Data Portals as Institutional Bridges: Connecting Scientific Observations to Stakeholder Needs in Sea Ice Social-Environmental Systems

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Abstract

This paper explores the linkages between scientific data production and related to sea ice loss in the Arctic. How can an arctic observing system prioritize data collection, facilitate its translation into usable information and deliver it in a manner that diverse interests can use it for adaptive governance in the sea ice system? The rapid decline of arctic summer sea ice is currently tracked and studied intensively but a comprehensive approach to address the changes is lacking. Scientific endeavors are more likely to respond to the needs of policymakers and stakeholders when those affected by change have the capacity to participate in decision-making. Currently, specific uses of sea ice are governed individually by a patchwork of institutions that have evolved independently over time; there is no interconnected suite of institutions or a single comprehensive process that governs the sea-ice system as a whole. Conflict arises when the objectives of one institution contradict or otherwise negatively affect another. High numbers of institutions found in the coastal zone (i.e. “density”) also imply a higher probability of policy debate over the uses of a particular ecosystem service or resource. Our work builds upon earlier research establishing the need to approach sea ice as a complex multi-jurisdictional geophysical-social-ecological system. We argue that in order to maximize data production, dissemination, and participatory capacity across stakeholders, scientific observations should be tied to institutional density and sea ice service. Secondly, information bridges across major institutional actors will facilitate creation and exchange of information and increase the availability and transparency. This can be in part achieved by mapping the institutional geography across the Arctic modeled on the NOAA Alaska region Environmental Response Management Application (Arctic ERMA) portal.

1. The Problem: Systems, Interests, and Science

The Arctic Ocean’s rapid loss of sea ice is shifting a system with a long history of indigenous subsistence use that was once closed to all but a few vessels during a short summer window to a more open system with attributes of great appeal to many interests in society. In the last half a century, the rule sets governing the Arctic that are tied to the annual cycle of sea ice (e.g., those related to oil and gas development or protected species) have grown more dense as the range of activities in Arctic has expanded. In parallel, Arctic Ocean regional interests have developed that represent a powerful set of actors with strong state, national and international lobbies to promote stability or change in governing institutions. For example, the number of whales that can be harvested using the ice as a platform, how the presence of ice affects oil and gas exploration, the quality of snow and sea ice that can serve as a polar bear or seal habitat, or the thickness and roughness of ice to support travel, subsistence hunting, and industrial activities are all linked to sets of rules governing human activity. In each case, governmental, indigenous rights, environmental, and other interest groups pursue their goals in relation to these rules.

Here, we briefly outline how such rule sets ("institutions" in the context of policy studies) may help in the design and prioritization of sustained observing programs. Policy- or decision-relevant research, largely funded by taxpayers, requires careful consideration of what to measure where and when in order to best benefit society as a whole. This challenge leads to a concern of balancing the information needs of different Arctic stakeholders. ***Given this problem context how can an arctic observing system prioritize data collection, facilitate its translation into usable information and deliver it across diverse interests to promote opportunities for adaptive governance in the sea ice system?***

Scholarly literature indicates that scientific endeavors are more likely to respond to the needs of policymakers and stakeholders when those affected by change have the capacity to participate in decision-making. Research indicates adaptive governance functions best when diverse networks of actors are involved to bring topic area or scale-specific knowledge to bear on conservation dilemmas and set the stage for a comprehensive approach focused on learning (Folke et al. 2005, Webster 2009, Brunner and Lynch 2010). In short, as stakeholders pursue their interests in the institutional milieu most familiar to them they will gather information. This learning can be facilitated, and thus the policymaking environment enriched through *information bridges* that can overcome institutional fragmentation (Sarker et al. 2008) to better connect scientific production of data to diverse stakeholders in meaningful ways.

