STUDY OF ENVIRONMENTAL ARCTIC CHANGE

SEARCH Science Steering Committee & Action Team Leads Meeting
19 February, 2016 - 11am-1pm AKST

Meeting Documents

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Year-2 Program Plan
Study of Environmental Arctic Change

Introduction

The Study of Environmental Arctic Change (SEARCH) provides a foundation for studying Arctic environmental change by facilitating collaboration between diverse research communities, funding agencies, and stakeholders. SEARCH Action Teams and working groups generate and synthesize research findings, facilitate research activities across scales and disciplines, identify emerging issues, collaborate with other national and international science programs, and engage Arctic stakeholders to inform their responses to environmental change.

Many research efforts in the Arctic focus on isolated aspects of Arctic environmental change. SEARCH facilitates a system-level approach that connects disciplines and integrates their results. The system view is necessary to anticipate the cascading consequences of rapid changes in the Arctic environment.

SEARCH recognizes that scientific syntheses require iterative feedback between scientists advancing process understanding, observers, modelers, and communities of stakeholders (NRC, 2012). Thus, we have structured our activities around organizing research communities that advance science through process studies and modeling, inform observational networks, and build enduring conversations with stakeholders (Figure 1).

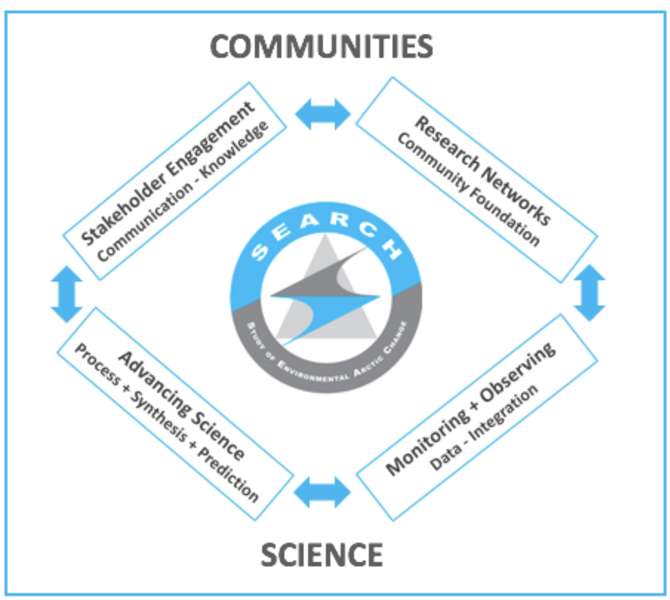

Figure 1. SEARCH's model of integration to advance Arctic environmental change science through engagement of research networks, the facilitation of monitoring and observing, and knowledge exchange with stakeholders. The activities feed one another iteratively.

The addition of an Executive Director allows SEARCH to support and extend the work of the Action Teams and their working groups by facilitating their research coordination efforts and by providing a common framework for system-level integration.

This Plan describes the year-2 efforts of the SEARCH Scientific Steering Committee (SSC), the Executive Director, the Project Office (ARCUS), and each of the Action Teams to facilitate integrated research in environmental Arctic change, to focus the Observing Change Panel priorities, and to advance crosscutting activities.

SEARCH Scientific Steering Committee

The SSC oversees the work of the Executive Director and the Action Teams. In year-2, the SSC will focus on ensuring that the new SEARCH organizational structure is implemented in an effective manner. Specific foci will include:

- Finalizing the terms of reference for the new program structure
- Developing the role of the Observing Change Panel
- Initiating cross-cutting activities
- Defining processes for forming and dissolving SEARCH Science Goals and related Action Teams

SEARCH Executive Director

The Executive Director receives office support in Fairbanks from the International Arctic Research Center, University of Alaska Fairbanks and in Monterey, California from the Center for the Blue Economy, Middlebury Institute for International Studies. The Executive Director takes direction from the Scientific Steering Committee and convenes bi-weekly in-person or by teleconference with the Science Steering Committee Chair. The Executive Director also confers regularly with the Action Team leaders.

In the first months on the job, the Executive Director assessed the state of each Action Team and noted that the teams reflect the different states of evolution of Arctic change research among the three communities they represent and have, thus, chosen to focus their efforts on distinct research priorities. Despite their different starting points, in year-2, the Director will encourage the teams to coalesce around the shared knowledge-to-action framework that emphasizes meaningful exchanges across disciplines and significant interactions between researchers and stakeholders. This common framework (Figure 1) envisions that individual Action Teams will unite strong and flexible research communities and networks that evolve with their scientific objectives. Driven by basic science questions, they will identify opportunities for advancing science, expose gaps in current scientific understanding and/or critical observational capabilities, and develop syntheses and knowledge exchanges. The Action Teams will facilitate the formation of short-lived, focused working groups to address specific issues as they emerge.

In year-2, the Executive Director will survey other research program leaders to determine best practices in the art of organizing scientific talent. The Executive Director will help the Action

Teams retain their focus on previously specified long-term goals with emphasis on synthesis and developing mileposts consistent with the goals. He will provide the SSC with read-ahead materials, draft actions, and written meeting notes specifying action items to help them ensure that teams are making progress. The Executive Director also will facilitate connections between the Action Teams (cross-cutting research) and other efforts in Arctic research (e.g., the Interagency Arctic Research Policy Committee [IARPC], the Polar Research Board, the International Arctic Science Committee, and others). Time for engaging external groups is often limited for researchers, and the Executive Director will assist Action Team members by identifying convenings with a high likelihood of return for the time invested. At the same time, the Executive Director will explore models for supporting and mentoring early career scientists, as well as models for assessing scientific communication across disciplines and to wider audiences.

The Executive Director will clarify in year-2 SEARCH's mission and structure for the broad research community. We shall increase transparency to facilitate the engagement of more scientists in SEARCH Action Teams and crosscutting activities. An updated web site will communicate regular and ongoing activities and offer opportunities for outside involvement. We shall also capitalize on existing venues (e.g., the Arctic Encounter Symposium) to reach broader audiences.

In year-2, SEARCH will continue to participate in IARPC Collaboration Teams to inform agencies about research developments and to provide information useful to the development of the next five-year Arctic research plan. Participation on IARPC Collaboration Teams also will help identify additional areas where SEARCH can enhance the work of Federal agencies. Where gaps and opportunities could be addressed in joint efforts, the SEARCH Executive Director will encourage IARPC agencies to support SEARCH activities through workshop funds and personnel support with an emphasis on postdoctoral fellows.

Arctic Research Consortium of the U.S. (ARCUS; SEARCH Project Office)

ARCUS supports SEARCH in areas of strategic planning and project management, meeting planning and support, and communications (through grant #PLR-1331083). The Executive Director convenes weekly with ARCUS staff by videoconference. ARCUS activity areas are summarized in Appendix A.

Sea Ice Action Team

SEARCH Goal "Improve Understanding, Advance Prediction, and Explore Consequences of Changing Arctic Sea Ice," led by Jennifer Francis and Henry Huntington

SEARCH led the development of a research forum to discuss, evaluate, and improve sea-ice forecasting for the research community and specific stakeholders by standing up and organizing the Arctic Sea Ice Outlook and the Sea Ice for Walrus Outlook. Those efforts are now formalized under separately funded networks, the Sea Ice Prediction Network (SIPN) and the Sea Ice for Walrus Outlook (SIWO). Overlapping membership in those networks and SEARCH's Sea Ice

Action Team (SIAT) ensures that SEARCH remains closely connected with these spin-off efforts and is able to include their work in synthesis activities. Similarly, the SIAT includes membership in the IARPC Sea Ice Collaboration Team and CLIVAR Arctic-Midlatitude working group. Together, these efforts improve our predictive abilities, particularly of sea-ice extent, and provide opportunities for new research to be informed by spatial and temporal information needs of stakeholders. With an explicit link to SEARCH (https://usclivar.org/working-groups/arctic-midlatitude-working-group), the CLIVAR Arctic-Midlatitude working group is assessing teleconnections of Arctic climate and its effects on mid-latitude weather through predictability studies and model assessment. Yet, the effects of sea-ice changes are more profound and affecting the Arctic in a broader way. Thus, the SIAT is filling a key gap by focusing on exploring consequences of the changing Arctic sea-ice cover. SEARCH recognizes the need for research leading to synthesis among the broad scientific community and for greatly enhanced communications with non-scientific communities, and those areas are the focus of the Sea Ice Action Team.

Organizational Activities

As the pace and diversity of sea-ice research has increased, there is a growing need to enhance communication across disciplines and to wider audiences. Making our new knowledge more accessible will help stimulate scientific syntheses and inform policy discussions. In response to this need, the Sea Ice Action Team convened in September 2015 in Bristol, Rhode Island to develop its approaches to better communicating scientific understanding of sea ice among lay and scientific audiences. The composition of the team reflects the diverse consequences of diminishing sea ice with experts in sea-ice forecasting, atmospheric interactions, ecosystem services, marine ecology, science communication, and policy. The team includes:

- Jennifer Francis (co-lead) – Rutgers University
- Henry Huntington (co-lead) – Huntington Consulting
- Matt Druckenmiller (science communicator/research enabler) – Rutgers and NSIDC
- Lawrence Hamilton – University of New Hampshire
- Bob Henson – Weather Underground
- Marika Holland – National Center for Atmospheric Research
- Martin Jeffries – Office of Naval Research
- Brendan Kelly – SEARCH Executive Director, University of Alaska Fairbanks
- Don Perovich – Cold Regions Research and Engineering Laboratory (CRREL)

The Action Team membership will be reviewed again in year-2 to assess whether additional member(s) should be added; small, ad hoc Task Teams, which are described below, also will bring in additional expertise to Action Team activities. The SIAT recognizes that improving public understanding of sea-ice processes is important to societal responses and that improving understanding among diverse scientific disciplines concerned with sea ice will enhance synthesis efforts at the system level. Thus, the Team's communication products and resources will be designed to educate the public, policy makers, and fellow scientists.

Advancing the Science
In year-2, the Sea-ice Action Team will advance understanding by engaging scientists and stakeholders, leading and promoting scientific syntheses, and developing methods to evaluate effectiveness of the Team's activities.

1. <u>Engage science and stakeholder communities</u>

The Team will build a web-based framework designed to link brief, up-to-date synopses of the state of sea-ice science with primary literature and data sets concerning sea ice and the impacts of sea-ice loss on the Arctic and beyond. The resource is envisioned to enable synthesis research related to sea ice, educational materials, and summaries of the science aimed at scientists in diverse disciplines and policy makers. As a strategy for communicating with broader audiences, however, we will focus on the upper-most level—the most direct point of entry to the website—to present concise, accessible digests. The top-level products will be supported by an underlying layers organized into educational materials, reviews and syntheses, and finally, the primary literature. Starting at the top of the pyramid (Figure 2) is an effective means of making science accessible to scientists in other disciplines (thus, promoting collaborations across disciplines), the media, public, and policy makers (Baron 2010).

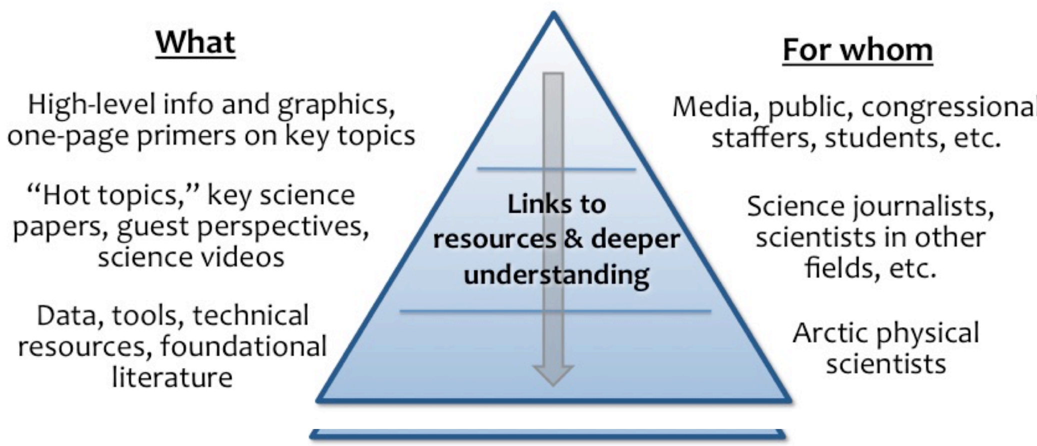

Figure 2. Knowledge pyramid showing tiered science products for communicating across disciplines and with wide audiences.

The Team—with the help of additional subject-area experts—will develop a website reflecting this structure with the entry point being a series of one-page digests – "Sea Ice and…" – summarizing what we know about sea ice and its interactions with a variety of system elements, such as:

- Sea Ice and Arctic navigation
- Sea Ice and climate variability
- Sea Ice and coastal communities
- Sea Ice and international security
- Sea Ice and sea level rise
- Sea Ice and permafrost
- Sea Ice and international relations
- Sea Ice and ocean currents
- Sea Ice and lower latitude weather
- Sea Ice and ecosystems
- Sea Ice and natural resources
- Sea Ice and forecasting and prediction
- Sea Ice and environmental stewardship

In year-2, the Team will build the framework and develop supporting materials for three of the summary documents (Sea Ice and Ecosystems, Sea Ice and Your Weather, and Sea Ice and Society), emphasizing the linkages from the top to the bottom to convey that the one-page summaries are authoritative, consensus-driven, and supported by the science community. The Team will engage appropriate members of the scientific community to select appropriate review papers and primary sources to fill in the mid and lower levels of the pyramid. Thus, scientists from other disciplines, policy makers, the media, and others will be able to enter the information pyramids at whatever levels are appropriate for their background and interest with the assurance that the upper levels are backed up by solid science.

Writing and sharing the summaries will have the heuristic value of making evident where there is community consensus and where additional research should be focused. Thus, in some cases, the information pyramid will be assembled from existing literature; in other cases, SEARCH will help the community identify gaps in need of further research and highlight topics ripe for syntheses. The approach will be tested and refined by short-term, issue-specific Task Teams that will be convened in year-2. Feedback on the effectiveness of the products will be sought from policy staffers on Capitol Hill and in the Administration. The team will work with ARCUS on the design of a sustainable website.

Beyond the website interface to the pyramid, scientists and stakeholders will be engaged through:

- Participation on the Sea Ice Outlook 2015 Post-Season Report Action Team (Oct-Dec 2015)

- Presentations on the societal and policy implications of sea-ice change at the Arctic Encounter Symposium (Seattle) and the Arctic Matters Symposium (Washington, DC) in January 2016

- A workshop in late summer 2016 to identify high-priority topics for collaborative research proposals and synthesis efforts and to develop a collaborative process to facilitate these activities; this workshop will present opportunities for involvement of the other Action Teams

- Leading up to the aforementioned workshop, the Team will prepare an overview paper that pulls together various recent sea-ice synthesis papers from a broad range of sea-ice related fields (i.e., a synthesis of the syntheses)

- A summary for the SEARCH community from a science communication workshop led by Andy Revkin at AGU 2015 Fall Meeting

- Scientific exchanges in venues including FAMOS, AOOSM, AGU, and AOS

- Participation in a SIPN conference in Palisades, NY (May 2016)

- Exploration with ARCUS's videographer of the opportunity to create a short film on sea-ice prediction and how the Sea Ice Prediction Network is advancing science in an innovative way

- Evaluations by congressional staffers and AAAS Fellows of the one-page sea-ice digests and the underlying informational structure

- Presentations to and close collaboration with the IARPC Collaboration Teams

- Addition of SIAT members as needed to develop the information pyramid

2. <u>Synthesis</u>

During year-2, the Sea Ice Action Team will plan a Knowledge Exchange workshop to be held in year-3 bringing stakeholders and scientists together to determine the syntheses needed for greater scientific understanding of sea ice and to address stakeholder needs. Proposed topics and leads for synthesis papers will be identified and circulated in advance of the workshop to generate robust cross-disciplinary consideration. Borrowing from a model employed successfully by the Permafrost Action Team, the Sea Ice Action Team will identify a senior and junior scientist to co-lead each proposed synthesis paper. The workshop also will help develop a scenarios approach to framing research questions.

Scientific syntheses require cross-disciplinary approaches, and the Team will use the one-page sea-ice digests as a means of engaging specialists in other fields. That is, the digests will convey—without jargon—the essentials of our current understanding of sea-ice dynamics and, thereby, promote the intellectual cross-fertilization necessary for syntheses.

3. <u>Evaluation</u>

Communication of scientific knowledge across disciplines and to the public can only be improved with feedback. In year-2, the Sea Ice Action Team will seek substantial feedback by:

- Developing a strategy for evaluating the web-resources using web-analytics (web-hits and one-pager downloads) along with online user feedback

- Developing and maintaining a sea-ice media watch to track high-visibility sea-ice information sharing. The watch will provide a means for tracking direct linkages to the Team's resources and a reference frame for what topics are getting a lot of attention

- Surveys of Congressional and Executive Branch science advisors through events with the AAAS Science and Technology Policy Fellows Program (Druckenmiller, as an alumni of the Program, is initiating a Fellows focus group on *Arctic Change*)

- Structured interviews of representatives of target audiences

Linkage to Observing
The Sea Ice Action Team will link its activities in year-2 to observing efforts through Task Teams, stakeholders, and modelers.

The Task Teams will assemble the information pyramids described previously. As part of that effort, they will be to articulate the observing needs for advancing scientific understanding of sea ice and for supporting operational efforts.

Sea-ice observation needs from the perspectives of stakeholders will be assessed via two approaches. First, the Team will map stated stakeholder needs on to available observations to identify gaps. Second, in establishing the information periods, the Team will invite guest perspectives that will include the stakeholders' own perception of observations needed. The Action Team will draw on activities and reports by the Sea Ice Prediction Network to inform this work.

Modelers rely on observations as inputs and for validation, and the sea-ice research community has been improving the iterative conversation between modelers and observers (NRC, 2012). The Sea Ice Action Team will encourage and contribute to SIPN's sensitivity studies that explore how models behave when certain datasets are withheld.

Land Ice Action Team

SEARCH Goal: "Improve Predictions of Future Land-ice Loss and Impacts on the ocean," led by Fiamma Straneo and Ted Scambos

Within the broad and longer-term SEARCH goal of improving predictions of Arctic land-ice loss and its impact on the ocean, including sea level rise and fresh water and nutrient discharge into the ocean, the most critical gap in our understanding is Greenland Ice Sheet-Ocean interactions. Progress on these questions requires cross-disciplinary research by glaciologists, oceanographers, climatologists, paleo-climatologists, and others. In year-2, the Land Ice Action Team (LIAT) will focus on facilitating exchanges between those communities to design observational campaigns in ways that will facilitate understanding and synthesis products.

Current team members are:

- Jakob Abermann (Asiaq, Greenland; glaciologist/hydrologist)
- Andreas Ahlstrøm (GEUS, DK; lead of PROMICE weather station network)
- Gordon Hamilton (U Maine, USA; glaciologist)
- Patrick Heimbach (UT Austin & MIT, USA; ocean modeler)
- Ruth Mottram (DMI, DK; atmospheric modeler)
- Sophie Nowicki (NASA Goddard, USA; ice sheet modeler)
- Ted Scambos (NSIDC, USA; remote sensing and field measurements ice sheets)
- Fiamma Straneo (WHOI, USA; oceanographer)
- Dave Sutherland (U Oregon, USA; oceanographer)

- Martin Truffer (U Alaska, USA; glaciologist)
- Bob Bindschadler (SEARCH SSC; glaciologist)

Additional members may be added as necessary.

Organizational Activities

The scientific community engaged in understanding Greenland ice sheet/ocean interactions gathered as such for the first time at an open, international workshop held in June of 2013 organized by a US CLIVAR Working Group (GRISO) and sponsored by US CLIVAR and NSF. The workshop attracted approximately 100 scientists (1/3 early career) from 10 countries, whose expertise covered the fields of glaciology, oceanography, paleoclimate, atmospheric science, and climate modeling. Discussions held at that workshop, and subsequent input from the broader scientific community, identified four main scientific priorities for understanding ice sheet/ocean interactions: targeted process studies, megasite experiments, data compilation and sharing, and the establishment of a Greenland Ice-Ocean Observing System (GrIOOS; Heimbach et al. 2014).

The Land Ice Action Team identified GrIOOS as a major priority in addressing ice sheet/ocean interactions and SEARCH as the entity to move the effort forward. The goal of GrIOOS is to design and implement collection of long-term time series of critical glaciological, oceanographic, and atmospheric variables at key locations around Greenland. Such time series will provide much needed information on the evolving relationships between climate forcings and glacier changes.

As a first step in facilitating the establishment of GrIOOS, the Land Ice Action Team convened a workshop to identify key variables, sites, and approaches to obtaining these data, in the light of existing measurements already being made in and around Greenland. The workshop, co-sponsored by CliC and the US Arctic Research Commission, was held on December 12-13, 2015 in San Francisco. The Action Team selected over 40 participants from 7 different countries based on expressions of interest and a balancing of career stages and genders. Additional participants included two US program managers (Eric Lindstrom, NASA; William Ambrose, NSF), Inuuteq Holm Olsen (Minister Plenipotentiary for Greenland to the US), and Gerhard Krinner, co-Chair of CliC. A joint session and reception with the Ice Sheet Modeling Intercomparison Workshop (ISMIP 6) participants provided input on how GrIOOS deliverables could address the needs of the ice sheet and ocean modeling community. Workshop discussions and sessions addressed important elements for the establishment of GrIOOS by identifying: 1) the essential variables to be collected; 2) the observations already in place; 3) prioritized sites; 4) prioritized instrumentation or synthesis products.

Work by the LIAT in year-2 will focus on compiling a report that synthesizes workshop outcomes and lays the foundation for the establishment of GrIOOS. Specific steps will involve an initial draft of the report (January 2016), incorporation of feedback from the participants (February 2016), incorporation of feedback from the broader scientific community (March 2016), and final publication (April 2016 – dates are approximate). Subsequent to the compilation of the report, the LIAT will widely circulate the workshop/report conclusions to US and international funding agencies, to international scientific groups, to Greenlandic government representatives, and international partners. A presentation to the CliC Steering Committee meeting is planned for February 2016. One important task for the LIAT is to aid international teams working in Greenland in adding GrIOOS measurements to their existing or planned measurements.

In 2016, the Team will hire a post-doctoral fellow. It is expected that the fellow will advance the establishment of GrIOOS by synthesizing existing measurements around Greenland into data products that can be used by the scientific community including the ice sheet and ocean modeling communities.

Advancing the Science

Priorities for understanding marine and atmospheric forcings on Greenland's marine-terminating glaciers were identified by the international research community (Heimbach et al. 2014) and include:

- Establishing a Greenland Ice Ocean Observing System (GrIOOS)
- Compiling and sharing bathymetric and other data
- Conducting targeted process studies
- Conducting selected megasite experiments

In year-2, the Land Ice Action Team will work with the research community, funding agencies, and stakeholders to establish the GrIOOS and will:

1. Draft, review, and publish a report on the December 2015 workshop

2. Follow up on the report's recommendations by:
   - Seeking funding from national and international agencies
   - Coordinating with existing networks
   - Participating in the CliC Steering Meeting (February 2016)

3. Discuss research plans with Arctic stakeholders in Alaska (Arctic Encounters Symposium) and Greenland with a focus on Greenlandic fisheries

Linkage to Observing

By facilitating the establishment of GrIOOS, the Land Ice Action Team is maximizing outcomes from existing observational capabilities and establishing a framework for the community-wide integration of useful observations. The international observing community will use the GrIOOS workshop report to leverage additional funding and coordinate activities. In addition, by identifying key synthesis products the GrIOOS report is expected to aid planning for future ground-based and remote sensing systems.

