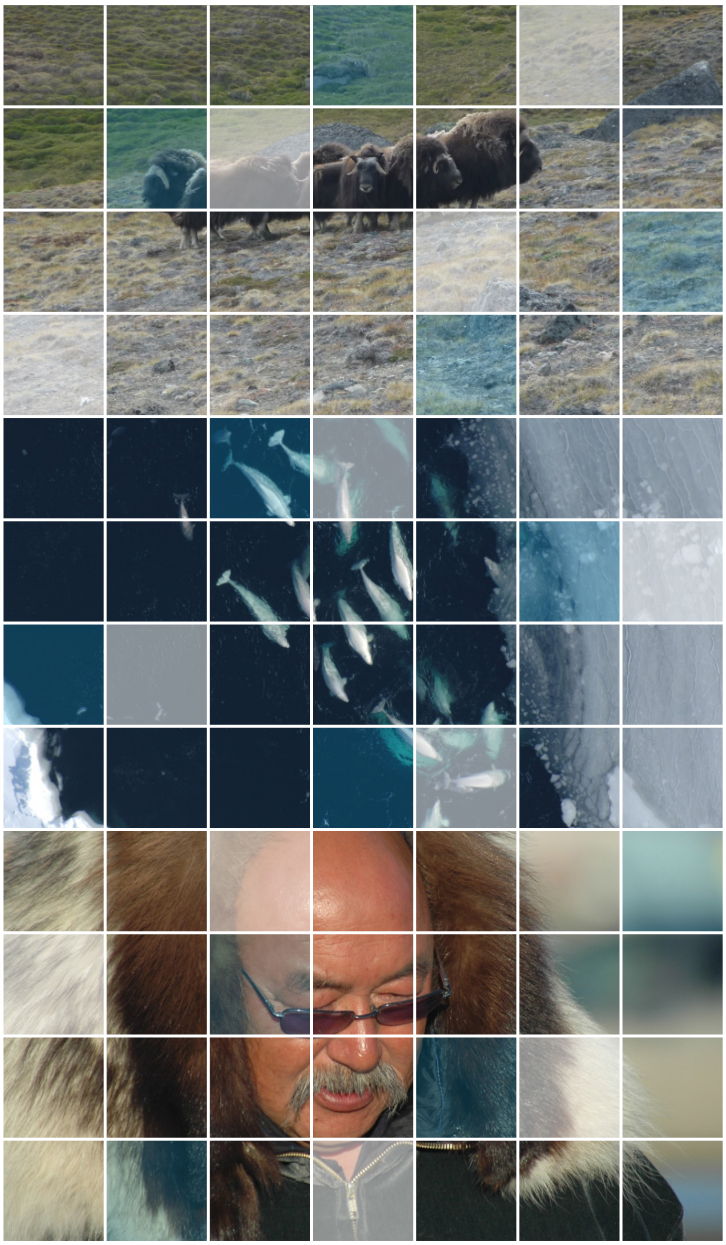
U.S. Arctic Observing Network Coordination Workshop Report

20 – 22 March 2012 ■ Anchorage, Alaska, USA



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We sincerely thank all of the workshop participants for their time, ideas, and expertise.

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Executive Summary

photo: Ute Kaden

The Arctic is undergoing tremendous change. Arctic landscapes are greening, permafrost is thawing, ice sheets are melting, sea ice is thinning and retreating. These changes are impacting ecosystems and human activities. The U.S. Interagency Study of Environmental Arctic Change (SEARCH) is a collaborative scientific program that brings together academic and government agency scientists as well as a broad representation of stakeholders in the Arctic to prioritize, plan, conduct, and synthesize research on arctic environmental change.

The Arctic Observing Network (AON) is a key piece of the U.S. SEARCH effort. The Arctic Observing Network Coordination Workshop, held in Anchorage, Alaska, in March 2012, brought together researchers, agency representatives, and stakeholders involved with long-term observations of arctic change to:

- Develop a shared vision of a successful AON
- Identify steps needed to accomplish that vision
- Identify specific tasks and timelines for activities associated with these steps
- Identify "showcase" projects for observing activities, with recommendations for short-term implementation (5 years or less), including designated task leads

The workshop was funded primarily by the National Science Foundation (NSF) Arctic Sciences Division with co-sponsorship from the North Slope Science Initiative (NSSI), the Arctic Landscape Conservation Cooperative (ALCC), the North Pacific Research Board (NPRB), the Office of Naval Research (ONR), and the Alaska Ocean Observing System (AOOS). The workshop was organized by the Arctic Research Consortium of the U.S. (ARCUS) and brought together 104 participants with broad representation from arctic scientists; local, state, and federal agencies; decision makers; data managers; and other stakeholders—with an equal mix of university researchers and agency representatives (Workshop Participants – Appendix 5).

The workshop consisted of plenary sessions, intensive breakout sessions, and a poster session (Workshop Agenda – Appendix 4). The plenary session presentations covered the observational needs of stakeholders, agencies, decision makers, and modelers, as well as the status of SEARCH science goals.

Workshop participants recommended showcase projects, data management plans, and next steps to improve coordination of long-term arctic observations.

Showcase Projects

The main focus of discussions was to develop showcase projects that would demonstrate effective approaches towards interagency collaboration for the AON. Criteria for showcase projects:

- An advanced level of readiness
- A high potential for cross-agency collaboration and support

- Balance between the research interests of the scientific community and the information needs of agencies and stakeholders
- Potential to use resulting datasets and information products for both fundamental and applied research

The breakout groups developed 11 showcase projects spanning disciplinary perspectives; these showcase projects are recommended for implementation through agency coordination and/or funding:

1. From Observations to Management: Science to Inform Decisions Regarding Offshore Oil and Gas Activities in the Chukchi Sea
2. A Distributed Environmental Observatory for Terrestrial Change Detection
3. What are the Causes and Consequences of the Greening of the Arctic?
4. The Distributed Biological Observatory
5. Multidisciplinary Drifting Observatory for the Study of Arctic Climate – MOSAiC
6. Community-based Observation Network for Adaptation and Security
7. Ocean Observations to Improve Sea Ice Forecasting
8. Long-term Sea Level Measurements Along the Alaskan Chukchi and Beaufort Coasts
9. Arctic Ocean Freshwater and Heat Observing System
10. Utilizing the State of the Existing Knowledge to Guide Infrastructure Development
11. Connecting Arctic Communities with One Another and with Scientists: Building a Community-based Observation Network

Summaries and in-depth descriptions of the showcase projects are given in Section III and Appendix 1, respectively.

Data Management

A data management group identified an important first step as the development and implementation of an Arctic Observations Data Policy; paramount is the exchange of data among all providers. Recommendations to foster the discovery of and access to a rich AON dataset are:

- Provide an inventory of data archives and access points
- Activate an interagency data collaboration team or forum to discuss an improved process for sharing arctic data
- Implement metadata exchange standards and protocols across the various archives
- Identify the most used or highest priority AON datasets and the science or management questions answered with those data

The showcase projects will foster the use of resulting datasets and information products, as well as demonstrate improved data and metadata collection, archiving, and sharing.

Next Steps

To move the workshop recommendations forward, the workshop Organizing Committee recommends that the SEARCH Observing Change Panel, under the guidance of the SEARCH Science Steering Committee, work with the showcase project contacts and the data management group to follow up with relevant funding agencies. The Organizing Committee also suggests that the workshop recommendations be formally presented to the Interagency Arctic Research Policy Committee (IARPC), for implementation where the workshop recommendations can contribute to the IARPC 5-year goals.

Other implementation activities may take the form of topical working groups created to focus on specific aspects of the recommendations and/or a combined focus on a flagship site or regional study that integrates more than one of the showcase projects and data management plans. These recommendations should also be considered by the International Study of Arctic Change (ISAC) during planning for the spring 2013 Arctic Observing Summit (AOS) in Vancouver, B.C., Canada (**www.arcticchange.org/arctic-observing-summit-2013/**) in concert with the recommendations from the report ***Designing, Optimizing, and Implementing an Arctic Observing Network*** (2012).

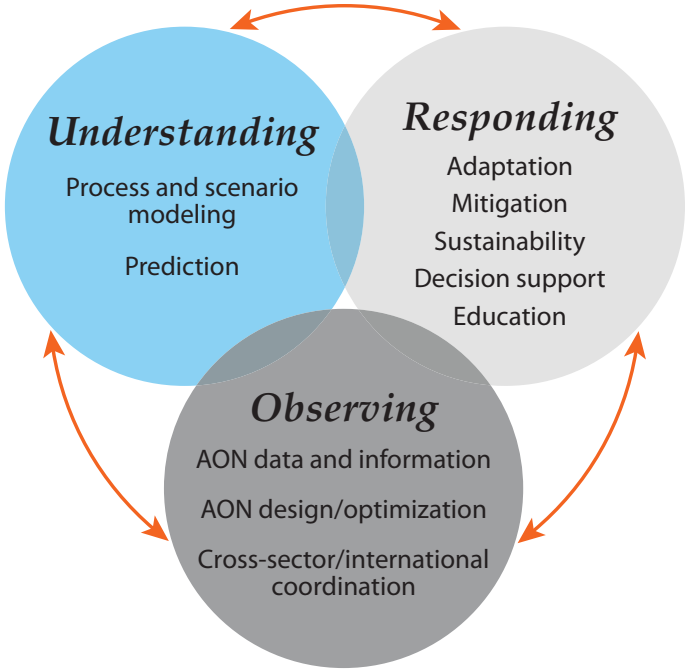
Participants achieved the workshop goals and developed a series of actionable and concrete recommendations. Because of the diversity of participants, a challenge in workshop discussions was the 'cultural' differences between academic scientists and agency personnel, for example, differences in vocabulary and scientific goals. This challenge should be recognized and addressed in future AON activities.

The Organizing Committee thanks the workshop participants' efforts and the sponsors' support, and looks forward to implementation of the workshop recommendations and a well-coordinated and successful Arctic Observing Network.

I. Introduction

The Arctic Observing Network (AON) is a key piece of the U.S. Interagency Study of Environmental Arctic Change (SEARCH; *National Research Council*, 2006). SEARCH (**www.arcus.org/search**) is a collaborative scientific program that brings together academic and government agency scientists as well as stakeholder representatives to prioritize, plan, conduct, and synthesize research focused on arctic environmental change. It is guided by a Science Steering Committee and several panels and working groups with broad representation of the research community. At a time of rapid arctic change, the SEARCH program is itself a response by the arctic research community to these major transformations under way in the North. The origins of SEARCH lie with the realization by key segments of the arctic research community that major changes are under way in the arctic ocean–ice–atmosphere system. This led to the development of a broadly interdisciplinary, cross-sector science plan (*Morison et al.*, 2001). In 2005, a community workshop resulted in the formulation of an implementation document (*SEARCH*, 2005), which in turn informed the plans for ramping up a key component of the program during the International Polar Year (IPY) 2007–2008.

SEARCH is conceived as an interagency program, led by the Science Steering Committee with an Interagency Program Management Committee focused on the technical details of supporting such interagency efforts. The program takes a tri-partite approach to arctic change, with activities grouped into Observing, Understanding, and Responding to Change categories. The activities associated with each of these are overseen by three topical panels and working groups addressing data issues or important topics deserving attention. Of these three, Observing Change has made the greatest advances, with the U.S. AON and its more than 50 component projects constituting the core effort. An overview of activities related to the Understanding Change component of SEARCH is provided by a recent report by the Understanding Arctic Change Task Force (*Elliott et al.*, 2010).



While many SEARCH activities developed natural ties to the Responding to Change theme, an explicit implementation of it has proven to be more challenging. Recently, however, an international workshop, organized by the International Study of Arctic Change (ISAC) with substantial contributions by SEARCH, has outlined a way forward and provided a framework to plan and coordinate Responding to Change activities (*Murray et al.*, 2012). The 2012 AON Coordination Workshop was designed explicitly to help achieve progress in linking observations of arctic change to improved understanding and effective responses, while at the same time developing and strengthening interagency (and stakeholder) ties for these activities.

The origins of the AON lie with the IPY when the National Science Foundation (NSF), based on the recommendations of the SEARCH implementation workshop report (*SEARCH*, 2005), funded a broad portfolio of AON projects, integrating existing long-term observatory projects that originated with the early phase of SEARCH. One of the defining aspects of the AON is the adherence to the ***SEARCH Data Policy*** (2007), developed by the SEARCH Data Working Group, with two key tenets:

- AON data are considered SEARCH community data with free and open access as quickly as possible after collection and quality control; timely data availability is part of the NSF AON proposal review criteria
- ***SEARCH Data Policy*** (2007) guidelines with respect to preparation and submission of data, metadata, and documentation should be followed, with data submitted to an appropriate data archive

These guidelines and recognition by lead investigators and NSF of the value of this open access approach for AON datasets have opened a door to much broader and more direct collaboration with agencies and stakeholders, preparing the ground for meetings such as the AON Coordination Workshop. At the same time, the (Advanced) Cooperative Arctic Data and Information Service (ACADIS) provides a mecha-

nism and platform to archive and access AON datasets. Continued efforts must be made to publicize to all stakeholders the availability of these datasets.

An overview of the status of the AON and its development and future directions at the end of the IPY is summarized in the ***AON Program Status Report*** (2010) based on a workshop held in December 2009 with leadership by the SEARCH Observing Change Panel. Recommendations emerged from that workshop that are relevant to the workshop reported here:

- Optimizing an AON capable of sustained, decadal-scale observing will require improved coordination between the agencies that support arctic observations
- AON must develop effective approaches to partner with industry and a broad range of federal, state, and local agencies to sustain long-term observing activities
- Standardization and coordination of measurements need to be advanced and improved
- An international collaborative framework for long-term arctic observations needs to be created

An AON Design and Implementation Task Force (**www.arcus.org/search/aon/adi**) is now providing guidance on how to achieve a well-designed, effective, and robust arctic observing system. This effort culminated in a final report, ***Designing, Optimizing, and Implementing an Arctic Observing Network*** (2012), with recommendations for the next steps in optimizing, coordinating, and enhancing the existing components of an international arctic environmental observing system, with emphasis on the U.S. AON.

The 2012 AON Coordination Workshop brought together researchers, representatives from the relevant agencies, and stakeholders involved with long-term observations of arctic change to work towards the following goals:

- Develop a shared vision of a successful AON
- Identify steps needed to accomplish that vision
- Identify specific tasks and timelines for activities associated with these steps
- Identify showcase projects for observing activities, with recommendations for short-term (5 years or less) implementation, including designated task leads

To keep the scope of the meeting manageable and achieve progress, the organizing committee, broadly representative of the workshop participants and interests, focused on the most urgent, relevant, and mature themes as identified in a range of agency documents and the SEARCH 5-year goals and objectives (**www.arcus.org/search/goals**). Focus themes were improved understanding and prediction of (1) sea ice changes and their consequences for ecosystems, human activities, and climate, and (2) the consequences of the loss and warming of near-surface permafrost on arctic and global systems. Both lend themselves most readily to cross-sector, cross-agency collaboration.

The purpose of the AON Coordination Workshop builds on the premise that the momentum generated by the ramping-up of NSF-supported AON projects during IPY now allows the broader research community, agencies, and stakeholders to identify specific, incremental steps of how to best achieve the original vision of an Interagency AON (IAON), as laid out by the Interagency Arctic Research Policy Committee (*IARPC*, 2007). Progress towards more coordinated networked efforts can occur along several pathways. Three themes or topical areas are of particular interest:

1. Balance and prioritization, in particular with respect to scientific research interests and societal, agency, or stakeholder information needs
2. Integration, e.g., through ingestion of AON data into models, partnering between community-based observations and academia, and through merging of in situ and remote sensing data
3. Coordination, such as through focusing on specific topics (e.g., ice-diminished Arctic Ocean, warming and thawing permafrost), methods-based prioritization (e.g., observations needed to improve climate models, community-based observations, etc.), local–national/regional–international scaling of activities, or information and data product-based coordination (e.g., through focused data portals)

Examples of how a focus on these three themes can help advance an improved, better coordinated network include the role of large-scale model improvements in driving observational programs, such as the U.S. Department of Energy's (DOE) Next Generation Ecosystem Experiments (NGEE) project or the priorities developed by the climate modeling community with respect to improved representation of sea ice (e.g., *Perovich et al.*, 2012). Such activities can also help with the prioritization of observations from a systems perspective. For example, SEARCH's Arctic Sea Ice Outlook (*Calder et al.*, 2011), an international synthesis effort focusing on improved seasonal prediction of the arctic ice cover, has helped constrain observing activities and was discussed in depth during the relevant breakout sessions. Finally, with respect to regional, national, and international coordination, the workshop provided a forum for location-specific discussions (such as the Barrow region breakout session) that cut across disciplines and domains and can then lead to further integration at the international level. The AON Coordination Workshop also provided an opportunity to discuss recommendations and plan for an international Arctic Observing Summit (AOS) under the auspices of ISAC and the Arctic Council's Sustaining Arctic Observing Networks (SAON) initiative.

II. Structure and Organization

photo: Robin Staup

The workshop was organized by plenary and breakout sessions (Workshop Agenda – Appendix 4). Part 1 of the plenary session began with the co-chairs of the organizing committee, John Payne and Don Perovich, describing workshop goals and expected outcomes. Talks by five speakers followed; each was asked to address broad, high-level topics to set the stage for the workshop. During Part 2 four speakers addressed specific SEARCH science goals in light of the question: "With the resources we have now, what are the greatest advances that could be made in observational data and products for use by scientists and stakeholders?"