While we focus on Alaska sea-ice management regimes in this case study, we also address trans-jurisdictional and global concerns. Building on three elements of the sea ice system in the Alaska region, we arrive at broader conclusions relevant for sustained observations at the pan-Arctic level. First, we explain why the nature of sea ice services requires cross-scale observations and data delivery channels. Second, to determine where and what kind of observations are of greatest societal interest we explain the institutional geography tied to its services. The capacity of society to obtain and use data related to government decision-making must be considered in order to provide varied stakeholders with information usable for debate and planning of resource management. By tying observations to institutional priorities the information produced is more likely to be taken-up by interested parties across sectors. Third, in order to ensure such a use of information within the competitive arena of democratic politics, we propose information bridges across formal institutions that prevent information from being "siloed" and potentially used in a hegemonic fashion to produce policy. Our case study examines the potential of a decision-support environment used in the United States, the Arctic Environmental Response Management Application (Arctic ERMA, Merten 2013) hosted by the National Oceanic and Atmospheric Administration's (NOAA) Office of Response and Restoration (ORR).

2. Background

2.1. The Sea Ice System and its Services

Sea-ice retreat is one aspect of a broader suite of transformations in the North comprising climate and large-scale socio-economic change that are fundamentally altering the ecosystems upon which human livelihoods depend (Chapin et al. 2006). The Arctic, and in particular its sea-ice cover, is both amplifier and driver of global climate change (Alley 1995, Serreze et al. 2007). Beginning in 2007, summer sea-ice extent has experienced a major decline compared to diminishing ice extent trends observed prior (Serreze and Stroeve 2015). With projections indicating a near-complete loss of Arctic summer sea ice by the late 2030s, the impacts of such changes on coastal communities, ecosystems, marine shipping and Arctic security have received increasing attention (Meier et al. 2014). While the loss of Arctic summer sea ice has clearly been documented as a concern of many governments, comprehensive plans to address the problem are only in their early stages. There are not yet mechanisms in place to consider the diverse and interdependent changes across scales; sea ice prediction and data delivery remains a challenge at the local scales (e.g., coastal villages). Additionally, while more data is required to ascertain long-term trends, the need to effectively manage new and existing data and design and optimize observing systems remains.

2.2. Institutions and Interests

Currently, specific uses of sea ice are governed individually by a patchwork of institutions that have evolved independently over time; there is no interconnected suite of institutions or a single comprehensive institution that governs the sea-ice system as a whole. Drawing on interdisciplinary research related to sustainability science, Eicken et al. (2009) have proposed the concept of Sea Ice System Services (SISS) to comprehensively address the hazards and opportunities presented by diminishing sea ice. By considering sea ice as a productive system, not simply a geophysical feature, one can recognize a suite of services or benefits that humans gain and identify the information needs relevant for different sea-ice users. We view sea-ice institutions as rule sets designed to govern human behavior, specifically in the context of sea ice services. Examples would be laws and policies affecting ice-dependent marine mammal hunting or the rules of ship passage in arctic waters.

Institutions matter because they create and channel power in social-environmental systems (Lovecraft 2008, Robards and Lovecraft 2010). Institutional linkages between the resources and places governed and the actors subject to governance create avenues of influence for particular actors over policy implementation (Selin and DeVeer 2003). In modeling different institutional types Chapin et al. (2006) categorize institutions into four major categories of human use of or benefit from environmental resources: resource harvest, resource conservation, hazard reduction, and externality producing (see Table 1 for examples from our case study). Conflict arises when the objectives of one institution contradict or otherwise negatively affect another.

3. Institutional Density as a Guide to Implementation of Sustained Observations: An Alaska Case Study

Rules tied to the sea ice system have grown alongside social priorities (e.g. conservation, harvest of subsistence foods), temporally based concerns (e.g. human overharvesting of marine mammals in the 19th and early 20th century, economic boom or bust), and the "institutional thickening" of the organization and cultures of administrative bureaucracies whose design is historically neither interdependent nor collaborative (Meek 2011). We use the phrase "institutional density" building on this three-fold phenomenon as a measure of the number of institutions associated with a particular location but which may focus on different attributes of the system. The Alaska coastline and nearshore waters have high institutional density because there are many sets of rules targeting different attributes of this particular social-environmental system, with some examples applicable in our sea-ice case study listed in Table 1.

A measure of the distribution and spatial density of a subset of these institutions is shown in Fig. 1 in relation to sustained observing program measurement sites. The map shows the spatial extent over which specific rule sets apply, such as the extent of U.S. territorial waters or the designation of critical habitat for protected species. Other categories plotted in the map are related to information needs or interests derived from specific institutions. These include the distribution density of walrus, the location of polar dens or the subsistence use areas by coastal communities all shown in the map. Similarly, sites for specific sustained observations plotted in the map are in part related to information needs or regulatory requirements derived from some of the same institutions. These elements of the map shown in Fig. 1 represent a subset of the full-scale institutional analysis carried out by Lovecraft et al. (2013) and summarized in Table 1.

