Arctic Services: A Framework for Effective and Sustained Observations in the Arctic

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Drafting of this summary vision document was co-led by Hajo Eicken, chair of the SEARCH Science Steering Committee (SSC), and Craig Lee, chair of the SEARCH Observing Change Panel (OCP), with input from the SEARCH SSC, SEARCH OCP and SEARCH Science Office.

Overview

- An effective observing network provides robust, well-calibrated measurements that serve scientific research, operations, and planning.
- The needs of scientific research and operations should drive network development and optimize choice of measurements, spatial and temporal coverage, accuracy, timeliness of information retrieval and data curation.
- The network should reflect a systems perspective that allows for integration of data across domains and scales in support of science, operations, testing and improving predictive models, and adapting to emerging or anticipated impacts.
- Clarifying roles and responsibilities for building and sustaining a coordinated Arctic observing system is urgent given the rapid pace of change and substantial environmental and societal impacts. While a single, all-encompassing network is difficult to achieve, a framework built around services and outcomes and drawing on existing components can help ensure efficient data gathering, integration, and dissemination.
- Together with Interagency Arctic Research Policy Committee [IARPC], SEARCH can play a key role representing the broad capabilities and needs of the science community by offering protocols to facilitate, organize, and coordinate necessary exchanges and help assemble the observations framework.

Rapidly changing environments pose big challenges to analysis, predictions, and operations. This is particularly true in the Arctic where access is difficult, observations are sparse, inherent variability in the system is large, and the changes are profound and punctuated rather than gradual. More than for any other part of the globe, Arctic changes are associated with fundamental transitions in the state of the system. Well-coordinated observations are therefore critical for tracking these changes across the subsystems, to test and improve predictive models, and to ensure safe and efficient operations. The current state of the observing system still suffers from significant gaps, spatial and temporal patchiness, and inadequate long-term sustainability. Additionally, there needs to be greater transparency in how science and operational needs can inform the further development and optimization of the network, and how the resulting data are integrated, condensed, and made useful.

Here, SEARCH outlines a vision for arranging components of the existing observing system around a common Arctic Services Framework, how the different elements can be *augmented and integrated, and how key stakeholders and agencies may more clearly identify their contributions. Building on SEARCH's past role in helping define key aspects of the IARPC 5-year strategy and leading discussions of observing system design and implementation (ADI 2012, Lee et al. 2015), it can help in taking the next decisive steps towards observing system integration.*

An Integrated Arctic Observation Network (IAON) is challenged by highly diverse needs and objectives

Current Arctic observation systems are not coordinated well because of their inherent diversity and the requirement that an agency or organization is required to focus on a limited set of objectives related to its specific mission. This constrains agency capacity to invest in more broadly coordinated approaches. In the Arctic, where the changes are profound and fast, data gathering is often logistically and technically challenging, expensive, and thus inherently sparse, making better integration of field deployed sensor systems and remote sensing data especially desirable. The challenge, therefore, is to identify science-based integration opportunities that enhance each agency's effectiveness in meeting polar observing objectives at no extra cost. An overview of current agency and organization roles and functions are listed here:

- **National Science Foundation - Observations for Research:** The NSF supported Arctic Observing Network (AON) is fundamentally driven by current and ongoing science needs. NSF's mission is the support of basic research, mostly in form of PI-driven individual research projects, and to develop system analysis and coupled modeling tools to explore key processes. NSF-supported science can also contribute to the optimal design of observational networks. Moreover, NSF increasingly recognizes that the traditional boundaries between fundamental and applied research are becoming increasingly porous and obsolete. Nevertheless, NSF's core mission is not consistent with sustaining an operational network.

- **Mission-agencies - Observations for Operations:** Mission agencies have operational needs and, therefore, require observations to manage resources and ensure safety of life and property and efficiency of information flow. They make investments in fundamental science but primarily focus on operational capacity or effectiveness.

- **Other stakeholders - Observations for real-time decisions and long-term planning:** Decision-makers often draw from publically available baseline observational data and forecast products provided by mission agencies. Specific needs often make it necessary, however, for some organizations and stakeholders to augment that information with additional observations taken at specific times and with tightly identified specifications. Even more than for mission agencies, these observations serve often a very narrow need.