PLENARY SESSION PART 1:

A. Observations on the Observations: Where We Might Go From Here? ..... *Fran Ulmer and John Farrell*

B. Overview of SEARCH and the AON..... *Hajo Eicken*

C. Data and Observational Needs from Agencies, Stakeholders, and Decision Makers..... *Larry Hartig*

D. Arctic Observational Needs For Modeling and Prediction ..... *John Walsh*

E. Back to the Future: A Conceptual Framework for Advancing the AON ..... *Martin Jeffries*

PLENARY SESSION PART 2:

F. SEARCH Science Goal #1: Sea Ice – Consequences of an Ice-Diminished Arctic Ocean... *Julienne Stroeve*

G. SEARCH Science Goal #2: Permafrost – Land Surface Change/Hydrology ..... *Larry Hinzman*

H. SEARCH Science Goal #3: Land Ice Loss .. *Tad Pfeffer*

I. SEARCH Science Goal #4: Society and Policy – Links Between Observational Data/Information and Public Understanding ..... *Henry Huntington*

After the main plenary session, workshop participants divided into four breakout groups (Ocean 1, Ocean 2, Land 1, and Land 2) to address SEARCH science goals 1 and 2. After each breakout session, participants returned to brief plenary sessions where each breakout group reported on its discussions.

During Breakout Session 1, each group was asked to develop a vision of a successful AON by addressing these questions:

1. Which audiences would an ideal AON serve?
2. Given these audiences, in an ideal world what would an AON look like in 5 years?
3. What would the 'value added' be, beyond the current way of business? What products and services would be created?

During Breakout Session 2, each group was asked to identify specific ways to achieve the vision by addressing these questions:

1. What activities are needed?
2. Can significant progress be made by combining existing resources or infrastructure, or by implementing targeted activities?
3. Are there cross-cutting activities or showcase

projects, e.g., data-focused, place-based/regional, etc., that could be implemented?

During Breakout Session 3, each group was asked to discuss details and showcase projects. Specifically, the charge was to develop showcase project descriptions organized into five categories: Why? What? How? Where? When? Breakout Session 3 included a special data issues group tasked to consider topics such as inter-operability, proprietary data, data formats, common archive structure, provision of data for showcase projects, etc.

The first day of the workshop concluded with a poster session. The posters covered a range of topics that included SEARCH, arctic observing activities, and arctic science.

III. Showcase Projects–Summaries

Due to the breadth and diversity of arctic (long-term) observation programs supported or carried out by different agencies, academia, and various stakeholder groups, the workshop organizers focused on incremental, bottom-up approaches towards improved coordination and integration of these activities. Breakout groups were thus charged with describing showcase projects that would identify and highlight effective approaches towards interagency collaboration in the context of the AON while at the same time serving as nucleation sites for incremental consolidation of core network activities.

Attributes of promising, viable showcase projects include the following criteria; breakout groups were asked to indicate how specific showcase project proposals would encompass them:

- An advanced level of readiness, as expressed, e.g., in the number of datasets available for synthesis, known plans for recurring field programs that would help sustain coordinated efforts, or existing databases accessible for observation planning, data discovery, or dissemination
- A high potential for cross-agency collaboration and support, including specific information on relevant funding opportunities, existence of interagency working groups or informal communities of practice that could help advance coordination and collaboration

Breakout groups were also asked to identify ways in which the respective showcase projects help to balance the research interests of the scientific community and the information needs of different agencies and stakeholders. Ideally, showcase projects foster dual-use of resulting datasets and information products, from fundamental and applied research perspectives. Finally, coordinators for these showcase activities were identified or recruited by the breakout groups.

	Proposed showcase projects and connections to plans and goals.	National Plans		SEARCH Themes			Self-contained	Depends on other
		National Ocean Council Arctic Plan	IARPC 5-yr plan	Observe	Understand	Respond		
INTEGRATED OBSERVING AND RESEARCH TO MANAGEMENT PROJECTS	1. From Observations to Management: Science to Inform Decision Regarding Offshore Oil and Gas Activities in the Chukchi Sea			√	√	√		√
	2. Distributed Environmental Observatory for Terrestrial Change Detection		√	√	√			√
	3. Causes and Consequences of the Greening of the Arctic				√	√		√
OBSERVING NETWORKS	4. Distributed Biological Observatory	√	√	√				√
	5. Multidisciplinary Drifting Observatory for Study of Arctic Climate		√	√	√		√	
	6. Community-based Observation Network for Adaptation and Security		√	√			√	
	7. Ocean Observations to Improve Sea Ice Forecasting	√	√	√		√		√
	8. Long-term Sea Level Measurements Along the Alaskan Chukchi and Beaufort Coasts			√			√	
	9. Arctic Ocean Freshwater and Heat Observing System			√			√	
OBSERVING NETWORK DEVELOPMENT	10. Utilizing the State of the Existing Knowledge to Guide Infrastructure Development					√		√
	11. Building a Community-based Observation Network			√		√		√

1. From Observations to Management: Science to Inform Decisions Regarding Offshore Oil and Gas Activities in the Chukchi Sea

Molly McCammon

The goal of this project is to develop linkages among changes in the large-scale pan-arctic ice pack and regional scale sea ice dynamics and ocean conditions, and their impacts on living resources in the Chukchi Sea. This information would be used to support policy decisions concerning whether, where, when, and how to explore for and produce oil and gas, as well as to prepare for potential impacts and responses to them in the Chukchi Sea outer continental shelf, especially in light of documented climate change. Although regulating offshore oil and gas activity is a policy matter, scientific observations and research results can provide relevant information to inform policy decisions and adaptive management of those activities. The needs of decision makers may not be fully apparent to scientists, and the results of scientific studies and observations may not be presented in ways that meet the needs of decision makers. In addition, the connections between large-scale arctic observations and regional- and local-scale science and management needs are typically not made. This showcase project addresses these challenges.

With interagency support, this project will develop:

- Coupled pan-arctic and regional sea ice models and forecasts of presence and characteristics on seasonal and annual time scales
- Annual and seasonal forecasts of freeze up and breakup in the Chukchi lease sale area
- Risk and vulnerability assessments and likely sensitivities of key marine species to disturbances from sea ice and storm hazards and human activities
- Projections of likely trajectories of spilled oil due to potential sea ice hazards
- Transparent steps for use of the above information in decision-support materials and processes for policy and regulatory issues pertaining to potential oil and gas activities in the Chukchi lease sale region

This project will also streamline access to and sharing of data for all agencies, universities, and companies that are important to the support of the showcase project goals.

2. A Distributed Environmental Observatory for Terrestrial Change Detection

Philip Martin

This project establishes a network to rescue, standardize, collect, distribute, and synthesize long-term observational data pertaining to the changes in permafrost and to the effects of permafrost degradation and changing hydroclimate regime on ecosystem services, including wildlife, habitat, and human infrastructure in northern Alaska. The environmental observatory will focus work in specific watersheds that collectively represent the diversity of landscape settings and dominant ecological processes within the region, take advantage of existing science and logistics capacity for the sake of efficiency, and provide opportunities to build on existing long-term data sets. Our intent is to measure key system drivers and processes in a standardized fashion across sites. For example, we will measure climate, snow cover, soil moisture, water balance components (e.g., precipitation, surface storage, runoff, evapotranspiration), active layer depth, soil temperature profile, vegetation composition and seasonality, and disturbance (fire, thermokarst, human activity). Candidate sites include those with active science programs (e.g., Barrow/Meade River, Kuparuk River, Fish Creek, Jago/Okpilak/Hulahula rivers) supported by NSF and federal resource agencies. We intend to institutionalize and strengthen the independent observation activities at each of these locations by providing support for central network functions and filling data gaps.

Network planning and design is being conducted under the auspices of the ALCC, with support from the U.S. Geological Survey (USGS). Operational funding, particularly for centralized network functions such as data management, synthesis, and outreach will likely be available from the ALCC and USGS Alaska Climate Science Center. This project is motivated by the identification of overlapping priorities expressed by the scientific community and management agencies. For this network to be sustainable, it will be important to maintain relevance to applied problems of interest to the resource management community as well as provide a suite of 'open source' environmental time series for use by the research community.

3. What Are the Causes and Consequences of the Greening of the Arctic?

Eric Kasischke and Craig Tweedie

Analyses of satellite remote sensing data show there has been a pronounced pan-arctic increase in greenness of vegetation over the past three decades. Changes to arctic vegetation have also been observed through many landscape to regional scale studies, and their consequences are important

to subsistence users, land managers, and policy makers. This showcase project will address three questions: What actual changes to vegetation are occurring? In particular, in different arctic ecosystems, what changes are occurring to community composition, vegetation growth, and vegetation phenology? What are the causes of vegetation change? In particular, how do changes in climate (temperature, precipitation, snow cover, etc.), disturbance (fire, insects, thermokarst, etc.), permafrost warming and thawing, hydrology, herbivory, and changes to nutrient availability interact to control changes to vegetation? What are the consequences of vegetation change? In particular, how do changes in vegetation influence biodiversity – especially wildlife habitat and migratory birds and mammals – permafrost dynamics, subsistence, and key feedbacks between the land surface and atmosphere (albedo, latent heat exchange, surface energy exchange, carbon balance, and radiative forcing potential)?

4. The Distributed Biological Observatory

Jackie Grebmeier

The Pacific Arctic region is experiencing rapid sea ice retreat and seawater warming that can have cascading impacts on many components of the marine ecosystem. Recent observations of altered pelagic and benthic prey bases for marine mammals and seabirds coincident with varying predator foraging areas and habitat use highlight changes in the region. It is essential to track biological response to changing environmental forcing to provide information to multiple end-users, including government agencies responsible for evaluating marine ecosystem health as well as societally-relevant concerns, about the impact of multiple stressors to the ecosystem.

The Distributed Biological Observatory (DBO) is being developed by an international consortium of scientists in the Pacific Arctic as a change detection array to systematically track the broad biological response to sea ice retreat and associated environmental change. The DBO is tracking select biological measurements at multiple trophic levels, coincident with physical and chemical data, in a latitudinal array of transect lines and stations in the northern Bering and Chukchi seas. Coordinated, regular ship-based observations, together with satellite and mooring observations at the designated sites, can provide an early detection system for biological and ecosystem response to climate warming.

The current 2010–2012 pilot program focuses on two areas in the Chukchi Sea where the highest number of ships from six Pacific countries agreed to participate and share data sets, both real time and post-cruise, through the Pacific Arctic Group (**pag.arcticportal.org/**). Successful implementation of the biological change detection array as envisioned by the DBO effort will provide for a national and international network of coordinated sampling. This network will provide up-to-date information on one of the most productive regions of the Arctic. The DBO efforts will facilitate data collection, sharing, and archiving through the U.S. ACADIS data program and associated international data agreements. More information on the DBO can be found at **www.arctic.noaa.gov/dbo/**.

5. Multidisciplinary Drifting Observatory for the Study of Arctic Climate — MOSAiC

Matthew Shupe

Multi-year, detailed, and comprehensive measurements extending from the atmosphere through the sea ice and into the ocean of the central Arctic Basin are needed to improve our understanding and modeling of arctic climate and weather, and to enhance arctic sea ice predictive capabilities. These observations will be designed to provide a process-level understanding of the new central arctic climate system, consisting of dramatically less and thinner sea ice than in the recent past, as well as a more detailed understanding of the processes leading to these sea ice changes. Scientific emphasis will be placed on processes that transfer heat, moisture, density, salt, and momentum through the system.

To obtain the needed measurements, an occupied, transpolar drifting observatory is proposed, wherein an ice-hardened ship serves as a central hub for intensive observations of atmospheric, oceanic, sea ice, and biogeochemical properties and processes. The comprehensive information from this central facility will be expanded to larger spatial scales using a coordinated network of distributed measurements using buoys, autonomous aerial systems and underwater vehicles, additional ships, aircraft, and satellites. A broad consortium of nations and funding agencies is needed to facilitate, coordinate, and support such a constellation of central arctic observations.

The data management requirements for such a multidisciplinary international facility are challenging. The early recognition and resolution of challenges such as streamlined international data exchange, unified formats and a MOSAiC data policy and archive framework will enhance the long-term preservation and use of data from this project.

6. Community-based Observation Network for Adaptation and Security

Lilian Na'ia Alessa and Andrew Kliskey

A pan-arctic community-based observation network for adaptation and security (CONAS) will:

- Monitor and understand environmental change
- Evaluate points of resilience and risk
- Ensure that undesired changes are met and managed before they become catastrophic

CONAS relies on data collected by local residents year-round on environmental variables and resources of importance such as water, weather, plants, and animals as well as the social and economic contexts in which they exist. The current phase exists as the Bering Sea Sub Network (**www.bssn.net**). Planned expansion will extend CONAS north of Bering Strait to the U.S. and Russian Far East peripheries of the Chukchi Sea.

CONAS will establish consensus on critical variables to be observed, the co-production of science, shared interpretation of data, and co-management of applications as appropriate. The tools to accomplish these goals involve:

- Structured survey forms and semi-structured narratives
- Architecture for information fusion (Architecture for Integrated and Dynamic Data Analysis – AIDA)
- Hand-held data capture devices for image, voice, and environment
- Distributed micro sensor arrays and data from intelligent uninhabited aerial vehicles, gridded at appropriate spatial geometries
- Computer programming, hardware, and other cyber infrastructure for discovery
- Social processes of discourse for knowledge sharing face-to-face and face-to-place to achieve a better understanding of arctic environmental variability and resilience.

7. Ocean Observations to Improve Sea Ice Forecasting

Julienne Stroeve

The showcase project for ocean observations is aimed at improving sea ice forecasting on several time scales: seasonal, interannual, and decadal. These time scales are important to a variety of stakeholders, including operational users (safety of life and property), crisis responders, resource managers, weather and climate forecasters, climate change detection researchers, politicians, and coastal communities. The initial target areas for observations include the Beaufort, Chukchi, and northern reaches of the Bering seas. Implementation of the project will be under guidance from the U.S. AON steering committee and a relevant international group (e.g., SAON), possibly forming a new program office for overall guidance. Collaborations with key stakeholders are important to ensure observational planning meets forecasting needs on various time scales.

Initial development of the project will build upon existing observational platforms (e.g., ships, aircraft, fixed offshore platforms, coastal stations, satellites) and will foster partnerships with national, international, and private industry. Consultation with modeling centers will help define data needs (e.g., format, parameters, time and space granularity), identify platforms of opportunity, and define high-priority products. Successful implementation of this project will provide continued and enhanced observations directly supporting various user needs — improved coordination among agencies and countries, improved model-based forecasts with error estimates, and extended data records to support climate science.

8. Long-Term Sea Level Measurements along the Alaskan Chukchi and Beaufort Coasts

Steve Okkonen

Sea level is arguably the most basic of oceanographic measurements. Coastal peoples have historically recognized that travel, commerce, and the harvesting of marine resources are influenced by changes in sea level and that the ability to predict these changes greatly improves efficiency and safety in pursuit of these activities.

Benefits of long-term sea level measurements along the Alaskan Chukchi and Beaufort coasts include:

1. Coastal sea level is a suitable proxy for near-shore, sub-tidal current velocities. A network of stations reporting in near-real time allows circulation along the Alaskan arctic coast to be described in a systematic sense.
2. Sea level measurements are used to both assess and validate numerical storm surge and circulation models. The ability of a numerical model to reproduce observed sea level is a fundamental measure of a model's skill. A skillful storm surge model is an emergency preparedness and response decision support tool for coastal Alaskan villages.
3. Sea level measurements that have been acquired along Alaska's arctic coast have generally been of too short duration to resolve seasonal and long period (e.g., associated with the Arctic Oscillation) changes in sea level.

4. Sea level measurements along the arctic coast of Alaska will provide a unique set of observations to validate sea height estimates derived from satellite remote sensing. Additionally validated remote sensing sea level estimates obtained from radar altimetry or synthetic aperture radar could be used to fill the gaps in the proposed tide station location in the Beaufort Sea. Satellite images of actual storm surge events can also be better interpreted using the coincident tide gauge observations.

Access to and archiving of sea level data will be coordinated through the National Oceanic and Atmospheric Administration (NOAA) National Ocean Service as they have primary responsibility for the collection and dissemination of sea level data.

9. Arctic Ocean Freshwater and Heat Observing System

Peter Schlosser

Freshwater and heat content determine the stratification and circulation patterns in the Arctic Ocean including its shelf seas. These fundamental features of the Arctic Ocean impact sea ice formation and melting, sea ice extent, meltwater distribution, biological activity, runoff from land (rivers and glacial melt water) and navigation in the Arctic Ocean, among others.

We propose to implement systematic, pan-arctic, multiplatform, long-term observations to determine the freshwater and heat contents of the Arctic Ocean, as well as their variability and trends. The system will cover observations of the central basins of the Arctic Ocean and its shelves and will allow us to narrow the errors in our estimates of freshwater and heat inventories and fluxes. Parts of the system are in place through national (mainly NSF AON, NOAA, ONR, and NASA), and international efforts. The proposed system can be completed in a 5-year time frame.

10. Utilizing the State of the Existing Knowledge to Guide Infrastructure Development

Larry Hinzman, Greg Balogh, and David Yokel

To date, infrastructure development, construction, and placement has not adequately considered future environmental conditions. Understanding generated by the AON and other climate scientists and ecologists could inform design and location of such structures in a way that would minimize disturbance and ensure long-term functional stability. Using research efforts to guide responsible development and using development projections to guide investment of scientific resources will ensure that research activities provide a useful product back to local communities, and tribal, state, and federal governments.

Any land or resource management agency, every community that anticipates growth and development, and every company that contemplates industrial developments in the Arctic must think strategically on at least a 30-year planning horizon, including consideration of how the changing climate will impact local environmental conditions. Civil projects that could benefit from consideration of climate and ecosystem analyses should interface with the AON to incorporate the state of the science into their designs. Civil projects offer the opportunity to collect unique datasets and an opportunity to collect pre-disturbance data and monitor impacts and recovery. To ensure successful execution and maximum value of such a program, it should include early involvement of industry, agencies, and governments, synthesis and incorporation of existing data, development of best management and design practices, incorporation of permit conditions that facilitate optimum data collection and sharing, and integration of best management and design practices with geographic data layers to develop ecologically and economically viable alternatives.

11. Connecting Arctic Communities with One Another and with Scientists: Building a Community-based Observation Network

Henry Huntington

Many arctic residents spend considerable time on the land and sea throughout the year, but their observations are rarely documented. Some community-based projects are under way, but there are few connections among them. A community-based observation network can provide mutual support for technical and other challenges, generate more interest among community members, and strengthen connections with scientists.