The density of such institutions (or relevant proxies) reflects the breadth and urgency of data and information needs because this density to some extent reflects society's response to pressing issues in a complex local context impacted by arctic change. High institutional densities also imply a higher probability of conflicting uses of a particular service or resource. At present, it is not yet possible to simply map the number of institutional regimes per unit area relevant for sea-ice use for a specific location to determine institutional density. While such efforts are part of the recommendations of this white paper, currently a map such as shown in Fig. 1 provides insight into spatial patterns, including key sea ice system services such as the distribution of sea ice as a platform for marine mammals and hunters and as a potential hazard for maritime activities. Figure 1 reflects the challenge to provide relevant data to actors across a range of different sectors in a region with major impacts as a result of rapid environmental change. The distribution of walrus densities in the map illustrates this issue with a major feeding area near the center of the map now less accessible due to lack of sea ice in the summer. This has forced walrus to congregate in large numbers on shore to rest (coastal location in southwestern part of map) with migration between these two sites during the summer. The distribution of measurement sites does not reflect these patterns, nor does it seem to fully reflect the distribution and density of associated institutions.

Analysis of such patterns can provide important guidance for and help prioritize sustained observations. For example, note that despite some of the highest institutional densities occurring in coastal areas where uses of the environment by hunters and villagers, industry and key protected species overlap, these regions do not exhibit corresponding densities of sustained observations. Instead, many of the sustained observations are clustered around lease areas and drill sites in the western and eastern parts of the map, where institutional density is also high due to regulatory requirements and industry standards. However, as illustrated by information derived from traditional knowledge and surface based measurements, prevailing patterns of currents and ice movement provide a direct link between offshore regions and coastal areas. In part of the region some of the oceanographic transect lines seem to reflect this circumstance. A key challenge throughout the Arctic is reduction in ice extent that puts potential stress on ice-associated organisms who utilize ice as an increasingly scarce resource, with Fig. 2 presenting an example for walrus. Such changes in ice conditions need to be related to associated institutions and the types of information storehouses and geospatial tools exemplified by NOAA Arctic ERMA environment shown here can also serve as resources to examine institutional mismatches.

Because institutions reflect and attract interests, an inventory and spatial mapping as shown in Table 1 and Figure 1 will increase the relevance of data collection and information gathering of interest to stakeholders. Nevertheless, we must still address the problem of translation from "policy elites" and "technocrats" to laypersons. Using the model of Chapin et al. (2006), Table 1 thus categorizes the major institutions governing use or protection of sea ice services with a focus on Arctic Alaska as a region that represents most if not all of the relevant interests and uses prevalent throughout the pan-Arctic. As noted earlier, the relative needs across the institutions for data are narrow but the span of interests is broad. To avoid duplication, maximize accuracy, and minimize costs, a better method of setting data priorities and sharing results must be developed.

4. Translating Observations into Stakeholder Information through Information Bridges: The Potential of Arctic ERMA

Mostly, decision-makers require information and not merely raw data sets to act on. The ability to extract information from a given data set can vary substantially among stakeholders. Hence, the acquisition and dissemination of data and information related to the sea ice system plays a vital role in the adaptive capacity of people affected by existing rule sets to both enforce current standards or change management to meet stakeholder needs. We separate the concepts with *data* referring to raw scientific observations and *information* as translated findings based on data sets (Zins 2007). This issue is not merely of semantic interest since any environmental observing system aiming to provide information relevant to decision-makers needs to explore effective ways in achieving this goal. A major challenge is the fact that typically scientific data acquisition is driven by the need to test a set of postulates in the context of an overarching scientific problem or question. Data collected under this premise may not easily lend themselves to interpretation and evaluation in the context of applied problems. Rather, obtaining data and more importantly information derived from such data that responds to decision-maker information needs requires a substantial engagement by both academia and stakeholders and needs to be part of an interactive process (van Kerkhoff and Lebel 2006). Information Bridges – with Arctic ERMA serving as an *ad hoc* example – can play important roles in this context.