The key to better integrating an Arctic observing system is to design one that recognizes the various objectives and identifies synergies.

An Arctic Information and Services Framework as an organizing structure

The ability of Arctic human and natural systems to adapt to change depends on high quality observations and predictions of past, current and future conditions. Figure 1 shows the data and knowledge streams required to support the social systems and understand the environmental systems that provide an array of services now challenged by climate change. There is often overlap in the types of data collected by researchers and operational entities. What differs are the ways in which the datasets are used. An information and services framework makes such common interests more obvious and, thus, facilitates coordination and collaboration. Beyond identifying the potential for shared responsibilities, an effective, integrated network adds value to the observations by:

- **Identifying common interests** at the level of basic observational data products and recognizing their over-arching societal importance as well as their importance for different missions and operations.

- **Coordinating between the agencies to delineate roles and responsibilities** thereby minimizing duplication.

- **Adding value to individual observations through a systems perspective,** designing a system that optimizes investments and returns value by embedding observations in a broader context of system-level understanding.

- **Developing a protocol for updating the sustained observation network.** New types of measurements and technologies often emerge from cutting-edge research. Still lacking, however, is an effective process for transferring the most valuable observational methods into the sustained network. The Interagency Arctic Research Policy Committee's Collaboration Teams, in collaboration with SEARCH and others in the non-Federal research community, is best positioned to facilitate making new observing methods operational.

- **Data standards for achieving interoperability** to optimize data exchange and, ultimately, integration. Data must be made available in a coherent fashion. The Earth System Grid is a standard for climate modeling research and might be employed in an Arctic observing network in close collaboration with the Advanced Cooperative Arctic Data and Information Service (ACADIS) and other agency climate related observation data portals. But most importantly, a successful discussion of an Arctic Observing System will have to find a good home for ACADIS or its successor.

Prioritizing and Implementing Key Elements of an Integrated, Interagency Arctic Observing System

We see collaboration between IARPC, SEARCH, and NSF AON with guidance from the President's Arctic Executive Steering Committee, as a key element in taking four critical steps towards a more efficient, robust, and integrated Arctic observing system. Specifically, such a collaboration would sequentially

- agree on a framework (e.g., ecological services, societal benefit areas, or some other) for assessing Arctic observing priorities,
- use that framework to iteratively assess priorities,
- coordinate Arctic observing efforts with international initiatives under the auspices of International Arctic Science Committee (IASC) and/or the Arctic Council through the Sustaining Arctic Observing Networks (SAON) process, and
- implement priority observations through a U.S. Interagency Arctic Observing System (IAOS).

At present, some pieces of a broader IAOS that draw upon an AON nucleus are in their early stages of implementation. Others are expected to develop in coming years, driven by information needs, e.g., in the context of resource development and protection of threatened species (Clement et al., 2013). Nevertheless, while an overarching, hierarchical approach for overall system design has been laid out in broad terms (ADI, 2012; Lee et al., 2015) and while methodology for parts of the network is mature enough to warrant application of approaches such as Observing System Simulation Experiments (OSSEs) to guide system design, much of the effort is still in the form of an opportunistic patchwork of activities.

We envision building on those initial efforts and drawing on concepts of services provided by the Arctic social-environmental system (Fig. 1a) to further the IAOS. Such services can be mapped onto agency missions and priorities; they also contribute to specific desired outcomes identified by different stakeholder groups in the context of responses to rapid Arctic change (Fig. 1b). At the same time, the system services framework provides a link to sustained observations carried out as part of research priorities identified by the scientific community, such as the collection of climate data records (Fig. 1b).

The benefits of this approach are its ability to provide an organizing framework for incremental prioritization, planning, and implementation of sustained observations while recognizing the diverse mandates of the agencies that must be involved. This broader concept emerged from consultations among the research community, agencies, the private sector and other entities as part of the AON Design and Implementation Task Force (ADI 2012; Lee et al. 2015) and the International Study of Arctic Change's Responding to Change Workshop (Murray et al. 2013). The Group on Earth Observations (GEO) prioritized observations based on societal benefit areas (SBA; GEO 2005) and used those priorities to inform the National Plan for Civil Earth Observations (OSTP 2014). Such an approach to prioritization may be more challenging to implement in the Arctic, where the breadth of activities, mandates and stakeholders is broader than in most other regions. IARPC and the Arctic Executive Steering Committee may be in the best position to designate such a coordinating function. Regardless of where such coordination takes place, it will require support beyond the currently available resources.