The showcase project will start with an evaluation of current efforts, to identify the factors that determine the success of community-based observation programs in terms of observer participation, quality of data, sustainability, and other parameters important to long-term observational efforts. Based on this analysis, the showcase project will design a network support system to foster greater community involvement, more interactions among communities, and better integration with other monitoring efforts. Once this system is in place, it can be evaluated and modified based on experience.

IV. Data Management Breakout Session–Summary

photo: Jim Pottinger

One dozen workshop participants including data managers, scientists, and agency program managers attended the breakout session. The objective was to focus on arctic observing data issues (e.g., interoperability, sharing of proprietary data, data formatting, common archive structures, provision of data for showcase projects) and how to set priorities for activities that will improve the discovery and access to the rich AON datasets that are held in dozens of archives across the region.

What does the community need? They need to be able to find and share the data, and be able to browse an inventory of available data to streamline the discovery and access process. There is certainly a need for special products for decision makers, politicians, and the public (by species, discipline, parameter, etc.) Discussions are ongoing to determine who is responsible for preparing these value-added products.

The group discussed a variety of issues with a focus on what is needed to promote arctic observing data (here defined as the union of the AON project data holdings plus state, federal, and local community operational and research data) to be shared by all groups. The fundamental question is how can these data be collected, archived, and distributed to maximize their utility by the decision makers, the research community, and local communities to help with analysis assessment and recommendations needed for improved products and services to describe the changes under way in the Arctic.

The audience for this diverse dataset and its products is broad: the research community (e.g., synthesis products), commercial fisheries, energy industry, general public (e.g., weather, ice, and sea state forecasts), indigenous population (e.g., whalers, hunters), regulators, resource managers, emergency services, military (e.g., U.S. Coast Guard – USCG), and politicians.

An initial step was made in preparation for this workshop—an inventory of federal, state, and local agencies and partnerships pertinent to U.S. arctic observing programs (Appendix 2).

There are several high-priority responsibilities and activities that can be considered for implementation by those responsible for archiving and disseminating arctic data. AON data must be accessible freely, openly, and quickly. The multi-agency nature of the AON requires collaboration among the various data archives to maximize this sharing — these help support and highlight the interagency aspect of AON. There should be consideration of an AON data policy that emphasizes open access and reflects multi-agency commitment to the process. Distributed archives are the norm today but they must be interoperable. This is done most effectively by considering consistent discovery-level metadata, formats standards, common collection practices, conforming units, and taxonomy. It is also vital that the international links be opened to permit sharing of regional and pan-arctic data and information.

The development, acceptance, and implementation of an AON data policy that facilitates the exchange of data among all providers is an important first step. Key attributes are to encourage the unrestricted access to some or all of the arctic data in the U.S. Second, it is vital that the policy respect

restrictions on data access but require open access of clearly specified embargo periods. The policy should emphasize the need for a common metadata schema to enhance exchange. The policy must emphasize the need for dataset attribution so their contributors are given proper credit and citation for the data provided.

Policy Goals

- Commitment from agencies to build an inventory on how the data are discoverable
- Propose a project to demonstrate metadata connectivity
- Expose data and metadata through open web services (Application Programming Interface – API)
- Provide tools for researchers to help them meet their data management requirements

Next Steps

- Provide an inventory of data archives and access points (Appendix 3) as well as the responsible person and agency (Geographic Information System – GIS – layers).
- Activate an interagency data collaboration team or forum to discuss key components of an improved process for sharing arctic data. This group would consist of working level data managers and curators who could comment and implement metadata standards and best practices. A primary task of the group would be to develop and implement procedures to overcome impediments to interagency exchange of existing data. The group could approach the very challenging aspects of international data exchange. This group would be responsible for completing and updating the inventory (Appendix 3).
- Achieve improved data discovery and sharing through implementation of metadata exchange standards and protocols across archives. One valuable statistic that may help prioritize efforts would be to identify the most used, highest priority AON datasets and the key questions being answered with those data.
- Use the showcase projects (Section III and Appendix 1) under consideration from this workshop as a demonstration of improved data and metadata collection, archiving, and sharing from all groups. There are clear and immediate challenges and opportunities within each showcase that fall within the key issues of discovery and access.

V. Issues and Challenges

Workshop participants identified issues and challenges relevant to achieving one of the major goals of the workshop: to better integrate AON activities with the needs of a broader group of stakeholders, and in particular, federal and state agencies. These challenges are listed in no particular order.

1. Participants discussed how to make scientific observations, in particular the long-term observations supported by the AON, more responsive to stakeholder information needs, agency management goals, and more pertinent as scientific guidance on policy development. It was noted that managers tend to need more highly integrated and interpreted data and information products that distill data from multiple sources for use in decision support tools. At present no clear pathway has been identified on how to generate such products based on the AON data streams.
2. The time scale for management policy decisions is often short, yet many AON goals span longer scales owing to the nature and long-term drivers of arctic environmental change. Arctic policy decisions are typically Alaska-focused, yet AON is a pan-arctic program. While this presents challenges with respect to funding support under shrinking federal budgets, many of the changes observed in recent years are driven by hemispheric-scale processes and have pan-arctic dimensions. A program such as the AON can provide a framework for understanding events and processes at the local scales, but stronger pathways need to be developed to link the pan-arctic observations to the regional (Alaska) management needs.
3. The academic science community, largely funded by NSF, often does not have forums for networking and collaborating with agency managers to assess and understand their observation needs, not only for current uses, but also to meet future needs. At the same time, there is still reluctance by some academic researchers to engage in such collaboration because of perceived or real threats to researchers' fundamental science research portfolio.
4. While it is relatively straightforward to identify who is accessing web-based AON observational data, it is very difficult to assess if and how it is being used. While the theme of responding to arctic change is driving part of the observing network, to date AON has not identified operational users as a key audience. Here, rigorous assessments of how the network is meeting user needs would be

of value. Moreover, exploring how gap analyses and conceptual models can be used to optimize the program in terms of site location, parameter observation, data collection, and analysis would also be of value.

5. While some progress has been made, integration of social science data, community-based observations, traditional and local knowledge, and data collected by industry into the AON remains a challenge. Because of different levels of readiness with respect to well-designed long-term observing programs, AON is perceived by some as focusing largely on physical parameters, and not the biological species and other parameters that agencies are responsible for managing.
6. Despite widespread consensus regarding the value of long-term, observational data, coordinating a cross-jurisdictional, cross-discipline observing program is not within the mission of any single agency. Existing successful programs are either limited geographically (i.e., the National Park Service Vital Signs Network is confined to National Park lands) or in topical breadth (DOE Atmospheric Radiation Measurement). Agencies are often reluctant to undertake long-term monitoring programs, because the cost commitment may conflict with their ability to perform other core functions in future years. Joint sponsorship of core monitoring activities would reduce the risk to any single agency and promote sustainability; neither the institutional mechanisms nor top-down direction to engage in such agreements are currently in place.
7. Federal agencies often find it difficult to co-mingle funds to support integrated projects, although established interagency programs, such as the National Ocean Partnership Program (NOPP), may serve as models for new approaches to integrated funding. Here, guidance from the U.S. Arctic Research Commission (USARC) and the IARPC may help raise awareness and identify solutions.
8. The NSF has not defined a set of core activities to be supported by its AON program. The portfolio of NSF AON projects is subject to change, relying on peer review of short-duration projects that focus on individual components of the network. This approach maintains maximum flexibility to adapt in response to changing science priorities and societal needs, but is not conducive to maintaining observational continuity and building durable partnerships with other agencies. An alternative model, where NSF investment in the AON is a catalyst for collaborative efforts of multiple agencies, should be considered.
9. AON is now focused on serving observational data, but some participants suggest that it be expanded to include developing synthesized products and services. The SEARCH goals of Observing, Understanding, and Responding to Change are useful for planning, but provide an artificial barrier to synthesis and integration. Here, topical, cross-sector working groups may help advance more integrated approaches.
10. While the AON operates under the open access ***SEARCH Data Policy*** (2007), data access and integration remain challenging and were a topic of discussion by the data breakout group. There is an immediate need to modify and/or expand the AON data policy to open avenues for agency and international data exchange. The formation of an AON interagency data coordination team may be a first step to facilitate U.S. federal, state, and local agency data sharing.
11. As a program, the AON needs to be better marketed and branded, beginning with an inventory of existing projects, datasets, and findings.

The NSF AON program is engaged solely in observing activities. Thus, at NSF there is a programmatic, and funding, gap between observing activities and analysis and synthesis of the observations. A stronger linkage between AON observations and science is needed to reap maximum benefit from AON observational activities.

VI. Future Directions and Opportunities

photo: Karl Horeis

One of the main goals of the AON Coordination Workshop was to provide a forum for information exchange that could also help set the stage for improved coordination between agencies, academia, and key stakeholders. This goal has largely been met by the workshop. The roughly equal mix of university researchers, many affiliated with ongoing AON projects, and agency representatives helped ensure that conversations explored approaches and topics not covered in previous meetings. The format of the workshop was also conducive to delve into more detailed planning discussions and helped identify potential challenges.

The biggest challenge remains to achieve a productive balance between the fundamental research questions driving the NSF-supported AON researchers and the data, synthesized products, and information needs of agency managers. This challenge has been discussed in the ***AON Program Status Report*** (2009) and the report from the SEARCH Implementation Workshop (*SEARCH*, 2005). The 2012 AON Coordination Workshop is only the first step towards a more coordinated approach that will require additional resources and efforts to achieve its goals. Specific actionable and concrete recommendations to meet these near- and mid-term objectives include:

Showcase Projects: The showcase project outlines developed by the breakout groups demonstrate the breadth of information needs and potential for collaboration and synergy, but they also highlight several areas where substantial benefits could be derived from improved planning and coordination, which in turn would substantially increase the scope and value of information obtained from long-term observations while increasing efficiency in the data collection effort. One example is the observations related to offshore oil and gas development in the Beaufort and Chukchi seas. Here, next steps would include efforts to bring together agency scientists and managers with university researchers to explore how the observing activities can be integrated best across the relevant scales, from the pan-arctic to the local. At the same time, some showcase project outlines are at a level of maturity where they are ready for funding support, either through responses to appropriate solicitations or through direct support.

Topical Working Groups: To make progress towards improved coordination, topical working groups composed of a broader spectrum of experts involved or interested in long-term observations in the context of responses to arctic change may be most effective. The SEARCH 5-year goals and objectives (**www.arcus.org/search/goals**) outline themes or topic areas that have matured to the point that they may serve as the starting point for such topical working groups that bring together researchers, managers, funders, and stakeholders.

Funders Circle: To improve coordination, suggestions to create an informal working group (perhaps through IARPC) that meets regularly to explore viable ways forward towards joint support of high-priority activities appear promising.

Data Management Working Group: Access to and management of data and data products is a common denom-

inator among all AON projects and similar efforts by other agencies. Harmonizing the various approaches and working towards best practices and improved interoperability are key issues that require a forum among data managers and representatives from the different data provider and user communities. Such a group would also benefit from links to the SEARCH Data Working Group that helped define some of the key guidelines (open, unembargoed access to AON data) for AON data management. Addressing the data management needs and requirements of the showcase projects before data collection begins will help assure that data are accessible to all interested groups and that the rich data legacy of the AON is preserved over the long term.

Flagship Sites and Regional Foci: Many of the issues that need to be resolved for improved coordination across agencies, stakeholders, and academia can be addressed best at specific sites where a high density of observation infrastructure, a history of collaboration between different entities, clearly articulated common data and information needs, and a more manageable spectrum of research projects have come together. At the AON Coordination Workshop, several locations were targeted as potential sites to explore and foster different approaches towards improved coordination. An evening meeting by researchers active in the Barrow, Alaska, region attracted over 30 participants and highlighted the potential for flagship observatories located at Barrow in both the marine and terrestrial realm to serve as one of several focal points for improved coordination.

To move this report's recommendations forward, the workshop Organizing Committee recommends that the SEARCH Observing Change Panel, under the guidance of the SEARCH Science Steering Committee, work with the showcase project contacts and the data breakout group to reach out to relevant funding agencies. Also, the workshop recommendations should be formally presented to the IARPC for possible implementation where they can contribute to the IARPC 5-year goals.

An important next step will be to distill and discuss the conclusions from the AON Coordination Workshop in a broader international context as planning for the Arctic Observing Summit, to be held in spring of 2013 in Canada, gets under way. The recommendations from the workshop should be considered by the ISAC for planning the summit in concert with the recommendations in the report ***Designing, Optimizing, and Implementing an Arctic Observing Network*** (2012). The workshop was an important contribution to the planning of this event; in particular, important issues identified at the meeting and showcase project outlines may serve as starting points for community white papers that will be solicited in the coming months to obtain and synthesize input from the broader international community towards improved coordination of long-term arctic observations.

Finally, the 2012 AON Coordination Workshop clearly highlighted two important aspects central to effective studies of and responses to arctic change. First, the meeting's discussions focused on the integration of Observing, Understanding and Responding to Change science, demonstrating that only a comprehensive, fully tri-partite approach to long-term observations addresses the key challenges and scientific questions in a viable and effective manner. Second, the breadth of information reviewed with respect to observing activities by different agencies, academia, stakeholders, and other entities demonstrated that the AON is in fact an Interagency AON, or IAON, that already contains many pieces or nuclei for cross-agency collaboration. While this is in part an issue of properly branding the IAON, it presents the broader arctic research community and stakeholders with an excellent foundation for more effective, cutting-edge approaches to societally relevant arctic research.

VII. References

Arctic Observing Network (AON) Design and Implementation Task Force, 2012: *Designing, Optimizing, and Implementing an Arctic Observing Network*. Study of Environmental Arctic Change (SEARCH), Fairbanks, Alaska, 64 pp.

Arctic Observing Network (AON), 2010: *Arctic Observing Network (AON) Program Status Report – 2009.* Results from the Third AON Principal Investigators (PI) Meeting, 30 November – 2 December, 2009, Boulder, CO.

Calder, J., H. Eicken, and J. Overland, 2011: The Sea Ice Outlook. In: Krupnik, I., and eight others (eds.), *Understanding Earth's Polar Challenges: International Polar Year 2007–2008 - Summary by the IPY Joint Committee*. University of the Arctic, Rovaniemi, Finland /CCI Press (Printed Version), Edmonton, Alberta, Canada and ICSU/WMO Joint Committee for International Polar Year 2007–2008, p. 405-410.

Elliott, S., J. Schimel, J. Walsh, and H. Wiggins, eds., 2010: *Recommendations for Understanding Arctic System Change: Report from a Workshop*. Arctic Research Consortium of the United States (ARCUS), Fairbanks, Alaska, 17 pp.

Hartman, C.W., and P.R. Johnson, 1984: *Environmental Atlas of Alaska*, 2nd edition. Institute of Water Resources/Engineering Experiment Station, University of Alaska, Fairbanks, 95 pp.

Interagency Arctic Research Policy Committee (IARPC), 2007: Arctic Observing Network: Toward a U.S. contribution to pan-Arctic observing. *Arctic Research of the United States*, **21**, 94 pp.

Morison, J. and the SEARCH Science Steering Committee, 2001: *SEARCH: Study of Environmental Arctic Change Science Plan, 2001*. Polar Science Center, Applied Physics Laboratory, University of Washington, Seattle, 91 pp.

Murray, M.S., et al., 2012: *Responding to Arctic Environmental Change: Translating Our Growing Understanding into a Research Agenda for Action.* An International Study of Arctic Change Workshop, 30 January – 1 February 2012, Kingston, Ontario, Canada. ISAC, Stockholm, Sweden and Fairbanks, Alaska, 35 pp.

National Research Council of the National Academies, 2006: *Toward an Integrated Arctic Observing Network*, National Academies Press, Washington D.C., 128 pp.

Perovich, D.K., H. Eicken, and W. Meier, 2012: International coordination to improve studies of changes in Arctic sea ice cover. *Eos, Trans. AGU*, **93**(12), 128.

Sprenke, J., S. Gill, J. Kent, and M. Zieserl, 2011: *Tides Under the Ice: Measuring Water Levels at Barrow, Alaska 2008–2010*. NOAA Technical Report NOS CO-OPS 062.

Study of Environmental Arctic Change (SEARCH), 2005: *Study of Environmental Arctic Change: Plans for Implementation During the International Polar Year and Beyond*. Report of the SEARCH Implementation Workshop, 23–25 May 2005. Arctic Research Consortium of the United States (ARCUS), Fairbanks, Alaska, 107 pp.

Study of Environmental Arctic Change (SEARCH) Data Working Group, 2007: *SEARCH Data Policy*. **www.arcus.org/search/search-science/datasets**

VIII. Abbreviations and Acronyms

ACADIS . . . . . .Advanced Cooperative Arctic Data and Information Service

ALCC . . . . . .Arctic Landscape Conservation Cooperative

AON . . . . . .Arctic Observing Network

ARCUS. . . . . .Arctic Research Consortium of the United States

BLM . . . . . .Bureau of Land Management

BOEM . . . . . .Bureau of Ocean Energy Management

DOE . . . . . .Department of Energy

IARPC . . . . . .Interagency Arctic Research Policy Committee

IASC . . . . . .International Arctic Science Committee

IPY. . . . . .International Polar Year

ISAC . . . . . .International Study of Arctic Change

NOAA . . . . . .National Oceanic and Atmospheric Administration

NPRB . . . . . .North Pacific Research Board

NSF. . . . . .National Science Foundation

NSIDC . . . . . .National Snow and Ice Data Center

NSSI . . . . . .North Slope Science Initiative

ONR . . . . . .Office of Naval Research

SAON. . . . . .Sustaining Arctic Observing System

SEARCH . . . . .Study of Environmental Arctic Change

USFWS . . . . . .U.S. Fish and Wildlife Service

USGS . . . . . .U.S. Geological Survey

IX. Appendices

photo: Bill Schmoker

Appendix 1. Showcase Projects – In Depth

1. From Observations to Management: Science to Inform Decisions Regarding Offshore Oil and Gas Activities in the Chukchi Sea

Contact: Molly McCammon

GOALS

- Develop linkages between changes in the large-scale pan-arctic ice pack and regional scale sea ice dynamics and ocean conditions, and their impacts on living resources in the Chukchi Sea
- Determine how well current observational data can be used to support policy decisions concerning whether, where, when, and how to explore for and produce oil and gas and prepare for potential impacts in the Chukchi Sea outer continental shelf, especially in light of documented climate change

CHALLENGES

Regulating offshore oil and gas activity is a policy matter. However, scientific observations and research results can provide relevant information to inform policy decisions. Management agencies such as the Bureau of Ocean Energy Management (BOEM) and oil and gas industries seeking permits to explore and develop in the outer continental shelf waters off Alaska have invested extensively in projects and activities designed to address scientific information needs. The connection between scientific input and specific policy decisions, however, should be strengthened. The needs of decision makers may not be apparent to scientists and the results of scientific studies and observations may not be presented in ways designed to meet the needs of decision makers. In addition, connections between large-scale arctic observations and regional and local scale science and management needs are typically not made. This showcase project addresses these challenges.