As a first step, an objective survey and prioritization of information needs must occur. We argue that this goal is achieved through analysis of the institutions governing resource uses or ecosystem services. For the case of sea ice services the results of research into the applicable rules and regulations for northern Alaska listed in Table 1 provide an indication of the scope of information needs. Moreover, through the link to specific ice services, institutions typically specify the type of information that is required for the regulation or management of a given service. Such information is mostly one or several steps removed from observable data and comes with requirements for the sampling design and data processing to meet the information need. For example, resource conservation for ice-associated marine mammals is closely linked to the habitat qualities of drifting and shorefast ice. Deriving suitable indices or parameters as measures of habitat quality from raw data is not straightforward and requires observation of a series of variables, such as ice thickness, morphology, and seasonality along with snow depth and the presence of sea-ice microbial communities (Table 1). Prioritization of such observations can be achieved by the institutions themselves, as the rules and regulations shown in Table 1 reflect the stakeholder concerns best represented in the governing system to date. A major challenge, nonetheless, is the compilation of an exhaustive inventory of applicable institutions across scales. Here, the scientific community and different stakeholder groups and decision-makers are located on either side of a divide that needs to be bridged. Mostly this is due to a lack of awareness or understanding of the frameworks that govern utilization of resources or services on the one hand, and misconceptions about the way scientific research operates on the other hand.

A key point is the fact that institutional density does not imply the presence of communication channels between institutions or between scientific data collection and institutions. Due to the sectoral management and regulation approaches, institutional regimes and associated data collection effort are often fragmented, as illustrated in parts of Figure 1 and Table 1. Information bridges in the form of structures that link stakeholder or actor structures and reduce duplicity can play an important role in observing system design. Such bridging organizations can also better identify long-term data needs than any single agency or management network.

In this context Arctic ERMA may serve as an illustrative example of the type of entity and associated tools that can evolve into information bridges. As stated on the relevant website, "ERMA integrates and synthesizes various real-time and static datasets into a single interactive map, thus provides fast visualization of the situation and improves communication and coordination among responders and environmental stakeholders" (ERMA 2014). This application is as close as we currently get to an interactive collection of rule sets that can be used by competing interests to evaluate their own priorities, data gaps, and the location of their goals in an institutionally crowded region. The key driver for implementing Arctic ERMA is its proven value in the context of emergency response planning with a focus on system services related to hazards or threatened assets, which includes not only the hazard-reducing institutions highlighted in Table 1, but all other relevant categories (resource conservation and harvesting, externalities producing) as well. What is missing in the context of the ERMA interface as currently implemented is an effective key, or legend, to categorize the system services clearly. It is not that ERMA is flawed, it is that it has great potential.

Moreover, while ERMA has been designed with emergency responders and environmental resource managers in mind, similar futures thinking – considering the future carefully in case of hazard and disaster scenarios – can be very useful to a wide range of interests and thinking about the future need not be limited to preparing for crisis. Those planning scientific observations, industry plans for development, Indigenous concerns related to activity near and offshore, conservationists, and communities can all benefit from a system that can plot major institutional regimes in geographic space. The key challenge is to allow for a system such as Arctic ERMA to serve both its core functions and grow into or spawn a tool and associated information bridge that helps address the broader mandate implicit in the approach to observing system design and prioritization proposed here. Some aspects are readily addressed, in particular as they relate to core aspects of Arctic ERMA's objectives & mission. For example, datasets and information reflecting Traditional Knowledge or other proprietary information can be made accessible in formats or altered forms that come with a permission to share or with access limited to specific decision-makers or researchers. The information shown in Figure 1 on current and ice movement patterns was obtained through such a process (Johnson et al. 2014).

A more challenging issue is the availability of relevant data sets on institutions and ongoing observations. In regards to the latter, Arctic ERMA draws on resources by the Alaska Ocean Observing System (AOOS), but the former can be more challenging to compile. What incentives are there for self-interested actors to facilitate the planning of data production and sharing of results required for an information bridge? Goldman et al. (2007) discuss the benefits and drawbacks of voluntary cooperation in ecosystem service conservation. In their work they seek to encourage landscape-scale coordination across local to global production of farm services and move away from farms as "independent units." In a similar fashion the sea ice system actors tend to function as independent units tied to one or more services.