The Land Ice Action Team also has strong and growing connections to policy makers needing information on global sea level change. Through presentations and discussions at meetings engaging Arctic stakeholders (industry, military, and policy-makers) such as *Predicting a changing Arctic* sponsored by the Consortium for Ocean Leadership Forum in Washington DC

(March 2015) and the *Warming Arctic Conference – Leadership, Diplomacy and Science: Resolving the Arctic Paradox*, held at the Fletcher School of Business, Tufts University (April 2015), the Land Ice Action Team has provided key information on Arctic land-ice changes and their impact on the ocean including highlighting uncertainties. In addition, through the involvement of Inuuteq Holm Olsen (Minister Plenipotentiary for Greenland to the US) and Greenland fisheries scientists in the GrIOOS workshop, the Land Ice Action Team is establishing direct channels for the exchange of information between the science community and Greenlandic stakeholders. The Team will seek to better understand the full scope of stakeholder concerns through participation in the Arctic Encounter Symposium (January 2016) and similar fora. The Team will also turn to SEARCH's Science Steering Committee and the Executive Director to help identifying opportunities to engage other Arctic stakeholders.

Permafrost Action Team

SEARCH goal: "Document and Understand How Degradation of Near-Surface Permafrost Will Affect Arctic and Global Systems," led by Ted Schuur, Christina Schädel, and Dave McGuire

In the first year of the award, the Permafrost Action Team set up structures to expand on the work of the Permafrost Carbon Network as well as pushed forward opportunities to expand synthesis science on the topics of permafrost degradation impacts on infrastructure and on ecosystem services. In year-2, the team will amplify those efforts by establishing a Science-to-Action Steering Committee to guide Permafrost Action Team activities, advancing synthesis science through coordinated workshops, establishing linkages between the permafrost research community and the broader Arctic observing community, as well as continuing to expand outreach to multiple stakeholders.

Organizational Activities

In year-1, the Permafrost Action Team has stood up a steering committee to guide and prioritize research activities. The committee was assembled with input from the SSC and includes members from academic institutions, Federal and state agencies, and stakeholders. Current members are:

- Cathy Wilson (DOE Los Alamos National Lab, NGEE Arctic)
- Eric Kasischke (NASA, ABoVE)
- Dave McGuire (UAF/USGS, PCN)
- Vladimir Romanovsky (UAF, GTN-P)
- Kevin Bjella (CRREL)
- Toni Lewkowicz (U Ottawa, IPA)
- Merritt Turetsky (U Guelph, PCN)
- Dave Schirokauer (Denali NPS)
- Michelle Walvoord (USGS Denver)
- Scott Rupp (UAF, SNAP, Alaska Climate Center)

The steering committee will be convened in quarterly teleconference calls with agendas and meeting notes distributed through our website.

The Permafrost Carbon Network was mature when absorbed under the umbrella of SEARCH's Permafrost Action Team. Many of the lessons learned in the establishment and operation of the network will inform the Team's work in understanding the additional topics of the impacts of permafrost degradation on infrastructure and ecosystem services. These areas will, no doubt, also require unique approaches and in particular collaboration with other groups that already have those topics as a focus. In the broader landscape of established networks, the emphasis on synthesis science that we developed through the Permafrost Carbon Network remains unique, and we will use this approach on both global and local/Arctic impacts of degrading permafrost. One striking example of how an underlying framework supported by SEARCH can facilitate contributions from other agencies is the new agreement with the U.S. Geological Survey (USGS) to support a synthesis science postdoctoral fellow. This agreement was made possible by the framework developed under the Permafrost Carbon Network that laid out a solid synthesis science foundation. This framework was recognized as an opportunity for USGS to meet its own complementary goals in an efficient manner. Coordinated research with funding across multiple agencies has always been a key goal of SEARCH, and this is an important step on that path. In year-2, we will recruit a postdoctoral fellow to organize the synthesis activities on either ecosystem services or infrastructure depending on the capabilities of the applicant pool. The synthesis science fellowship will be supported for two years with funds provided by the U.S. Geological Survey's Alaska Climate Science Center.

In year-2, the Team will advance scientific syntheses by developing scoping documents for new synthesis activities and by leading crosscutting research with the other SEARCH Action Teams on terrestrial and subsea methane fluxes, including the coastal interface zone. These crosscutting efforts in year-2 will serve as models for additional crosscutting efforts in subsequent years (see Cross-cutting Activities below).

Advancing the Science

The SEARCH Permafrost Action Team will help the community continue its productivity in generating synthesis publications through a series of meetings and other activities in year-2:

- 5th Annual Meeting of the carbon component of the Permafrost Action Team in San Francisco (December 13, 2015) – at this meeting, we have vetted 11 synthesis topics in collaboration with more than 120 scientists in the permafrost research community. Scoping documents describing the synthesis topics are posted at permafrostcarbon.org.

- Permafrost sessions as part of the American Geophysical Union (AGU) Fall Meeting in San Francisco (December 2015); the *XIth International Conference on Permafrost (ICOP) in Potsdam*, Germany (June 2016). These meetings build on related sessions held in *Our Common Future under Climate Change conferences in* Paris, France (July 2015).

- Kick-off meeting for the infrastructure component of the Permafrost Action Team (virtual or in person, TBD). Development of the infrastructure component in year-2 will serve as a model for subsequent development of the Ecosystem Services component.

- Arctic methane synthesis workshop (Seattle, Sept/Oct 2016)

- Lead synthesis workshop for the Permafrost Action Team prior to ICOP in Potsdam, Germany (June 2016)

- Participation in the CliC Permafrost Modeling Forum (Copenhagen, Denmark Feb 2016)

Linkage to Observing
In year-2, the Permafrost Action Team will plan observing efforts with international colleagues based on a white paper contributed by the Team leads to the Arctic Observing Summit. Based on broad community discussions at the Summit and elsewhere, the Team will also:

- Begin identification of structural and functional benchmark datasets for model evaluation such as soil carbon distribution and active layer thickness-to-temperature relationships

- Identify strengths and weaknesses of existing methane datasets

- Finalize protocols for soil incubations, identifying data and knowledge gaps

- Identify data and knowledge gaps for the eleven proposed synthesis topics

Communication and Outreach
Stakeholders affected by the state of permafrost are diverse, and developing and sustaining conversations with those communities requires translating our syntheses in multiple venues. In year-2, the Permafrost Action Team will reach audiences concerned with local and global impacts through:

- A 5-year synthesis report from the Permafrost Carbon Network written for diverse audiences and available for download and as printed hand outs

- 1-page synopses of the state of the science (modeled on the Sea Ice Action Team's template) concerning the carbon network and, subsequently, the infrastructure and ecosystem services components.

- Press releases, interviews, and articles prepared for the non-scientific community

- A presentation at the Arctic Encounter Symposium in Seattle (January 2016) to participants including: members of Congress, representatives of Alaska's legislature and

Governor's office, indigenous leaders, the academic community, industry, NGOs, and the press

- A website for the Permafrost Carbon Network component of the Permafrost Action Team (www.permafrostcarbon.org)
- A permafrost update to the Snow, Water, Ice and Permafrost in the Arctic report
- Participation in the development of the 2nd State of the Carbon Cycle Report
- A briefing to IARPC on Milestone 3.2.3., Permafrost Carbon Research Coordination Network

Conclusion

This year-2 program plan outlines a suite of activities that will be undertaken collectively by the SEARCH program. Taken together, these activities reflect SEARCH's model to advance Arctic environmental change science through engagement of research networks, the facilitation of monitoring and observing activities, and through knowledge exchange with stakeholders. Through these efforts SEARCH will continue to broaden our interdisciplinary understanding of Arctic change, highlight emerging issues, and advance the SEARCH mission to provide a foundation of Arctic change science.

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Appendix A. ARCUS Tasking for SEARCH Project Office

Year 2

Introduction

ARCUS serves as the SEARCH project office and performs a variety of planning, management, and coordination activities; these activity areas are listed below. The overall priorities for SEARCH are set by the SEARCH Science Steering Committee (SSC) and ARCUS staff work closely with the SEARCH Executive Director (B. Kelly) and SSC Chair (C. Ammann) to set ARCUS priorities and tasks in support of the SEARCH vision.

The ARCUS budget supports ARCUS staff time (approximately 1.2 FTE), travel and meeting costs for SSC meetings, and communications and materials costs.

Activity Areas

ARCUS' SEARCH activities are summarized below; specific tasks are determined in collaboration with the SEARCH SSC Chair and SEARCH Executive Director.

- **Strategic Planning & Project Management -** Work with the SEARCH Executive Director, Science Steering Committee (SSC), and Action Teams to plan and execute strategic and organizational development of the program: develop annual work plans; develop and track resulting milestones, review progress, help guide organizational adjustments as needed to achieve evolving needs and goals.

- **Conference/Meeting Planning -** Work with relevant groups to: develop meeting goals and desired outcome(s); convene and manage organizing committees; develop agendas; invite participants; arrange logistics; meeting announcements and communications; meeting website development and maintenance; onsite meeting support, including note-taking, presenter/AV support, and web streaming/video when appropriate; and work the meeting participants to develop and disseminate final product(s).

- **Science Steering Committee (SSC) Management -** Work in collaboration with the SEARCH Executive Director and SSC Chair on all aspects of SSC management, including; manage the SSC membership rotation process; provide project management support to track SSC action items and tasks; organize twice-yearly in-person SSC meetings; organize monthly SSC teleconferences; and other project management and administrative support for the SSC.

- **Communications and Outreach -** ARCUS will: develop and maintain two-way communication and collaboration strategies between SEARCH components—the SEARCH Science Office, the SSC, the Action Teams and Working Groups, and the broader scientific and stakeholder communities (communications with agency heads and representatives will primarily be the responsibility of the SEARCH Executive Director); develop, launch, and maintain a new SEARCH website; organize and facilitate teleconferences; organize "Town Hall" activities and science sessions at large scientific conferences; and other communications activities.

- **Minor Action Team Support** - Specific support will be dependent on the group, activity, and needs beyond what is provided by the post-doctoral support through the IARC budget, but may include activities such as: provide administrative support (e.g., arranging teleconferences, drafting memos), work with individual Team members to ensure timely completion of tasks and milestones, develop communications and website content, and facilitate lines of communication with other Action Groups, the SSC, and the broader research and stakeholder communities.

SEARCH external program review communications with NSF

On Jan 21, 2016, at 5:11 PM, Brendan Kelly <bpkelly@alaska.edu> wrote:

Neil,

As we discussed, it will be helpful to review the SEARCH effort this year, and I include some preliminary thoughts here to help start planning.

We suggest that involving representatives of other IARPC agencies would bring in additional perspectives on SEARCH's work and provide another opportunity for those agencies to consider where they might benefit by contributing resources. An efficient format might be to hold the review in DC in conjunction with a meeting the SSC and Action Team leaders. We envision a morning of reports on accomplishments, challenges, and next steps by the SSC and AT leads followed by an afternoon of questions and evaluation by NSF and other agencies. The following day, it might be useful for Caspar, Helen, perhaps a few SSC members, and me to meet with you to go over issues that surfaced in the review and to brainstorm ways to improve our efforts.

In terms of timing, it would work well for our meeting schedule if we could meet with you in spring or early summer to fully develop plans for the review and then convene for the review in late September or early October. We recognize, however, that there may be other constraints on the timing and would appreciate your thoughts. Whatever the format and timing, it will be important for the SSC to know what metrics you envision judging our progress against. We would expect to show progress in developing research networks but knowing the metrics you envision will help us focus the work of the action teams.

We look forward to hearing your thoughts on the review and, of course, on the year-two program plan and when you think we can restart the year-2 clock.

Hope you young backs lined up to keep your paths clear in case the storm storm is as big as forecasted!

Brendan

Brendan P. Kelly, Ph.D.
Executive Director
Study of Environmental Arctic Change
International Arctic Research Center
University of Alaska Fairbanks

Senior Fellow

Center for the Blue Economy
Middlebury Institute of International Studies at Monterey

907-209-6531
---------- Forwarded message ----------
From: **Swanberg, Neil R.** <nswanber@nsf.gov>
Date: Fri, Jan 29, 2016 at 10:51 AM
Subject: Re: SEARCH review
To: Brendan Kelly <bpkelly@alaska.edu>
Cc: Caspar Ammann <ammann@ucar.edu>, Helen Wiggins <helen@arcus.org>

I was on top of mail during the government closing, but think what happened here is I saw your name and thought 'That's the second-year plan Brendan sent' - which I had distributed to the others in the section. All are now eagerly reading it, but obviously that was not what the mail was about.

My knee jerk reaction on the plan was that it would be really nice to have clearer tasks - may just be presentation as a lot seems to be buried in prose. And that we are going to be most interested in Science results (there are some there) rather than how many meetings are to be held, though those are clearly part of the activity for the year. We will see what the others think.

On the topic below, we need to be clear. There are two things that could get confused. One is the site visit which we can opt to use if we want. We may well do that sometime in the next 8-9 months. That is an NSF review panel, most likely composed of academics who we select.

The other thing is that the proposal outlined an external advisory committee that would review SEARCH. I would think that would be pretty much up to you.

More later.

Have a great weekend all.

Neil

Dr. Neil Swanberg
Director, Arctic System Science Program
Division of Polar Programs, Geosciences Directorate
National Science Foundation
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fax: (+1-703) 292 9081

STUDY OF ENVIRONMENTAL ARCTIC CHANGE

Proposed 2016 Quarterly Meeting Schedule
for the SEARCH SSC/AT Leads

As part of the SEARCH leadership team's planning discussions in January, a proposal was put forward to change the full SSC/AT Leads monthly call schedule to a quarterly schedule consisting of two virtual meetings (Feb & Aug) and two in-person meetings (May & Nov). Other ad-hoc meetings to address targeted issues or opportunities with the Action Teams &/or smaller SSC working groups may also be convened during the interim months. With this change, we are hoping to use your time more efficiently and better leverage your specific talents and expertise to advance SEARCH goals and activities.

The proposed meeting schedule for 2016 is as follows:

- **February 19, 2016**: First virtual meeting
- **May (Dates TBD)**: First in-person meeting (likely to be in Boulder, CO)
- **August (Dates TBD):** Second virtual meeting
- **November (Dates TBD):** Second in-person meeting (location TBD)

STUDY OF ENVIRONMENTAL ARCTIC CHANGE

MEMORANDUM

DATE: 3 February 2016

FROM: Brendan P. Kelly, Executive Director

TO: Scientific Steering Committee

SUBJECT: SSC oversight of Action Team progress

The Scientific Steering Committee is responsible for overseeing the SEARCH program including its Action Teams and Work Groups. SSC meetings are important for exchanging information and tracking progress. One measure of progress is the timely spending of awarded funds, and NSF expresses concern when spending deviates too far from the proposed timeline.

The Executive Committee proposes that:

Action Teams and Work Groups submit brief written reports for inclusion in the read-aheads for each quarterly meeting of the SSC. The reports should succinctly indicate progress during the quarter and indicate how spending is progressing relative to the proposal timeline. The reports should make clear to the SSC and the Executive Director how the science is progressing and how they might help solve challenges and better communicate the work of the teams and groups. Spending should be summarized using the same terms that appear in the NSF budget and reported using the attached template.

At each quarterly meeting the SSC should either verify that the teams and groups are making appropriate progress and meeting their budgetary responsibilities or recommend alternative actions.

Brendan P. Kelly, Ph.D.
SEARCH Executive Director
Phone: 907-209-6531 • Email: bpkelly@alaska.edu

Proposed SEARCH Budget Template (DELIBERATIVE DRAFT)

1. Ask each of the following to fill out a general Year 2 Budget Plan:

- IARC – Overall (non-Action Team budgets)
- IARC – Permafrost AT sub-award
- IARC – Sea Ice AT sub-award
- IARC – Land Ice AT sub-award
- ARCUS – For ARCUS grant

Template for General Year 2 Budget Plan

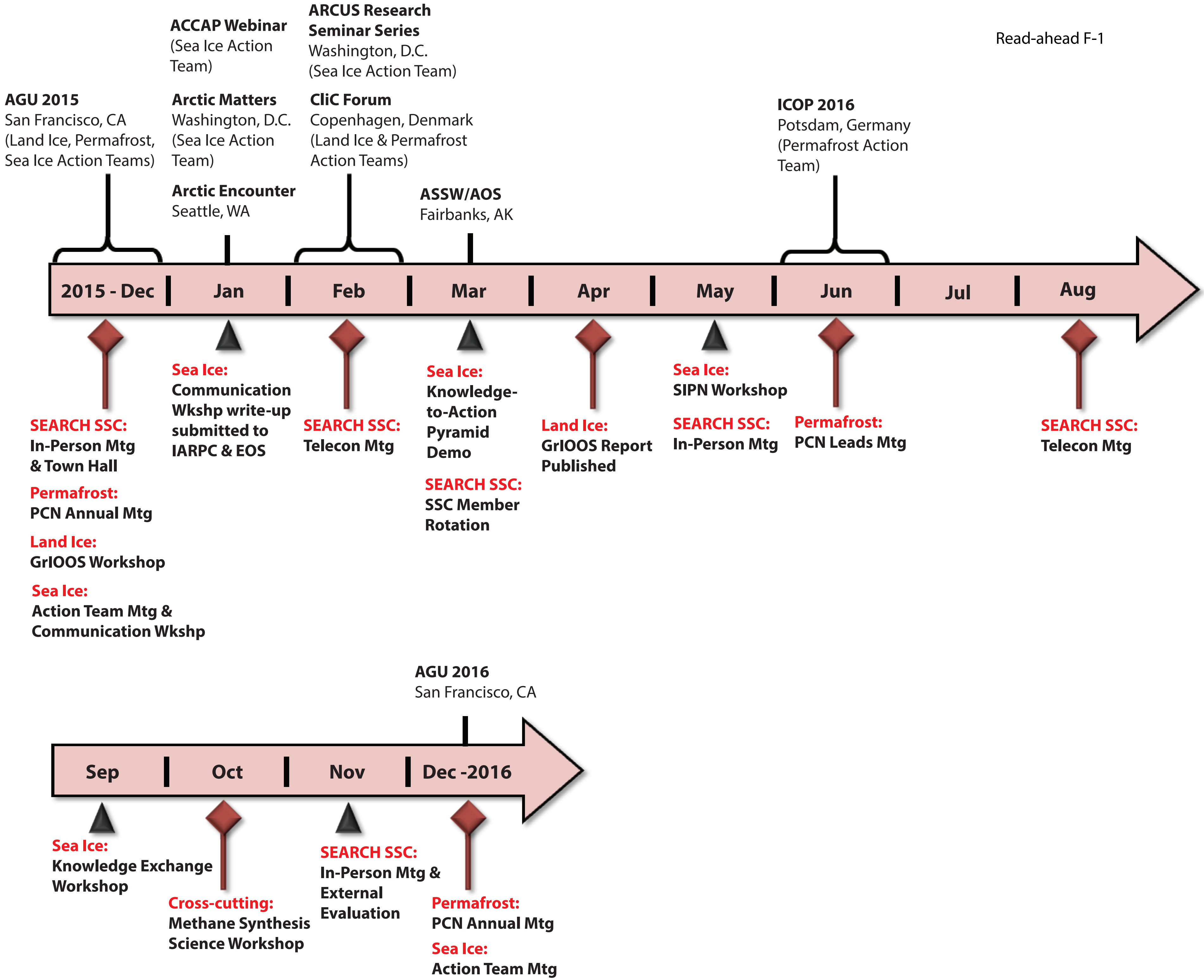
Year 2 Budget Plan for:		
Item	**Budget**	**Explanation** (e.g., who/what it is supporting, what meetings or travel is planned, any key milestones that will impact spending)
Personnel/Staffing		
Meeting/Workshop support & travel		
Other travel		
Other items (add separate row if an significant item)		
Total Amount		

Other, non-NSF, financial contributions in progress or to note:

2. Quarterly Reports

Year 2/Quarter 1 Budget Report for: ____________ **Expenditures as of:** [date]				
Item	**Original Budget**	**Expended**	**Remaining**	**Explanation** (e.g., what major tasks were supported, if there is a variance from original plan)
Personnel/Staffing				
Meeting/Workshop Support				
Other travel (not related to workshop)				
Other items				
Total Amount				

Other, non-NSF, financial contributions in progress or to note for the period:


AGU 2015
San Francisco, CA
(Land Ice, Permafrost, Sea Ice Action Teams)
ACCAP Webinar
(Sea Ice Action Team)
Arctic Matters
Washington, D.C.
(Sea Ice Action Team)
Arctic Encounter
Seattle, WA
ARCUS Research Seminar Series
Washington, D.C.
(Sea Ice Action Team)
CliC Forum
Copenhagen, Denmark
(Land Ice & Permafrost Action Teams)
ASSW/AOS
Fairbanks, AK
ICOP 2016
Potsdam, Germany
(Permafrost Action Team)
2015 - Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
SEARCH SSC:
In-Person Mtg & Town Hall
Permafrost:
PCN Annual Mtg
Land Ice:
GrIOOS Workshop
Sea Ice:
Action Team Mtg & Communication Wkshp
Sea Ice:
Communication Wkshp write-up submitted to IARPC & EOS
SEARCH SSC:
Telecon Mtg
Sea Ice:
Knowledge-to-Action Pyramid Demo
SEARCH SSC:
SSC Member Rotation
Land Ice:
GrIOOS Report Published
Sea Ice:
SIPN Workshop
SEARCH SSC:
In-Person Mtg
Permafrost:
PCN Leads Mtg
SEARCH SSC:
Telecon Mtg
AGU 2016
San Francisco, CA
Sep
Oct
Nov
Dec -2016
Sea Ice:
Knowledge Exchange Workshop
Cross-cutting:
Methane Synthesis Science Workshop
SEARCH SSC:
In-Person Mtg & External Evaluation
Permafrost:
PCN Annual Mtg
Sea Ice:
Action Team Mtg

SEARCH Year-2/2016 Internal Timeline: 1/27/16

	Year 1 - 2015	Year 2 -2016											
	15-Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SEARCH SSC & Science Office Activities													
• Weekly Science Office Meetings													
• Science Steering Committee/Action Team Lead Meetings	X		X			X			X			X	
• Survey other program offices for best practices													
• Science Steering Committee Member Rotation													
• Develop overall SEARCH Communications Plan													
• Participation in IARPC Collaboration Team Meetings													
• Polar Research Board Fall Meeting	X												X
• Polar Research Board Arctic Matters Symposium		X											
• Arctic Encounters Symposium		X											
• Participation in Arctic Science Summit Week				X									
• American Geophysical Union Fall Meeting: Town Hall, Workshops, Sessions, Side Meetings	X												X
• Develop broader funding model for SEARCH activities													
• Communications, Dissemination, & Outreach													
• Explore additional funding for select activities													
• External Review of SEARCH													
Sea Ice Action Team Activities													
• Andy Revkin Science Communication Workshop	X												
• Andy Revkin Science Communication Wkshp Write-Up Published		X											
• Sea Ice Action Team In-Person Meeting	X												X
• Science of Sea Ice Prediction Video Development													
• Production of 1-Page Topic Synthesis Briefs (13+)													
• Evaluation of Synthesis Briefs w/ key audiences													
• Knowledge-to-Action Pyramid Content Demo				X									
• Sea Ice Matters website developed													
• Sea Ice Matters web content produced w/ guest input													
• Polar Research Board Arctic Matters Symposium		X											
• Arctic Encounter Symposium		X											
• Participation in ACCAP Webinar		X											
• Participation in ARCUS Arctic Research Seminar Series			X										
• Participation at the Arctic Observing Summit				X									
• Gap analysis of sea ice observing needs													
• Marika Holland sea ice modeling dataset sensitivity studies													
• Participation in Sea Ice Prediction Network Workshop						X							
• Sea Ice Knowledge Exchange Workshop planning													
• Sea Ice Knowledge Exchange Workshop										X			
Land Ice Action Team Activities													
• GrIOOS Workshop	X												
• Arctic Encounter Symposium		X											
• Create GrIOOS Workshop Report & Recommendations													
• Journal article(s) published on proposed GrIOOS													
• Follow-up on GrIOOS Implementation													
• CliC Steering Committee Meeting			X										
• Production of 1-Page Topic Synthesis Briefs													
• Recruit Land Ice Action Team PostDoc													
Permafrost Action Team Activities													
• Permafrost Carbon Network Meeting	X												X
• Arctic Encounter Symposium		X											
• Quarterly Action Team Steering Committee Telecons													
• Kick-Off Infrastructure/Fish & Wildlife network mtgs					?				?				
• Science Synthesis Scoping & Product Development													
• Recruit PostDoc Funded by USGS AK CSC													
• Intl Conference on Permafrost (ICOP I)							X						
• Synthesis Leads Workshop for PCN							X						
• White Paper for Arctic Observing Summit													
• ID & evaluate key data sets for modeling improvement													
• Finalize protocols for soil incubations & ID data gaps													
• ID & evaluate existing methane data sets													
• Production of 1-Page Topic Synthesis Briefs													
• Publish 5-year overview of PCN products/activities													
• Maintain existing PCN website													
• Develop Infrastructure/Fish & Wildlife web presence													
• Assist with the SWIPA update for Permafrost			X										
• Contribute to SOCCR2 Report development													
• Ongoing news/media development & engagement													
Cross-Cutting Activities													
• Scenario Task Planning													
• Arctic Observing Summit				X									
• Arctic Observing Activities													
• CLIVAR Working Group Activities													
• Methane Synthesis Workshop											X		
• Develop Research Networks													
• Network Analysis													

STUDY OF ENVIRONMENTAL ARCTIC CHANGE

MEMORANDUM

DATE: 3 February 2016

FROM: Brendan P. Kelly, Executive Director

TO: Scientific Steering Committee

SUBJECT: SSC membership

The Scientific Steering Committee has 4 members due to rotate off of the committee. We need to select replacement members giving careful consideration to areas of expertise needed as well as gender, age, and disciplinary diversity.