OBJECTIVES

- Predict the survivability of different ice types in the Chukchi region between breakup and freeze up on seasonal and annual time scales and identify their potential to create hazards to exploration activities
- Assess current observing resources and their ability to identify and predict breakup and freeze up timing on a seasonal basis
- Assess the impacts of changes in sea ice and ocean conditions on living resources that are of biological or cultural significance in the region and evaluate the likely sensitivities of these species to disturbance from sea ice and storm hazards, as well as various human activities
- Determine likely trajectories of spilled oil based on hazards that could be created by sea ice under varying conditions

DELIVERABLES AND ANTICIPATED OUTCOMES

- Coupled pan-arctic and regional sea ice models and forecasts of presence and characteristics on seasonal and annual time scales
- Annual and seasonal forecasts of freeze up and breakup in the Chukchi lease sale area
- Risk and vulnerability assessments of likely sensitivities of key biological species to disturbances from sea ice and storm hazards and human activities
- Projection of likely trajectories of spilled oil due to potential sea ice hazards
- Development of transparent steps for use of the above information in decision support materials for policy and regulatory issues pertaining to potential oil and gas activities in the Chukchi lease sale region

COLLABORATIVE ACTIVITIES

- Convene a small team of agency officials and scientists from appropriate disciplines to work iteratively to identify key policy questions regarding outer continental shelf activities and the scientific information needed to support decisions; assess existing information; evaluate the showcase project and its potential usefulness for future decision support; and develop recommendations for improvements
- Iterate as needed to create suitable approaches for future decision support
- Share and distribute the experiences and results broadly to foster better use of scientific information in policy decisions in the Department of the Interior and other agencies

READINESS

Outer continental shelf decisions are being made now. There are also observational datasets and results from many research projects in the Chukchi. One goal of this project is to determine how to use the information that is available (not the information that one would like to have available) in the time frame of decision-making. Thus, "readiness" is not really a consideration in the sense that delaying this project in the expectation of new data in the future would ignore the fact that decisions will be made soon with or without optimal scientific support.

For sea ice, existing data include satellite observations, ice-based buoys, and ongoing local aerial surveys for ice thickness. Continuing gaps are validation of remotely sensed ice data, accurate ice edge data, increased temporal and spatial coverage, and improved models that couple pan-arctic basin data with weather and ocean condition data to products such as regional and local forecasts. For living resources, significant data exist from work done by the BOEM and industry in the lease area region and efforts are under way to integrate these data and develop synthesis products. All the datasets have spatial and temporal gaps, with a need for more sustained observations of the pelagic and benthic systems over annual cycles and the long term.

BALANCING SCIENTIFIC, MANAGEMENT, AND COMMUNITY INTERESTS

This project looks squarely at the intersection of management/policy and scientific interests. It does not focus specifically on communities, although community concerns and cultural significance of certain areas are among the considerations of policy makers. That said, arctic communities will be keenly interested in the results of an exercise of this kind, and should be involved in a substantive way to ensure that (a) traditional knowledge is incorporated both from previous research and from engagement of knowledgeable individuals, and (b) the results and the process for achieving them are transparent and not seen as yet another imposition of knowledge or decisions from outside the region.

AGENCY SUPPORT AND FUNDING

The project should be of interest to the Department of the Interior, NOAA, and other departments (including state, tribal, and local governments and other institutions). Funding opportunities could be available through the BOEM, the U.S. Fish and Wildlife Service (USFWS) ALCC, NSSI, NPRB, and the AOOS.

2. Distributed Environmental Observatory for Terrestrial Change Detection

Contact: Philip Martin

WHY

Change is occurring in the arctic terrestrial system, but understanding its rate and character is impossible without a continuous, long-duration time series of basic variables. As fewer and fewer monitoring sites are operated on a long-term basis, we are losing our ability to quantify change. This project will address the SEARCH goal to "understand the consequences of the loss of near-surface permafrost on arctic systems" by establishing a network to rescue, standardize, collect, distribute, and synthesize long-term observational data. A comprehensive terrestrial monitoring program must measure elements in three categories: (1) physical (climate, water, permafrost, energy), (2) chemical (trace gases, nutrients, and soils/sediments), and (3) biological (primary productivity, plant and animal dynamics, species composition and distribution). Because these elements are interrelated, it is critical to establish sites at which coincident time series measurements are collected and made available for analysis. As a collaborative venture that extends beyond the research

community to serve the needs of management agencies and local communities, the focus is on providing a foundation for interdisciplinary study of the effects of permafrost degradation and changing hydroclimate regime on ecosystem services, including wildlife, habitat, and infrastructure in northern Alaska.

WHAT

The environmental observatory will concentrate work in specific focal watersheds that are collectively representative of the diversity of landscape settings and dominant ecological processes within the region. The network will take advantage of existing science and logistics capacity for the sake of efficiency, and provide opportunities to build on existing long-term data sets. Our intent is to measure key system drivers and processes in a standardized fashion across sites. For example, we will measure weather, snow cover, water balance components (e.g., precipitation, surface storage, runoff, evapotranspiration), active layer depth, soil temperature profile, soil moisture, vegetation composition and seasonality, and disturbance (e.g., fire, thermokarst, and human activity). High-resolution topographic surveys and ecological mapping of vegetation and soil characteristics (texture, ice content) will provide the basis for scaling results of in situ measurements up to the landscape level. Data products and services will include data in standardized formats for use by researchers, as well as synthesis documents (e.g., annual summary statistics, trend analysis, 'report card' publications) in a variety of formats intended for researchers, resource managers, and the general public.

WHERE

Candidate sites include Barrow/Meade River, Fish Creek (northeast National Petroleum Reserve - Alaska – NPR-A), Kuparuk River, and the area encompassing the Jago, Okpilak, and Hulahula river basins. Depending on availability of funding, a Noatak River site and a river basin draining into the Kasegaluk Lagoon (Chukchi Sea coast) are also under consideration. Site selection criteria explicitly reflect the value of capitalizing on the legacy of past investments by NSF and other federal research programs, as well as study sites operated by land management agencies.

WHEN

Observing activities are currently under way at these sites, but they are not yet organized into a cohesive network. The ALCC will complete a field monitoring plan in 2012; subject to steering committee approval, the ALCC will support some build-out of observing capacity and complete a data management plan in 2013. As a showcase AON project, additional observing activities will be added in 2013, with full implementation by 2017. The intention is that long-term (multi-decadal) environmental monitoring will be sustained via a multi-agency collaboration.

PARTNERS

Network planning and design is ongoing under the auspices of the ALCC, with support from the USGS. Funding, particularly for centralized network functions such as data management, synthesis, and outreach will likely be available from the ALCC and USGS Alaska Climate Science Center. Operational funds are anticipated to come from the Bureau of Land Management (BLM), USFWS, and Toolik Field Station for individual sites within their respective areas of operation. Funding for some aspects of data collection is available from current AON projects (Circumpolar Active Layer Monitoring and Thermal State of Permafrost projects, Circumarctic Lakes Observation Network project), and a proposed AON project (Arctic FLOW: Flagship Observational Watersheds of the Arctic, submitted by the University of Alaska Fairbanks). Future AON calls are expected to provide further opportunities for funding, particularly for the sites that already support a broad spectrum of NSF-funded research. Synergies with the DOE Next Generation Ecosystem Experiments (NGEE) activities in Barrow are likely. A mutually beneficial relationship with the NASA Arctic Boreal Vulnerability Experiment is anticipated, particularly in the arena of local-to-regional scaling via remote sensing techniques. Observations associated with the National Ecological Observatory Network sites at Toolik Lake (Kuparuk watershed) and Barrow will also contribute to our proposed network.

ANTICIPATED FIVE-YEAR ACCOMPLISHMENTS

The project design explicitly builds upon existing long-term data sets, while also identifying and filling data gaps. Many physical process monitoring activities are already under way; filling gaps and coordination of activities at multiple sites could be accomplished incrementally, and build-out is anticipated to take 3–5 years. Vegetation and other biotic monitoring activities of various types also occur at these sites, but methods and targeted taxa vary by site and over time; further coordination and organization of biotic monitoring will be required, but is achievable within this period. Data sharing and dissemination will be coordinated among the ALCC, NSSI (through the Geospatial Information Network for Alaska), and the U.S. ACADIS program. The network will provide updated and comprehensive information to local, state, and federal agencies and to the research community regarding status and trend of key indicators of terrestrial environmental conditions.

ADDITIONAL DEVELOPMENT

The goal is to establish a program of long-term (multi-decadal) observations, so funding solutions beyond the initial 5-year build-out must be developed. Network design must be periodically re-examined to optimize effort, and additional sites added to address research and management needs. It will be important to periodically engage target audiences to help assess the utility and relevance of the information products emanating from the environmental

observatory. To derive full benefit from the foundation provided by long-term observations within focal watersheds, process-based studies must also be encouraged through announcements of opportunity from related research programs. Local scale work within focal watersheds must be scalable to the ecoregion and system levels, so iterative development of models that expand the geographic domain of inference are critical; many of these models will rely on remote sensing products to extrapolate to coarser spatial scales.

CROSS-LINKAGE WITH OTHER SHOWCASE PROJECTS

Two of the candidate watersheds (Kuparuk and Fish Creek) overlap current or planned oil and gas infrastructure, and the Barrow site encompasses the largest community in the region. Therefore, information collected by the observatory would be relevant input into the project Utilizing the State of Existing Knowledge to Guide Infrastructure Development. The observatory's vegetation monitoring component, coupled with hydroclimate and soils data, would provide key information for the project What Are the Causes and Consequences of the Greening of the Arctic? The observatory could also support data integration and programmatic coordination among a variety of vegetation studies.

Existing datasets for each of five candidate focal watersheds, and enumeration of the number of sites at which each parameter is measured.

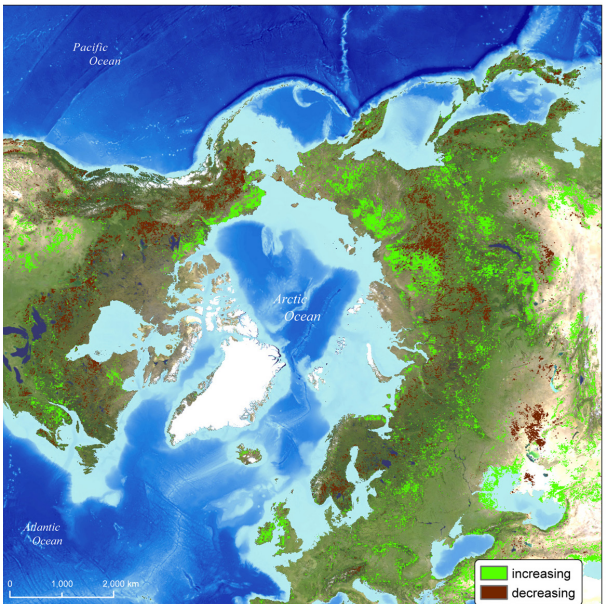
PARAMETER	Hulahula/ Jago Rivers Area	Kuparuk River Area	Fish Creek Area	Barrow/ Meade River Area	Kasegaluk Lagoon Area
Meterology – Logger, Power, Communications	1	4	2	2	0
Meterology – Profile of Air Temperature	1	4	2	2	0
Meterology – Wind Speed and Direction	1	4	2	2	0
Meterology – Radiation	0	4	2	2	0
Meterology – Precipitation (liquid and solid)	1	4	2	2	0
Meterology – Pressure and Relative Humdity	0	4	0	2	0
Hydrology – River Stage	2	3	3	2	0
Hydrology – River Discharge	1	3	3	2	0
Hydrology – Wetland and Lake Stage	0	2	7	8	0
Water Quality – Temperature	0	2	0	0	0
Water Quality – Conductivity	0	2	0	0	0
Water Quality – Turbidity	0	2	0	0	0
Water Quality – Dissolved Oxygen	0	2	0	0	0
Water Quality – pH	0	2	0	0	0
Water Chemistry - various	Yes	Yes	No	Yes	No
Soils/Permafrost – Temperature Profile	0	7	2	3	0
Soils/Permafrost – Active Layer Depth	0	2	0	1	0
Soils/Permafrost – Soil Moisture	0	5	0	5	0
Soils/Permafrost – Texture and Character	No	Yes	No	Yes	No
Soils/Permafrost – Carbon and Ice Content	No	Yes	No	Yes	No
Soils/Permafrost – Gas Fluxes	No	Yes	No	Yes	No
Soils/Permafrost – Vegetation Cover	No	Yes	No	Yes	No
Topography – River Geometry	No	Yes	Yes	No	No
Topography – Wetland and Lake Geometry	No	Yes	Yes	Yes	No
Interval Camera	0	1	3	3	0

3. What Are the Causes and Consequences of the Greening of the Arctic?

Contacts: Eric Kasischke and Craig Tweedie

WHY

Analyses of satellite remote sensing data show there has been a pronounced pan-arctic increase in greenness of vegetation over the past three decades. A number of changes to arctic vegetation have also been observed through many studies of landscape to regional scale, and their consequences are important to subsistence users, land managers, and policy makers.



WHAT

This showcase project will address three questions:

1. What actual changes to vegetation are occurring? In different arctic ecosystems, what changes are occurring to community composition, vegetation growth, and vegetation phenology?
2. What are the causes of vegetation change? How do changes in climate (temperature, precipitation, snow cover, etc.), disturbance (fire, insects, thermokarst, etc.), permafrost warming and thawing, hydrology, herbivory, and changes to nutrient availability interact to control changes to vegetation?
3. What are the consequences of vegetation change? How do changes in vegetation influence wildlife habitat and migratory birds and mammals, permafrost dynamics, subsistence, and key feedbacks between the land surface and atmosphere (albedo, latent heat exchange, and surface energy exchange)?

WHO

A number of organizations (NSF, NASA, DOE, BLM, USFWS, National Park Service, Department of Natural Resources, North Slope Borough, USGS) are sponsoring and developing projects and programs focused on monitoring and understanding the causes and consequences of arctic vegetation change (Circumpolar Active Layer Monitoring, National Ecological Observatory Network, International Tundra Experiment, Back to the Future, Landscape Conservation Cooperatives, Arctic Long Term Ecological Research Network, Next Generation Ecosystem Experiments, Circumpolar Biodiversity Monitoring Program, Thermal State of Permafrost, Atmospheric Radiation Measurement Program, NASA Arctic–Boreal Vulnerability Experiment) and data from these organizations and projects are available through a number of established archives (CADIS, Barrow Environmental Observatory, International Tundra Experiment, Geographic Information Network of Alaska, Circumarctic Rangifer Monitoring and Assessment Network, Arctic Long Term Ecological Research, National Snow and Ice Data Center, NASA Distributed Active Archive Centers, etc.) and data not currently available through an archive (e.g., BLM and USFWS).

NEEDS

While the agencies and programs involved in this monitoring and research have all acknowledged the need for cooperative efforts, a number of challenges exist, including developing an effective mechanism for programmatic coordination, establishing monitoring and research priorities, establishing and maintaining long-term monitoring of key variables, and synthesizing and integrating results from individual researchers as well as coordinated groups of scientists working on large projects.

4. The Distributed Biological Observatory

Contact: Jackie Grebmeier

WHAT

The Distributed Biological Observatory (DBO) is being developed by an international consortium of scientists in the Pacific Arctic as a change detection array to systematically track the broad biological response to sea ice retreat and associated environmental change. The DBO is tracking select biological measurements at multiple trophic levels, coincident with physical and chemical data, in a latitudinal array of transect lines and stations in the northern Bering and Chukchi seas. Coordinated, regular ship-based observations, together with satellite and mooring observations at the designated sites, can provide an early detection system for biological and ecosystem response to climate warming. The purpose of designating the DBO as a showcase project is to transition its current pilot-scale effort to a full-scale implementation.

WHERE

The core study region is the northern Bering Sea to the Chukchi Sea/Barrow Sea ice arc in the Pacific Arctic region, with sampling focused at five biological hot spot sites on a latitudinal S–N array where some time series data already exist. The 2010–2012 pilot program focused on two areas in the Chukchi Sea where the highest number of ships from the six Pacific countries agreed to participate and share data sets, both real time and post-cruise, through the Pacific Arctic Group (PAG; **pag.arcticportal.org**). In addition, the group is expanding the DBO concept to both a pan-arctic and Antarctic scale for time series transects and sites through cooperation within the International Arctic Science Committee (IASC) marine working group and Arctic–Antarctic bipolar action working group (**iasc.info/index.php/home/groups**).

WHEN

The DBO project will continue to ramp up in 2012 to a full implementation phase starting in 2013 as a showcase AON project for a 5-year period through 2017, and with appropriate adjustments to be continued in some longer term form beyond. The time series transect and station occupations will occur from spring to fall (and opportunistically in winter), depending on national and international collaborations to collect biological, chemical, and physical oceanographic samples from ships transiting north, using both varying temporal and spatial sampling to evaluate biological and ecosystem response to environmental change. The expectation is that this biological change detection array will be the basis of a long-term (decadal scale) ecosystem monitoring program.