Goldman and co-authors propose three major incentives; we retain their original labels but have altered their function to relate to data and information design rather than conservation: (1) *cooperation bonuses* where system users are rewarded for individual activities that facilitate broader scale data collection and dissemination, such as that implemented in the context of AOOS or the Arctic ERMA mapserver, (2) *competitive design incentives* tied to cooperation that would reward individual or group proposals of new ways to share data (such as through cooperative proposals for exploratory research), and (3) *ecosystem service districts* that would use legal means to create data sets to be used at the system scale, possibly mandated by stipulations that are part of resource leasing agreements or through other means such as voluntary cooperation and sharing as in the case of an extant data sharing agreement between NOAA and Shell for Alaska Arctic waters. Arctic Council Working Groups, such as the Emergency Preparedness, Prevention and Response (EPPR) may play an important role in setting the stage for such national or international strategies.

5. Recommendations for the Design and Implementation of Sustained Observations and Coordinated Observing Systems

Drawing on the examples discussed above, we propose next steps and recommendations to help implement information bridges that can foster the use of institutional density as a criterion in guiding observing system design and implementation. This approach relates to a key goal of AOS 2016 Thematic Working Group #4 on Stakeholder and Actor Engagement, i.e., the call for contributions that discuss "capacity building or development of observing systems that can support community emergency response plans and adaptation". Specifically, we identify the following action items, with a focus on marine and coastal environments.

(1) Build pan-Arctic databases of institutions associated with Arctic system or ecosystem services relevant to actor and stakeholder activities (i.e., along the lines of examples given in Table 1 and Fig. 1). Arctic ERMA represents an ad hoc model of what such an approach might look like, but there are a number of efforts underway both within Arctic Council Working Groups, as part of regional assessments (e.g., Beaufort Sea Regional Environmental Assessment) or through initiatives such as the World Wildlife Fund's ArkGIS system (http://arkgis.org). The objective of this effort would be to provide the foundation for any type of evaluation of institutional geography. Ideally, such a resource would link to or tie into a database with up-to-date information on sustained observations. Efforts by the Arctic Council's Sustaining Arctic Observing Networks (SAON) Initiative to keep track of such programs at the national level are an important step in the right direction.
(2) As a first step in implementing recommendation #1, the focus could be on regions of particular interest or hotspots. This should not simply reflect ongoing activities, but also draw on future projections, such as those reviewed by the Arctic Council's Adaptation Actions for a Changing Arctic Project. One region of interest would be the Pacific Arctic sector that covers Russian, U.S. and Canadian waters with numerous international research programs (Lee et al. 2015).
(3) For a specific problem or subregion, a full-scale evaluation of institutional geography and its application in guiding observing system design and implementation would be an important case study and identify the efficacy of this approach. Drawing on the example of Arctic ERMA

(and referencing a white paper submitted to the AOS 2016 by Eicken et al.) the topic of community emergency prevention, preparedness and response lends itself readily for such an effort. The mandate for such an EPPR framework is clear and sufficiently focused, while at the same time the benefits of sustained observations in providing background information for situational awareness are recognized. Moreover, by default such an effort would focus on areas of higher vulnerability and exposure, such as coastal regions (see discussion above) and areas of high maritime activity. Such an effort could also link to recommendations and action items emerging from two other AOS 2016 Working Groups, #6 Traditional Knowledge Interface, where the role of local and indigenous experts in identifying relevant institutions and informal rule systems can be explored, and #3 Private-Public Partnerships with a focus on platforms of opportunity which by default are active in regions experiencing higher levels of activity and associated higher institutional density.

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Type of institution	Sea ice system service	Institution	Monitoring variable
Resource conservation	E.g., Shoreline protection	National Environmental Policy Act	Shorefast ice extent and duration
Resource harvesting	E.g., Bowhead whales	Convention for the regulation of whaling	Distance, morphology and persistence of leads and polynyas
Hazard reduction	E.g., Sea ice as geological agent and coastal hazard	Trajectory of oil spill, encapsulation and biodegradation of oil	Distribution of ice biota
Ecological externality-producing	E.g., Platform for industrial activities	Outer Continental Shelf Lands Act	Extent, persistence, thickness, strength and morphology of pack and shorefast ice

Table 1. Examples of sea ice system service types (Lovecraft, Meek and Eicken, 2013), relevant institutions and suggested monitoring variables.