The Executive Committee proposes the following actions and timeline.

<u>19 February 2016</u>
The SSC decides what, if any, areas of expertise would be most important in new membership.

<u>23 February 2016</u>
The Executive Director call for nominations through the SEARCH website, Witness the Arctic, the Arctic Daily Update, and the IARPC Collaborations website. The announcement should outline the duties of the SSC, the meeting schedule, and desired traits of candidates.

<u>30 March 2016</u>
Nominations closed. Applications collated and distributed to SSC by ARCUS.

<u>15 April 2016</u>
Each SSC member votes for their top 4 candidates. ARCUS tabulates and circulates results.

<u>May 2016</u>
SSC discusses top candidates and chooses 4. Executive Director communicates results to each nominee (successful and unsuccessful).

Brendan P. Kelly, Ph.D.
SEARCH Executive Director
Phone: 907-209-6531 • Email: bpkelly@alaska.edu

STUDY OF ENVIRONMENTAL ARCTIC CHANGE

MEMORANDUM

DATE: 25 January 2016

FROM: Brendan P. Kelly, Executive Director

TO: Scientific Steering Committee & Action Team Leads

SUBJECT: SEARCH Communications Work Group membership nominations

An important activity that cuts across each of the Action Teams of SEARCH is communication of our science to multiple audiences. The recent Arctic Encounter Symposium and the Arctic Matters presentations yielded some good feedback on how we make our results accessible, and there are many other opportunities ahead. Clearly, we need to find a good balance between energy devoted to our research and to communicating what we know to those many audiences. I would like to convene a work group to help strike that balance and lay out an overall communications strategy that is consistent with our resources. I invite Matt Druckenmiller, Christina Schädel, and Jessica Rohde to serve with me and the ARCUS project office staff on the SEARCH Communications Work Team, and I would welcome nominations for additional participation from the Land Ice Team, the Observing Change Panel, and/or elsewhere.

****

Communications Working Group nominations received prior to 5 February 2016:

Matt Druckenmiller (Sea Ice Action Team Staff) – Nominated by Brendan Kelly
Christina Schädel (Permafrost Action Team Staff) – Nominated by Brendan Kelly
Jessica Rhode (IARPC) – Nominated by Brendan Kelly
Bob Henson (The Weather Company) – Nominated by Jennifer Francis
Olivia Lee (UAF/IARC) – Self-nomination
Ned Rozell (UAF) – Nominated by Betsy Baker
ARCUS Staff Participation

Brendan P. Kelly, Ph.D.
SEARCH Executive Director
Phone: 907-209-6531 • Email: bpkelly@alaska.edu

Study of Environmental Arctic Change (SEARCH)
Communications Working Group Charge
DRAFT

Purpose
The SEARCH SSC may convene volunteer *ad-hoc* working groups to bring in additional expertise and supplement the work of the SEARCH program. The SEARCH Communications Working Group will provide advice to the SEARCH SSC on a coordinated SEARCH communications strategy. The Working Group reports to the SSC.

Membership
Membership of the working group will be composed of representatives from various SEARCH groups, partners, and others to provide the needed expertise. The SSC will appoint a Working Group Chair. Project management support will be provided by ARCUS.

Role
The role of Working Group is to identify:

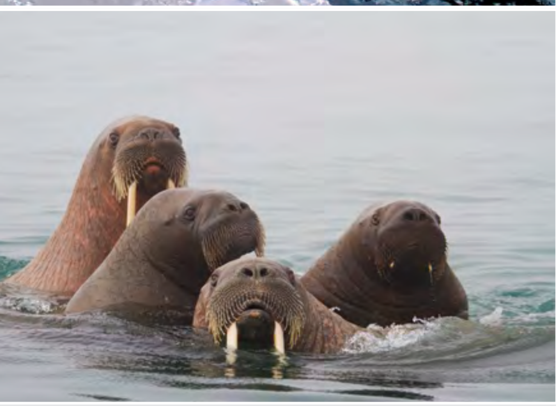
- Key goals and audiences for SEARCH communications efforts.
- Suggested communication tools/types and formats (web, printed, etc.).
- Mechanisms to ensure coordinated outward communications across all SEARCH components (e.g., Action Teams, overall program).
- Priorities for communication activities.

The Working Group is expected to provide a report of findings to the SEARCH SSC during a May meeting (could be done virtually, if needed).

Term and Meetings
Length of term: through June 2016. The SSC may extend the duration of the work group as needed.

The Working Group will meet via tele/web conference and communicate via email; the specific meeting schedule and formats may be determined by the group. No travel support is available for an in-person meeting of the Working Group.

Note that *implementation* of the recommended activities are not the purview of the Working group; however, members of the group may choose to contribute to the implementation of SEARCH communications activities on an individual basis.



Read-ahead J

IARPC envisions a prosperous, sustainable, and healthy Arctic understood through innovative and collaborative research coordinated among Federal agencies and domestic and international partners.

Interagency Arctic Research Policy Committee

2015 Biennial Report

Interagency Arctic Research Policy Committee

2015 BIENNIAL REPORT

Committee on Environment,
Natural Resources, and Sustainability

National Science and Technology Council

DECEMBER 2015

About the National Science and Technology Council

The National Science and Technology Council (NSTC) is the principal means by which the Executive branch coordinates science and technology policy across the diverse entities that make up the Federal research and development enterprise. A primary objective of the NSTC is establishing clear national goals for Federal science and technology investments. The NSTC prepares research and development strategies that are coordinated across Federal agencies to form investment packages aimed at accomplishing multiple national goals. The work of the NSTC is organized under five committees: Environment, Natural Resources and Sustainability; Homeland and National Security; Science, Technology, Engineering, and Math (STEM) Education; Science; and Technology. Each of these committees oversees subcommittees and working groups focused on different aspects of science and technology. More information is available at www.WhiteHouse.gov/administration/eop/ostp/nstc

About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976. OSTP's responsibilities include advising the President in policy formulation and budget development on questions in which science and technology are important elements; articulating the President's science and technology policy and programs; and fostering strong partnerships among Federal, State, and local governments, and the scientific communities in industry and academia. The Director of OSTP also serves as Assistant to the President for Science and Technology and manages the NSTC. More information is available at www.WhiteHouse.gov/administration/eop/ostp

About the Interagency Arctic Research Policy Committee

The Arctic Research and Policy Act of 1984 (ARPA), Public Law 98-373, July 31, 1984, as amended by Public Law 101-609, November 16, 1990, provides for a comprehensive national policy dealing with national research needs and objectives in the Arctic. The ARPA establishes an Arctic Research Commission (ARC) and an Interagency Arctic Research Policy Committee (IARPC) to help implement the Act. IARPC was formally created by Executive Order 12501. Its activities have been coordinated by the National Science Foundation (NSF), with the Director of the NSF as chair. On July 22, 2010, President Obama issued a Memorandum for the Director of OSTP making NSTC responsible for IARPC with the Director of the NSF remaining as chair of the committee.

About this Document

This report was developed by the IARPC Collaboration Teams as a summary of accomplishments since the release by the NSTC of the *Arctic Research Plan: FY2013-2017*. It is intended to inform the NSTC, Congress, and the public about progress in implementing the research plan. This report is published by OSTP.

Copyright Information

Cover: A fishing boat passes in front of an iceberg calved from Jakobshavn Glacier, Ilulissat, Greenland (Photo: Nick Salava). Top Left: Anthropologist Stephen J. Langdon with George Ramos Sr., Tlingit elder and science project adviser, en route to visit traditional seal camp locations in Disenchantment Bay, neat Yakutat, Alaska. (Photo: Aron Crowell, Copyright 2011, Smithsonian Institution). Researchers prepare for an early spring snowmobile traverse (Photo: UMIAQ, LLC). The USCGC R/V HEALY works alongside the Canadian Coast Guard cutter *Louis S. St-Laurent* (Photo: USCG). Walruses near Svalbard Archipelago, Norway (Photo: Roy Stehle).

Members of Congress, the Arctic Research Community, and Interested Parties:

We are pleased to forward the Interagency Arctic Research Policy Committee (IARPC) 2015 Biennial Report. This report, called for in the Arctic Research Policy Act of 1984 (15 U.S.C. § 1408), highlights progress on implementing the five-year Arctic research plan released by the Office of Science and Technology Policy in February 2013. Sixteen Federal agencies collaborated through IARPC to implement the Arctic research plan and to enhance interagency communication and coordination to leverage emerging research and data to greatest effect. This report describes important knowledge gained through IARPC-enabled work conducted over a two-year period ending in autumn 2014. The report also forecasts activities to be addressed through the IARPC framework over the next several years.

The rapid pace of change in the North has tremendous implications for human well-being, national security, transportation, and economic development well beyond the Arctic Circle. Having entered a two-year chairmanship of the Arctic Council in late spring 2015, the United States has an opportunity to establish scientific research priorities for the Arctic region that will enhance our ability to forecast change and to support policy and management decisions based upon solid scientific findings.

IARPC's Federal agencies collaborate with partners in the State of Alaska, local communities, indigenous groups, academia, and the private sector to facilitate implementation of the plan. The effort ensures that scientific research in the Arctic addresses the interests and needs of those communities, and that scientific talent wherever it exists is tapped to provide the global community with the best information about this rapidly transforming region of our planet.

This IARPC Biennial report does not cover all Federally-funded research activities carried out in the Arctic, but rather provides a snapshot of the programs undertaken to implement the five-year research plan. These efforts ranged from improving access to scientific data to conducting field studies of the Arctic marine ecosystem in the Beaufort Sea north of Alaska.

We appreciate your support as we continue to implement the plan and coordinate our broad Federal research efforts in the Arctic region.

Thomas Burke EPA Co-Chair, CENRS	Tamara Dickinson OSTP Interim Co-Chair, CENRS	Kathryn Sullivan NOAA Co-Chair, CENRS

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Table of Contents

Acknowledgements

Simon Stephenson, Executive Director IARPC, defined the vision for this report and inspired the team's efforts to communicate it. Brendan C. Kelly, Former Executive Director IARPC, provided guidance from 2010 to 2014. NSF Division of Polar Programs provided financial support for the development and printing of this report.

Sincere thanks are due to the IARPC team members for their contributions to enhancing interagency research collaborations and also to the IARPC team leads who helped focus the considerable energy produced by collaboration team activities. Named writers within this document generated and reviewed content.

Editorial team: Sara Bowden, Executive Secretary IARPC; Sandy Starkweather, Implementation Scientist IARPC; and Anjuli Bamzai, Program Director, Climate and Large-Scale Dynamics, Geosciences Directorate, NSF

Additional writing, editing and conceptual development: Penelope (Kip) Rithner

Graphic design: Stacie McMullen, Edge Design Studio, Inc., with contributions from Mark Lesh Design

For centuries, Alaskans have navigated coastal waters in skin-covered boats called umiaqs, hunting for sea life. How is the warming Arctic changing marine ecosystems, and what impacts can be expected for Arctic communities that rely on these waters for sustenance? IARPC encourages research collaborations to advance Arctic knowledge. Better understanding may help people predict and prepare for the future. Photo: Faustine Bernadac

IARPC: Setting a Coordinated Research Agenda

The Arctic environment is undergoing rapid transition as sea and land ice diminish, with tremendous implications for natural environments, human well-being, national security, transportation, and economic development. The United States and the other Arctic nations require strong, coordinated research efforts to understand and forecast changes in the Arctic.
—John P. Holdren, Letter to Congress presenting *Arctic Research Plan: FY2013–2017*[1]

In the 2 years since Dr. Holdren, Director of the White House Office of Science and Technology Policy, called for "strong, coordinated research efforts" in the Arctic, scientists have gained new understanding of rapid Arctic change—and of the "tremendous implications" thereof.

The Arctic Report Card for 2014[2] describes significant climate and environmental change in the Arctic: for example, increases in air and sea temperatures, with accompanying changes in sea ice cover. The report includes impacts to animals adapted to living in the polar habitat.

Implications for people living in the changing Arctic are, not surprisingly, significant. Some living south of the Arctic Circle may perceive the region as a beautiful and isolated place, a closed landscape with little impact on theirs. The distance allows the Arctic to become "like a snow globe on a shelf," as Senator Lisa Murkowski (Alaska) offered in a

[1] This plan was developed by the Interagency Arctic Research Policy Committee, which reports to the NSTC Committee on Environment, Natural Resources, and Sustainability (CENRS), Office of Science and Technology Policy, Executive Office of the President.
[2] "The Arctic Report Card: Update for 2014." www.arctic.noaa.gov/reportcard

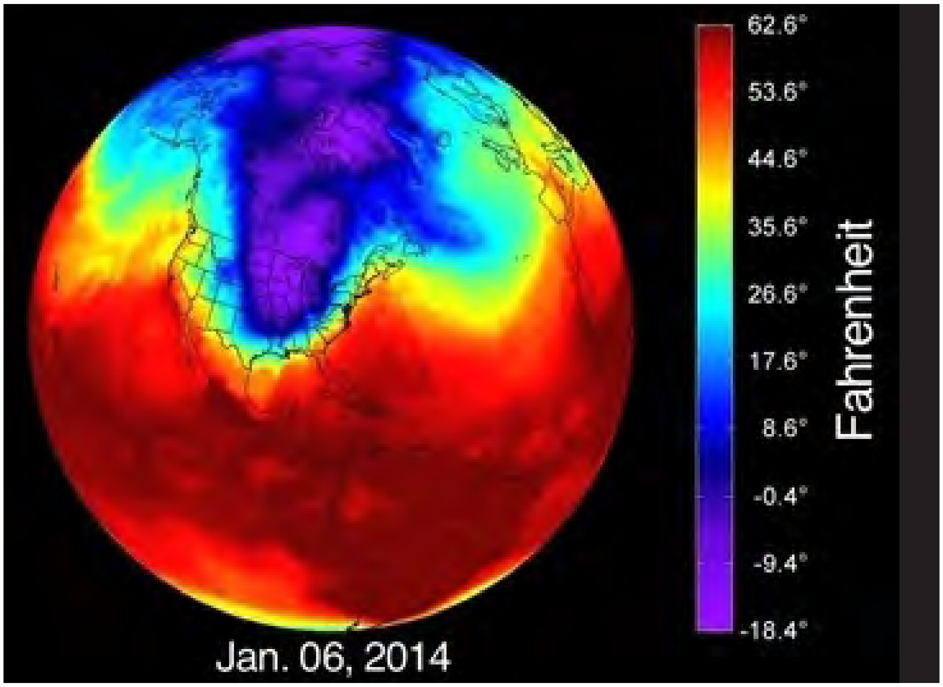


FIGURE 1
A GLOBAL SYSTEM
Big temperature differences between the mid-latitudes and the Arctic keep a cold air current circling the North Pole in winter, locking cold air over the pole. Scientists are studying whether warming temperatures in the Arctic can weaken that stream, causing it to wobble and spill frigid air into lower latitudes, as indicated by dark blue and purple areas, above. Low temperature records in the United States during the winter of 2014—including over 50 such records on January 6 alone—may have been caused by the dipping jet stream. SOURCE: NASA's Goddard Space Flight Center

recent article encouraging economic development for Arctic states.[3] But the scientific consensus suggests that the Arctic system is part of a global system—and so what happens in the Arctic impacts us all on time scales of days to decades (FIGURE 1).

Federal agencies providing national security, resource management, human services, and scientific discovery are challenged by the prevailing shift to a warmer, ice-diminished Arctic. They are galvanized by rapid environmental changes to accelerate the pace of research and knowledge growth through cooperation, data sharing, and the use of a variety of methods and tools.

Promoting such cooperation is the aim of the Interagency Arctic Research Policy Committee, or IARPC. Congress created IARPC to strategically enhance the effectiveness of Federal Arctic research efforts through interagency collaboration and cooperation with the state of Alaska and other relevant participants. IARPC is composed of principal members from 16 Federal agencies or offices[4] working in the Arctic. Through meetings, webinars, workshops, and an interactive website, IARPC provides a forum to leverage resources and maximize research outcomes.

IARPC helps the Federal Government coordinate a response to emerging opportunities in the Arctic. The United States chairmanship of the Arctic Council, lasting from May 2015 until April 2017, is one such opportunity. The Council was created in 1996 as a forum to promote cooperation and dialogue among the eight countries whose territories extend into the Arctic (Canada, Denmark [via Greenland], Finland, Iceland, Norway, Russia, Sweden, and the United States). The Arctic Council primarily focuses on fostering environmental stewardship and sustainable development. Chairmanship from 2015 to 2017 gives the United States a unique opportunity to shape the agenda and direction of the Arctic Council's work.

This biennial report describes how IARPC-enabled activities have addressed research ranging from coordinated field deployments to data sharing and interoperability. These activities generate knowledge that will inform key national priorities such as homeland security; energy, water, and food security; transportation infrastructure maintenance; and natural resources protection.

This report presents current progress on implementing a cross-agency Arctic research plan, developed by IARPC. The plan is informed by the 2013-2014 U.S. Arctic Research Commission's[5] Goals Report,[6] which focuses on the following goals:

1. Observe, understand, and respond to environmental change
2. Improve Arctic people's health
3. Understand natural resources
4. Advance civil infrastructure research
5. Assess indigenous languages, identities, and cultures

Published by the Office of Science and Technology Policy (OSTP) in February 2013, IARPC's *Arctic Research Plan FY13-17*[7] describes a vigorous research agenda to understand the Arctic's most vulnerable systems.

[3] www.adn.com/article/20141119/lisa-murkowski-alaska-must-lead-us-takes-arctic-council-chair

[4] These agencies are: Office of Science and Technology Policy (OSTP), Department of Commerce (DOC), Department of Defense (DOD), Department of Energy (DOE), Department of Health and Human Services (HHS), Department of Homeland Security (DHS), Department of Interior (DOI), Department of State (DOS), Department of Transportation (DOT), Environmental Protection Agency (EPA), Marine Mammal Commission (MMC), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF, Chair), Office of Management and Budget (OMB), Smithsonian Institution (SI), and United States Department of Agriculture (USDA). United States Arctic Research Commission (USARC), ex-officio.

[5] www.arctic.gov/index.html

[6] www.arctic.gov/reports_goals.html

[7] www.WhiteHouse.gov/sites/default/files/microsites/ostp/2013_arctic_research_plan.pdf

Who's Participating in IARPC Implementation?

NON-LEAD AGENCY   **LEAD AGENCY**

Collaboration Team	Participating U.S. Federal Agencies																Non-Federal Partners
	DHS	DOC	DOD	DOE	DOI	DOS	DOT	EPA	HHS	MMC	NASA	NSF	OSTP	SI	USARC	USDA	
Arctic Communities	1	3	1		7	2			1		2	4	1	**4**		4	29
Arctic Data		7	4	1	14			1			**6**	3	1		2	2	15
Arctic Observing Systems	1	7	3	2	11						**2**	3	1		1		29
Atmosphere		9	1	**3**			1	1			6	2	1				13
Chukchi & Beaufort Seas		18	4	1	**10**					1	3	2	1		2		**15**
Distributed Biological Observatory		**9**	5		5					1	4	2	1		2		**14**
Glaciers & Fjords		2	1	3	1						3	**5**	1				8
Human Health	6	1	1		2			1	**7**		2	2	1		1		12
Modeling		7	2	**4**	6		1				6	2	1			2	9
Sea Ice	1	16	**7**	2	3						3	3	1				19
Terrestrial Ecosystems		1	1	3	**11**						5	2	1				16
Wildfires		2	1	1	**9**						3	1	1			1	**9**

FIGURE 2
TEAM EFFORTS
IARPC's 12 collaboration teams focus on research areas identified in the 5-year plan that involve interinstitutional and interdisciplinary cooperation. To achieve the richest perspective available, IARPC welcomes diverse input from State, local, and tribal entities, as well as academia, nongovernmental institutions, and industry. Each collaboration team is headed by a Federal agency or agencies, which report(s) back to the IARPC on progress. Some teams (Chukchi & Beaufort, DBO, and Wildfires) are co-chaired with external parties. The number of people from each agency participating on a team are shown in the boxes. These numbers indicate participation as of January 2015; they change as collaboration teams gain new people.

The report focuses on seven research themes: sea ice and marine ecosystems; terrestrial ice and ecosystems; atmospheric studies of surface heat, energy, and mass balances; observing systems; regional climate models; adaptation tools for sustaining communities; and human health. Instead of describing all federally funded research in the Arctic, the IARPC plan includes efforts that benefit most from collaboration. In addition to describing urgent research needs, the plan specifies the network of agency activities that will support them.

To assure rapid implementation, in 2013 IARPC created an association of 12 collaboration teams (FIGURE 2), each led by an IARPC member agency. In 2014, the teams opened to non-Federal partners such as universities and private agencies. This collaboration structure reflects the mandate of IARPC's enabling legislation[8] and provides a means for harnessing the talent of the broader scientific community. It creates a virtual public commons where a growing network of Federal funders, Federal researchers, and outside partners discover information, develop new research ideas, and build strategic alliances (FIGURE 3).

These research efforts support IARPC's vision of a prosperous, sustainable, and healthy Arctic understood through innovative and collaborative research coordinated among Federal agencies and domestic and international partners. They reflect our growing grasp of the vast network of activities and individuals with a stake in Arctic research. Thus, whether they are land managers, Alaska infrastructure planners, global environmental change researchers, indigenous hunters, or taxpayers, all Arctic stakeholders may find evidence in this report of the progress made by IARPC and its new collaboration structure.

