the vehicles for this progress. The following timeline is thus tied to the AOS schedule.

By the 2022 Arctic Observing Summit, ROADS should accomplish:

- Completed value-tree assessment of 2 to 4 Societal Benefit Areas and their underlying *Key Objectives*;
- Development of 3-6 Essential Arctic Variables through at least Phase II of the ROADS process, ideally at least one EAV will have gone through all 3 Phases of development.

By the 2024 Arctic Observing Summit, ROADS should accomplish:

- Completed value-tree assessment of 5 to 8 Societal Benefit Areas and their underlying *Key Objectives*;
- Development of further Essential Arctic Variables, as relevant, through all 3 Phases of development;
- Development of cyberinfrastructure to support EAVs.

By the 2028 Arctic Observing Summit, ROADS should accomplish:

- Completed value-tree assessment of all Societal Benefit Areas and their underlying *Key Objectives*;
- Development of further Essential Arctic Variables, as relevant to the above, through all 3 Phases of development;
- Development of cyberinfrastructure to support EAVs.

### **III. Where will ROADS take us?**

ROADS is both a holistic concept, building from the systematic approach of the IAOAF, and one that can proceed step-wise so that the most imperative Arctic observing elements can be rapidly improved. For each EAV identified, ROADS will result in well-specified requirements for observing and a strategy for

## SAON – ROADS

their implementation and timely dissemination. ROADS is an inclusive and transparent process that is initiating in collaboration with funding agencies and observing organization, as represented by the membership of the SAON Board. Inclusive Expert Panels will generate strong grassroots support for plans. Active advising from SAON will provide the glue to hold the system of EAVs together. If successful, ROADS will unify the community of Arctic observing activities through providing mechanisms for structured requirements and implementation strategies. Funding agencies will recognize the merits of an integrated and systematic process with coordinated international engagement, while global networks will recognize the value of regional facilitation through EAVs that extend the definitions and utility of their own essential variables.

ROADS development will support each of the three goals outlined in SAON's Strategy: 1) It will directly result in the Roadmap called for under Goal 1, and 2) It will support ethical access to Arctic data through well-defined data management strategies ties to each EAV. And finally, it will ensure the sustainability of the Arctic Observing System through an integrated system of community endorsed observing targets that have been justified based on their societal and economic value.

SAON has matured since its inception into an organization with a clear mandate, compelling vision and robust partnerships. With the recent attention of the Arctic Science Ministerial process and the convening power of the Arctic Observing Summit, it is poised to deliver a Roadmap that will mobilize substantial sustained investments in well-defined and coordinated Arctic observing. We call upon SAON's partners in networks, infrastructures and observing activities to take up this call to join the ROADS process.

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## SAON – ROADS

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