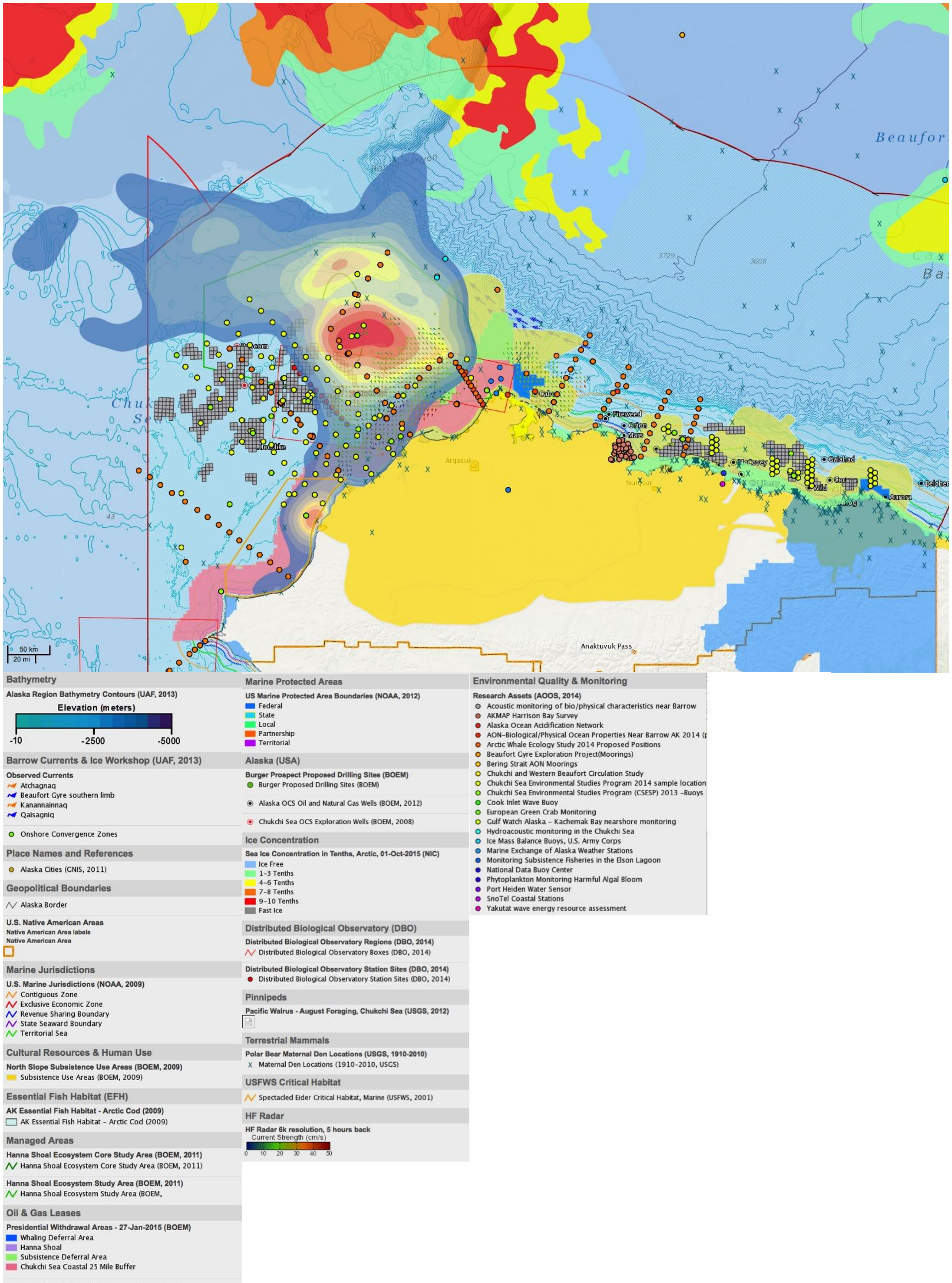

Figure 1: Map of key institutions and other relevant environmental data and sustained observations in the Alaska region, as obtained from Arctic ERMA.