[8] "Arctic Research and Policy Act of 1984, as amended," www.nsf.gov/geo/plr/arctic/iarpc/arc_res_pol_act.jsp

IARPC by the numbers

16 Federal agencies provide principal leaders

12 Collaboration Teams focus on an area of study supporting…

7 major research themes

145 milestones to organize Collaboration Team activities

With IARPC encouragement, scientists representing diverse disciplines collaborate on Arctic research. Photo: Stan Wullschleger

Who's Talking to Whom?

A Visualization of Federal Arctic Research Coordination

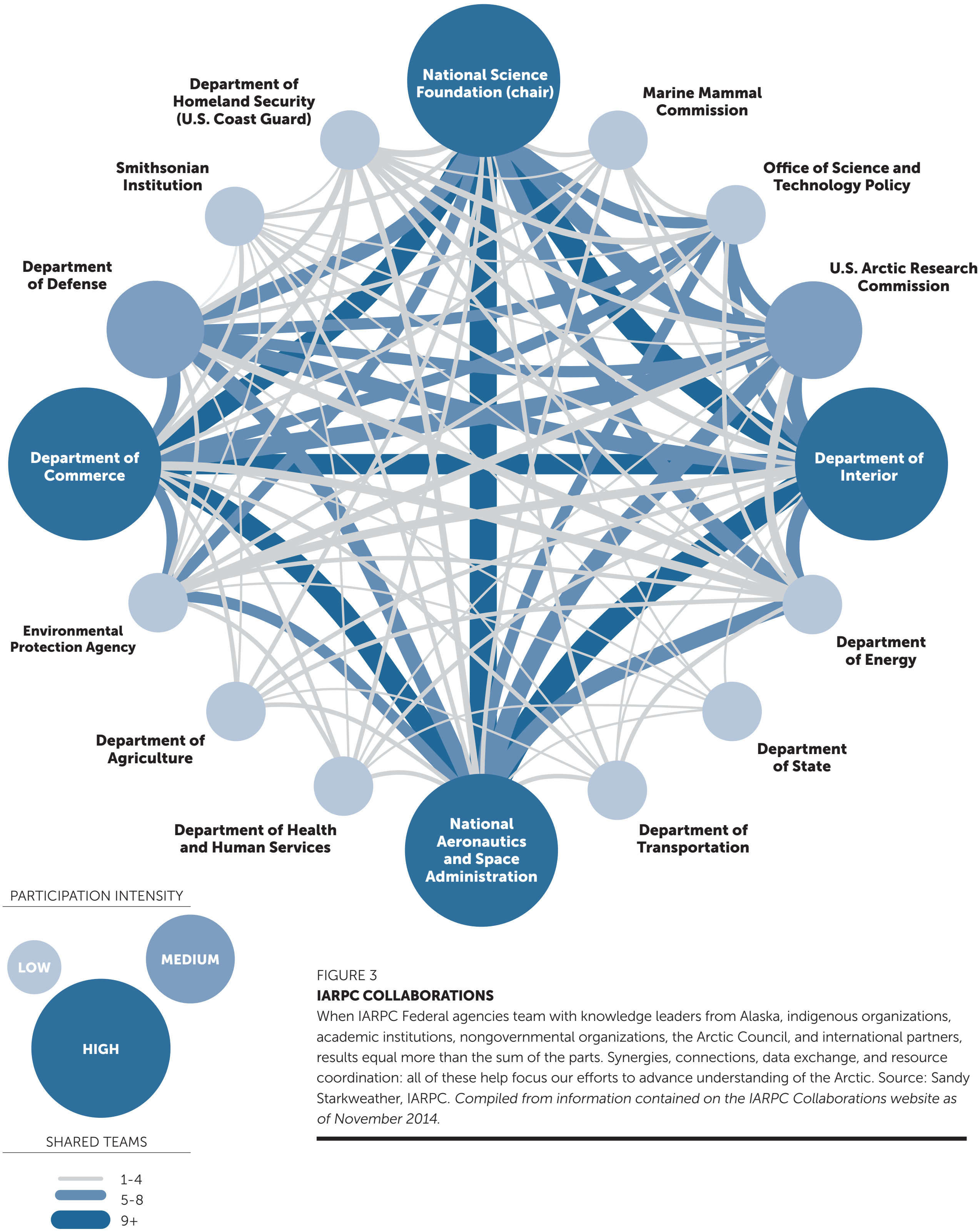


FIGURE 3

IARPC COLLABORATIONS

When IARPC Federal agencies team with knowledge leaders from Alaska, indigenous organizations, academic institutions, nongovernmental organizations, the Arctic Council, and international partners, results equal more than the sum of the parts. Synergies, connections, data exchange, and resource coordination: all of these help focus our efforts to advance understanding of the Arctic. Source: Sandy Starkweather, IARPC. *Compiled from information contained on the IARPC Collaborations website as of November 2014.*

Arctic Executive Steering Committee

In January 2015, President Obama issued an Executive Order* establishing an Arctic Executive Steering Committee (AESC) to augment Arctic policy coordination across the Federal Government. OSTP Director John Holdren chairs the committee, which includes Deputy Secretary or equivalent personnel with Arctic interests from all quarters of the Federal Government. This body provides cohesive guidance to Federal departments and agencies, and it also seeks to enhance collaboration with State, local, and Alaska Native organizations and tribal governments, academic and research institutions, and the private and nonprofit sectors. IARPC contributes to the AESC in areas related to coordination of federally funded research in the Arctic.

The AESC calls attention to the President's priorities, as described in the *National Strategy for the Arctic Region (NSAR):*** advancing U.S. security interests; pursuing responsible Arctic region stewardship; and strengthening international cooperation. The importance of IARPC's efforts is recognized in the implementation plan for the NSAR. The IARPC research plan is fully embedded in the NSAR implementation plan, ensuring that IARPC efforts are contributing to the overall Federal Arctic effort. A working group reviewed ongoing Federal activities to identify possible areas of overlap or gaps in implementation; this group's recommendations will help to maximize resource investments (e.g., expert talent, dollars, and activities).

President Barack Obama visited Alaska, including areas north of the Arctic Circle, in late summer 2015. Photo: Jonathan Ernst/Reuters

* "Executive Order: Enhancing Coordination of National Efforts in the Arctic." The White House, Office of the Press Secretary. January 21, 2015, www.WhiteHouse.gov/the-press-office/2015/01/21/executive-order-enhancing-coordination-national-efforts-arctic

** *National Strategy for the Arctic Region*. Office of the President of the United States. May 2013, www.WhiteHouse.gov/sites/default/files/docs/nat_arctic_strategy.pdf

IARPC's Communication Tools Encourage Cooperation

IARPC Toolbox

IARPC Collaborations www.iarpccollaborations.org

Distinctly Innovative Ways of Doing Business, Not Business as Usual

The website is an experiment in new ways to "do" science, an effort to help funders and researchers work together across agencies, sectors and disciplines. Users can post their own content about IARPC collaboration team activities, as updates, documents, and events. Users also can comment on posts about the research being done, opening the conversation to new talent that may be missing on established email lists.

IARPC Collaborations takes the best part of social media—the ability to connect people—and leverages it to:

- Let new people contribute to the conversation—unlike email or phone calls
- Help users keep the community updated—no waiting for the webmaster
- Provide access to information all in one place—go beyond Google!
- Keep people connected through contact information, user profiles, and topical groups
- Track progress on NSAR milestones
- Filter milestones by agency—see each agency's work!

IARPC Collaborations: Join the conversation!

Scientists study melt-water channels ribboning Greenland's ice cap as part of a broader effort to understand regional warming and the complex ways in which the Arctic is changing. IARPC's collaboration teams help focus our efforts and resources to accelerate knowledge gain—and, ultimately, future preparedness. Photo: Sarah Das, Woods Hole Oceanographic Institution

2: Addressing Scientific Challenges through Collaboration

Understanding Sea Ice, Glacier-Ocean Interactions, and Marine Ecosystems

Diminishing sea ice cover and increasing open water in the summertime Arctic Ocean raise questions about the region's future—and the severity of global impacts. Some speculate that changes will bring more commercial activity in the Arctic: offshore oil and gas development, mining, shipping, fishing, and tourism.[9]

For Arctic coastal community members whose traditional way of life depends on sea ice, changes present both challenges and opportunities. The rapid pace of environmental change has ramifications for homeland and national security, public policy, and decision-making at all levels of government.

In this section, efforts to address a number of scientific questions laid out in the 5-year plan are reported: a series of experiments in the Marginal Ice Zone (MIZ) north of Alaska; field investigations in Greenland to better understand marine-terminating glaciers; and the launch of an IARPC-inspired Marine Arctic Ecosystem Study. These topics require large, coordinated efforts to examine complex components of the Arctic system (FIGURE 4). IARPC collaboration teams successfully contributed to research on these issues.

[9] For more on potential increases in commercial activities in the Arctic, see: Clement et al (2013). "Managing for the future in a rapidly changing Arctic. A report to the President." Interagency Working Group on Coordination of Domestic Energy Development and Permitting in Alaska (D. J. Hayes, Chair). www.doi.gov/sites/doi.gov/files/migrated/news/upload/ArcticReport-03April2013PMsm.pdf

The Arctic System

Understanding the connections between physical, biological, chemical, and human processes

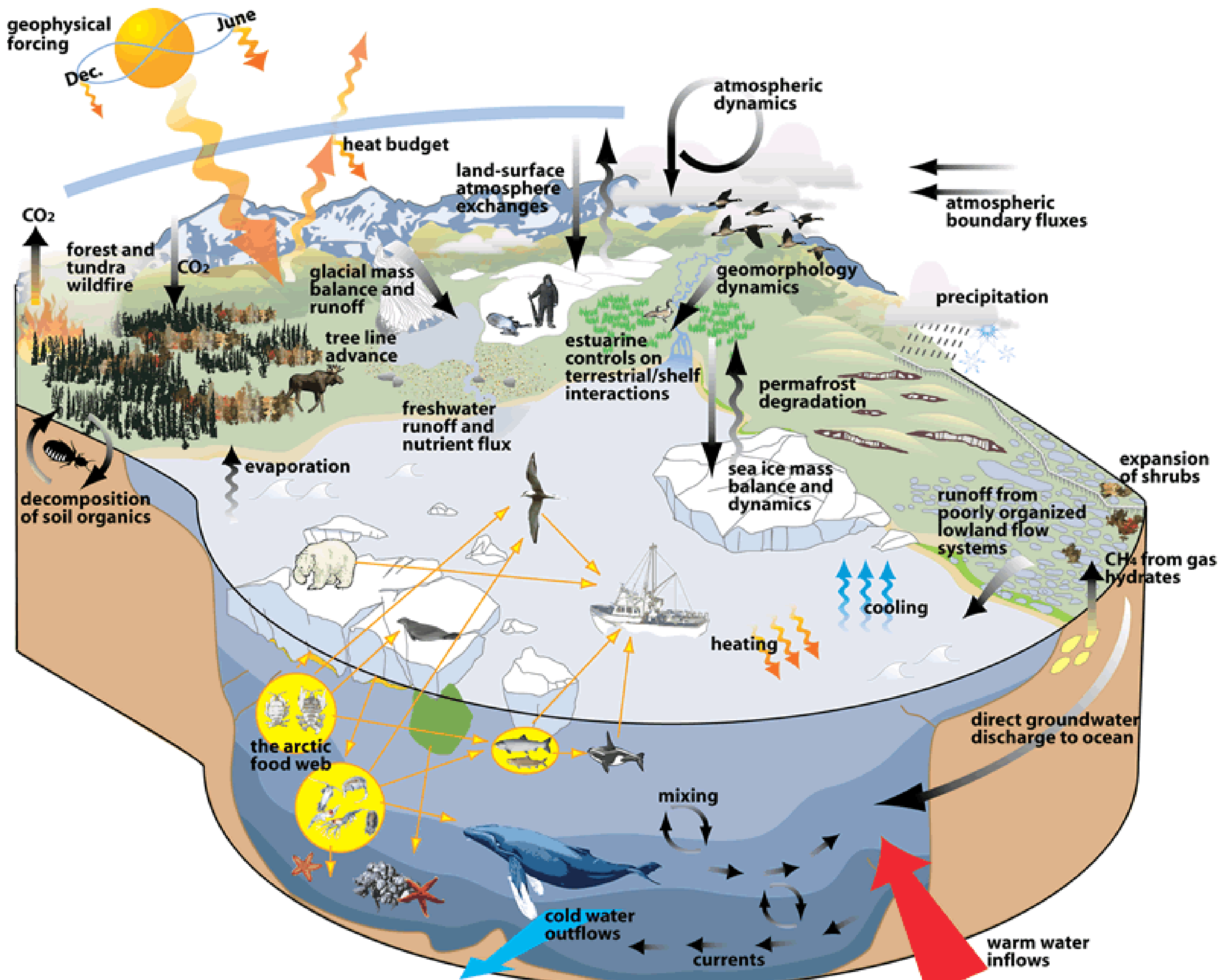


FIGURE 4
COMPLEX INTERACTIONS
This schematic describes the Arctic system and demonstrates the interconnections among components. Important changes in one component may influence other parts of the system. To accurately predict how the Arctic system will evolve with a changing climate, the linkages and feedbacks among systems must be understood. IARPC coordinates activities of U.S. Federal agencies to maximize the science investment in progressing toward this goal. Source: Study of Environmental Change (IARC, 2014).

Marginal Ice Zone Research

Declining summer sea ice extent off the northern coast of Alaska is leading to the emergence of a full MIZ, an area where consolidated pack ice meets the open ocean and has increased exposure to waves and swells. The MIZ is a complex and dynamic region of interactions and feedbacks among the atmosphere, ice, ocean, and ocean surface waves that affect the rate of ice advance and retreat.

Scientists must understand physical processes in the MIZ to explain the observed decline in sea ice extent and to improve sea ice prediction. This knowledge is critical for agencies operating in the maritime Arctic and for weighing potential risks and benefits of increased ship traffic in the region.

The MIZ is an inherently challenging place to conduct traditional field work due to unstable ice, wave action, and poor weather. The IARPC Sea Ice Collaboration Team has coordinated multi-agency sea ice research and technology demonstrations focused on the MIZ to increase knowledge, understanding, and predictive capabilities.

MIZOPEX

In the summers of 2012 and 2013, NASA and National Oceanic and Atmospheric Administration (NOAA) researchers collaborated on a field program called The Marginal Ice Zone Observations and Processes Experiment (MIZOPEX). The main aim of the program was to evaluate unmanned aerial systems (UAS) or "drones" for science in the MIZ of the Beaufort Sea off the northern coast of Alaska. These systems have the potential to greatly expand observational capabilities in the MIZ, complementing in situ instruments and remote sensing from space.

Based from Oliktok Point, Alaska, the MIZOPEX team launched a variety of UAS, including a tiny drone that could land on a surface and collect ground-based information. Each UAS was equipped with instruments, including visible and infrared cameras and a lightweight synthetic aperture radar (SAR). These instruments collected information on sea ice surface topography, melt pond size and distributions, and ice floe size and number (FIGURE 5). The UAS was also outfitted to drop small buoys to measure salinity and temperature in the uppermost ocean layer.

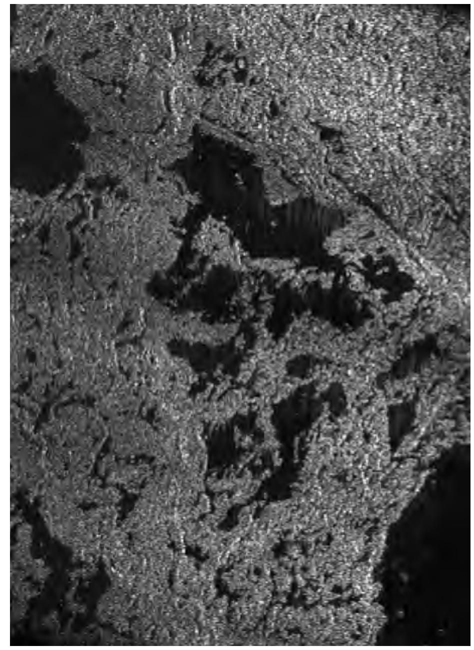


FIGURE 5
SAR IMAGERY
Water (dark tone) and ice floes (lighter tones) are shown in the MIZ taken from a Sierra UAS during MIZOPEX. Source: Jim Maslanik, University of Colorado Boulder

MIZOPEX demonstrated that UAS are a viable means to collect detailed data on multiple points of interest in an Arctic marine setting. This work also showed that pairing air-dropped instruments drifting in the ocean with high-resolution, repeated satellite coverage, is a powerful approach to investigating ice-ocean interactions in the dynamic MIZ.

Ice reflects solar radiation, isolates water from wind currents, and calms waves, processes that can break up ice. MIZ research can help people make knowledge-based decisions to prepare (for example) for increased vessel traffic resulting from a more open ocean. Photo: US Fish & Wildlife Service

ONR Marginal Ice Zone Departmental Research Initiative (MIZ DRI)

In 2014, the United States Department of the Navy's Office of Naval Research (ONR) led a 6-month Beaufort Sea MIZ field study. The experiment was part of a multi-institution, multi-nation, 5-year (2012-2016) investigation to improve understanding of the physics of atmosphere-ice-ocean-wave interactions and feedbacks in the summer MIZ. The research team also planned to develop and demonstrate new robotic networks for making observations in environments that present severe challenges for people-centric field investigations.

Operating from two small ice camps with fixed-wing aircraft and helicopter support in March 2014, the ONR team deployed an initial array of over 50 autonomous instruments and platforms on, in, and under the multiyear pack ice of the eastern Beaufort Sea. The array included automatic weather stations; ice-mass-balance, wave and ocean-flux buoys; ice-tethered profilers; polar-profiling floats; and acoustic sources. The acoustic sources provided navigation and communication services for Seagliders and polar-profiling floats deployed in July.

The initial array was supplemented during two summer field operations. In late July, scientists deployed Seagliders, Wavegliders, and a moored wave buoy and free-drifting wave floats from a small research vessel, the *Ukpik,* out of Prudhoe Bay. Then, in mid-August, an international collaboration with the Korea Polar Research Institute (KOPRI) allowed the deployment of additional weather stations, ice mass balance and wave buoys, and an ice-tethered profiler from the R/V *Araon*. An early result of this project was the discovery of an underwater acoustic channel between 50 m and 200 m below the ice in which acoustic signals travelled as much as 500 km to serve the Seagliders and Polar Profiling Floats and provided underwater positioning accuracy of 100 m. This has exciting implications for future sustained autonomous observing under the Arctic pack ice.

As the ice-based instrument array (FIGURE 6) drifted westward through the Beaufort Sea, it was imaged regularly from space by SAR[10] and, in an unprecedented Arctic collaboration with the intelligence community, by National Technical Means (NTM).[11] Scientists studying the SAR data and the 2014 NTM high-resolution, electro-optical image collections are measuring ocean surface waves, ice floe size, melt pond size and number, and ice fractures.

[10] The ONR array was seen by RADARSAT-2 and TerraSAR-X.

[11] Declassified visible band NTM images are publicly available at the United States Geological Survey (USGS) Global Fiducials Library www.gfl.usgs.gov

A wave buoy sits on the sea ice. It was deployed from the R/V *Araon* (in the background) of the Korea Polar Research Institute (KOPRI). Photo: Martin Doble (Villefranche Oceanographic Laboratory, France)

Additional campaigns

NASA's Operation IceBridge and the European Space Agency's CryoVEX projects placed scientists on the ice in March 2014 to take advantage of the ONR MIZ camps in the eastern Beaufort Sea. The scientists measured snow depth and ice thickness in situ, while aircraft overhead measured the same properties remotely. The data will improve algorithms for deriving sea ice information from instruments aboard the CryoSat-2 and ICESat-2 satellites. NASA's Operation IceBridge also sped up its data delivery by developing a quick-look snow depth and ice thickness product available as soon as possible after data collection from the National Snow and Ice Data Center. Such rapid data access allows the research community to assess the response of the pack ice to the 2014 summer minimum extent and to project pack ice behavior as it retreats in the upcoming summer. The experiment will improve computer models simulating ice advance, retreat, extent and volume.

NASA returned to the Beaufort and Chukchi seas in September 2014 when the ARISE (Arctic Radiation and IceBridge Sea and Ice Experiment) project flew a C-130 to investigate Arctic sea ice change and cloud radiative properties. ARISE will improve our understanding of the regional energy budget (i.e., how much energy is received from the Sun, and how much is reflected and radiated back into space). An October NOAA/ONR project used a P-3 research aircraft to investigate the impact of the advancing pack ice on ocean-to-atmosphere heat transfer, atmospheric temperature and pressure fields, and atmospheric circulation. The 2014 campaign repeated measurements made in the same region the previous fall.

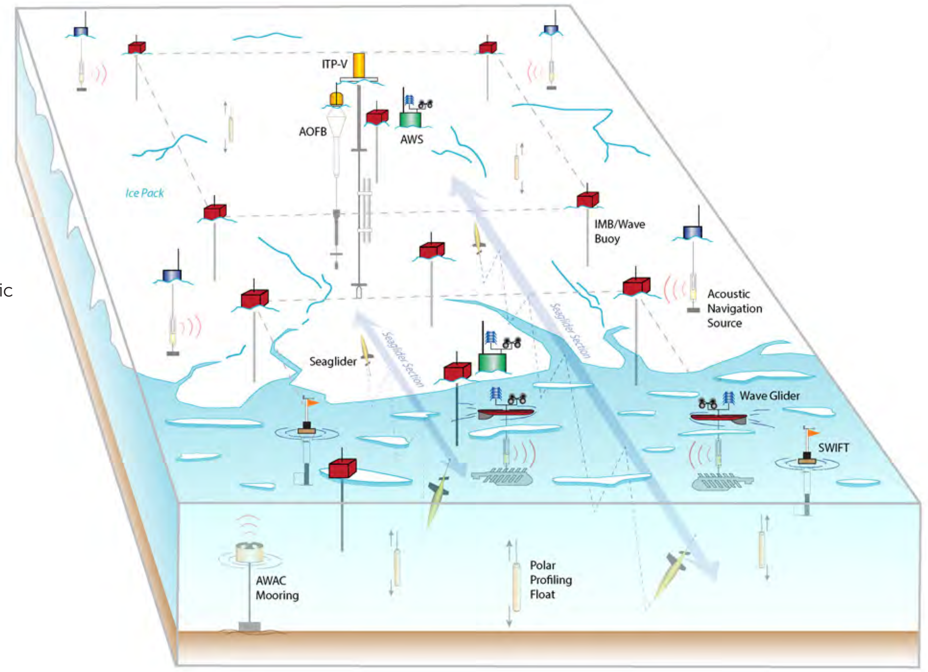


FIGURE 6
MARGINAL ICE ZONE SENSORS
This illustration depicts sensors installed in the Marginal Ice Zone of the Arctic Ocean. By the end of summer 2014 the ONR marginal ice zone observing array, consisting of almost 100 autonomous instruments and platforms, was demonstrating the value of robotic technology for scientific investigation of complex processes in a challenging environment. Credit: UW Applied Physics Laboratory

Greenland Ice Sheet Studies

Global sea level is rising due to the expansion of ocean water as it warms, and the melting of mountain glaciers and ice sheets.[12] Sea level rise has consequences for the 123 million people in the United States who dwell along the coasts, and for many more coastal residents around the globe. Should some sea-level predictions bear out, many Americans may be displaced or subject to increasing storm-related flooding and other associated problems. In addition, the release of freshwater into the Arctic Ocean and subarctic seas due to glacier and ice sheet melting will impact ocean circulation and climate.