The schematics in Figs. 1 and 2 illustrate key aspects of a broader vision for an IAOS. Specific services provide organizing criteria for individual sets of observations that map onto agency missions. Arguably, part of the observing activities patchwork structure (Lee et al. 2015) results from the different motivations and organizing principles adopted by entities carrying out sustained observations. For example, the AON was based on disciplinary divisions (e.g., ocean and ice, atmosphere, terrestrial ecosystems, human dimensions) aimed at tracking changes in the state of physical, biological, and social system subcomponents (SEARCH 2005). Similarly, agency activities are often based on specific mission elements or infrastructure (National Aeronautics and Space Administration focuses on satellite remote sensing; Bureau of Ocean Energy Management focuses on marine environments in the context of resource development, etc.). IARPC Collaboration Teams are currently structured based on a number of different criteria, such as specific programs (Distributed Biological Observatory Collaboration Team), specific system components (Sea Ice Collaboration Team) or specific approaches (Arctic Observing Collaboration Team). GEO Social Benefit Areas, on the other hand, are removed from specific services and differentiated based on desirable outcomes (Fig. 1b).

Design and implementation of an IAOS will have to consider these different approaches, but we propose that the Arctic system services framework would provide the most effective structuring principle. Thus, relating specific agency mission elements to specific services can be fairly straightforward, as illustrated by the more detailed example of system services provided by Arctic sea ice and permafrost (Fig. 1). System services can serve as a link between broader research and operational observations and specific outcomes needed to respond to rapid change in the Arctic system. The concept outlined in Fig. 1 may help address a number of challenges currently faced by sustained Arctic observing efforts.

The framework sketched in Figures 1 and 2 illustrates a narrow subset of relevant services. Full-scale implementation will require a broader range of relevant services and functions, such as energy and resource development, environmental protection from pollution, national and environmental security, emergency response etc. In addition, the important role of the Arctic in a global context as a climate regulator, source of teleconnections with mid-latitude weather, and through the Greenland ice sheet and other ice caps and glaciers as a key factor in projected sea level rise will need to be taken into consideration and will require some restructuring of ongoing activities. An example would be the services derived from sea ice and permafrost, which can be related to a core set of well-defined variables to be tracked (Fig. 1).

Agency programs are motivated and constrained by their specific mandates. While missions themselves do not overlap, observations carried out in support of a specific mission may; drawing on a services approach would help identify synergies between different programs and consolidate observations without compromising the constraints and requirements associated with the tracking of a specific system service. One way to explore the efficacy of this approach would be to identify a specific service or set of services and charge a team (possibly under the auspices of the IARPC Arctic Observing Collaboration Team) to develop an implementation plan for required observations down to the tactical site level. NOAA’s mission and role in providing information and prediction across a range of scales may serve as a potential starting point for such an initial approach. At the same time, the important role of remote sensing data sets in establishing and tracking climate variables poses questions, e.g., about effective integration of data from surface-based sensor systems with remote sensing data sets. Here, NASA as well as overarching national and international efforts through GEO have an important role to play in the establishment of space-based observing systems.

It requires a concerted effort by all agencies – in the context of IARPC and the Arctic Executive Steering Committee – to address the urgencies and priorities previously identified and highlighted at the U.S. Department of State’s Conference on Global Leadership in the Arctic (GLACIER) in Anchorage in August 2015. The SEARCH program can serve as a conduit for the research community – both at the national and international level – to provide a broad perspective on rapid Arctic change and critical Arctic observing needs to inform the formalization of an IAOS through IARPC and ultimately the White House. An important next step would be to identify appropriate roles and responsibilities and agree on a plan of action for the next 12 months. This plan of action will also have to address actual research and development efforts that would underpin and support the broader approach outlined above. The Arctic Observing Summit in March 2016 provides an opportunity to calibrate the approach at the national level with international organizations. The Summit itself will specifically address better integration of sensor networks and remote sensing efforts into global programs, in particular those under the auspices of the Group on Earth Observations (GEO), World Meteorological Organization (WMO) and the World Climate Research Program (WCRP) as well as the European Union’s initiative on long-term observations through the Horizon 2020 program.