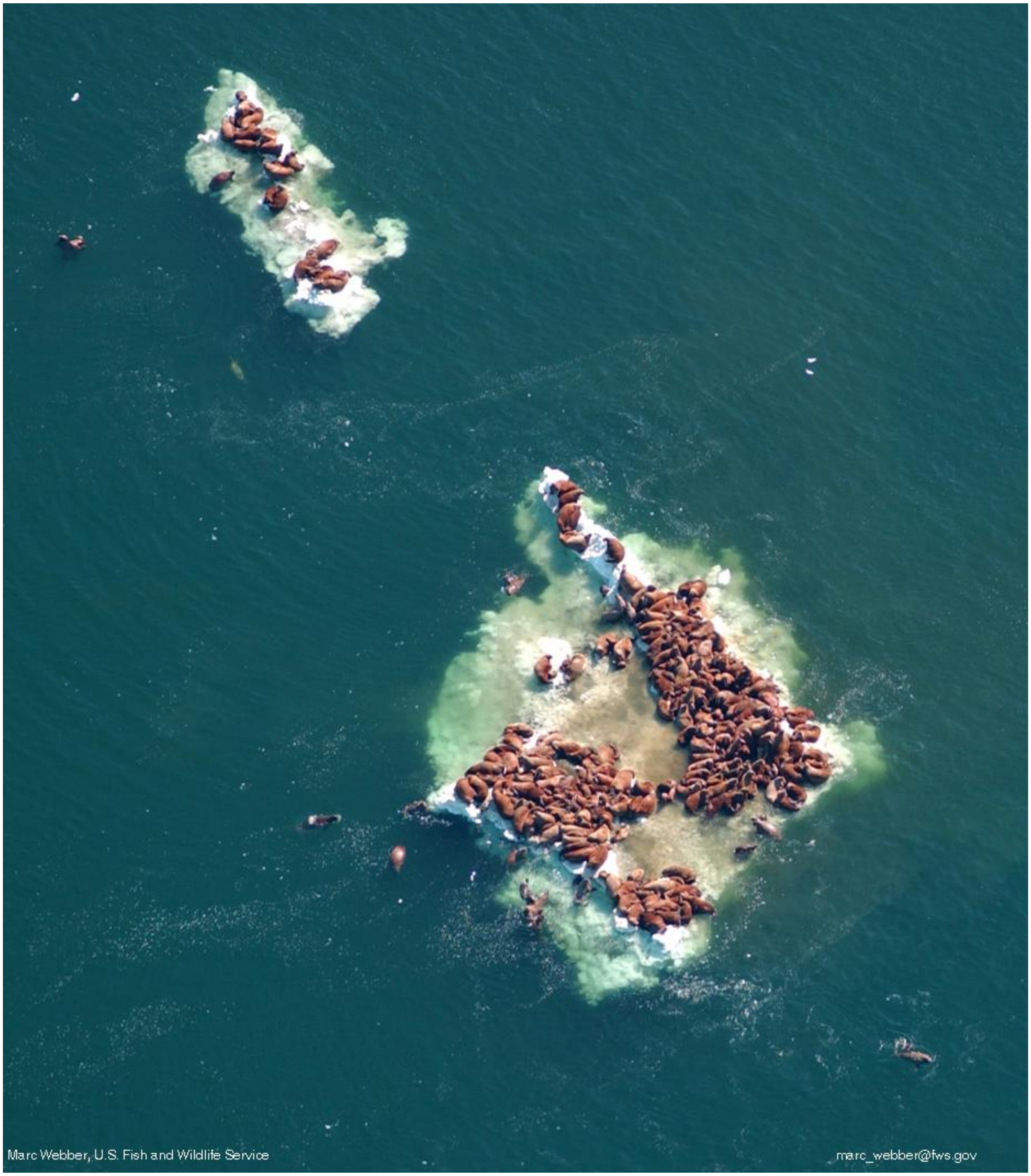

Figure 2: Aerial photograph of walrus congregating on an ice floe in the Chukchi Sea, illustrating ice use and crowding of animals into a limited area in late stages of ice melt (photo taken by Marc Webber, U.S. Fish and Wildlife Service, Anchorage, AK).