To prepare for this future, scientists need to understand the processes by which ice is lost, and also how much is being lost, from the Greenland Ice Sheet and Arctic glaciers. DOE, NASA, and NSF are supporting research projects, field campaigns, satellite missions, and modeling to answer these questions and improve estimates of current and future contributions from Arctic land ice to sea level rise. A key uncertainty is the fate of marine-terminating Arctic outlet glaciers that transport ice from land to the ocean. The processes controlling ice transport at the ice sheet margins are poorly understood and are not well represented in current climate models[13] (FIGURE 7).

IARPC's Glacier-Fjord Collaboration Team (GFCT) was formed in 2012 by members[14] already engaged in efforts to coordinate Greenland Ice Sheet research *via* US CLIVAR (United States Climate Variability and Predictability Program), a Federal interagency effort to coordinate U.S. research on global climate variability and predictability.

The US CLIVAR Working Group on Greenland Ice Sheet Ocean Interactions (GRISO) published recommendations in 2012 that highlighted the need for research on glacier/ocean interactions and became a touchstone for the IARPC team's efforts. A key international workshop was held in June 2013 in Beverly, MA involving 90 stakeholders, including 47 U.S. scientists, 3 Federal agency program officers, and 40 international experts from 10 different countries. The workshop identified ways to reduce uncertainties in the ice/ocean/atmosphere interactions influencing the evolution of the Greenland ice sheet, including observational, synthesis, and modeling strategies; communication, coordination, and collaboration between diverse communities (e.g., oceanography, geology, glaciology, climatology, and paleoclimatology); synergies between national and international projects; and capacity-building with specific focus on advanced graduate students and early career scientists. Attendees discussed plans for a long-term Greenland observing system.[15] The workshop resulted in one funded research project and detailed planning for future projects, including a meeting in Europe for logistics in September, 2014.

[12] NOAA's State of the Coast. www.stateofthecoast.noaa.gov

[13] Stocker et al. (eds.). *Climate Change 2013: The Physical Science Basis: Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA 1535 pp, doi: 10.1017/CBO9781107415324

[14] Four IARPC agencies also participate in U.S. CLIVAR: DOE, NASA, NOAA, and NSF.

[15] Heimbach et al. (eds.). *International Workshop on Understanding the Response of Greenland's Marine-terminating Glaciers to Oceanic and Atmospheric Forcing: Challenges to Improving Observations, Process Understanding and Modeling.* Report 2014-1, US CLIVAR Project. doi: 10.1017/CBO9781107415324. www.usclivar.org/sites/default/files/documents/2014/2013GRISOWorkshopReport_v2_0.pdf

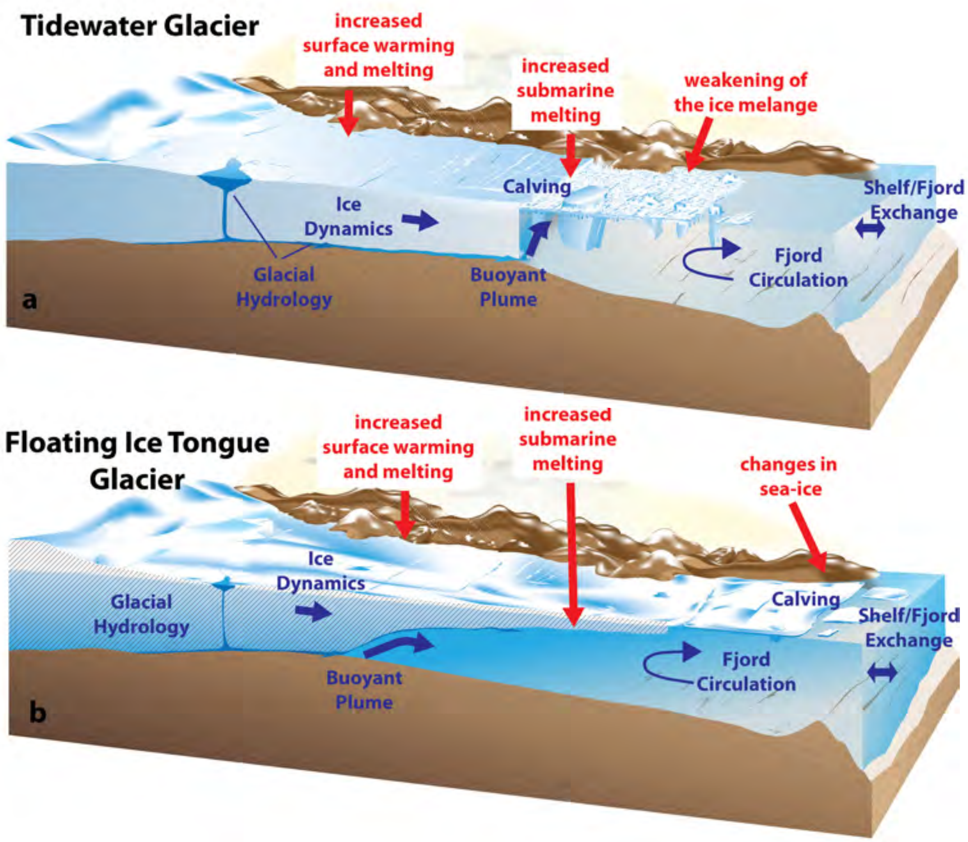


FIGURE 7
GLACIER MODELS
Glaciers that end in the ocean deliver both runoff (as do land-terminating glaciers) and solid ice, which later melts, to the ocean. Greenland has many such glaciers—and they are melting at accelerated rates. IARPC's GFC team coordinates efforts to accelerate our understanding of marine-terminating glaciers, a significant area of uncertainty for those predicting sea-level rise. Source: Straneo et al. (2013): "Challenges to Understanding the Dynamic Response of Greenland's Marine Terminating Glaciers to Oceanic and Atmospheric Forcing." *Bull. Amer. Meteor. Soc.*, 4, 1131–1144. doi: 10.1175/bams-d-12-00100.1

Chukchi and Beaufort Sea Studies

As IARPC developed its 5-year research plan, members identified the Chukchi Sea and Beaufort Sea ecosystems as areas of critical importance to U.S. national interests that would benefit from coordinated, interagency collaboration in association with non-Federal entities. IARPC's Chukchi-Beaufort Ecosystem Collaboration Team (CBCT) tackled this complex issue.

The Chukchi and Beaufort Seas border Alaska's northwestern and northern coasts and comprise the United States' Arctic Ocean holdings. They are biologically productive and diverse, as well as important to U.S. national security and economic interests for oil, and potentially to U.S. mineral and commercial fishing. These waters represent a vital component of traditional life for Alaskan communities (e.g., as a source of nutritional, cultural and spiritual sustenance).

Conceptual Development

The CBCT started by organizing a workshop[16] that involved international experts from academia, industry, and traditional communities in activities aimed at assessing the state of knowledge. The CBCT viewed the activity as a first step in studying how the Chukchi and Beaufort ecosystems may respond to climate change.

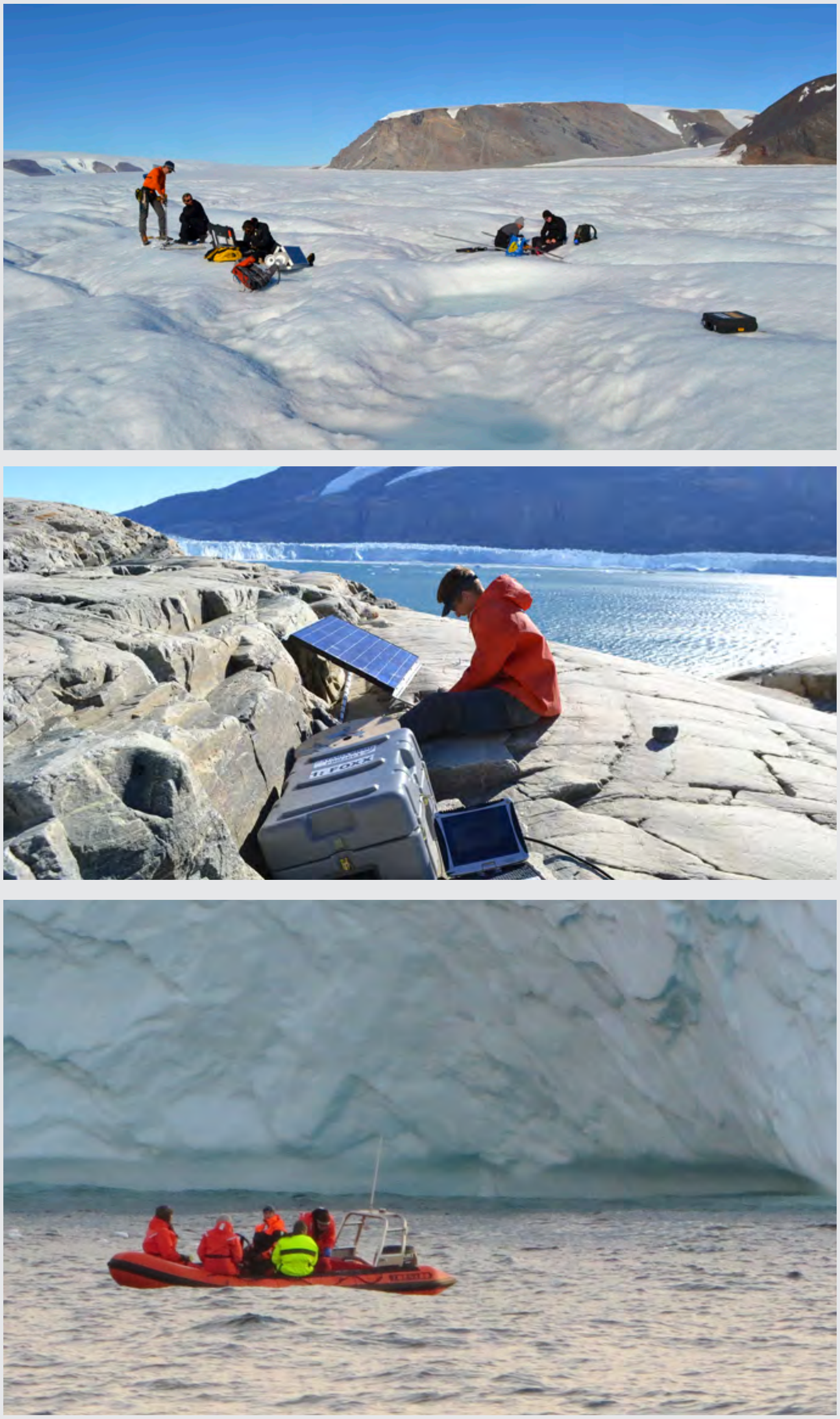
To this end, the CBCT encouraged development of a "framework document[17]" to foster and guide the scientific collaboration needed to achieve a common understanding of the U.S. Arctic marine ecosystem and its likely changes in coming decades. The CBCT developed a conceptual model that described the physical, biological, chemical and human aspects of the Arctic marine ecosystem.

The framework document brings together the thinking of academic and industry leaders, indigenous communities, conservation organizations, and government scientists to describe an intellectual and organizational approach to the research.

The document provides examples of ongoing and new affiliations, highlighting their different scopes, approaches and durations. It is aligned with several national plans, such as the *National Ocean Policy-Implementation Plan*[18] and the *Implementation Plan for the National Strategy for the Arctic Region.*[19]

[16] "Developing a Conceptual Model of the Arctic Marine Ecosystem. April 30 – May 2, 2013, Washington, DC." www.nprb.org/news/detail/arctic-conceptual-model-workshop-report-available
[17] www.iarpccollaborations.org/uploads/cms/documents/framing_arctic_marine_research_initiatives_report_p2b_lowres.pdf

[18] www.WhiteHouse.gov/administration/eop/oceans/policy
[19] www.WhiteHouse.gov/sites/default/files/docs/nat_arctic_strategy.pdf



NASA-funded researchers collect information on atmospheric, glaciological, and ocean processes. To understand how an outlet glacier interacts with the fjord into which it terminates, team place global positioning instruments up on the ice sheet for information about the glacier's movement (top panel); install instruments (e.g., the solar-powered tide gauge near the glacier's face) to record information about calving events (middle panel); and collect water samples in the fjord as they drift by a melting iceberg (bottom panel). Photos: 1&2: Lauren Andrews, UTIG Photo 3: Dustin Carroll, University of Oregon

Marine Arctic Ecosystem Study

The Marine Arctic Ecosystem Study is led by Bureau of Ocean Energy Management (BOEM). MARES scientists aim to identify areas of increased productivity and different ecosystem dynamics (e.g., inner shelf versus outer shelf), and provide a better understanding of intra- and intersystem feedbacks, an important goal noted in IARPC's 5-year research plan. The CBCT provided coordination, ensuring that the MARES request for proposals supported the high level of integration, cooperation, and flexibility required for this complex undertaking.

Once the MARES organizers released a request for proposals in mid-June 2014, the team moved swiftly and announced an award in November. The compressed timeline demonstrates the effectiveness of the CBCT in coordinating interagency activity and illustrates IARPC's commitment to accelerate understanding of the Arctic marine environment (FIGURE 8).

MARES is relevant to the missions of many of the IARPC agencies and to our National priorities because it addresses energy security, climate change and monitoring, oil spill risk analysis, fundamental scientific questions on ecosystem structure and function, environmental protection, and exploration and discovery.

Contributing writers: Guillermo Auad, Danielle Dickson, Martin Jeffries, Bill Wiseman

Collaboration Team Meetings

Through Collaboration Teams, IARPC has enabled the engagement of the research community, as well as leveraged Federal investments through assocations that maximize scientific outcomes. Collaboration Teams meet regularly to discuss progress towards milestones that support the goals identified in IARPC's 5-year plan. Most meetings are open to the Arctic research community.

IARPC Toolbox

MARES

An Integrated-Science Approach

FIGURE 8
ACCELERATING RESEARCH THROUGH COOPERATION
The Marine Arctic Ecosystem Study was organized and championed by IARPC because the subject area is:

- **Vast** – involving most U.S. Arctic Ocean holdings north of Alaska
- **Complex** – involving land, ocean, atmosphere, ice, animals, traditional communities
- **Important** – to tribal, Alaska, U.S., and international interests
- **Precious** – one of the most biologically diverse and productive regions in the world
- **Changing** – disappearing sea ice, changing ecosystems bring opportunities and risks
- **Difficult** – a remote and fragile region with little infrastructure, dangerous ice cover, changing ecosystems that are difficult to study without impact

MARES agencies developed the science plan using concepts from a framework document established by the IARPC collaboration team. Refer to “The Common Objective” (see right). They also defined the process by which they would continue to advance group goals using a single contractor to conduct the work. Refer to “Getting it Done: Partnership Decision Model” (see below).

THE COMMON OBJECTIVE

INTEGRATED PERSPECTIVE OF THE OCEANIC-ATMOSPHERIC-SEA ICE-LAND SYSTEM FEEDBACKS

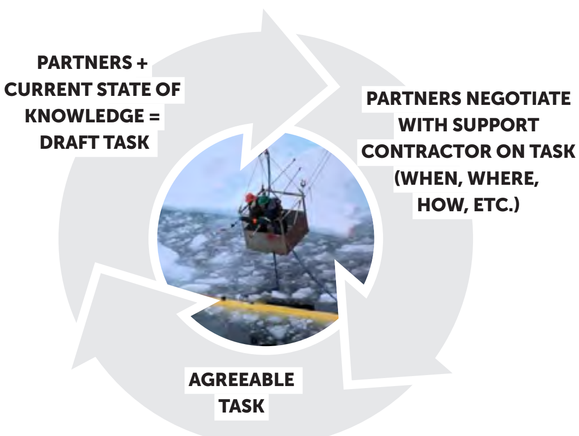
BIOLOGICAL
Ecosystem structure and functioning, emerging hotspots, resilience and sensitivities, ice algae studies

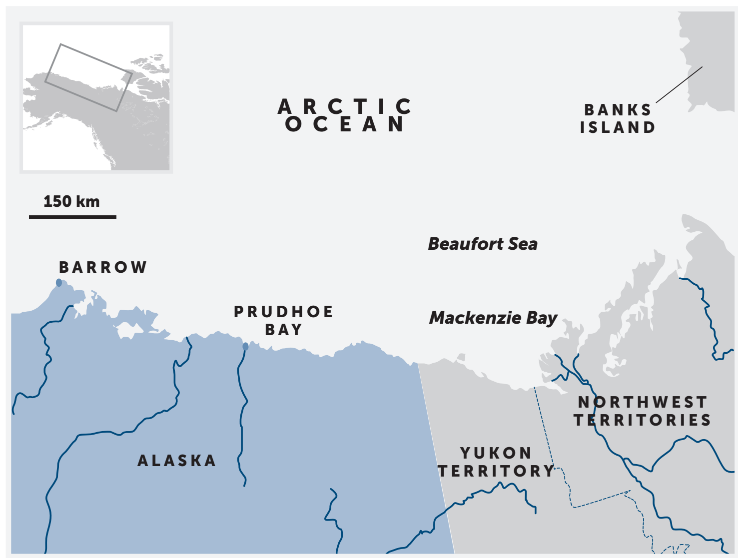
PHYSICAL
Circulation, sea ice and snow, river runoff and external drivers

SOCIAL
Subsistence, traditional environmental knowledge

CHEMICAL
Ocean acidification, biogeochemical impact of Mackenzie River Plume

GETTING IT DONE: PARTNERSHIP DECISION MODEL





The MARES study area

Leading up to 2011:
- Consideration of common and complementary information needs and National policies

2011-2013:
- Conceptual framework developed
- Identify opportunities: Integration starts
- Planning & alignment of common objectives

2014:
- Identify MARES implementation team
- Identify procurement vehicle
- Issue request for proposal (June)
- Proposal review panels (August/September)
- Single award to contractor

2015:
- Begin science program
- Task 1: Determine next steps meeting
- Task 2: Marine tagging pilot program

2016 – 2019:
- Continue science program
- Science review board feedback
- MARES colleagues feedback
- Participants jointly develop subsequent task orders based on current state of knowledge; then they negotiate with input from MARES contractor
- Tasks: TBD

2019
- Results
- Identify next steps

The aurora borealis rises over Summit Station on the peak of Greenland's ice cap. Sponsored by the NSF, Summit is home to year-round, long-term measurements for monitoring and investigations of the Arctic environment. In addition to NSF studies, NOAA maintains a suite of measurements, as do European collaborators. Photo: Ed Stockard, Blue Marble Photography

3: Building Networks for Observing, Data, and Modeling

IARPC's cross-cutting efforts promote data integrity, exchange, and accelerated knowledge gain.

The activities within IARPC's *Plan for Arctic Research (FY 2013-2017)* encourage research integration—that is, efforts that cut across science from different fields (e.g., atmospheric science, terrestrial ecology, social science); geographic contexts (e.g., single field sites to pan-Arctic studies); and/or tools and practices (e.g., modeling, field observations, satellite observations, physical process studies). Such efforts merge what often might be isolated efforts.

There is a need to integrate diverse contributions. IARPC's collaboration teams have focused on enhancing tools that allow agencies to combine complementary observing, data collection, and modeling efforts.

In most cases, IARPC collaboration teams build on and broaden participation in existing integration efforts, rather than create new ones. This section describes IARPC contributions to an atmosphere observing portal, an Alaska-focused data collaboration, the Sea Ice Prediction Network, and ways to assess and access information needed by people living in the Arctic and other stakeholders.

IARPC Aids Data-Sharing Among Atmosphere Observatories

Modifying an existing data-access portal improves access for all

FIGURE 9

COMPATIBLE METADATA

As an important step toward scientific collaboration, the International Arctic Systems for Observing the Atmosphere (IASOA) portal stored information about data sets collected by 10 independent Arctic atmosphere observatories. But each collection had its own identifying information—metadata—which hampered access and use by others. IARPC collaboration team efforts to standardize metadata improved access and usability. Further, an innovative process developed through the IARPC collaboration automates the way information on additional data sets is collected, facilitating future "crowd-sourced" data collection.

Piecing Together Atmosphere Studies

DOE, NASA, NOAA, NSF, and many international groups collect long-term atmospheric observations in the Arctic. To advance Arctic atmospheric science, researchers must combine all these data to test models, establish climatologies, and detect change. Automated data discovery is critically needed but is impeded by the many incompatible standards used for describing and archiving data.

IARPC's Atmosphere Collaboration Team (ACT) tackled this challenge by encouraging agency participation in the International Arctic Systems for Observing the Atmosphere (IASOA) data portal funded by NOAA and NSF. The IASOA portal provides access to metadata from a consortium of 10 independently funded Arctic atmospheric observatories (FIGURE 9).

Most IASOA observatories are already active participants in global networks with robust data management capabilities, such as Global Atmosphere Watch and the Baseline Surface Radiation Network.[20] IASOA observatories also are funded and maintained by sponsor agencies with their own long-term repositories.

Automated data discovery, or harvesting, hits roadblocks when repositories use incompatible metadata formats and keyword vocabularies. IASOA worked across global, institutional, and project-level repositories to identify and

[20] www.wmo.int/gaw; www.bsrn.awi.de/

integrate common descriptors into its data harvesting process. A metadata design based on the International Standards Organization format, ISO-19115, was adopted. This was already in use by most global networks, though U.S. agencies had yet to migrate.

The IARPC ACT helped IASOA clear the roadblocks. NSF funded the initial concept design and development of IASOA's data portal. NOAA developed an authoring tool for ISO-19115 metadata, identifying compatible keyword vocabularies and creating 150 structured metadata records for its observations. DOE's Atmospheric Radiation Measurement (ARM) program and the NSF-funded Advanced Cooperative Arctic Data and Information Service (ACADIS) translated existing metadata into the ISO-19115 format. IASOA rapidly assembled metadata for nearly 1000 datasets,[21] an accomplishment that benefits the entire Arctic atmospheric science community.

Alaska Data Integration Working Group

IARPC's Terrestrial Ecosystems Collaboration Team (TECT) adopted an existing process that Alaskan managers have developed to share metadata for information related to Federal research activities within the state of Alaska.

The Alaska Data Integration Workgroup[22] (ADIwg) was created to allow program and project managers from participating groups[23] to share information about their funded activities in standard format.

Enabling discussions on project tracking and metadata across multiple agencies, ADIwg allows participants to examine and address technical barriers to efficient integration and sharing of data within and among member organizations. ADIwg then developed a set of dynamic tools for data-sharing as well.

With IARPC's help, ADIwg developed tools to expand the exchange of project and data information throughout Alaska. These include broader sharing of information on research projects across multiple agencies using standardized protocols. Like IASOA, ADIwg identified ISO 19115-2 International Standard for Geospatial Data (2009) to facilitate metadata exchange with local and international colleagues, to conform to metadata trends, and to allow for a broader participation from the ADIwg organizations

ADIwg recently developed a set of flexible, open-source tools allowing organizations to generate ISO metadata without having to learn the ISO standard. These tools will support additional metadata standards in the future, such as that of the Federal Geographic Data Committee. Another tool allows independent researchers to create ISO metadata themselves, reducing the delay associated with making data broadly available.

Several IARPC collaboration teams, including the Arctic Data Collaboration Team, adopted ADIwg tools to help increase agency involvement in their use.

Coordinating Ecosystem Science

Understanding Arctic ecosystems and how they are changing is a multidisciplinary challenge involving biology, geology, anthropology, chemistry, hydrology, and other disciplines. Collaboration among agencies leverages knowledge, expertise, and capabilities and distributes the costs of ecosystem research. This is particularly important in the Arctic given the logistical difficulty and expense of working in remote locations. IARPC enables a coordinated Federal investment to improve predictive understanding of Arctic ecosystems.