WHO

Implementation is occurring through both national and international community collaborations, with coordination by the international PAG. Interaction with a proposed U.S. AON steering committee and other international groups, such as SAON, will occur in the 5-year implementation phase.

HOW

Implementation will expand upon the successful 2010–2012 DBO international pilot program by providing incremental funding for ongoing national and international cruises to sample the full five time series transect array in the Bering and Chukchi seas. The project will support coordinated efforts for opportunistic, international sampling by ships transiting to the U.S. northern Chukchi Sea to develop seasonal time slices of physical, hydrographic, and sentinel plankton, benthos, and higher trophic level measurements.

WHY

It is essential to track biological response to changing environmental forcing to provide information to multiple end users, including local, state, and national agencies responsible for evaluating marine ecosystem health as well as societally relevant concerns about the impact of multiple stressors to the ecosystem (e.g., climate change impacts, renewable and nonrenewable resource extractions, and increased shipping). Scientific surveys have shown changes in benthic biological hotspots supporting marine mammals and seabirds, including several that are listed as threatened species under the U.S. Endangered Species Act. We are observing changes in the prey base for benthic- and water column-feeding marine animals, and the northward expansion of Pacific species of zooplankton and benthic invertebrates. New fish species are being reported in the Beaufort Sea, and changes have also been observed in marine mammals and seabird foraging areas and habitat use.

PARTNERS

The DBO is supported by sampling contributions funded by NSF, BOEM, NOAA, NASA and facilitated by international collaborators from Canada, China, Japan, Korea, and Russia through the PAG. Collaborative sampling within the DBO network includes:

- Funded U.S. AON investigators participating in the DBO
- NOAA: Oceanographic and biological sampling as part of the RUSALCA (Russian–American Long-term Census of the Arctic) annual sampling in the Bering Strait region; also R/V *Fairweather* hydrographic sampling
- Ongoing collaboration through the C3O (Canada's Three Oceans) annual July sampling on the Canadian Coast Guard Ship *Sir Wilfrid Laurier*
- BOEM Chukchi Sea Acoustics, Oceanography, and Zooplankton (CHAOZ) project and Chukchi Offshore Monitoring in Drilling Area (COMIDA) Hanna Shoal research program (2012–2014)
- NASA Impacts of Climate on the Eco-Systems and Chemistry of the Arctic Pacific Environment (ICESCAPE) program
- Japanese 4-year science program in the Chukchi Sea including biophysical moorings and sampling program around two of the Chukchi DBO sites (2012–2016)
- Planned industry occupation of the northern DBO line through their Chukchi Sea Environmental Assessment Program (CSEAP)

ANTICIPATED FIVE-YEAR ACCOMPLISHMENTS

Successful implementation of the biological change detection array as envisioned by the DBO will provide for a national and international network of coordinated sampling. This network will provide up-to-date information to local, state, and federal agencies responsible for maintaining a standard of ecosystem health of one of the most productive regions of the Arctic. The DBO efforts will facilitate data collection, sharing and archiving through the U.S. ACADIS data program and associated international data agreements.

ADDITIONAL DEVELOPMENT

There is a need to expand and integrate existing local community research partnerships, currently in the developmental stage, thus extending the DBO transect lines to the coast and engaging local community users of the living resources. In addition, consideration of dedicated U.S. cruises for the full implementation of the DBO in coordination with opportunistic national and international cruises, should be considered in future planning efforts to ensure that seasonal, annual, and decadal ecosystem responses to change will be detected. Finally, it is important to point out the need to expand the DBO to include process studies to understand the mechanisms responsible for change and to enable the forecast of future ecosystem states.

CROSS-LINKAGE WITH OTHER SHOWCASE PROJECTS

We anticipate that data needs for the DBO effort are cross-linked with the sea ice forecast project, Arctic Ocean freshwater and heat observations, and coastal zone observation infrastructure, including both the local community observatory and sea level observatory efforts. Incorporation of satellite products through involvement of NASA would add value. Inventories of higher trophic organisms through NOAA, USGS, and USFWS efforts will also be necessary within a fully operational DBO.

5. Multidisciplinary Drifting Observatory for the Study of Arctic Climate – MOSAiC

Contact: Matthew Shupe

CONCEPT

Multi-year, coordinated, and comprehensive measurements, extending from the atmosphere through the sea ice and into the ocean are needed in the central Arctic Basin to provide a process-level understanding of the changing central arctic climate system that will contribute towards improved modeling of arctic climate and weather, and prediction of arctic sea ice concentrations. To meet this need, an international group of scientists has envisioned a drifting, multidisciplinary, occupied observatory (ocean–ice–atmosphere) in coordination with a network of distributed observations and coastal land-based multidisciplinary observatories, for developing a process-level understanding of the central arctic climate system. The intention is for the central drifting observatory to be an ice station supported by icebreaker, with intensive local supporting measurements, installed in the ice for a drift of at least one year (and potentially multiple years) through the Arctic Basin. This central observatory and distributed network will serve as a test bed for model process studies, evaluation, and parameterization development.

WHAT IS THE QUESTION/CHALLENGE?

The overarching question guiding the MOSAiC effort is: What are the causes and consequences of an evolving and diminished arctic sea ice cover? This question is driven primarily by model difficulties and shortcomings related to insufficient process parameterizations, lack of arctic process-level evaluation data, difficulties with sea ice prediction, and the complexities of understanding large-scale implications of sea ice decline. In support of the overarching question is a set of sub-questions that address specific components of the climate system, all of which are focused on developing a detailed understanding of process interactions, feedbacks, and linkages within the arctic atmosphere–ocean–sea ice system. Importantly, this understanding must be developed for the 'new' Arctic, which is characterized by increasingly abundant first-year sea ice, changing seasonal evolution of the surface energy budget, and evolving responses to these changes.

WHO ARE THE PLAYERS?

MOSAiC has been conceived and promoted via the IASC and the efforts of many individual, multidisciplinary scientists (atmosphere, ocean, sea ice, biogeochemistry). While the overall project leadership will remain linked to international science groups, strong national contributions are needed to make the project a success. From the U.S. perspective, there are many agencies that may have critical roles for MOSAiC in support of their arctic programmatic efforts, including (but not limited to) NSF, DOE-Atmospheric Radiation Measurement Program, ONR, NOAA, and NASA. Strong coordination both at the national (via U.S. AON) and international level will be critical for MOSAiC. From a participation level, MOSAiC will bring together broad multidisciplinary interests representing observational and modeling efforts (climate, weather, and sea ice forecasting). Results from the project, including both enhanced understanding and modeling capabilities, are expected to have broad applications for continued climate research, resource development, transportation, local communities, and ecosystems.

WHERE DOES PREVIOUS INFORMATION EXIST?

Many of the key motivational issues and requirements for a project like MOSAiC have been outlined in national documents such as the report from the SEARCH Implementation Workshop (*SEARCH*, 2005) and IARPC plan. Central Arctic multi-disciplinary processes have been targeted by past projects including: the Russian drifting station program, Surface Heat Budget of the Arctic Ocean (SHEBA), the Arctic Leads ARI field experiment (LeadEx), other ice stations, drifting buoy programs, etc. However, each of these prior perspectives is limited by a combination of the following:

- Not comprehensive with respect to critical coordinated measurements
- Short term and/or no seasonal continuity

- No adequate represention of the spatial context and variability
- Not in the 'new' arctic environment

PERCEIVED CHALLENGES AND POTENTIAL PROGRAMMATIC BARRIERS

MOSAiC will face a number of major programmatic and logistical challenges. The first and foremost of these will be scientific and agency coordination at an international level, as there is relatively little foundation for such coordination and collaboration. There will also be significant logistical challenges in terms of implementing an observing program in the harsh central Arctic, including remote access to the central Arctic, identifying appropriate infrastructure (platforms, autonomous aerial vehicles, aircraft, transportation), obtaining observations in very thin, new sea ice, etc.

WHAT IS THE ROADMAP FOR IMPLEMENTATION?

Scientific planning for MOSAiC is well under way, with two planning workshops completed and a team of writers now composing a science plan. Broader scientific input will be gained via an open MOSAiC science meeting, anticipated for 2014. International coordination continues under the auspices of IASC, and MOSAiC has been encouraged to apply to be a cross-cutting theme within IASC. Initial plans for an implementation planning workshop are under way. In the future, specific efforts are needed within the U.S. and in other countries to secure the needed funding, infrastructure, logistical support, and science support. The observational, drifting station component of the project is anticipated to occur in the 2017–2018 time frame, in strong coordination with the World Weather Research Programme (WWRP) Polar Predictability Project 'Year of Polar Prediction'.

CONTACTS AND ORGANIZERS

MOSAiC is being organized via IASC, with initial support from the atmosphere, cryosphere, and marine working groups. Initial scientific leadership for the program is provided by Matthew Shupe and Ola Persson (University of Colorado), Klaus Dethloff (Alfred Wegener Institute), Michael Tjernstrom (Stockholm University), Don Perovich (Cold Regions Research and Engineering Laboratory), Alexander Makshtas (Russian Arctic and Antarctic Research Institute), and others.

6. Community-based Observation Network for Adaptation and Security

Contacts: Lilian Na'ia Alessa and Andrew Kliskey

WHAT

The Bering Sea Sub Network (BSSN) will evolve to a pan-arctic community-based observation network for adaptation and security (CONAS) using multiple methods and technologies. Key components include local observations of environmental variables and resources of importance to local communities such as water, weather, plants, and animals. These data are collected by residents year-round and in situ and provide socioeconomic and cultural contexts. Such observations will provide linkages between biophysical change, social adaptation, and resource security.

WHERE

Study region is the U.S. and Russian Far East peripheries of the Bering and Chukchi seas including coastal land, nearshore, and marine environments.

WHEN

In its current rendition BSSN will continue to operate through 2014 with data inflows occurring every month. Data acquisition occurs via several hundred observers across all locations who report to community coordinators in each village. In addition, data obtained from biophysical observing networks are integrated with resident observations to derive products such as maps reflecting hotspots of specific types of change.

WHO

Implementation is occurring through partnerships and agreements with local community and regional governments. Oversight is provided by a science oversight committee, comprised of the community coordinators and the project principal investigators. Interactions with other AON efforts should increase as BSSN/CONAS is an excellent means to acquire fine resolution, societally relevant data across seasons.

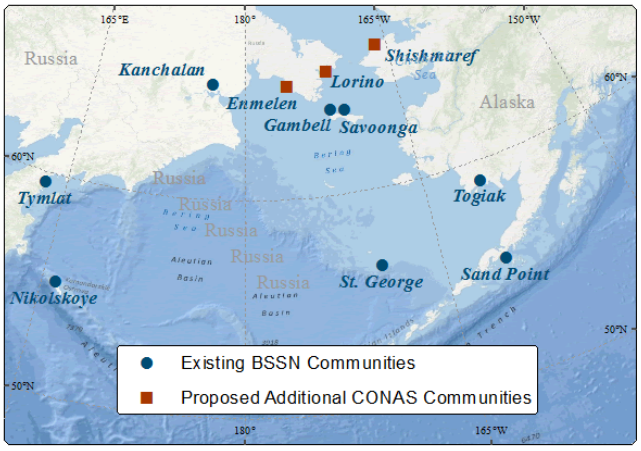
HOW

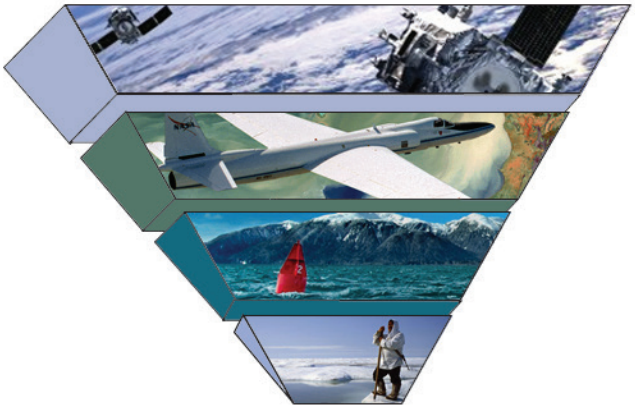
The foundation of the proposed approach involves consensus on critical variables to be observed, the co-production of science, shared interpretation of data, and co-management of applications as appropriate. Needed tools are:

- Structured survey forms and semi-structured narratives obtained through high-trust community coordinators for information capture
- Architecture for Integrated and Dynamic Data Analysis (AIDA)
- Hand-held data capture devices for image, voice, and environment

- Distributed micro sensor array, gridded at appropriate spatial geometries
- Computer programming, hardware, and other cyber infrastructure for discovery
- Social processes of discourse for knowledge sharing face-to-face and face-to-place

The application involves simultaneous data acquisition through instrumentation, surveys, narratives, information fusion, and image capture and can be phased over time to add different variables at various temporal and spatial scales. Synthesis of data coupled context as defined by community observers will allow rule-based algorithms to be developed for the purpose of targeted forecasting. Such an effort will yield high-quality and socially relevant information as well as advance education (of both western and indigenous scientists), diversity (of personnel and ontologies), and workforce development to increase under-represented minorities in science, technology, engineering, and mathematics (STEM) fields.





Nested scales of observation in the AON: from remote satellite observing at global scales, airborne observing at regional scales, and buoy/instrument-based marine terrestrial networks. BSSN/CONAS adds a scale of resolution that works synergistically with these networks to better resolve the heterogeneity of change. It also behaves as a local scale human sensor array capable of detecting change at the scale of daily human lives.

WHY

One of the goals of observing networks is to enhance place-based resilience under changing environmental conditions through 'early warnings' of specific types of change. The rapid proliferation of new technologies and the growing amount of data being generated begs an organizing framework that has utility to local adaptation and policy settings.

Indigenous, place-based science is spatially localized, spans immediate short-term periods to extended temporal periods, and includes systematic and integrative understanding of natural and human processes as cause and effect. Additionally, the application of indigenous science to sustain observing networks will assist in a better understanding of uncertainty and variability within arctic ecosystems. It is important to note that an indigenous place-based science is not just indigenous or traditional knowledge but rather a process that allows the co-production of science, which is (a) culturally and spatially appropriate (and hence more likely to inform decision making) and (b) inter-operable with other data derived through experimentation, instrumentation, or other means of acquisition.

A pan-arctic, community-operated, place-based (bottom-up) observing system will address the need to link biophysical science driven efforts to coordinate and synthesize multiple sources of data (a top-down approach). A community-based network, to be successful, should be developed at the community level first, and then be expanded to the regional and pan-arctic scale. Two of the major challenges in achieving this include (a) establishing systematic observing networks whose data are interoperable and timely and (b) formalizing place-based observations through structured instruments. The utility of integrating local and indigenous knowledge with western science, ideally from first processes, lies in placing data in societally relevant contexts. Many practitioners are reluctant to entertain circumstances to enable this, in part because of poor returns on funded projects that have included 'traditional ecological knowledge, traditional local knowledge', etc., as well as the perception that this knowledge cannot be structured for interoperability with other, quantitative data. However, there are ways to integrate community-based observing and knowledge systems within the existing structures of AON. In this way we believe that we will be better able to inform the Arctic's mounting sustainability challenges.

PARTNERS

BSSN is facilitated by international collaborators from the U.S. and Russia. Collaborative sampling within BSSN now includes:

- Funded U.S. AON investigators and data sites: ACADIS, National Snow and Ice Data Center (NSIDC), Exchange for Local Observations and Knowledge of the Arctic (ELOKA)
- Alaskan and Russian communities (see map)

- SAON, an initiative of IASC and Arctic Council
- Arctic and Antarctic Research Institute (AARI)
- Integrated Ecosystem Approach to Conserve Biodiversity and Minimize Habitat Fragmentation in the Russian Arctic (ECORA), a Russia-based project of the United National Environment Programme (UNEP-GRID Arendal) **www.grida.no/ecora/**
- Beringovsky District of Chukotka, Ministry of Natural Resources
- Norwegian Polar Institute
- CAFF (Conservation of Arctic Flora and Fauna working group of Arctic Council), BSSN reports are published by CAFF in the Monitoring series; see **www.caff.is**

Expansion to communities in the Chukchi region is planned and currently includes: Lorino and Meinypylgino in Russia, and Wales, Kivalina, Wainwright, and Point Hope in Alaska, U.S.A.

ANTICIPATED FIVE-YEAR ACCOMPLISHMENTS

Observations will be made of several key species of fish, marine mammals, sea state, weather, temperature, precipitation, resource use patterns, and linkages of various environmental changes to social impacts. Observations include historic patterns over multiple generations with low resolution and over a person's lifetime with more specificity.

ADDITIONAL DEVELOPMENT

Build linkages to the Distributed Biological Observatory and its goal to include local community research partnerships. This linkage will enhance our understanding of teleconnectivities with the nearshore, if any. Utilize community-obtained data for decision support and forecast tools such as in agent-based models (e.g., Forecasting Environmental Resilience in Arctic Communities – FERAL). Acquire new, micronized technologies to enable simultaneous, spatio-temporally correlated data collection of basic variables (e.g., air and water temperature, image capture of biota, etc.)

CROSS-LINKAGE WITH OTHER SHOWCASE PROJECTS

Linkages are implicit and easily made with each of the other showcase projects, particularly those involving biota and sea ice. BSSN-CONAS is a dynamic, adaptive network able to collect diverse environmental variables at multiple time scales and locations. Its strengths lie in (a) the resolution (local); (b) the approaches, data streams, and synthesis methods; (c) its ability to collect data that allow relationships between environmental change and social dynamics to be better understood for forecasting and decision support.

7. Ocean Observations to Improve Sea Ice Forecasting

Contact: Julienne Stroeve

WHAT

This showcase project is designed to provide the necessary ocean observations to improve sea ice forecasting on daily, seasonal, inter-annual, and decadal time scales. These time scales are needed for safe marine operations, infrastructure and community planning, and ecosystem stewardship in the Arctic.