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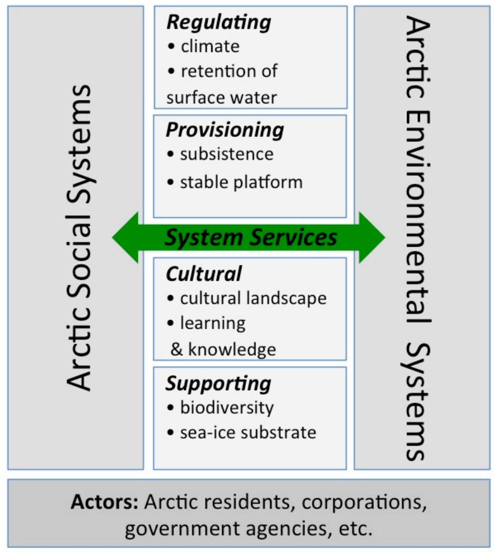

Fig. 1a: Schematic providing an example of services provided by Arctic social-environmental systems, here specifically for the example of terrestrial permafrost and sea ice.

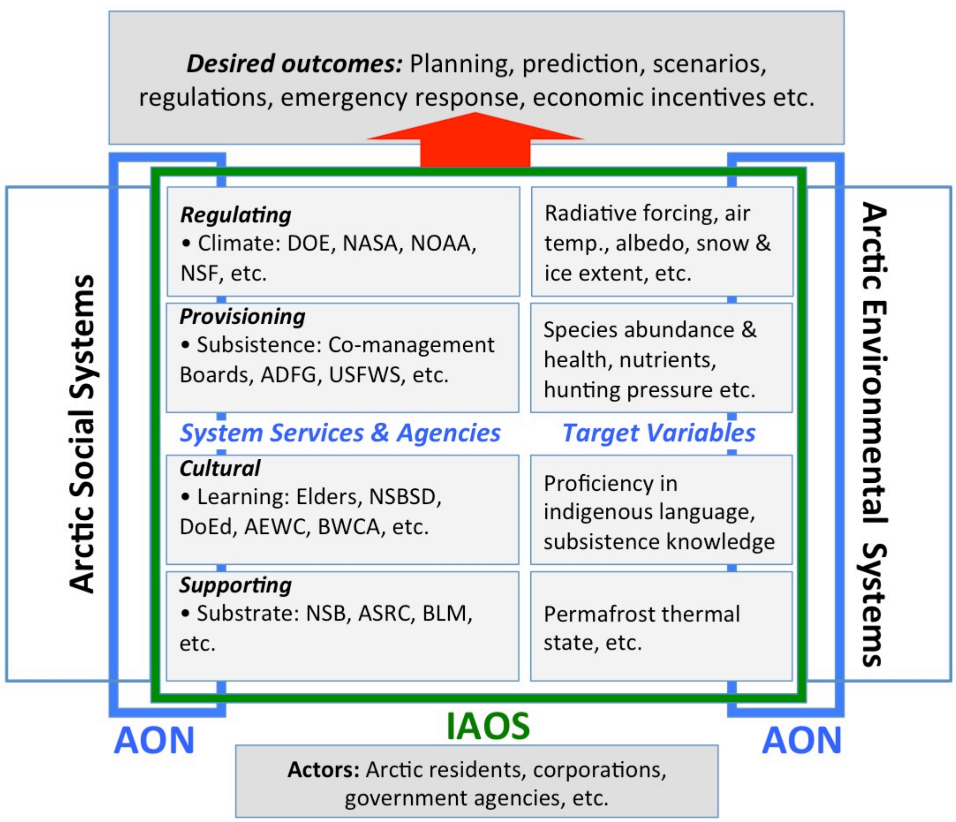

Fig. 1b: Schematic illustrating how example services shown in Fig. 1a map onto agency sustained observing activities and relate to specific target variables.