Recognizing the need for improved coordination, DOE and NASA used the IARPC network to exchange information and to identify other Federal offices (e.g., DOI, USDA, and USGS) with a stake in terrestrial ecosystem science. Agencies worked together through IARPC to coordinate programs such as NASA's Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE),[24] Arctic-Boreal Vulnerability Experiment (ABoVE),[25] and DOE's Next-Generation Ecosystem Experiment-Arctic (NGEE-Arctic).[26]

Launching an instrumented balloon to collect weather information. Photo: Kevin Hammonds

NASA's CARVE and ABoVE programs are large-scale activities to study ecosystem responses to environmental change. CARVE is an airborne campaign to collect and quantify greenhouse gases in the Alaskan Arctic using new remote sensing and improved modeling capabilities. CARVE coordinates closely with NGEE-Arctic and other Federal research activities so that the airborne data can be compared with ground-based measurements. ABoVE will utilize NASA's field, aircraft, and satellite remote-sensing capabilities, coupled with in situ activities, to study the vulnerability and resilience of ecosystems and society to environmental change in the Arctic. An emerging NASA campaign that integrates field and airborne activities will be carried out over an 8-to 10-year period. The initial ABoVE science team will be selected in 2015, and ABoVE solicitations will emphasize field and process understanding of ecosystem and societal vulnerabilities to environmental change. Airborne campaigns are envisioned in 2017 and 2019.

[21] www.esrl.noaa.gov/psd/iasoa
[22] www.aoos.org/adiwg
[23] North Slope Science Initiative Oversight Group (NSSI); Alaska Ocean Observing System Board (AOOS); North Pacific Research Board (NPRB); Alaska Climate Change Executive Roundtable (ACCER)
[24] www.science.jpl.nasa.gov/projects/CARVE
[25] www.above.nasa.gov
[26] www.ngee-arctic.ornl.gov

NGEE-Arctic engages DOE's modeling capabilities to help scientists explore the future of permafrost carbon in a warming Arctic. NGEE-Arctic combines field and laboratory process research to improve the representation of ecosystem processes in Earth system models. Now completing its third year of operation, NGEE-Arctic expects to extend for a decade and bring unprecedented insights to how climate change affects permafrost landscapes—and how permafrost landscape changes are in turn affecting climate (FIGURE 11).

ABoVE will leverage the DOE investment in NGEE-Arctic's Barrow location and use DOE's Earth system modeling capabilities, using ABoVE sites as test beds for testing NGEE-Arctic's improved representations of Arctic ecological processes in Earth system models. NGEE-Arctic scientists joined the ABoVE Science Definition Team and helped develop a science plan synergistic with NGEE-Arctic.

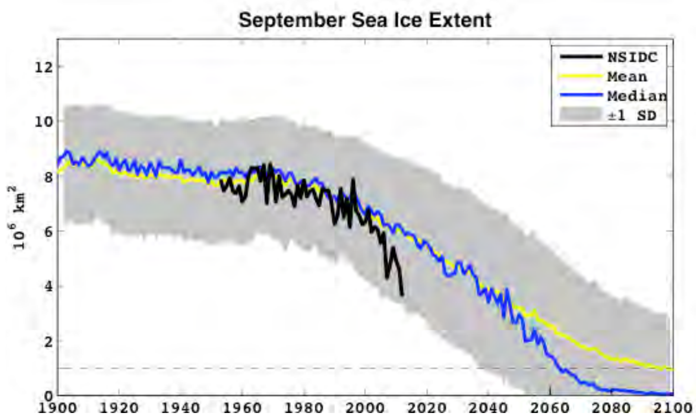


FIGURE 10

SIPN PREDICTION SUMMARY

Eighty-four sea ice extent predictions to the year 2100 by 36 different computer models. Clear differences between actual observations (black line) and predictions (the blue and yellow lines) point to the need to increase observations and process understanding to help improve models. Source: M. Jeffries, J. Overland and D. Perovich (2013)

Sea Ice Prediction Network

Forecasts of increased economic activity in the Arctic are based on recent declines and future projections of sea ice extent. But sea ice extent varies significantly year to year, and model simulations do not match recent observations well. There is high uncertainty about the future state of the sea ice cover, stemming from the challenge of modelling complex interactions and feedbacks in the atmosphere-ice-ocean-waves system.

Sea ice prediction is needed by a broad spectrum of users (e.g., Federal policy makers, community leaders, wildlife managers, hunters, etc.) for planning support and policy-making. Improved predictive skill is required on time scales ranging from hours to decades, and on spatial scales ranging from local to regional. How can scientists improve predictions to meet these growing and varied needs?

The Sea Ice Prediction Network (SIPN) is a response to this challenge. Initiated in 2013 by IARPC's Sea Ice Collaboration Team and funded by DOE, NASA, NOAA, NSF, and ONR, SIPN focuses on seasonal prediction. This is particularly challenging due to high variability in weather and ocean influences, limited instrumental observations, current model limitations, and an Arctic that is changing in ways unseen in recent history (FIGURE 10).

SIPN organized an open meeting at a December 2013, American Geophysical Union conference in San Francisco to engage the broader research community. Attended by 40 people, the meeting contributed to a doubling of inputs to the 2014 SEARCH[27] Sea Ice Outlook (SIO).

In April 2014, SIPN organized its first workshop, hosted by the National Center for Atmospheric Research[28] in Boulder, Colorado. The meeting planned for the 2014 SEARCH Sea Ice Outlook and advanced the science of sea ice prediction by coordinating model experiments; developing data sets for model initialization and validation; and improving metrics for evaluating model skill.

In June 2014, the National Snow and Ice Data Center released a new compilation of Arctic Ocean sea ice data sets. This valuable product offers scientists undertaking sea ice predictions easy access to the same data sets, enabling meaningful model intercomparisons and evaluations.

A busy year for SIPN culminated in a session at the December 2014 AGU Fall Meeting. The session, "Polar Climate: Processes and Predictability," addressed the processes that govern seasonal to multi-decadal polar climate variability; sources of polar climate predictability; uncertainty in polar climate prediction; model errors related to polar predictability; reanalysis data; and links between polar climate predictability and mid-latitude phenomena (e.g., Arctic amplification of climate change and its impact on the polar vortex and mid-latitude weather extremes).

SIPN leverages a decade of independently funded agency activities and is well-connected to international sea ice and polar prediction efforts.[29] Through SIPN, the Arctic modeling community maintains a vibrant and productive interchange. SIPN activities advance the state of knowledge about Arctic system processes that inform regional climate models.

Assessing and Sustaining Observations in the Arctic

Given the urgent need for improved societal resilience to Arctic change, strong linkages between information providers, interpreters, and users are critical. Web-based tools and visualization packages make Arctic observations more

[27] SEARCH is the Study of Environmental Arctic Change. www.arcus.org/search-program

[28] www.ncar.ucar.edu

[29] An IPY-like effort, the Year of Polar Prediction, is discussed in the last section.

IARPC Enhances Research to Clarify Permafrost Impacts in Earth System Models

The question: How do thawing permafrost and associated changes to the landscape, water, soil, and plant community affect the climate system?

FIGURE 11

NGEE-ARCTIC

Department of Energy (DOE) scientists at Oak Ridge National Laboratory are leading the Next-Generation Ecosystem Experiment – Arctic Landscapes (NGEE-Arctic) project. With support from IARPC, NGEE-Arctic draws on a myriad of talent funded by additional agencies, including NSF and NASA. Together, field and laboratory scientists and mathematicians develop studies to provide new information about permafrost ecosystems. Improved models can help community leaders and others better understand Arctic change and how to address uncertain futures.

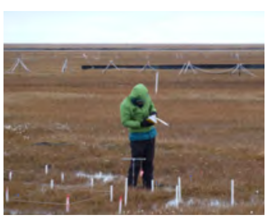
Left: Different research disciplines work on the Barrow Environmental Observatory (BEO). Top right: Polygon wedges like these on the BEO are sensitive to permafrost thaw, potentially releasing stored carbon and reshaping Arctic landscapes. Bottom right: A wider view showing polygons and water after snowmelt in the spring. All photos on this page: Roy Kaltschmidt, Richard Norby, Cathy Wilson, and Stan Wullschleger

NGEE-ARCTIC'S TWO LINES OF INQUIRY:

THE CARBON DEPOT: Frozen plant material in permafrost holds rich stores of carbon. What happens when the permafrost thaws?

LANDSCAPE TRANSFORMATION: Thawing of Ice-rich permafrost can start a cascade of interacting processes, including changes in topography (collapsed ground), water distribution across the landscape (new lakes and streams), and impacts on plants. These interactions will determine the role of Arctic ecosystems in future climate. What are they?

SCIENTISTS AT WORK



HYDROLOGY: Measuring thaw depth in field plots.

MODELING: An ecosystem modeler examines organic layers preserved in a permafrost core.

LABORATORY STUDIES: Analyzing permafrost cores using computer tomography.

BIOGEOCHEMISTRY: Coring tundra samples for biomass and carbon-nitrogen measurements.

GEOPHYSICS: Exploring subsurface characteristics using ground-penetrating radar.

ECOLOGY: Harvesting plant material from a plot to understand species composition.

COLLABORATION

NGEE team members discuss possible field sites.

High school students participating in a biology field course visit NGEE in Barrow.

accessible to a broad user base, encourage collaboration and coordination, and help identify areas where stronger partnerships are needed to improve the delivery to Arctic communities of basic and actionable information. Information needs include community-based monitoring programs to track changes in food resources, biodiversity, cultural identity, health, language, livelihoods, and traditional knowledge.

Building off complementary White House efforts (i.e., U.S. Group on Earth Observations),[30] IARPC's Arctic Observing Systems Collaboration Team (AOSCT) developed an Arctic Observing Assessment process allowing groups throughout the Arctic to identify information priorities at local, regional, national, and international levels.

This process identified 13 major priorities, which form the basis for a relational database of existing Arctic information. Analysis of this database shows how informational needs intersect between priorities. For example, common information resources serve the goals of three of the priorities, i.e., food security, ecosystem health, and climate change adaptation and mitigation (FIGURE 13). Data sources meeting multiple priorities are identified, as well as gaps where information products are lacking. The developing database is available through an online search and visualization tool located on the Arctic Hub.[31]

The Arctic Hub also has news, opportunities, and collaborative tools to advance observing design and implementation. The team completed the Arctic Observing Assessment in spring/summer 2015, using metadata techniques that support complex user searches and a visualization and export interface. Crowd-sourcing will support the continued build-out of the assessment and keep it "living" for years to come.

Activities of the Sustaining Arctic Observing Network (SAON) coordinate pan-Arctic observing systems for environmental, social, economic and cultural issues. The Arctic Council

[30] www.WhiteHouse.gov/administration/eop/ostp/nstc/committees/cenrs/usgeo

[31] www.arctichub.net

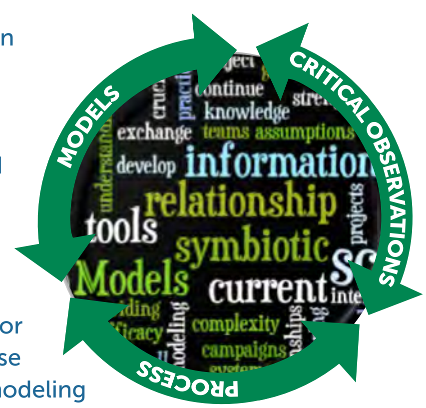
CARVE uses instruments aboard a NASA C-23 Sherpa aircraft to measure air and surface conditions and concentrations of greenhouse gases (carbon dioxide, methane, etc.). See page 17 for a description of the CARVE field campaign. Photo: NASA/Wallops

From Measurements to Process Understanding to Modeling

Earth System Models are tools that incorporate our state-of-the-science understanding of processes operating in nature. The science of climate and Earth system modeling has matured through finer spatial resolution, the inclusion of a greater number of physical and biogeochemical processes, and comparison to a rapidly expanding array of observations. Simulations of the Arctic from models have not converged, however, since different groups approach uncertain model aspects in distinctive ways.

Ideally, the relationship between model development and field work is symbiotic. Models are based on knowledge of process understanding from observations. In turn, models can guide the development of field campaigns to target and gather crucial observations—which can further advance the fidelity of model simulations.

In practice, the relationship between model development and field work has oftentimes been disconnected. Given the complexity of model development, there is a need to continue and strengthen collaboration amongst model developers, and between model developers and observational scientists. These opportunities include establishing intercomparison projects and providing an exchange of knowledge between modelers and field scientists.



IARPC's collaboration teams create a space for symbiotic relationships to develop between these groups; this bodes well for the efficacy of our modeling tools and for the scientific field work that informs them.

established two committees to provide leadership to implement SAON. The Committee on Observations and Networks focuses on collecting data and information on all observing capabilities, including access to platforms and geographical areas to present options for long-term funding. The committee will also develop a set of early warning indicators—the indicators network—initially focusing on climate change. This network will use existing and ongoing assessments to provide a status of the health of specific natural and human systems in the Arctic.

The Committee on Information and Data Services focuses on ensuring free and easy access to data and information in the SAON network. The Circum-Arctic Information System is responsible for integration and dissemination of data and information with guidance from the Committee. Through these and other activities, SAON will continue to develop the network of observations and make these observations available and applicable to environmental and societal issues.

Contributing writers: Kathy Coon, Renée Crain, Martin Jeffries, Erica Key, Mike Kuperberg, Sandy Starkweather, Stan Wullschleger

Focus on the Sea Ice Outlook

In response to the dramatic loss of Arctic summer sea ice in 2007, the research community initiated the Sea Ice Outlook (SIO) effort in 2008 under the umbrella of SEARCH.*

On a voluntary basis, each June the science community takes available information and populates models to predict the size of the lowest extent of sea ice (marked in September each year), and the lowest extent for the current month. This exercise is repeated each month through the summer.

In April 2014, four SIPN investigators published results of an analysis of more than 300 contributions to 6 years of sea ice outlook calls (Figure 12). The report summarized the findings as follows:

> Individuals and teams employ a variety of modeling, statistical, and heuristic approaches to make these predictions. Viewed as monthly ensembles, each with one or two dozen individual predictions, they display a bimodal pattern of success. In years when observed ice extent is near its trend [or long-term decline], the median predictions tend to be accurate, but in years when the observed extent is anomalous, the median and most individual predictions are less accurate. The latter at least partly reflect weather events, such as summer temperatures and wind conditions, which are much harder to forecast. Statistical analysis suggests that year-to-year variability, rather than methods, dominate the variation in ensemble prediction success. Furthermore, ensemble predictions do not improve as the season evolves.

In other words, a limitation to obtaining accurate sea ice predictions is the inherent uncertainty in the prediction of atmospheric and oceanic conditions. About a half-dozen models have evaluated skill in retrospective forecasts prior to 2007, with a much greater level of success than was found in the assessment of SIO contributions. Further, idealized studies also show much greater promise. More research is needed to understand whether skill is lower in the SIO contributions because ice is greatly diminished in recent years or if there is another explanation.

A month after the report was published, the first call for contributions to the SEARCH/SIPN Sea Ice Outlook for 2014 was issued. Between June and August, with contributions from 28 different groups, the SIO received a total of 88 outlooks, i.e., predictions of the sea ice extent to occur in mid-September 2014. The large number of outlooks and contributing groups reflects the growing value of the SIO as a forum for discussion of the challenges of sea ice prediction and how to overcome them.

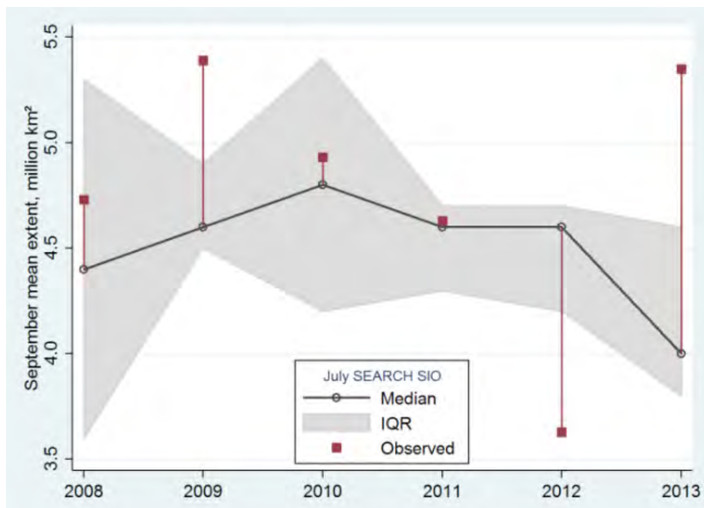


FIGURE 12
SEA ICE OUTLOOK
Median and interquartile range (IQR) of Sea Ice Outlook predictions made in July compared with observed mean sea ice extent in September. In years when observed ice extent is near its trend, the median predictions tend to be accurate (2008, 2010, 2011), but in years when the observed extent is anomalous, the median and most individual predictions are less accurate (2009, 2012, 2013). Source: Stroeve et al. (2014). "Predicting September sea ice: Ensemble skill of the SEARCH Sea Ice Outlook 2008–2013," *Geophys. Res. Lett.*, 41, 2411–2418, doi: 10.1002/2014GL059388

*Study of Environmental Arctic Change, a multi-agency/institutional collaboration formed in 1999 to study system-scale Arctic change.

The Changing Seasonal Wheel

Knowledge of Traditional Subsistence Activities Can Enhance Observations of Changing Seasonality

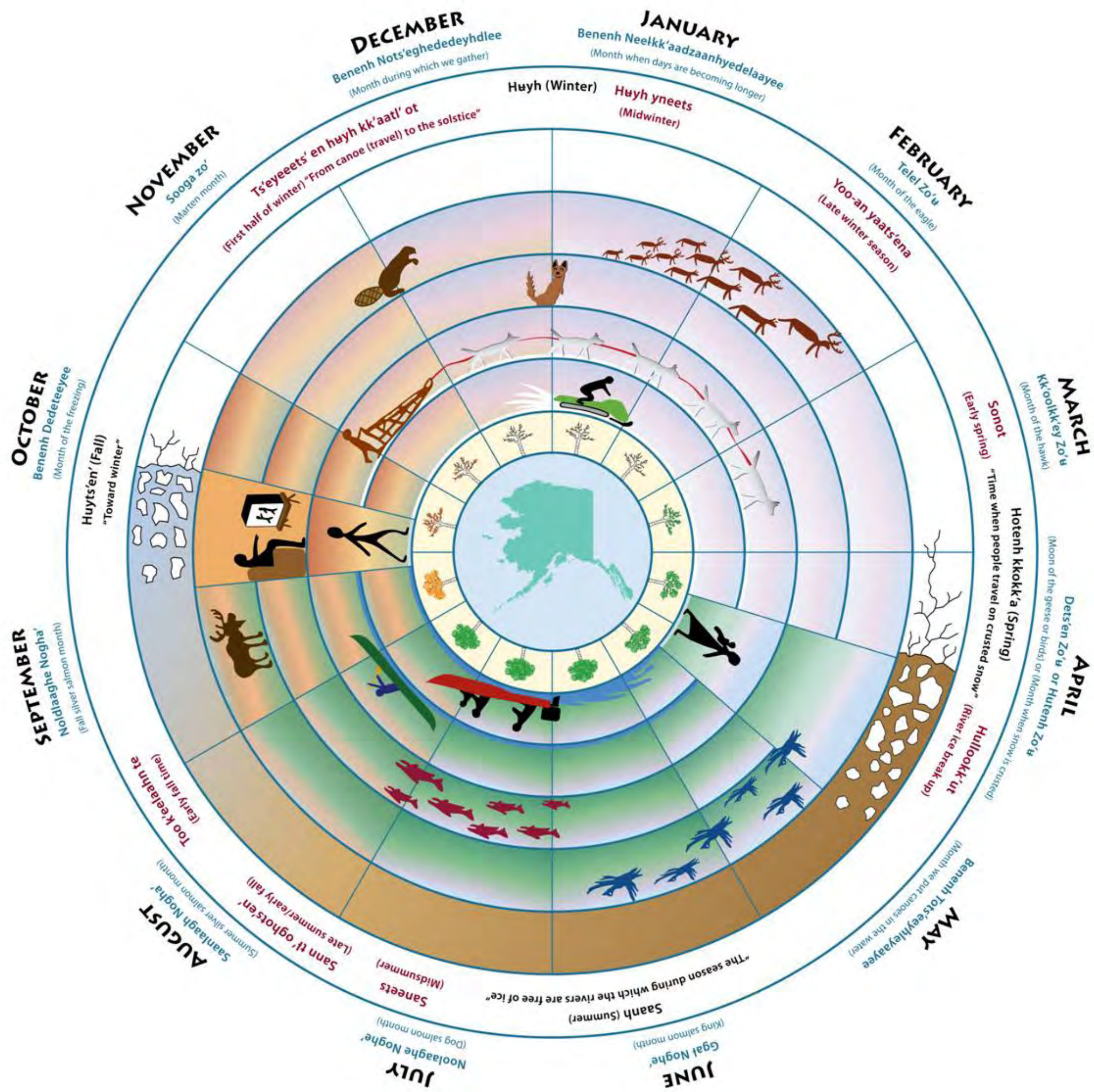


FIGURE 13

THREE KEY PRIORITIES

How will hunting, gathering, and harvesting activities, depicted in seasonal context for communities in Alaska's interior, be impacted by changing seasonality? While completing her Ph.D. dissertation at University of Alaska, scientist Shannon McNeeley (Colorado State University) developed this wheel with community members from Hughes, Huslia, and Koyukuk, Alaska, to help scientists understand local observations and understanding of seasons and seasonal change.

The wheel demonstrates the interconnectedness of three key priorities identified in the Arctic Observing Assessment: food security, ecosystem health, and climate change adaptation and mitigation. Information such as this can inform research to make it more salient to the needs of local people. Source: "The Koyukon. Seasonal Round," Original artwork by Shannon McNeeley, Travis Cole, and Michael Shibao. *Seasons out of Balance: Climate Change Impacts, Vulnerability, and Sustainable Adaptation in Interior Alaska: A Dissertation*. Shannon McNeeley, University of Alaska, Fairbanks, August, 2009, page 61


A young resident of Shishmaref, Alaska, enjoys some outdoor play during recess. Photo: “Kanigruaq” courtesy of Alaska Teacher/flickr/CC BY 2.0

4: New Tools to Support Arctic Research and Community Resilience

IARPC helps policy makers, community leaders, and residents adjust to the new Arctic.

Traditional Arctic communities are tied closely to the polar environment. In the past, these communities have adapted to change through age-old practices, for example, relocating or hunting different wildlife. But rapid Arctic change may challenge these communities in ways that require new adaptive responses. More broadly, State and Federal agencies will need resources with which to make knowledge-based decisions about transportation, resource management, and infrastructure as these are affected by the changing Arctic.

One of IARPC’s focus areas is to provide the basic scientific knowledge necessary for community leaders and government agencies to develop sustainable pathways for successful adaptation amid rapid environmental change and a variety of other stressors—all while juggling diverse Federal, State, and local interests.

In this section, several examples are offered of how the IARPC has helped develop tools that provide decision support to policy makers and community leaders as they help residents adjust to the new Arctic.

Monitoring Ecosystem Health

Climate change is altering the incidence of disease among people and wildlife in the Arctic. Higher temperatures increase risks of disease from food poisoning; contaminated water; illness passed between humans and animals; and

Case Study: Local Environmental Observer Network

While harvesting a bearded seal, a Shishmaref resident noticed the animal had suffered unusual hair loss. The resident took a picture and reported the event.

Her photo and observation were posted to a public map on the Internet, and the observer was directed to the marine mammal stranding coordinator in Nome for more information.

That's Alaska's Local Environmental Observer (LEO) Network in action.

The LEO network provides rural communities with tools to improve monitoring for events such as extreme weather, damage to infrastructure, invasive species, and outbreaks of illness in wildlife included in subsistence diets (such as the bearded seal with hair loss in this example).

Through LEO, Alaskans become reporters bearing witness to change when they contribute their observations *via* a simple webpage maintained by LEO.