WHERE

The initial target areas are the Chukchi Sea, Beaufort Sea, and northern reaches of the Bering Sea. This regional study will allow researchers and forecasters to work together to test different models, different model parameterizations, data assimilation, observational error impacts, etc. It will also allow for process studies on how sea ice changes in the Beaufort/Chukchi Sea are impacting the evolution of the arctic-wide sea ice cover. While initially regionally focused, a pan-arctic perspective is needed to provide upstream information for the target areas, support international goals, and provide the basis for longer-term projections of sea ice.

WHEN

The project could begin in 2013 and extend for 5 years, through 2017, for its initial phase. Observations will be required year round to enable the desired forecast products.

WHO

Implementation will draw from the broad national and international community, under guidance from the U.S. AON steering committee and a relevant international group (e.g., SAON), with implementation (possibly) guided by a (new) program office. Collaboration with weather forecasters will be critical to increase accuracy of sea ice forecasts at the shorter time scales. The existing International Arctic Buoy Programme will be a key partner in this project, and its leadership will be invited to participate in planning this project. Remote sensing will be a key component as it can provide near-real time pan-arctic maps of ice motion, ice edge location, ice thickness, ice concentration, melt pond fraction, timing of melt onset and freeze up, sea surface temperature (at the ice edge), surface albedo, surface temperature, and leads and polynyas. Effort must be expended to turn some of these remote sensing data sets into operational products.

HOW

Implementation will be based on existing activities and is likely to include most of the following:

- Planning for observations must include input from modeling centers to ensure that modelers will have

access to and use the data they require for initialization, validation, and assimilation of various forecast models. Key modeling centers include NOAA/National Centers for Environmental Prediction, U.S. Naval Research Laboratory/Stennis, and Canadian Ice Service. For pan-arctic and longer-term time scales, the climate modeling centers must be consulted as well.

- Both in situ and remotely sensed observations will be needed, taking full advantage of international remote sensing assets. In situ observations are key for better understanding of the processes impacting ice melt and growth, predicting storm surges and coastal impacts, and for ecosystem assessment and habitat management, whereas remote sensing provides pan-arctic sea ice state variables needed for data assimilation and model initialization.
- Key data needs include: temperature and salinity profiles; ocean heat content; sea ice thickness and snow cover; web cams for land fast ice, near-shore leads, and melt ponds; and sea ice extent on the pan-arctic scale and in the focus areas.
- In situ platforms that directly measure snow depth, sea ice thickness, bottom and top ablation, surface air temperature, mixed layer ocean temperature, tides, bathymetry, and circulation are needed. Floe size and shape are also important for ecosystem studies.
- Remote sensing provides large-scale characteristics of sea ice, such as ice concentration, ice thickness, ice type (first-year vs. perennial), ice motion, leads and polynyas, melt pond fraction, surface albedo, and temperature. Snow depth over sea ice remains a critical remote sensing gap, and efforts are needed to develop snow depth estimates over large spatial scales.
- Continuous or frequently repeated data collection will be needed, including surveys in at least spring and fall, to allow forecasts of ice loss and regrowth.
- International collaboration will be a necessary component of this project, not only because Canada and Russia share the target region with the U.S., but also because international collaboration is needed for data sharing (e.g., European Space Agency CryoSat-2 for ice thickness).
- To meet the observational requirements in a cost-effective way, it will be necessary to take opportunistic advantage of all available observing platforms (e.g., ships, aircraft, fixed offshore platforms, coastal locations). Partnerships with national, international, and private industry are needed so that platforms could be equipped with instrumentation for many of the needed observations on a mutually beneficial basis.
- For the shorter-term forecast needs, real time access to data will be essential, requiring most data transmitted in near-real time to data centers and modeling centers. Whenever technically possible, data should be placed on the Global Telecommunications System for use by modeling centers.
- For seasonal forecast needs, improved access to sea ice buoy data, satellite data products, and aircraft and ship observations are needed, particularly during late spring (initialization), late summer (ocean), and early autumn (verification).
- Model output should include a measure of uncertainty or probability so that different stakeholders can perform their own risk analysis. Deterministic output is required for accurate marine and coastal storm surge forecasts.
- The Sea Ice Outlook activity should continue as a means to synthesize and disseminate seasonal sea ice forecasts, with efforts to become a more formal program that includes cooperation with SEARCH and international participation.

To initiate the project, several near-term actions have been identified, including:

- Consult with modeling centers to agree on data needs
- Identify platforms of opportunity and arrange for relevant observations from them
- Strengthen the ongoing Sea Ice Outlook effort, and take advantage of that experience to guide enhanced observing and forecast efforts
- Identify a subset of potential users and consult with them to define high-priority products and establish a process to create them
- Consult with selected living marine resource managers (species specific and ecosystem-based), harvesters (commercial and subsistence), and researchers to define data and product requirements to support their objectives and build these requirements into the observing strategy to the extent possible
- Evaluate need for a program office or some structure to facilitate coordination and implementation and then establish the desired structure
- Evaluate the potential of the National Ocean Partnership Program (NOPP) as a means of implementing interagency support for this project

WHY

Sea ice forecasts have value to a broad range of stakeholders, including operational users (safety of life and property), crisis responders, resource managers, weather and climate forecasters and their users, climate change detection researchers, politicians, and coastal communities.

ANTICIPATED FIVE-YEAR ACCOMPLISHMENTS

Successful implementation of this project will provide continued and enhanced observations directly supporting various user needs — improved coordination among agencies

and countries to enhance quality, efficiency, and coverage; improved model-based forecasts with error estimates; and extended data records to support climate science.

CROSS-LINKAGE WITH OTHER SHOWCASE PROJECTS

This project shares observational needs with the freshwater and heat project and also links closely with the Distributed Biological Observatory project and the coastal projects (sea level and place-based community observations). Should all projects go forward, a means of sharing data between projects will be essential, with real time exchange important for many variables.

8. Long-term Sea Level Measurements along the Alaskan Chukchi and Beaufort Coasts

Contact: Steve Okkonen

WHAT

This project envisions a network of long-term stations to monitor coastal sea level along the Alaskan arctic coast and report those measurements in near-real time.

WHERE

The sea level recording stations would be sited at Little Diomede, Wales, Kotzebue, Point Hope, Point Lay, Wainwright, Barrow, and Kaktovik. Long-term stations presently exist at Red Dog (seasonal) and Prudhoe Bay.

WHY

- Sea level is arguably the most basic of oceanographic measurements. Historically, coastal residents have recognized that travel, commerce, and the harvesting of marine resources are influenced by changes in sea level and that the ability to predict these changes greatly improves efficiency and safety in pursuit of these activities.
- Coastal sea level is a suitable proxy for near-shore, subtidal current velocities. A network of stations reporting in near-real time allows systematic description of circulation along the Alaskan arctic coast.
- Sea level measurements are used to both assess and validate numerical storm surge and circulation models. The ability of a numerical model to reproduce observed sea level is a fundamental measure of a model's skill. A skillful storm surge model is an emergency preparedness and response decision support tool for coastal Alaskan villages.
- Although the tidal variations in sea level have been identified at many locations along Alaska's arctic coast, the measurements have generally been of too short duration to resolve seasonal and long-period (e.g., associated with the Arctic Oscillation) changes in sea level. Long-term (decadal) measurements are needed to investigate these long-period signals.
- Sea level measurements along the arctic coast of Alaska would provide a unique set of observations to validate sea height estimates derived from satellite remote sensing. Additionally validated remote sensing sea level estimates obtained from radar altimetry or synthetic aperture radar could be used to fill the gaps in the proposed tide station network in the Beaufort Sea. Satellite images of actual storm surge events can also be better interpreted using the coincident tide gauge observations.

HOW

It is NOAA's mission to provide water level information. Responsibility for the installation, operation, and maintenance of water level stations lies with the National Ocean Service: Center for Operational Oceanographic Products and Services (CO-OPS). Logistics associated with recent two-year (2008–2010) deployments of water level gauges near Barrow are described in ***Tides Under the Ice: Measuring Water Levels at Barrow, Alaska 2008–2010*** (*Sprenke et al.*, 2011) and serve as a model for deployment of similar gauges at other locations. Value is added if these water level recorders are able to report in near-real time.

WHEN

As soon as is practical, the goal is to have the entire proposed suite operational within two years.

9. Arctic Ocean Freshwater and Heat Observing System

Contact: Peter Schlosser

WHAT

We propose to implement systematic, pan-arctic, long-term observations to determine the freshwater and heat contents of the Arctic Ocean, as well as their variability and trends. The system would cover observations of the central basins of the Arctic Ocean and its shelves and would allow us to narrow the errors in our estimates of freshwater and heat inventories and fluxes. Parts of the system are in place through national (mainly NSF AON, NOAA, ONR, NASA) and international (e.g., Ice–Atmosphere–Arctic Ocean Observing System – IAOOS) efforts. The proposed system can be completed in a 5-year time frame.

WHY

- Freshwater and heat content determine the stratification and circulation patterns in the Arctic Ocean including its shelf seas. These fundamental features of the Arctic Ocean impact sea ice formation and melting, sea ice extent, meltwater distribution, biological activity, runoff from land (rivers and glacial melt water), and navigation in the Arctic Ocean, among others.
- As many of these Arctic Ocean components and processes are undergoing rapid change it is important to obtain a more complete picture of the freshwater and heat budgets of the Arctic Ocean both from a point of understanding present and future changes and for producing information of immediate relevance for stakeholders (e.g., sea ice trends, ecosystem dynamics, navigation).
- The freshwater export from the Arctic is a major link to low latitudes and influences stratification in areas of deep convection such as the Greenland/Iceland/Norwegian seas or the Irminger and Labrador seas, i.e., major components of the global ocean circulation system.
- The need for this information is urgent as demonstrated by the abrupt decline in sea ice extent in 2007. Similar events could be in a preconditioning phase and only a complete set of observations would allow us to identify them before we are faced with further surprises.

WHERE

The system should cover the main basins of the Arctic Ocean, its shelves, and the main gateways (Bering Strait, Fram Strait, Canadian Archipelago).

WHEN

The first U.S. components of the system were put in place during the Freshwater Initiative. Major additions were completed during the IPY period by U.S. and international groups. The highest priority is to finish implementation of the original design of the system as laid out in the report of the SEARCH Implementation Workshop (*SEARCH*, 2005) and the Developing Arctic Modeling and Observing Capabilities for Long-term Environmental Studies (DAMOCLES) program. Coordination with other international groups such as ArcticNet will be enhanced during the spring 2013 Arctic Observing Summit. It is a realistic goal to complete the initial plan for the system in a 5-year time frame (depending on availability of resources).

COMPONENTS

The Freshwater and Heat Observing System consists of Eulerian (e.g., moorings, bottom pressure gauges) and Lagrangian (e.g., ice tethered platforms, gliders, autonomous underwater vehicles) instruments, hydrographic and tracer sections (e.g., icebreakers, airborne surveys, submarines), and satellites. This mix of platforms has the demonstrated potential to resolve the major features of the freshwater and heat distribution and their fluxes through gateways. Development of new technology is an important priority but the system can be implemented with existing technology and components can be substituted by new technology as it becomes available (e.g., gliders, ARGO-type array). Some of the platforms can be shared to carry additional sensors such as those needed by the Distributed Biological Observatory.

WHO

There is an international core community that has tested and deployed essential components of the system including moorings, ice tethered profilers, airborne survey methods, icebreaker sections, or sampling from submarines (e.g., the Submarine Arctic Science Program – SCICEX – missions). Other groups are working to adjust new technology such as gliders or Profiling Autonomous Lagrangian Current Explorer (PALACE) floats for deployment in (partially) ice-covered regions.

SPECIFIC NEEDS

- Complete the system by filling gaps in coverage
- Add more autonomous sensors to the array
- Achieve seasonal resolution on a pan-arctic scale
- Include model simulations into the design and further develop the system
- Work on access to exclusive economic zones (EEZs), especially the Russian EEZ

SYNERGIES

Scientifically, the Freshwater and Heat Observing System will contribute to the data flow needed to understand sea ice dynamics and change, ecosystem changes and evolution, navigability of the Arctic and its shelf seas through its impact on sea ice, interaction of terrestrial and oceanic freshwater cycles, and fluxes of freshwater to the global ocean. Logistically, there will be synergies through sharing of platforms for sensors and joint use of platforms such as icebreakers, aircraft, or submarines.

10. Utilizing the State of the Existing Knowledge to Guide Infrastructure Development

Contacts: Larry Hinzman, Greg Balogh, and David Yokel

WHAT

Use science to guide responsible development and use development projections to guide scientific efforts. This project will be focused upon information transfer and identifying mechanisms to convert knowledge into action, understanding into implementation.

WHERE

There are several land and resource management agencies in Alaska, both state and federal. We need to establish a dialogue to enable agency needs to guide research investments and to permit these agencies to optimally utilize the understanding that can be derived from the research.

WHEN

An initial workshop should be held as soon as possible after a champion and funding are found to organize the effort. This first workshop should include all stakeholders, i.e., land managers, private and public entities likely to be involved in infrastructure development, and relevant arctic investigators. The initial program should be an introduction to: (1) the concept of science informing development and projected development guiding science; (2) the organizations that produce the science; and (3) what science is currently available and what is proposed for the near future.

Subsequent workshops should be focused on individual development projects as they are conceived or on smaller geographic regions with multiple projects proposed for development. An annual or semi-annual electronic newsletter should be distributed to participants of the initial workshop to keep them informed of progress and new developments.

WHO

Communication at a level where science informs development and projected development guides science requires engagement of land management agencies, industry partners, climate modelers, economists, local residents, engineers, and scientists (ecologists, biologists, hydrologists, geophysicists, remote sensing and geospatial analysts, climatologists, modelers). In essence, everyone who is concerned about resource or community development, and especially those who must plan on a thirty-year or longer time horizon, should have information on climate scenarios and environmental and ecological responses to make the most informed decisions.

HOW

Civil projects that would benefit from consideration of climate and ecosystem analyses should interface with the AON program to enable most efficient analyses and optimum design incorporating the state of the science. Civil projects offer an opportunity to collect unique datasets; they afford an opportunity to peer into the system by collecting pre-disturbance data to monitor impacts and recovery of the disturbed system. Such projects will require early involvement of industry and agencies to ensure development of best management and design practices in advance of conducting pre-disturbance assessments. Preliminary efforts will include synthesis and incorporation of existing data, and incorporation of permit conditions that facilitate optimum data collection. Integration of best management and design practices with geographic data layers to develop ecologically and economically viable alternatives will permit optimum scenarios that lead to development that is appropriate for projected climatic and environmental conditions.

The program will require compilation and integration of all relevant data sets, which may include, but is certainly not limited to, information on the following: digital terrain, erosion rates, thermokarst processes, land cover and vegetation changes, fire regimes, permafrost temperature and ice content, seasonal thaw depth, air and water temperature, amount and seasonality of precipitation, seasonal streamflow, species phenology, distribution and movement, ecological response analyses, down-scaled climatologies and scenarios, surface geology, hydrography, and any other existing ecological, hydrological and geophysical data. Both recent and legacy data would comprise an ideal information foundation. Additional relevant information may be extracted from National Environmental Policy Act (NEPA) and Endangered Species Act Section 7 consultation documents, existing infrastructure design and construction information, the ***Environmental Atlas of Alaska*** (*Hartman and Johnson*, 1984), and other sources.

There are now many well-developed tools and models that may be applied to these analyses. The Lake Fate Model simulates lake dynamics on long time scales. The Alaska Integrated Ecosystem Model brings together component models for projecting climate effects on fire regime, vegetation dynamics, and permafrost, and incorporates hydrologic information so that feedback from each model informs subsequent projections for the component models to better project ecosystem response to changing conditions. The Scenarios Networks for Alaska and Arctic Planning (SNAP) down-scaling model and climate forecasts provide the best estimates of climate forecasts on community scales. Dynamic vegetation modeling would provide information on which species may be expected to flourish and which may become maladapted to future conditions. Permafrost models and hydrologic models are critical to define local physical conditions. Several ongoing federal field programs could contribute to this

process and foster the progression of incorporating scientific studies into resource management practices. These include, but are not limited to: USGS Changing Arctic Ecosystem, NSSI Landcover, BLM Assessment Inventory and Monitoring in National Petroleum Reserve-Alaska (NPR-A), and Arctic Rapid Ecological Assessment project, Fish and Wildlife Service Inventory and Monitoring Program, and the National Park Service Arctic Vital Signs Network. Additional programs that are projected or are under development include the NASA Arctic–Boreal Vulnerability Experiment, the Arctic Council's Circumpolar Biodiversity Monitoring Program, and the ALCC Terrestrial Ecosystem Observing Network.

This program should also identify ways to balance interests of the scientific community and land managers and stakeholders. It is necessary to weigh appropriately the influence of proponents pushing infrastructure construction with the mission of natural resource agencies to preserve essential habitats and protect the integrity and connectivity of natural systems. As science informs development and development guides science, there is great potential and need for collaboration among agencies and among private and public sectors. There is clearly interest from resource management agencies to gain information that will inform their management decisions. There are also clear opportunities for funding as agencies and others seek to undertake investigations that are more interdisciplinary in nature, spatially extensive in scope, and have applications for current and near-future decision making.

WHY

To date, persistent infrastructure placement has not adequately considered future environmental conditions. Science generated by AON and other climate scientists and ecologists could inform design and placement of such structures in a way that would minimize disturbance and enhance long-term functionality of infrastructure.

PARTNERS

There are several unrelated scientific and management programs that should be tapped to advance this effort. These include NSSI (which, among other functions, hosts workshops to facilitate interagency communication on scientific activities on the North Slope of Alaska), the ALCC (dedicated to better understanding the effects of climate on arctic ecosystems, and development and delivery of tools and data useful to land managers), the Department of Transportation (which is presently engaged in design of new roads in northern regions), the Alaska Departments of Natural Resources (ADNR) and Environmental Conservation (ADEC), which jointly share numerous permitting responsibilities.

ANTICIPATED FIVE-YEAR ACCOMPLISHMENTS

At the least, this effort will make all relevant parties aware of the potential for using science to improve the planning of future infrastructure, and use planned infrastructure to guide future investigations. At best, all parties will understand the benefits of this marriage of knowledge, and we will begin seeing more science with direct applications to management and better planned and designed infrastructure.