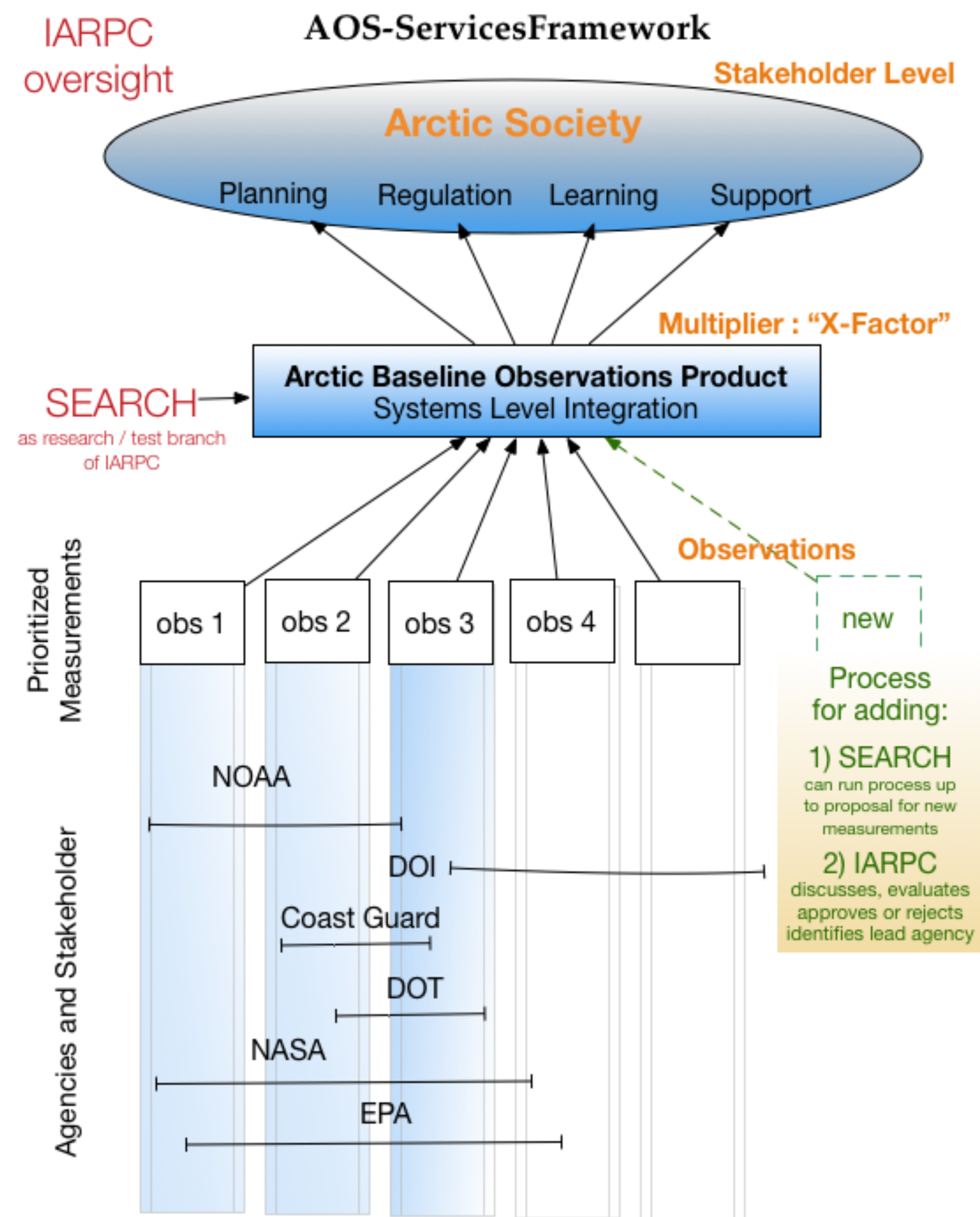

Figure 2. Schematic illustrating broader IAOS Framework.