LEO distributes these reports to traditional knowledge experts, scientists, and others (in this case, NOAA and the SeaGrant Marine Advisory Program specialists) who then provide information and resources about the event to the original reporter *via* a monthly Google Map tool.

LEO archives the reports and the expert feedback to provide a lasting record. In addition to documenting change across Alaska, the LEO network improves communication and connects local environmental and health managers with organizations that can provide technical assistance and resources.

accelerated mobilization and biological amplification of toxic chemical contaminants such as mercury, and persistent organic pollutants circulating within terrestrial and aquatic ecosystems.

Because disease can spread through the food chain, traditional subsistence communities—i.e., those which hunt, harvest and produce most of their own food instead of purchasing it from grocery stores[32] — are particularly vulnerable to changes in wildlife resources and in the shared environment.

In addition to disease transmitted from animals or caused by contaminants, important emerging challenges include the overall health, abundance and availability of subsistence resources. Food security is becoming a challenge in much of the North. While traditional foods are nutritional and integral to healthy lifestyles, store-bought foods meant to augment or replace subsistence diets can be costly, highly processed, and/or nutrient-poor. All of these issues cause concern.

They also make the Arctic a region uniquely suited to a "one health" approach to public health—an interdisciplinary collaboration between medical providers (i.e., doctors, nurses, osteopaths, dentists, etc.) and experts in other health and environmental sciences-related disciplines—to sustain the health and resilience of landscapes, seascapes, wildlife, and human inhabitants.[33]

To help advance this approach, IARPC's Human Health Collaboration Team (HHCT) participates in Alaska's One Health working group. The group was formed in 2013 and is hosted by the Alaska Native Tribal Health Consortium and the U.S. Centers for Disease Control and Prevention (CDC). Participants include public health officials, veterinarians, farmers, environmental managers, wildlife harvesters, researchers, and resource managers. HHCT meets quarterly to share updates on activities, to discuss emerging issues, to consider events that are indicative of environmental and climate change, and to provide a forum for identifying areas of common interest.

The Alaska One Health Working Group uses interagency, interdisciplinary, and community-based collaborations to monitor the impacts of climate/environmental change and environmental contaminants on human health in the Arctic, and to implement adaptive measures.

Elements of the approach include:

- Conducting community health assessments
- Initiating training and deployment of monitoring technology
- Developing a web-based monitoring network to assess environmental and health impacts and to provide feedback and adaption strategies to tribal leaders, tribes and tribal organizations
- Developing, deploying, and assessing a surveillance and response toolkit to promote community-based adaptation planning for climate change

The group uses a Google mapping tool to review and share recent environmental health events. Map posts include articles scanned from Alaska news media, observations provided by community-based members of the Local Environmental Observer (LEO) Network, as well as

[32] Subsistence goes beyond food provision to include important resources for living, cultural activities, and local economy.

[33] The broader definition of One Health is based on the premise that human health is connected with the health of the environment and that of wildlife and livestock health.

content provided by One Health group members themselves.

These inputs result in a tracking system for current and emerging events: a comprehensive environment, wildlife, and public health information fusion tool; and a constructive network for raising awareness and enhancing interagency collaboration.

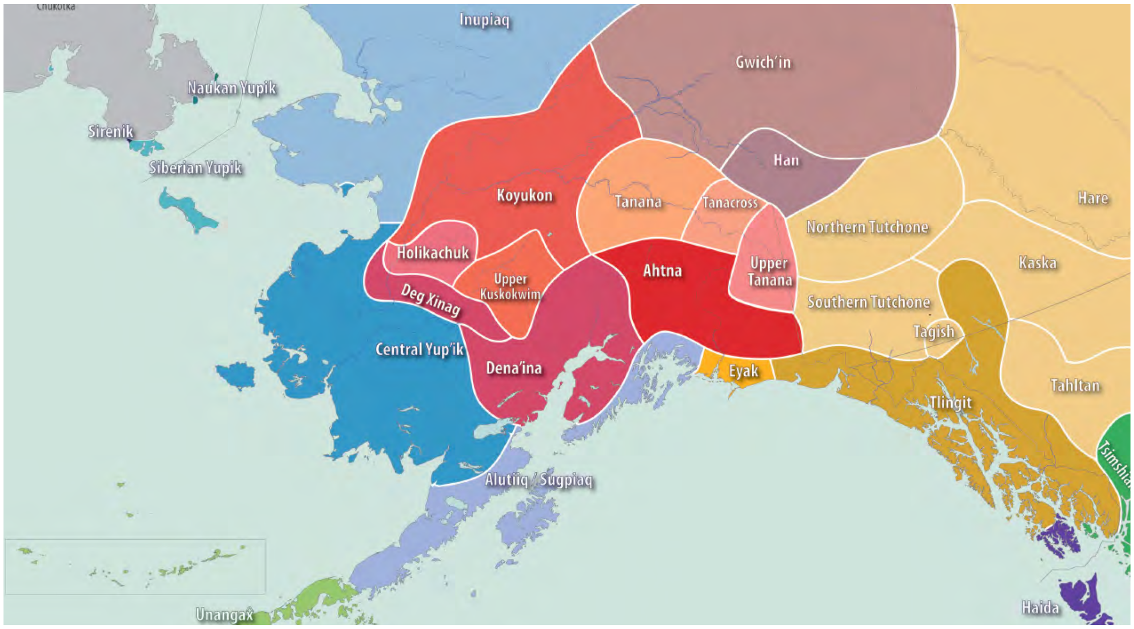


FIGURE 14

TWO MAIN BRANCHES

Map showing indigenous language distribution in Alaska. Source: University of Alaska, Fairbanks

Documenting Endangered Languages

Alaska is home to about 20 distinct indigenous languages primarily belonging to 1 of 2 main language branches: Eskimo-Aleut and Athabascan-Eyak-Tlingit (FIGURE 14). Except for Central Alaskan Yup'ik, only a small number of Alaskan children learn to speak a language other than English.[34] Because traditional communities tend to pass culture, subsistence practices, and language through story-telling and song, many of the indigenous languages are endangered. To support preservation, IARPC's Arctic Communities Collaboration Team (ACCT) is working with Federal and local agencies to develop tools that Arctic and Alaska Native communities can use to develop new indigenous language preservation strategies.

The ACCT promotes activities that support all cultural aspects of Arctic societies. Specifically for language preservation, the team focuses on encouraging the Documenting Endangered Languages (DEL) program, a partnership between the National Endowment for the Humanities, the Smithsonian, and the NSF to develop and advance knowledge concerning endangered human languages.

The DEL program uses information technologies and supports a range of field work and other activities to record, document, and archive endangered languages. Activities include preparing lexicons, grammars, text samples, and digital databases.

A unique achievement for Arctic language preservation is the development of a digital repository providing access to a world-renowned collection of Native American language documentation housed at the University of Alaska, Fairbanks' Alaska Native Language Archive. ACCT discussions on Arctic languages helped to focus Federal agency efforts on this topic and encouraged funding for the archiving project. When completed, the digital archive will provide the foundation for a new era of language and culture scholarship in the Arctic. To date, digitization efforts have already been undertaken in tandem with build-out of the necessary digital repository infrastructure. A local digital mass storage server resides at the Alaska Native Language Archive[35] hosted by the Arctic Region Supercomputing Center. The University of Alaska's Office of Information Technology hosts and maintains a web-based catalog and document-retrieval interface.

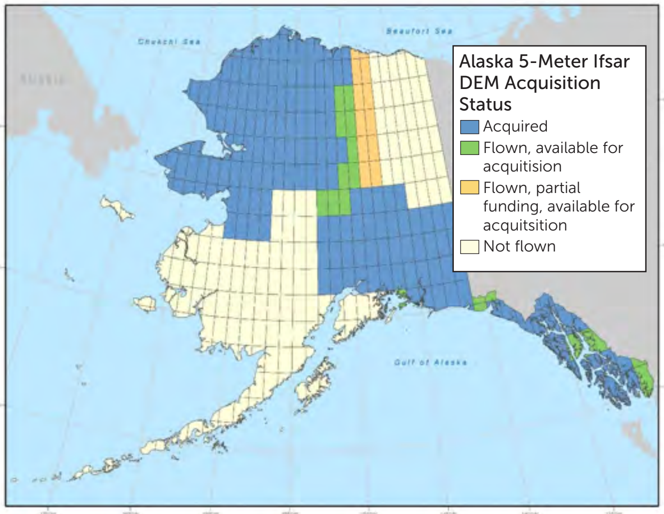
High-Resolution Digital Elevation Models for Alaska

Collaboration with the state of Alaska is called out in IARPC's enabling legislation. One area of successful collaboration is acquisition of high-resolution digital elevation models for Alaska. In early summer 2012, Federal and State experts met to review and address the state of Alaska's mapping documents. Because maps inform many government interests (e.g., land management, air and marine traffic control, resource development, etc.), agency managers wanted to assess best approaches to updating the largely outdated inventory.

To help address the issue, the IARPC Terrestrial Ecosystem Collaboration Team is working with members of the Alaska Mapping Executive Committee, which draws on members from State and Federal departments and agencies including Executive Office of the President, DHS, DOE, DOI, DOT, EPA,

[34] Alaska Native Language Center, University of Alaska, Fairbanks. www.uaf.edu/danl/about/index.xml?__noframe=2882

[35] www.uaf.edu/anlc



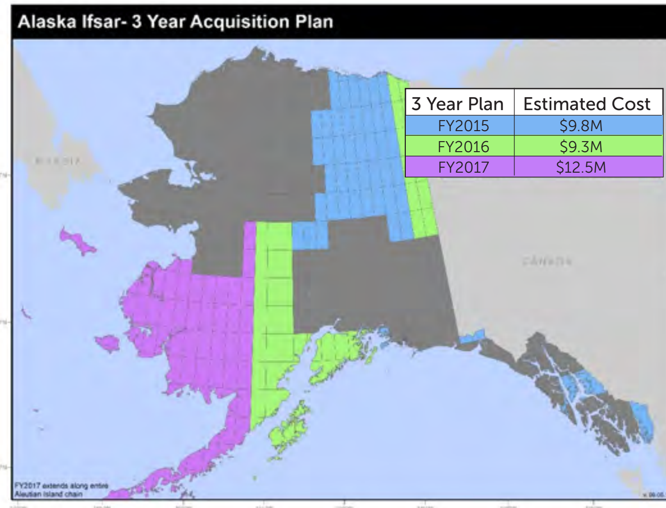


FIGURE 15

IMPROVED MAPS TO TRACK LANDSCAPE CHANGES

The status of Alaska interferometric synthetic aperture radar (IfSAR) Elevation Data Collection as of September, 2014 (left); Alaska Mapping Executive Committee IfSAR Elevation Data Collection showing areas covered by the 3-year Aquisition Plan as of July 2014.

NOAA and USDA. The committee intends to develop improved mapping for Alaska, producing high-resolution Digital Elevation Models for the entire state, including the coastal areas.

The Alaska Mapping Executive Committee coordinated the collection and purchase of new statewide 5-meter resolution digital-elevation data for Alaska using radar technologies that can penetrate the cloud cover persistent in many areas of Alaska. The data products include a Digital Terrain Model portraying the bare surface of the Earth, a Digital Surface Model depicting the highest features on the landscape (such as trees), and a terrain-corrected radar reflectance image.

This enhanced data collection greatly improves the existing Alaska statewide National Elevation Dataset, at 60-meter resolution, which was created from information on 1950s- and 1960s-era topographic maps.

The digital elevation models provide a baseline for current elevations and thus, are important data for use in better understanding coastal erosion, storm surges, vegetation communities, and sea-level rise—all of which are expected consequences of climate change. Digital elevation models can be used to delineate coastlines for maps, and, if repeated at time intervals, can elucidate changes in coastline. These data can be used to anticipate inundation and high elevation areas during storm surges and are helpful in tracking changes in flora and fauna communities, as well as impacts to human settlements. Additionally, the models are valuable to baseline vegetation mapping, and have been used in wetland mapping on the Seward Peninsula by the U.S. Fish and Wildlife Service, National Wetlands Inventory.

As of September 2014, 5-meter resolution elevation data was funded for over 50 percent of Alaska, including over 113,000 square miles of the Arctic (FIGURE 15). In line with the Alaska Mapping Executive Committee's 3-year plan, near-term elevation data acquisitions and purchases will most likely continue to concentrate on the Arctic and southeast Alaska, moving to south-central and southwestern Alaska in subsequent years.

Contributing writers: Mike Brubaker, Roberto Delgado, Alan Parkinson

Kivalina, Alaska, is located on a barrier island. Loss of sea ice has exposed the coast to bashing waves during storms, and threats to the community are worsened by sea-level rise. If not relocated, Kivalina likely will be inundated by 2025. Photo: "Kivalina, a village facing coastal erosion" courtesy of ShoreZone/flickr/CC BY 2.O

Spectacled eiders use openings in sea ice cover in the northern Bering Sea to reach clam populations on the sea floor. These birds are listed as threatened species under the Endangered Species Act. Photo: Matt Sexson, USGS

5: Developing International Research Networks

By promoting international activities, IARPC helps accelerate progress on issues of common concern through scientific research and traditional knowledge.

Many of the accomplishments described in this report draw on international cooperation. For example, atmosphere observatory network IASOA could not provide pan-Arctic observations without the participation of our Canadian, Danish, Greenlandic, Norwegian and Russian colleagues. Others, such as the MARES project or the SIPN, are now expanding international collaboration elements to enrich their activities. In this section, an activity critically dependent on international associations is described: the Distributed Biological Observatory (DBO) of the Pacific Arctic.

The Distributed Biological Observatory

Among IARPC's science themes is a commitment to advance research related to the influence of sea ice and other physical parameters on marine ecosystems. Over the last 2 years, IARPC has focused on enabling the DBO[36] of the international Pacific Arctic Group (PAG).

[36] www.arctic.noaa.gov/dbo

Early efforts

In 2009, in response to significant physical changes in the region, notably record seasonal sea ice retreats, ocean freshening, and warming, an international group of researchers formed the DBO. Their goal is to make sustained and consistent observations of the biophysical environment in five regions extending from the Northern Bering Sea to the Beaufort Sea (FIGURE 16).

Through coordinated planning, systematic observations, and data-sharing, the DBO pilot study (2010-2014) focused on five "hot spots" of high productivity and rich biodiversity along a latitudinal gradient in the Pacific Arctic. The scientific community vetted the DBO concept; subsequently, multiple Federal agencies, including BOEM, NASA, NOAA, and NSF, sponsored the activities. Internationally, Canadian, Chinese, Japanese, Korean and Russian agencies contributed as well, *via* the PAG and national agency support.

After a successful start, IARPC included the DBO in its 5-year plan in 2012, forming a collaboration team from among participating agencies. In 2012, the NSF Arctic Observing Network (AON) program awarded a 5-year collaborative grant.[37] Since forming, the IARPC DBO collaboration team has held regular teleconferences to achieve the overarching goal of routine sampling in all five DBO regions by 2015.

Interagency Collaborations and Achievements

The DBO collaboration team has received strong support and collaboration from a number of U.S. agencies and academic institutions (FIGURE 17).

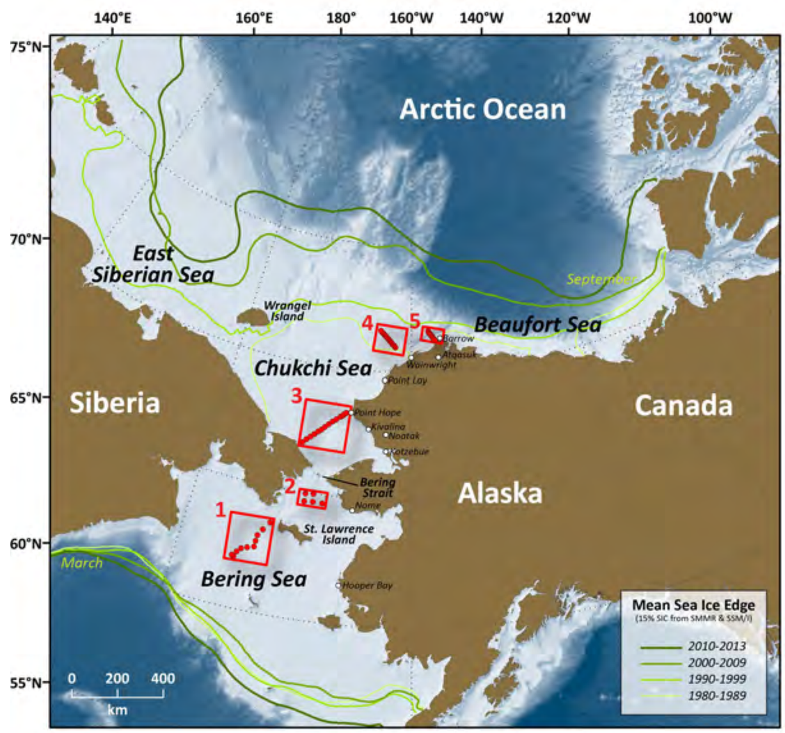


FIGURE 16

FIVE HOT SPOTS

The Distributed Biological Observatory (DBO) focuses multidisciplinary sampling at oceanographic stations across a latitudinal gradient from the northern Bering Sea to the Beaufort Sea; map is updated from Grebmeier 2012.

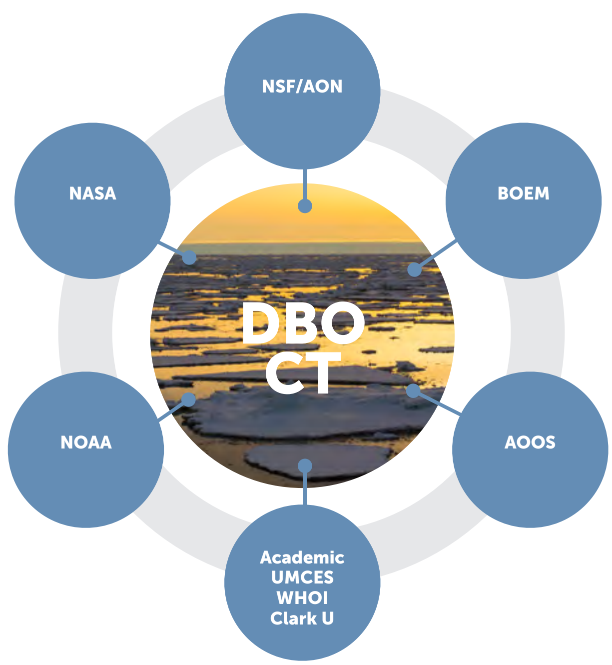


FIGURE 17

IARPC COLLABORATORS

U.S. agencies and academic allies comprising the DBO Collaboration Team.

[37] www.arctic.cbl.umces.edu/#_DBO
This website describes the DBO, lists the collaborators, and links to the NSF award page.

Participants at academic institutions and Federal agencies[38] provide a synergistic flow of data and expertise. Examples of key contributions include:

- Annual ship-based sampling and the provision of a physical oceanographic data portal (WHOI) to enhance data access and coordination
- Development of a DBO specific portal by NASA to facilitate researcher access to regional satellite products[39]
- Sampling during the RUSALCA[40] program (the only program to sample in Russian waters), and coordination of national and international contributions to the DBO, *via* the PAG
- Contribution to sampling during various multidisciplinary research programs in the Chukchi Sea
- Provision of web-based assets mapping and a password-protected data workspace, and an open-web data portal

The DBO provides a framework to focus and coordinate standardized sampling and analytical efforts that link biological changes to physical drivers. A key DBO science achievement has been the ability to track shifts in benthic community biomass and structure concomitant with measures of annual sea ice persistence in the five DBO regions. These observations build upon research initiated in the 1980s, where decadal patterns, shifts in species composition, and northward faunal range were identified.[41] In addition, scientists are observing an east-to-west gradient in zooplankton populations that vary with water mass type through the season,[42] and more frequent occurrence of temperate whale species in DBO region 3.[43]

An important physical oceanographic achievement through observation of the DBO5 (Barrow Canyon) line (FIGURE 16) has been to observe the seasonal seawater freshening and warming of water transiting northward on the eastern and surface layers of the Chukchi Sea, with the maximum temperature observed in September.[44] Upwelling events are observed roughly one-third of the time (7 of 24 occupations), which significantly alter hydrography in the canyon.

The DBO International Network

	COUNTRY	SHIP NAME
	Russia	*Professor Khromov*
	Korea	*Araon*
	China	*Xueê Lóng*
	Japan	*Oshoru-Maru, Mirai*
	Canada	*Sir Wilfrid Laurier, Louis S. St-Laurent, Amundsen*
	USA	HEALY, *Oscar Dyson, Aquila, Annika Marie*
INDUSTRY	Shell, ConocoPhillips	*Norseman ll, Westward Wind*

FIGURE 18
SHIP SUPPORT
Summary of international entities coordinated through Pacific Arctic Group (PAG) and industry agencies working on the Distributed Biological Observatory (DBO) program.

International and Industry Collaborators

The PAG is a consortium of institutions and individuals having a Pacific perspective on Arctic science. Organized under the International Arctic Science Committee (IASC), the PAG has as its central mission to serve as a Pacific Arctic regional organization to plan, coordinate, and cooperate on science activities of mutual interest. The four principal science themes of PAG are climate, contaminants, human dimensions, and structure and function of Arctic ecosystems.

With reference to the fourth theme, the PAG assumed a leadership role in coordinating international contributions to DBO sampling during the pilot-study program, including linking projects for sampling the DBO lines. These international contributions to DBO sampling provide an unprecedented capability to track inter- and intra-annual variability in DBO regions (FIGURE 18). An annual listing of DBO cruises undertaken through the PAG network is available on the PAG and DBO websites.

[38] These institutions include Clark University (Clark U); University of Alaska, Fairbanks (UAF); University of Florida (UF); University of Maryland, Center for Environmental Science (UMCES); University of Texas (UT); and Woods Hole Oceanographic Institution (WHOI).
[39] www.neptune.gsfc.nasa.gov/csb/index.php?section=270
[40] Russian-American Long-term Census of the Arctic. www.arctic.noaa.gov/aro/russian-american
[41] Grebmeier, J.M. "Shifting Patterns of Life in the Pacific Arctic and Sub-Arctic Seas." *Annual Review of Marine Science*, Vol. 4 (2012): 63-78. doi: 10.1146/annurev-marine-120710-100926
[42] Pomerleau et al. (2014). "Spatial Patterns in Zooplankton Communities and Stable Isotope Ratios (13C and 15N) in Relation to Oceanographic Conditions in the Sub-Arctic Pacific and Western Arctic Regions during the Summer of 2008." *Journal of Plankton Research*. doi: 10.1093/plankt/fbt129
[43] Clarke et al. (2014). "Subarctic Cetaceans in the Southern Chukchi Sea: Evidence of Recovery or Response to a Changing Ecosystem." *Oceanography* 26(4): 136-149. doi: 10.5670/oceanog.2013.81
[44] Nobre et al. (2014). "Evolution of Water Masses in Barrow Canyon during Summer/Fall." AGU Ocean Sciences Meeting, Honolulu HI

Future Directions

The DBO CT is now focused on compiling data from the pilot study sampling period, to demonstrate the value of this national and international shared-data approach to the investigation of biological responses to a rapidly changing Arctic marine ecosystem.

Three goals included in both the DBO CT activities table, and the National Strategy for the Arctic Region work plan[45] are to publish an updated national/international DBO concept plan for decadal-scale implementation by the end of 2015; prepare periodic assessments on the physical and ecological state of the Pacific Arctic marine environment; and integrate DBO data with that from collaborating agencies and other sources by the end of 2016.