ADDITIONAL DEVELOPMENT

There are numerous real and perceived challenges and programmatic barriers that may forestall full implementation. These include limitations with fully utilizing proprietary private sector data. Such data abounds due to large private investment in natural resource extraction in Alaska, but it is rarely available for subsequent analyses by other parties. The uncertainty surrounding climate projections limits the willingness of some individuals to accept or believe what is the best information available. Economic barriers will always present obstacles to implementing optimum solutions (for example, relocating villages may be necessary, but also cost prohibitive). Land ownership patterns and social, cultural, and ecological impacts could also complicate execution of some well-designed plans.

CROSS-LINKAGE WITH OTHER SHOWCASE PROJECTS

While this project was conceived mostly with the terrestrial environment in mind, the concept readily transfers to the marine environment. As such, information from the Distributed Biological Observatory and Arctic Ocean Freshwater and Heat Observing System will contribute directly to achieving the vision of this effort. The distributed environmental observatory will be a key component of this effort, especially when aspects of the observatory are informed by planned resource development actions.

11. Connecting Arctic Communities with One Another and with Scientists: Building a Community-based Observation Network

Contact: Henry Huntington

GOAL

Create a functioning network connecting community-based observation efforts with one another and with the wider arctic observation network.

CHALLENGE

There are several community-based observation projects in operation in Alaska, but there are few connections among them. Furthermore, the connections between community observers/observations and scientists/scientific data are typically sparse and serendipitous rather than robust and planned. We are thereby missing opportunities to identify broader patterns by recognizing similar observations in different communities, to connect community concerns and

scientific understanding, to link local observations with gaps and questions in current science, to support and encourage the collaboration of community members and scientists, and other ways of fostering greater overall engagement in observing, understanding, and responding to arctic change.

OBJECTIVES

1a. Identify several community-based observation efforts that are willing to take part in the showcase project

1b. Determine, for each effort, the parameters observed, the degree of engagement with scientists within and outside the project, the data management approach, observing protocols adhered to, duration, time and work required to become operational, time and work devoted to connecting among communities or with scientists, etc.

2a. Identify several community observers who are willing to take part in the showcase project

2b. Evaluate observers' experiences to determine what factors foster satisfactory interactions with other communities or scientists outside the project and provide information of relevance with regards to community concerns, and what factors impede success

3a. Identify several scientists, not affiliated with community-based projects, who have interacted with these efforts and are willing to take part in the showcase project

3b. Evaluate scientists' experiences to determine what factors foster satisfactory interactions with community observers and result in observations of interest to the scientific community, and what factors impede success

4. Analyze the results of 1–3 to identify promising ways to foster networking among communities and between communities and scientists

5. Design a network support system (e.g., social networking, data portal, communication platform, etc.) to support the goal, implement the design, evaluate how it works, modify as appropriate, and continue

READINESS

Several projects are under way, such as Seasonal Ice Zone Observing Network (SIZONet), the Bering Sea Sub-Network (BSSN), the Exchange for Local Observations and Knowledge in the Arctic (ELOKA), the Nelson Island Project, the Local Environmental Observers (LEO) project, and others. Collectively, these efforts have accumulated a great deal of experience, but have had few opportunities to share the lessons learned.

BALANCING SCIENTIFIC, MANAGEMENT, AND COMMUNITY INTERESTS

This project looks squarely at the intersection of community and scientific interests. It does not focus specifically on management, except to the extent that some community concerns will be related to practical applications or issues such as coastal erosion, sanitation, subsistence, etc.

AGENCY SUPPORT AND FUNDING

The project will be of interest to several agencies already engaged in or providing funding for community-based efforts. These include NSF, NPRB, and others. Other than annual calls for proposals, we are not aware of specific funding opportunities, but note that NSF and others have small grant programs that can provide modest funding under the right circumstances. Management agencies may have an interest in the results, to the extent that they are interested in community-based observations. Whether they would be willing to support this showcase project is not known.

Appendix 2. Federal, State, and Local Government Programs and Partnerships Pertinent to U.S. Arctic Observing Programs

U.S. Government Programs

DEPARTMENT OF AGRICULTURE

Climate Change Assessment for Alaska Region. **www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_038171.pdf**

Forest Inventory and Analysis. The nation's continuous forest census projects how forests are likely to appear 10 to 50 years from now. **www.fia.fs.fed.us/**

Forest Service Research and Development. Conducts biological, physical, and social science to promote sustainable management of nation's diverse forests and rangelands. **www.fs.fed.us/research/**

Major Land Resource Areas of Alaska. Natural Resources Conversation Service coordinates the collection of soils and related natural resource data for the state of Alaska. **www.ak.nrcs.usda.gov/soils/index.html**

Natural Resources Conservation Service. Works with landowners through conservation planning and assistance designed to benefit the soil, water, air, plants, and animals that result in productive lands and healthy ecosystems. **www.nrcs.usda.gov/wps/portal/nrcs/main/national/about**

Natural Resources Conversation Service Snow Survey Program. Provides mountain snowpack data and streamflow forecasts for the western United States. **www.ak.nrcs.usda.gov/Snow/index.html**

U.S. Forest Service. Comprised in Alaska by the Chugach and Tongass National Forests as well as the State and Private Forestry Program.

DEPARTMENT OF THE INTERIOR

Alaska Climate Science Center. Provides scientific information, tools, and techniques to anticipate, monitor, and adapt to climate change. **www.doi.gov/csc/alaska/index.cfm**

BOEM Alaska Environmental Studies Program. Conducts environmental studies to obtain information pertinent to sound leasing decisions as well as to monitor the human, marine, and coastal environments. **www.boem.gov/About-BOEM/BOEM-Regions/Alaska-Region/Environment/Environmental-Studies/Index.aspx**

Bureau of Land Management (BLM). Administers approximately 75 million surface acres of federal public land in Alaska. **www.blm.gov/ak/st/en.html**

Bureau of Ocean Energy Management (BOEM). Oversees more than one billion acres on the outer continental shelf and more than 6,000 miles of coastline in Alaska – more coastline than in the rest of the United States combined. The Alaska region encompasses the Arctic Ocean, the Bering Sea, and the northern Pacific Ocean. **www.boem.gov/About-BOEM/BOEM-Regions/Alaska-Region/Index.aspx**

Landscape Conservation Cooperatives. The Arctic Landscape Conservation Cooperative (ALCC) supports conservation in the Arctic by providing applied science and tools to land managers and policy makers. **www.fws.gov/science/shc/lccinfocontacts.html**

Murie Science and Learning Center. Supports scientific research fellowships that assist park managers in making informed decisions about the protection of natural and cultural resources and visitor experiences in arctic and subarctic parks. **www.nps.gov/dena/naturescience/upload/2012-MSLCFellowship.pdf**

National Park Service. Manages over 54 million acres of national parks in Alaska and some of the most spectacular and remote natural places in the country. **www.nps.gov/akso/nature/science/index.cfm**

National Park Service Inventory and Monitoring Program. Develops scientifically sound information on the current condition and long-term trends in park ecosystems to determine how well current management practices are sustaining those ecosystems. **science.nature.nps.gov/im/units/AKRO/**

Ocean Alaska Science and Learning Center. Supports marine and coastal research that addresses high-priority resource management concerns for Alaska's coastal national parks. **www.oceanalaska.org/**

Rapid Ecoregional Assessment. Establish landscape-scale baseline ecological data to gauge the effect and effectiveness of future management actions. **www.blm.gov/wo/st/en/prog/more/climatechange/reas/seward.html**

Shared Beringian Heritage Program. Supports projects of scientific and local importance in western Alaska and eastern Chukotka, in partnership with community organizations and academic institutions. **www.nps.gov/akso/beringia/projects/index.cfm**

U.S. Fish and Wildlife Service (USFWS), National Wildlife Refuge Inventory and Monitoring Program. Developing a nationally-coordinated program of inventory and monitoring on FWS lands. **ecos.fws.gov/ServCatFiles/Reference/Holding/5527**

U.S. Geological Survey (USGS), Alaska Science Center. Provides timely, relevant, and impartial study of the landscape, natural resources, and natural hazards for Alaska and the nation. **alaska.usgs.gov/**

DEPARTMENT OF COMMERCE

National Marine Fisheries Service, Alaska. Oversees sustainable fisheries that produce about half the fish caught in U.S. waters, and works to ensure the viability of protected species, principally marine mammals. **www.alaskafisheries.noaa.gov/**

National Oceanic and Atmospheric Administration (NOAA), Alaska. Conducts a wide range of programs focused on the condition of the oceans, marine resources, the atmosphere, climate and weather. **www.legislative.noaa.gov/NIYS/NIYSAK.docx**

National Weather Service, Alaska. Provides weather, hydrologic, climate forecasts, and volcanic ash and tsunami warnings for the state of Alaska and its surrounding waters. **www.arh.noaa.gov/**

DEPARTMENT OF DEFENSE

Office of Naval Research (ONR). Supports innovative scientific and technological solutions to address current and future Navy and Marine Corps requirements. **www.onr.navy.mil/en.aspx**

U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory (CRREL). Applies science and engineering to complex environments, materials, and processes in all seasons and climates, with unique core competencies related to the Earth's cold regions. **www.crrel.usace.army.mil/**

DEPARTMENT OF HOMELAND SECURITY

U.S. Coast Guard (USCG). Safeguards our nation's maritime interests and environment around the world. USCG icebreakers serve Arctic/Antarctic science and research as well as provide supplies to remote stations. **www.uscg.mil/datasheet/icepolr.asp**

DEPARTMENT OF ENERGY

Argonne National Lab. Energy research and regionally-focused ecological and climate interactions and their impact on local economy and policy decisions. **https://blogs.anl.gov/major_initiatives/**

Atmospheric Radiation Measurement (ARM) Program. Supports a network of climate research facilities for observing the atmosphere, including a comprehensive facility in Barrow, Alaska. **www.arm.gov/**

Sandia National Laboratory. Enhancing the nation's security and prosperity through sustainable, transformative approaches to our most challenging energy, climate, and infrastructure problems. **www.sandia.gov/mission/index.html**

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA's Earth Observing System is a coordinated series of polar-orbiting and low inclination satellites for long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans. **eospso.gsfc.nasa.gov/**

NATIONAL SCIENCE FOUNDATION

Advanced Arctic Cooperative Data and Information System (ACADIS). The primary archive for all AON data generated by NSF investigators. It is collaborative effort between the National Snow and Ice Data Center, National Center or Atmospheric Research, and University Corporation for Atmospheric Research. **www.aoncadis.org**

National Ecological Research Observatory Network (NEON): A continental-scale observatory designed to gather and provide 30 years of ecological data on the impacts of climate change, land use change, and invasive species on natural resources and biodiversity. **www.neoninc.org/**

Office of Polar Programs (OPP). Manages and initiates National Science Foundation funding for basic research and its operational support in the Arctic and the Antarctic. **www.nsf.gov/dir/index.jsp?org=OPP**

State of Alaska Programs

Alaska Department of Environmental Conservation. Conserves, improves, and protects Alaska's natural resources and environment (e.g., air, water, environmental health) to enhance the health, safety, economic and social well-being of Alaskans. **dec.alaska.gov/**

Alaska Department of Fish and Game. Protects, maintains, and improves fish, game, and aquatic plant resources of the state, and manages their use and development. **www.adfg.alaska.gov/index.cfm?adfg=about.divisions**

Alaska Department of Natural Resources. Manages all state-owned land, water, and natural resources, except for fish and game, on behalf of the people of Alaska. **dnr.alaska.gov/commis/pic/about.htm**

Governor's Subcabinet on Climate Change. Advises the Office of the Governor on the preparation and implementation of the Alaska climate change strategy. **www.climatechange.alaska.gov/**

Local Government

North Slope Borough, Department of Wildlife Management. Facilitates sustainable harvests and monitors populations of fish and wildlife species through research, leadership, and advocacy from local to international levels. **www.north-slope.org/departments/wildlife/**

Multi-Partner Programs

Alaska Climate Change Coordinating Committee (C4). The bridging group for the Alaska Climate Change Executive Roundtable (ACCER), Landscape Conservation Cooperatives (LCCs), Department of the Interior Alaska Climate Science Center, and NOAA. **nccwsc.usgs.gov/?q=ACCER_AND_C4**

Alaska Climate Change Executive Roundtable (ACCER). Comprised of senior level executive, both federal and non-federal, agencies from throughout Alaska, the Climate Change Executive Roundtable meets regularly to share information and facilitate cooperation among agencies. **www.aoos.org/adiwg/accer/**

Alaska Committee for Noxious and Invasive Plants Management (CNIPM): Interagency collaboration for management of invasive plants. **www.uaf.edu/ces/cnipm/**

Alaska Data Integration Working Group (ADIWG). Initiated by ACCER, this group was created to promote policies and procedures to help streamline data sharing in Alaska. The primary effort of the technical subgroup thus far has been to improve data integration and project tracking among federal and state agencies in Alaska. **www.aoos.org/adiwg/**

Alaska Geographic Data Committee (AGDC). Statewide group organized in 1990 to promote data sharing among federal, state, native, local, commercial, and non-government organization member agencies. The USGS hosts the Alaska Geospatial Data Clearinghouse for the committee. **agdc.usgs.gov/contact/**

Alaska Invasive Species Working Group (AISWG). Interagency collaboration for management of all invasive species (including marine invasives) across Alaska. **www.uaf.edu/ces/aiswg/**

Alaska Marine Ecosystem Forum. Organized by North Pacific Fishery Management Council to improve coordination and cooperative understanding between federal agencies on issues of shared responsibilities related to the marine ecosystems off Alaska's coast, other than fisheries. The initial focus of the AMEF has been on the Aleutian Islands marine ecosystem. **www.fakr.noaa.gov/npfmc/conservation-issues/amef.html**

Alaska Nanuuk Commission. Represents villages in North and Northwest Alaska on matters concerning the conservation and sustainable subsistence use of polar bear. **www.nanuuq.info/**

Alaska Ocean Observing System (AOOS). Working to develop a unified, comprehensive, cost-effective approach to providing ocean observations (biological, chemical, and physical) from a permanent monitoring system and developing the information products based on those observations to meet the needs of users of coastal ecosystems. **www.aoos.org/about-aoos/**

Alaska Shorezone. A Coastal America project for coastline mapping and classification that specializes in the collection and interpretation of low-altitude aerial imagery of the coastal environment. **alaskafisheries.noaa.gov/shorezone/**

Arctic Observing Network (AON). AON was initiated by the NSF during International Polar Year (IPY). AON is integral to the Study of Environmental Arctic Change (SEARCH). **www.arcus.org/search/aon**

Arctic Research Consortium of the United States (ARCUS). A nonprofit member consortium of educational and scientific institutions that have a substantial commitment to arctic research. **www.arcus.org/**

Bering Sea Project (Bering Sea Ecosystem Study—BEST and Bering Sea Integrated Ecosystem Research Program—BSIERP). A six-year partnership project between the North Pacific Research Board and the National Science Foundation, that seeks to understand the impacts of climate change and dynamic sea ice cover on the eastern Bering Sea ecosystem, from the benthos and the atmosphere to human communities, and everything in between. **bsierp.nprb.org/index.html**

Centers for Ocean Science Excellence (COSEE) Alaska. Strives to spark and nurture collaborations among research scientists and educators to advance ocean discovery and make known the vital role of the ocean in our lives. **www.coseealaska.net/**

Circumarctic Environmental Observatories Network (CEON). A network of terrestrial and freshwater observation platforms, science experts, and network partners promoting the collection and dissemination of environmental data from the Arctic. **www.ceon.utep.edu/**

Coastal America. An action-oriented, results-driven collaboration process dedicated to restoring and preserving coastal ecosystems and addressing critical environmental issues. **www.coastalamerica.gov/index.php?option=com_content&view=article&id=1550&Itemid=81**

Coastal and Marine Spatial Planning (CMSP) for Western U.S. To promote better understanding of current and future science needs in the realm of coastal and marine spatial planning. **pubs.usgs.gov/of/2011/1152/**

Cooperative Ecosystems Studies (CESU) Network. A network of federal agencies, universities, and other organizations striving to facilitate research in local and regional ecosystems. The University of Alaska hosts the North and West Alaska CESU. **www.uaf.edu/snras/cesu/**

Eskimo Walrus Commission. Works on walrus and related resource co-management issues, on behalf of Alaska Natives as an essential cultural, natural, and subsistence resource to the Alaskan coastal Yupik and Inupiaq communities. **www.kawerak.org/servicedivisions/nrd/ewc/**

Exxon Valdez Oil Spill (EVOS) Trustee Council. A state and federal partnership formed to oversee restoration of the injured ecosystem through the use of EVOS civil settlement. **www.evostc.state.ak.us/**

Federal Subsistence Management Program. A multi-agency effort to provide opportunities for a subsistence way of life by rural Alaskans on federal public lands and waters while maintaining healthy populations of fish and wildlife. The Federal Subsistence Board is the decision-making body that oversees the program. **alaska.fws.gov/asm/board.cfml**

Geographic Information Network of Alaska (GINA). Works with agencies, non-governmental organizations, and private sector organizations to serve the geospatial data covering Alaska. **www.gina.alaska.edu/information**

Incorporated Research Institutions for Seismology (IRIS). An NSF-supported consortium of over 100 U.S. universities dedicated to the operation of science facilities for the acquisition, management, and distribution of seismological data. **www.iris.edu/hq/about_iris**

Interagency Working Group on Coordination of Domestic Energy Development and Permitting in Alaska. This group was established by an Executive Order and works to coordinate the efforts of federal agencies responsible for overseeing the safe and responsible development of onshore and offshore energy in Alaska. **www.doi.gov/alaskaenergy/index.cfm**

Interagency Arctic Research Policy Committee (IARPC). IARPC was established by Congress through the Arctic Research and Policy Act, is chaired by the National Science Foundation, and provides cross-agency coordination regarding federal arctic research. **www.nsf.gov/od/opp/arctic/iarpc/start.jsp**

Interagency Hydrology Committee for Alaska (IHCA). An organization of technical specialists working at the federal, state, and local levels, who coordinate the collection and implementation of water resources related data throughout the state of Alaska. **ak.water.usgs.gov/ihca/**

International Study of Arctic Change (ISAC). ISAC was initiated in 2003 by the International Arctic Science Committee (IASC) and the Arctic Ocean Sciences Board (AOSB) following the SEARCH Open Science Meeting in Seattle in October 2003. **www.arcticchange.org/**

Inuit Circumpolar Council Alaska. Represents and advocates for the Iñupiat of the Arctic Slope, Northwest, and Bering Straits; St. Lawrence Island (Siberian) Yupik; and Central Yup'ik and Cup'ik of the Yukon–Kuskokwim Delta in Southwest Alaska. **www.iccalaska.org/servlet/content/home.html**

North Pacific Fisheries Management Council (NPFMC). One of eight regional councils established by the Magnuson Fishery Conservation and Management Act in 1976 (which has been renamed the Magnuson–Stevens Fishery Conservation and Management Act) to oversee management of the nation's fisheries. **www.fakr.noaa.gov/npfmc/**

North Pacific Research Board (NPRB). Congress created the North Pacific Research Board in 1997 to recommend marine research initiatives to the U.S. Secretary of Commerce, who makes final funding decisions. **www.nprb.org/**

North Slope Science Initiative (NSSI). The NSSI is an intergovernmental effort to increase collaboration at the local, state, and federal levels to address the research, inventory, and monitoring needs as they relate to development activities on the North Slope of Alaska. **www.northslope.org/**

Porcupine Caribou Herd Management Board. The Porcupine Caribou Management Board works to manage the Porcupine Caribou Herd, one of the largest herds of migratory caribou on the continent, and to protect and maintain its habitat in Canada. **www.taiga.net/pcmb/**

Study of Environmental Arctic Change (SEARCH). SEARCH is an interagency effort to understand the nature, extent, and future development of the system-scale change presently seen in the Arctic, in terrestrial, oceanic, atmospheric, and human systems, including: air temperatures, ocean circulation and sea level, sea ice cover, and permafrost. Nine U.S. agencies, including Department of the Interior, collaborated to begin this program starting in 2001. **www.arcus.org/search/index.php**

Sustaining Arctic Observing System (SAON). Continues International Polar Year efforts to research, monitor, preserve and share information about arctic environments. **www.arcticobserving.org/**

U.S. Arctic Research Commission (USARC). USARC commissioners facilitate cooperation among the federal government, state and local governments, and other nations with respect to basic and applied arctic research. **www.arctic.gov/**

U.S.–Canada Northern Oil and Gas Research Forum. Department of the Interior bureaus and Canadian agencies formed the U.S.–Canada Northern Oil and Gas Research Forum looking at research and opportunities related to oil and gas activities on the North Slope, Mackenzie Delta, and Beaufort Sea.
www.arcus.org/meetings/2010/northern-oil-and-gas-research-forum

U.S.–Russia Polar Bear Commission. Works to ensure that polar bear populations in Alaska remain a healthy, functioning component of the Bering, Chukchi, and Beaufort seas ecosystems. Management responsibilities are described in the ***Conservation Plan for the Polar Bear in Alaska***. **alaska.fws.gov/fisheries/mmm/polarbear/bilateral.htm**

Western Arctic Caribou Herd Working Group (WACH WG). Established by an interagency agreement to provide interagency support for the cooperative management of the western arctic caribou herd. **westernarcticcaribou.org/**

Western Regional Air Partnership (WRAP). The purpose of the WRAP is to develop data, tools, and policies needed by states and tribes to improve visibility in parks and wilderness areas across the West. **www.wrapair.org/**

Yukon River Inter-Tribal Watershed Council. An Indigenous grassroots organization, consisting of 70 First Nations and Tribes, dedicated to the protection and preservation of the Yukon River watershed. **www.yritwc.org/About_Us/About_Us.aspx**

Appendix 3. Alaska and Arctic Regional Data, Data Archives, and Information Resources

Weather and Climate Data

Alaska Climate Research Center **climate.gi.alaska.edu/**

Alaska Department of Transportation Road Weather
http://www.dot.state.ak.us/iways/roadweather/forms/IndexForm.html

Alaska Railroad Weather Network **http://www.akrr.com/wthr/**

Alaska Remote Automated Weather Stations Network **http://www.raws.dri.edu/wraws/akF.html**

Alaska Satellite Facility **www.asf.alaska.edu/**

Alaska Snow, Water and Climate Services **http://ambcs.org/**

Atmospheric Radiation Measurement (ARM) Data Archive **http://www.archive.arm.gov/**

Fairbanks Mesonet **http://www.tanana-watershed.org/mesonet/**

Federal Aviation Administration Alaska Aviation Cameras **http://akweathercams.faa.gov/**

National Weather Service Alaska Region HQ **http://www.arh.noaa.gov/**

National Weather Service Anchorage **http://pafc.arh.noaa.gov/**

National Weather Service Anchorage Mesonet **http://pafc.arh.noaa.gov/mesonet.php**

National Weather Service Fairbanks **http://pafg.arh.noaa.gov/**

Neighborhood Environmental Watch Network **http://environweb.lanl.gov/newnet/**

NASA/Langley Research Center Atmospheric Science Data Center **http://eosweb.larc.nasa.gov/**

NOAA Climate Research **http://www.arctic.noaa.gov/arp/resources.html**

NOAA Climate Services **http://www.climate.gov/#dataServices**

NOAA/Earth System Research Laboratory Global Monitoring Division (Barrow, AK Observatory)
http://www.esrl.noaa.gov/gmd/obop/brw/

NOAA International Arctic Systems for Observing the Atmosphere **http://iasoa.org/iasoa/**

Prince William Sound Weather Station Network **http://www.pwsrcac.org/projects/OSRplan/weather.html**

SNOTEL Network **http://www.wcc.nrcs.usda.gov/snow/**

University of Alaska Fairbanks Water and Environmental Research Center Data **http://ine.uaf.edu/werc/current–data/**

USGS Permafrost and Climate Monitoring Network Arctic Alaska
http://data.usgs.gov/climateMonitoring/region/show?region=alaska

Geographic Information System (GIS) Data

Alaska Bureau of Land Management GIS Data **http://sdms.ak.blm.gov/sdms/**

Alaska Department of Fish and Game GIS **http://www.adfg.alaska.gov/index.cfm?adfg=maps.main**

Alaska Interagency Coordination Center Fire GIS **http://fire.ak.blm.gov/predsvcs/maps.php**

Alaska Mapped **http://www.alaskamapped.org/**

Alaska Mapper **http://mapper.landrecords.info/**

Alaska State Geo-Spatial Data Clearinghouse **http://www.asgdc.state.ak.us/**

The Atlas of Canada **http://atlas.nrcan.gc.ca/site/english/index.html**

Barrow Area Information Database **http://baid.utep.edu/**

Canadian GeoConnections – Discovery Portal **http://geodiscover.cgdi.ca/web/guest/home**

Circumpolar Arctic Vegetation Mapping Project **http://www.geobotany.uaf.edu/cavm/**

Glacier Bay Ecosystem GIS **http://www.inforain.org/glacierbay/**

Geographic Information Network of Alaska **http://www.gina.alaska.edu/**

International Bathymetric Chart of the Arctic Ocean **http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html**

State of Alaska Forestry GIS **http://www.forestrymaps.alaska.gov/**

USGS Alaska Geospatial Data Clearinghouse **http://agdc.usgs.gov/data/**

Other Multidisciplinary Data

Advanced Cooperative Arctic Data and information System (ACADIS) **http://www.aoncadis.org/**

Alaska Department of Natural Resources Division of Geological and Geophysical Surveys **http://www.dggs.dnr.state.ak.us/**

Alaska Energy Data Inventory **http://www.akenergyinventory.org/data/data-archive**

Alaska Fisheries Science Center **http://www.afsc.noaa.gov/**

Alaska Native Knowledge Center **http://www.ankn.uaf.edu/**

Alaska Native Language Archive **http://www.uaf.edu/anla/**

Alaska Ocean Observing System (AOOS) **http://www.aoos.org/**

Alaska Volcano Observatory **http://www.avo.alaska.edu/**

Arctic Borderlands Ecological Knowledge Co-op **http://www.taiga.net/coop/index.html**

Arctic Data at National Center for Atmospheric Research/Earth Observing Laboratory **http://arctic.eol.ucar.edu/**

Arctic Data Portal **http://www.arcticdata.is/**

Arctic Long Term Ecological Research **http://ecosystems.mbl.edu/arc/**

Arctic Regional Ocean Observing System (Arctic ROOS) **http://arctic-roos.org/observations**

Arctic Research Assets Map **http://data.aoos.org/maps/arctic_assets/**

Arctic Research Mapping Application (ARMAP) **http://armap.org/**

Canadian Cryospheric Information Network **http://www.ccin.ca/cms/en/home.aspx**

Canadian Ice Service **http://www.ec.gc.ca/glaces-ice/default.asp?lang=En&n=D32C361E-1**

Chinese National Arctic and Antarctic Data Center **http://www.chinare.org.cn/pages/index_en.jsp**

Circumarctic Environmental Observatories Network (CEON) **http://www.ceon.utep.edu/**

Distributed Biological Observatory **http://www.arctic.noaa.gov/dbo/**

Exchange for Local Observations and Knowledge of the Arctic (ELOKA) **http://eloka-arctic.org/**

Fisheries and Oceans Canada **http://www.dfo-mpo.gc.ca/index-eng.htm**

International Arctic Buoy Program (IABP) **http://iabp.apl.washington.edu/**

International Arctic Research Center **http://www.iarc.uaf.edu/index.php**

International Arctic Science Committee (IASC) and Arctic Council sponsored Arctic Portal **http://arcticportal.org/**

High-Frequency Active Auroral Research Program (HAARP) **http://www.haarp.alaska.edu/haarp/data.html**

Lamont–Doherty Earth Observatory **http://www.ldeo.columbia.edu/**

Nansen and Amundsen Basins and Canadian Basin Observational Systems **http://nabos.iarc.uaf.edu/index.php**

NASA/Jet Propulsion Laboratory Pacific Ocean Data (Prince William Sound) **http://ourocean.jpl.nasa.gov/PWS/**

National Data Buoy Center – Alaska Marine Data **http://www.ndbc.noaa.gov/maps/Alaska.shtml**

National Ice Center **http://www.natice.noaa.gov/**

National Park Service Alaska Region Inventory and Monitoring Program **http://science.nature.nps.gov/im/units/AKRO/**

National Petroleum Reserve Alaska Legacy Data Archive **http://www.usgs.gov/science/cite-view.php?cite=981**

National Snow and Ice Data Center (NSIDC) **http://nsidc.org/**

Natural Resources Canada **http://www.nrcan.gc.ca/earth–sciences/home**

NOAA Coastal Data Development Center **http://www.ncddc.noaa.gov/**

NOAA Near Shore Fish Atlas of Alaska **http://www.fakr.noaa.gov/habitat/fishatlas/**

Russian–American Long-term Census of the Arctic **http://www.arctic.noaa.gov/aro/russian-american/**

Scenarios Network for Alaska and Arctic Planning **http://www.snap.uaf.edu/index.php**

Seasonal Ice Zone Observing Network (SIZONET) **http://www.sizonet.org/**

Soil Landscapes of Canada **http://sis.agr.gc.ca/cansis/nsdb/slc/intro.html**

Sustained Arctic Observing Networks (SAON) **http://www.arcticobserving.org/**

Toolik–Arctic Geobotanical Atlas **http://www.arcticatlas.org/index**

Toolik Field Station/Institute of Arctic Biology **http://toolik.alaska.edu/**

U.S. Department of Agriculture Natural Resources Conservation Service Alaska Soil Survey **http://www.ak.nrcs.usda.gov/soils/index.html**

USGS Alaska Science Center **http://alaska.usgs.gov/**

USGS Biological Resources of Alaska **http://alaska.usgs.gov/science/biology/index.php**

USGS Water Resources of Alaska **http://alaska.usgs.gov/science/water/index.php**

Appendix 4. Workshop Agenda

Tuesday, 20 March 2012

DAY 1 OBJECTIVES: Set the stage and develop a vision of a successful Arctic Observing Network

PLENARY SESSION: Overview and setting the stage

8:30 a.m. . . . . Welcome, Introductions, Meeting Goals, and Expected Outcomes
John Payne, North Slope Science Initiative
Don Perovich, U.S. Army Cold Regions Research and Engineering Laboratory
workshop co-chairs

9:00 a.m. . . . . Observations on the Observations: Where We Might Go From Here
Fran Ulmer, U.S. Arctic Research Commission Chair
John Farrell, U.S. Arctic Research Commission

9:30 a.m. . . . . Overview of Study of Environmental Arctic Change (SEARCH) and the Arctic Observing Network (AON)
Hajo Eicken, University Alaska Fairbanks and SEARCH Science Steering Committee Chair

9:50 a.m. . . . . Data and Observational Needs from Agencies, Stakeholders, and Decision Makers
Michelle Bonnet, Director, Alaska Department of Environmental Conservation Division of Water

10:10 a.m. . . . . Arctic Observational Needs for Modeling and Prediction
John Walsh, International Arctic Research Center, University of Alaska Fairbanks

10:45 a.m. . . . . Back to the Future: A Conceptual Framework for Advancing the AON
Martin Jeffries, Office of Naval Research

ADVANCES IN OBSERVING ACTIVITIES BY SEARCH SCIENCE THEMES

GUIDING QUESTION: With the resources we have now, what are the greatest advances that could be made in observational data/products for use by scientists and stakeholders?

11:05 a.m. . . . . SEARCH Science Goal #1: Sea Ice and Consequences of Ice-Diminished Arctic Ocean
Julienne Stroeve, National Snow and Ice Data Center

11:20 a.m. . . . . SEARCH Science Goal #2: Permafrost, Land Surface Change, and Hydrology
Larry Hinzman, International Arctic Research Center, University of Alaska Fairbanks

11:40 a.m. . . . . SEARCH Science Goal #3: Land Ice Loss
Tad Pfeffer, Institute of Arctic and Alpine Research, University of Colorado

12:00 p.m. . . . . SEARCH Science Goal #4: Society and Policy – Links Between Observational Data/Information and Public Understanding
Henry Huntington, PEW Environment Group, Arctic Program Science Director

BREAKOUT SESSION 1: Develop a vision of a successful Arctic Observing Network

1:45 p.m. – 3:45 p.m.. . . . Breakout groups are split into two thematic areas: ice-diminished Arctic Ocean, and warming permafrost/land surface linkages; two groups for each theme (four groups total). Participants are assigned to each group to encourage cross-disciplinary discussion and interaction.
To develop a shared vision of a successful Arctic Observing Network, breakout groups address the following guiding questions:
1. *Which audiences would an ideal AON serve?*
2. *Given these audiences, in an ideal world, what would an AON look like in 5 years? What would the 'value added' be, beyond the current way of business?*
3. *What products and services would be created?*

3:45 p.m. . . . . Reports from breakout sessions and goals for Day 2

POSTER SESSION AND RECEPTION

5:00 p.m. – 7:30 p.m. . . . Opportunity for participants to present specific projects or activities related to SEARCH, observing activities, or arctic science

Wednesday, 21 March 2012

DAY 2 OBJECTIVES: With the vision discussed in Day 1, identify specific ways to achieve the vision. The exact structure of the day will be adaptive to the groups' progress, so breakout times and structure can change, if needed.

9:00 a.m. . . . . Review of Day 1 progress, Day 2 goals, and charge to breakout groups
John Payne and Don Perovich

BREAKOUT SESSION 2: Specific ways to achieve the vision

9:30 a.m. – 12:00 p.m. . . . Breakout groups tasked with outlining specific recommendations for how to achieve the vision for each science theme

1. *What activities are needed?*
2. *What can be done from combining existing resources or infrastructure? (Or where can targeted activities make great progress?)*
3. *Begin thinking about cross-cutting activities or showcase projects – data-focused, place-based/ regional, etc.*

1:15 p.m. . . . . Brief breakout group reports to plenary discussion of emerging, common themes

BREAKOUT SESSION 3: Details and showcase projects

2:30 p.m. – 4:30 p.m. . . . Flesh out the activities needed

1. *Discuss specific tasks, next steps, timelines, possible mechanisms, and possible showcase projects.*
2. *Be prepared to report to plenary on Day 3.*
3. *One breakout group to focus on data issues (e.g., interoperability, proprietary data, data formatting, common archive structures, provision of data for showcase projects)*

4:30 p.m. . . . . Adjourn

EVENING: Groups to meet informally to further ideas, areas of collaboration, etc. Possible side meetings focusing on Bering Sea, Barrow region, Toolik Lake and Kuparuk watershed, data issues, etc.

Thursday, 22 March 2012

DAY 3 OBJECTIVES: Identify showcase projects for observing activities, with recommendations for short-term (5 years or less) implementation, with identified task leads.

PLENARY REVIEW AND DISCUSSION

9:00 a.m. . . . . Goals for the day
Breakout group reports from Day 2
Plenary discussion: How are ideas resonating with the group? What priorities are emerging?
Charge to final breakout groups

MORE DETAILS, SHOWCASE PROJECTS, AND NEXT STEPS

9:30 a.m. – 10:45 a.m. . . . Breakout groups focus on showcase projects that could be launched in the near-term: theme-based, regional-focused, and/or data-focused
Discuss details of showcase project – scope, specific next steps, identify key participants
Identify key lead(s) that could convene an ad-hoc task group after the workshop

11:00 a.m. . . . . Final plenary discussion

1. *What are the key recommendations for a successful observing network?*
2. *Showcase projects – what and how they can be accomplished*
3. *Specific next steps and recommendations*

12:00 p.m. . . . . Workshop wrap-up and next steps
12:15 p.m. . . . . Adjourn
1:00 p.m. . . . . Small writing group to meet in afternoon to begin workshop report

Appendix 5. Workshop Participants

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