The DBO CT is on track to accomplish these goals, drawing upon outcomes of international meetings such as discussions of the DBO held at the 2014 Arctic Science Summit Week in Helsinki, Finland, and the second DBO Data Workshop in October 2014. Expanding from the Pacific Arctic sector, the DBO also serves as a framework for international research coordination *via* the Arctic Council Circumpolar Biodiversity Monitoring Program, and is recognized as a task of the pan-Arctic Sustaining Arctic Observing Network program.

Additional discussions are ongoing to expand the DBO concept to the pan-Arctic scale as part of the Norwegian Strategic Initiative-Arctic for placing DBO-transect lines in the northern Barents Sea and through National Oceanographic Partnership Program for placing additional DBO-transect lines in both the U.S. and Canadian Beaufort Sea.

Contributing writers: Jacqueline Grebmeier, Sue Moore

[45] www.WhiteHouse.gov/sites/default/files/docs/nat_arctic_strategy.pdf

A herd of walrus rest on patchy sea ice. Photo: Karen Frey, Clark U

The Pacific Arctic: Why it Matters

The region is home to animals thought vulnerable to sea ice loss, notably walruses, ice seals, polar bears, and ocean-going bird species, which feed and breed on sea ice. Sea ice habitat loss impacts both walrus and diving sea ducks who use it as a resting platform between feeding periods. These animals lose more energy in the ocean than they do when resting on ice. Seasonal sea ice loss in the region increases access for ships and for those seeking natural resource extraction. Given these potentially competing interests—and the unknown potential for cascading impacts—scientists seek to understand the relationships between physical and biological systems in the Pacific Arctic. Improved understanding of the marine ecosystem would support information-based decisions for local, State, and Federal managers.

Next-generation scientists plan their field work in Alaska's Brooks Range (the opportunity) while garbed in head-nets to protect against swarms of mosquitoes (a challenge). Photo: Jason Briner, State University of New York at Buffalo

6: Looking Forward

The best scientists in the world are all telling us that our activities are changing the climate, and if we do not act forcefully, we'll continue to see rising oceans, longer, hotter heat waves, dangerous droughts and floods, and massive disruptions that can trigger greater migration, conflict, and hunger around the globe. The Pentagon says that climate change poses immediate risks to our national security. We should act like it.
—President Barack Obama, State of the Union Address. January 20, 2015

IARPC's expanding collaborations will help policy-makers develop informed approaches to meet challenges and opportunities arising in the new Arctic.

IARPC's next course is an exciting one, with challenges and opportunities centered around people. Arctic residents must adapt to rapid change in social and natural systems. People living below the Circle are increasingly aware of the linkages between the region and their weather, water supply, the changing prices of food, fuel, and other goods, and of issues such as coastal vulnerability and wildfire expansion. Rapid change may also alter people's perceptions of the Arctic itself—its innate beauty, and the indigenous heritage Arctic Nations share.

Improving knowledge of Arctic systems will remain a vital centerpiece of the U.S. research agenda, even as Federal budget managers strain to address broad challenges of national security, energy independence, food and water security, health care, and more. Strong agency coordination

Ride-Sharing in the Arctic

Arctic field work frequently calls for specialized support (e.g., ice-strengthened vessels, ruggedized field gear, and expensive air support). Sharing logistics resources when possible allows scientists and Federal funding agencies to stretch logistics dollars—and pays big benefits in terms of research collaboration as well.

The NSF's Division of Polar Programs manages the Arctic research support and logistics (RSL) program, working through agreements and contracts with a variety of organizations that provide services and infrastructure to researchers. Through economies of scale and efficiencies gained through years of experience, the RSL program leverages its investment to provide camps, ships, aircraft, risk management, environmental compliance, and proposal estimates. RSL funds the operation of facilities, including Summit Station in Greenland, and Toolik Field Station on Alaska's North Slope; and it maintains the science capability on the United States Coast Guard Cutter HEALY. RSL extends these resources, on a reimbursable basis, to other agencies and organizations. U.S. and international organizations can and should do more to share resources, coordinate field campaigns, and utilize best practices developed by one another.

At a 2013 RSL workshop, stakeholders and providers met to explore the logistic infrastructure that needs to be in place to facilitate Arctic research over the next 20 years. Key workshop themes acknowledged that science needs must drive logistics requirements; that research, and therefore logistics, needs to be Arctic-wide and year-round; and that logistics capabilities need to be flexible and agile, leveraging existing capabilities, emerging technologies, and the desire and willingness of the next generation of researcher and logistician to learn and succeed.

Specifically, workshop participants suggested IARPC as a forum for U.S. agencies to better coordinate logistics resources in support of research. NSF is working with other agencies towards a sustained dialogue regarding logistical needs and resources, so as to improve both coordination and collaboration.

At an international level, collaborations continue. The Swedish Polar Research Secretariat (SPRS) approached NSF in 2014 to discuss using the Swedish research icebreaker *Oden* in the Arctic on a more regular basis. In 2015 and 2017, NSF and SPRS intend to implement a pilot arrangement to support projects led by researchers from each country. In winter of 2015, researchers from both countries attended a workshop to discuss potential collaborations that could result in a long-term arrangement.

The arrangement would allow funding agencies to alert the research community in advance of the ship's availability so they may propose to use it. If proposals are funded through the merit review processes of both countries, coordinated cruises would emerge. The discussion is on-going and will be informed by an NSF-funded research project onboard *Oden* in 2015 in the Nares Strait region of Greenland.

RSL is active in the Forum of Arctic Research Operators (FARO), a body to discuss facilities and infrastructure in an international setting. FARO meets annually at Arctic Science Summit Week. RSL has taken the lead in facilitating information-sharing on field safety risk management in the Arctic, enabling each country to share best practices and possibly share opportunities for field safety training and other expertise. FARO is an opportunity for each country to discuss field research plans to improve coordination and collaboration, particularly among research vessels, ecological research stations, and other areas of emphasis, such as the upcoming Year of Polar Prediction.

Two small helicopters move scientists to field sites on Alaska's North Slope.
Photo: Nancy Brandt

is more important than ever before, not simply from the standpoint of leveraging resources, but because the problem is complex. This complexity moves IARPC forward.

Year of Polar Prediction

Future internationally coordinated activities present opportunities for U.S. agencies to cooperate in productive ways with other nations. One such example is the proposed Year of Polar Prediction (YOPP), developing under the auspices of the World Meteorological Organization's Polar Prediction Project[46] , and commencing in 2017,' YOPP is a centerpiece activity—similar in nature to the International Polar Year[47]—intended to coordinate broad international polar observing activities with the aim to improve weather and climate model predictions for polar environments.

YOPP has the potential to improve weather predictions in polar environments by reducing uncertainty due to poor process understanding and sparse observational networks. The research program will also improve seasonal forecasts of Arctic sea ice concentrations, which would support safer transportation and development in the region, and help scientists understand the polar vortex and cold-air outbreaks that wreak havoc with mid-latitude winter weather. YOPP's success will rely on well-coordinated observations targeted at specific model-improvement opportunities.

Well-coordinated U.S. participation in YOPP is a challenge because it requires both mission-based agencies and competitive-funding agencies to recognize and support their unique roles, while working together in a mutually beneficial way. A series of planned U.S.-specific discussions will lead to more unified U.S. participation on the international stage—and IARPC will enhance this cooperation *via* collaboration teams and net-working tools.

[46] www.polarprediction.net/yopp.html

[47] A coordinated pulse of polar research activity, 2007-2008. www.ipy.org

NOAA measures key atmospheric indicators of global climate from Greenland's Summit Station. The NSF funds the station in cooperation with the Government of Greenland. Photo: Ed Stockard, Blue Marble Photography

U.S. Chairmanship of the Arctic Council

In May 2015, the United States assumed chairmanship of the Arctic Council for a 2-year period. The council was formed in 1996 as a forum to promote cooperation and dialogue among the eight countries whose territories extend into the Arctic (Canada, Denmark [via Greenland], Finland, Iceland, Norway, Russia, Sweden, and the United States). The council is unique as an international forum in that it also includes representation from six indigenous peoples' organizations. An "observer" category includes non-Arctic nations, intergovernmental organizations, and nongovernmental organizations that have been granted accreditation through an application process. The most recently accredited observers were approved in 2013, and included six nations—China, India, Italy, Japan, Singapore, and South Korea.

The Arctic Council primarily focuses on fostering environmental stewardship and sustainable development. Chairmanship from 2015 to 2017 gives the United States more opportunity to influence the direction of the council's work while focusing on three overarching goals for its term: continue strengthening the Arctic Council as an intergovernmental forum; introduce new long-term priorities into the Arctic Council; and raise U.S. and global awareness of the Arctic and climate change.

Along with these goals, the United States will focus Arctic Council activities on the following three organizational themes:

- **Improving Arctic Ocean Safety, Security, and Stewardship** by promoting search-and-rescue exercises; coordinating marine environmental protection research and information, including that related to oil-spills; enhancing activities to develop a Pan-Arctic network of marine protected areas; and expanding the monitoring coverage of ocean acidification in the Arctic Ocean.
- **Improving Economic and Living Conditions for Arctic Peoples** by demonstrating the potential of renewable energy to replace expensive diesel sources; internationalizing efforts to improve access to clean drinking

water, reliable sanitation and freshwater supplies; developing telecommunications infrastructure; and adapting suicide / mental illness prevention research and resources to suit the unique circumstances of Arctic communities.

- **Addressing the Impacts of Climate Change** by implementing efforts to reduce, monitor, and study short-lived climate pollutants; promoting and evaluating recommendations for climate adaptation and resilience for Arctic residents; and enhancing Arctic climate science.

Through its collaboration teams, IARPC contributes to the research components of these themes and ensures coordination across Federal agencies. These themes each benefit Arctic residents while helping to promote a considered approach to the new Arctic that emphasizes environmental stewardship. Another area of focus will be public outreach—that is, efforts to educate the general public about the Arctic, why it matters, and how the effects of climate change in the Arctic impact other areas of the planet. The U.S. chairmanship of the Arctic Council provides a seat from which the United States can promote its strategic national interests in the Arctic, as well as make the American public aware that these national interests exist.

Emerging Science Questions and Expanding Networks

IARPC set out in 2013 to provide guidance on future Arctic research over the next 10 to 20 years. Multiple IARPC agencies (DOE, NASA, NOAA, NSF, the Smithsonian Institution, and USARC) sponsored a committee under the Polar Research Board (PRB) of the National Academy of Sciences to develop and issue the report. The resulting study, *The Arctic in the Anthropocene: Emerging Research Questions*,[48] was issued in April 2014. It addresses the urgent need to understand the rapidly changing Arctic by defining the current state of knowledge and connecting the dots among emerging science questions to guide future science opportunities. The goal: to leverage science talent and agency resources, thus maximizing opportunities to fill in critical knowledge gaps.

IARPC encouraged contributions from the science community, agency personnel, international colleagues, and Arctic residents. With input from this constituency, the report identified questions that have arisen as rapid change has pervaded the Arctic system, questions that have yet to receive the

[48] Available for download on the IARPC Collaborations website: www.iarpccollaborations.org

Barrow, Alaska: a person flings treats to the crowd below as he rides on the blanket toss, a traditional game celebrating a successful community harvest. Photo: Faustine Bernadac

Strategies for Addressing Future Research Challenges

As described in *The Arctic in the Anthropocene*

Enhance Cooperation. No single entity can address all Arctic research topics. Cooperation is essential among researchers, between agencies, among nations, across disciplines, between Arctic residents and visiting scientists, and within the private sector.

Sustain Long-term Observations. Long-term observational data are essential for detecting change and for putting research findings into context.

Manage and Share Information. Understanding the Arctic system will continue to evolve through the ability to compare data sets from disparate fields and regions to see connections and commonalities.

Maintain and Build Operational Capacity. Technology advances allow new approaches to research in many fields. At the same time, decisions-makers must sustain current capabilities, including ships, satellites, and research stations.

Grow Human Capacity. Arctic research depends on sufficient human capacity, including scientists trained in the necessary fields who are capable of interdisciplinary collaboration, and Arctic residents who can offer a great deal to research efforts.

Invest in Research. Given the emerging research questions, pressures are growing for comprehensive systems and synthesis efforts, research on rapid changes, social science, stakeholder-initiated research, international research, and long-term observations.

attention they require, and/or that can only now be addressed given technological or other advances.

The report reveals a future Arctic research agenda that will challenge existing practices to bridge disciplinary and functional gaps. In particular, the ground for collaboration between natural, social, and human health sciences will grow as will the need to translate scientific knowledge into decision-relevant contexts (e.g., scientists advancing sustainability research working with those planning infrastructure development). Research sponsorship will need to adapt to meet these challenges, and IARPC is positioned to lead.

As the Arctic research 5-year plan is updated, IARPC will explore opportunities more broadly in the context of the National Strategy for the Arctic Region, the Arctic Council chairmanship, and the new Arctic Executive Steering Committee. IARPC will work with the state of Alaska, Arctic communities, and other interagency committees to cooperatively address research priorities. With all these imperatives, IARPC is well-placed to continue and expand its efforts to create networks of collaborators to tackle urgent research questions that must be addressed as the Arctic undergoes rapid climate and environmental change.

The call for collaboration points back to IARPC's enabling legislation.[49] What happens in the Arctic has far-reaching implications for the entire planet. Fostering a sense of shared purpose among different stakeholders—from U.S. Federal, State, and international organizations to private industry and other non-governmental entities—to manage change is essential. So is a continued commitment to study what exists, what is emerging, and what awaits us in the Arctic through activities that have been and will continue to be addressed by IARPC and its collaboration teams.

Contributing writers: Sara Bowden, Renée Crain, Lauren Everett, Sandy Starkweather, Michael Young

[49] www.WhiteHouse.gov/sites/default/files/microsites/ostp/ARPA.pdf

New Webinar Series

IARPC webinars often cut across teams and themes, acting as a node in the network that encourages communities to get to know and understand potential collaborators' activities.

In addition to webinars hosted by collaboration teams, IARPC launched a series of webinars in 2015 to engage and inform people on a broader range of topics, including research questions, new technologies, and questions related to science policy. IARPC encourages the community to offer webinar suggestions.

IARPC Toolbox

Photo: Faustine Bernadac

Interagency Arctic Research Policy Committee
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INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

5-YEAR PLAN COLLABORATION TEAMS

2015 SUMMARY OF ACCOMPLISHMENTS AND 2016 PRIORITIES

The accomplishments described here represent highlights for each IARPC collaboration team during FY 2015, presented in order of appearance in the 5-Year Plan. Each team also has contributed an update on priorities for the coming year. The latest milestone updates can be obtained from the secretariat and are available online on the member side of the IARPC Collaborations website.

IARPC Collaboration Teams

Sea Ice Collaboration Team

Distributed Biological Observatory Collaboration Team

Chukchi & Beaufort Seas Ecosystem Collaboration Team

Glaciers & Fjords Collaboration Team

Terrestrial Ecosystems Collaboration Team

Wildfires Collaboration Team

Atmosphere Collaboration Team

Arctic Observing Systems Collaboration Team

Arctic Data Collaboration Team

Modeling Collaboration Team

Arctic Communities Collaboration Team

Human Health Collaboration Team

These Federal agencies comprise IARPC: Department of Commerce (DOC), Department of Defense (DOD), Department of Energy (DOE), Department of Health and Human Services (HHS), Department of Homeland Security (DHS), Department of Interior (DOI), Department of State (DOS), Department of Transportation (DOT), Environmental Protection Agency (EPA), Marine Mammal Commission (MMC), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF, Chair), Office of Management and Budget (OMB), Office of Science and Technology Policy (OSTP), Smithsonian Institution (SI), and United States Department of Agriculture (USDA).

Sea Ice Collaboration Team (SICT)

Accomplishments

To advance the SICT's goal of continuing and expanding Arctic sea ice observations to understand freezing and melting processes, from March through May 2015, the NASA Operation IceBridge project flew 10 missions over the Arctic Ocean—a total distance of 25,000 km. By May 2015, Operation IceBridge posted the Quicklook ice freeboard, ice thickness, and snow depth data at the National Snow and Ice Data Center (NSIDC). Scientists also made available a pan-Arctic sea ice thickness product of blended IceBridge and CryoSat-2 data for March 2015. Operation IceBridge overflew several validation sites where snow depth, ice freeboard, and ice thickness were being measured by scientists on the ice. Scientists are using these and other in situ data to validate the airborne measurements, and the larger-scale airborne data will help them to develop and improve algorithms for deriving ice freeboard and ice thickness from Cryosat-2 data and ICESat-2.

Researchers at NASA, NSIDC, the National Ice Center (NIC), and the Naval Research Laboratory (NRL) of the ONR made significant progress in using remotely sensed sea ice products to improve numerical ice predictions. In one case, a blended, high resolution sea ice concentration product assimilated into the Navy's ice forecasting systems reduced the overall pan-Arctic ice edge error by 36 percent for a year-long period, while the error reduction during the summer melt season was 56 percent, compared to results using ice concentration derived from lower resolution, single sensors. In the second case, assimilating a blended, high-resolution sea ice concentration product into the Navy's ice forecasting systems yielded June ice edge error reductions of 8 to 49 percent, depending on region, relative to the assimilation of data from lower resolution, single sensors.

In summer and autumn 2015, NRL and NOAA provided sea ice, wave, and weather predictions to the R/V *Sikuliaq*, the USCGC *Healy*, USCG Arctic Domain Awareness airborne missions, and a NOAA/BOEM marine mammal survey based in Barrow, Alaska. The goal was to improve prediction capability by providing forecasts to a variety of users who return feedback on the forecasts' accuracy and operational value of the predictions to identify areas for model improvement.

Understanding sea ice predictability and improving prediction at seasonal time scales is the goal of the interagency (DOE, NASA, NOAA, NSF, ONR) Sea Ice Prediction Network (SIPN). One of the network's tools is the Sea Ice Outlook, which received a record number of predictions—a total of 105 from June through August—of average sea ice extent in September 2015. NISDC declared a sea ice minimum extent of 4.4 million km^2 on 11 September 2015; the average September extent was 4.63 million km^2. Both values are the fourth lowest in the satellite record (1979-present). In June, July, and August, 6, 6 and 7 Sea Ice Outlook predictions, respectively, fell within ±5 percent of the average extent (a range of 463,000 million km^2, almost the area of California). Only two organizations sent predictions that were in that range each of the three months.

Priorities for 2016

ONR's "Sea State and Boundary Layer Physics" Department Research Initiative conducted its main field experiment in October 2015 aboard the R/V *Sikuliaq* in the Beaufort and Chukchi seas. Operation IceBridge will conduct further sea ice missions over the Arctic Ocean in winter/spring 2016. The Sea Ice Outlook and Sea Ice for Walrus Outlook will continue, and the SIPN will organize a workshop in May 2016.

Distributed Biological Observatory Collaboration Team (DBOCT)

Accomplishments

The DBOCT completed Year 6 of sampling in DBO/Chukchi regions 1 through 5 and began expanded sampling in new DBO/Beaufort regions 6 to 8. Colleagues from 14 projects representing 6 countries contributed to field sampling efforts. The DBOCT provided a framework to focus and coordinate sampling and analytical efforts that link biological changes to physical drivers in the Arctic. In a key science achievement, researchers could track shifts in benthic community biomass and structure associated with measures of annual sea ice persistence in the five DBO/Chukchi regions[1]. An important physical oceanographic achievement, through occupation of the DBO region 5 (Barrow Canyon), was the observation of the seasonal freshening and warming of sea water transiting northward on the eastern and surface layers of the Chukchi Sea, with the maximum temperature observed in September. DBOCT members presented these accomplishments at the second DBO Data Workshop, the 2015 Arctic Science Summit Week in Toyama, Japan, and at other national and international venues.

To provide a foundation for data sharing among DBO contributors and collaborators, the team issued Data Policy and Release Guidelines and initiated the DBO Data Archive at the Earth Observing Laboratory, University Corporation for Atmospheric Research. The guidelines are essential for the long-term success of the DBO. To complement the archive, a DBO data workspace was added to the Alaska Ocean Observing System website. When added to the existing collection of sea ice, sea surface temperature, wind, cloud fraction, and ocean-color images on the NASA Satellite Data Visualization Portal, new sea surface height and salinity images of the DBO region will enhance available data products.

Internationally, the DBO continues to benefit from organizational support provided by the Pacific Arctic Group (PAG), to include sampling in Russian Arctic waters, via the Russian-American Long Term Census of the Arctic program. Discussions within PAG led to the development of a Canadian DBO region in the Beaufort Sea, as well as an agreement to establish a Pacific Arctic climate ecosystem observatory that will be sampled in concert with DBO activities in the Chukchi Sea. These achievements in international cooperation lay the groundwork for a truly pan-Arctic biological observatory. Discussions are continuing with Canada's ArcticNet program office to include their western Beaufort and Arctic Archipelago time-series lines within the DBO framework, and the Institute of Marine Research (IMR) in Norway is considering DBO lines in the northern Barents Sea as part of their annual ecosystem surveys.

Priorities for 2016

The DBOCT will complete a decadal DBO Implementation Plan. The plan will focus on preparing periodic assessments on the physical and ecological state of the Pacific Arctic marine environment, using, in addition to DBO-generated data, information from projects supported by the NSF, BOEM, NASA, North Pacific Research Board (NPRB), and others. The DBOCT will seek linkages to complementary sampling programs, including transects identified by the Arctic Council Conservation of Arctic Flora and Fauna/Circumpolar Biodiversity Monitoring Program. The updated DBO Implementation Plan will suggest ways to foster connections with existing community based observation networks.

[1] Grebmeier et al. 2015. *Progress in Oceanography*; [2]Itoh et al. 2015. *Deep-Sea Research I*

Chukchi & Beaufort Seas Ecosystem Collaboration Team (CBCT)

Accomplishments

To capture information on existing research in the Chukchi and Beaufort seas, the CBCT completed several information-gathering activities in 2015. CBCT members created a Gantt chart illustrating the temporal overlap of projects in the Chukchi and Beaufort seas, and also provided a detailed inventory of those projects that includes their degree of relevance to the five priority research themes identified in an earlier document, “Framing Arctic Marine Research Initiatives: A Framework for Coordinated Marine Ecosystem Research in the U.S. Chukchi and Beaufort Seas.” The inventory will serve as a source of public information for those interested in opportunities to collaborate or leverage resources.

Research teams launched a number of interdisciplinary marine science programs in the Chukchi and Beaufort seas, due in large part to the activities of the CBCT. A consortia of entities, many of which include Federal and private partners, fund these efforts. The Marine Arctic Ecosystem Study (MARES) led by the Bureau of Ocean Energy Management (BOEM) is centered in the Beaufort Sea and includes international collaborations and public-private partnerships. In partnership with BOEM and the North Slope Borough/Shell Baseline Studies Program, the NPRB issued a call for pre-proposals in May 2015 to initiate an ecosystem program centered in the Chukchi Sea that will include the northern Bering Sea and Bering Strait. The CBCT plays a central role in coordinating the activities of these programs.

The CBCT established a Chukchi/Beaufort Marine Steering Group (CBMSG) to maintain awareness of the direction and progress of ecosystem programs such as MARES. The CBMSG provides advice to the broader CBCT about areas where additional work is needed. It also exposes instances when proposed activities might duplicate ongoing work. The CBCT was informed about existing partnering mechanisms through presentations from the National Oceanographic Partnership Program (NOPP) and the National Fish and Wildlife Foundation during 2015. Different mechanisms and options were discussed after those invited talks.

Priorities for 2016

To complement the discussion initiated by the co-chairs on partnering mechanisms, the CBCT is planning a presentation on the MARES NOPP partnership. Challenges, opportunities, alternatives and lessons learned will be discussed. This presentation will address the entire IARPC community.

Because the team seeks to improve efficiency in planning and using resources (e.g., icebreakers), the CBCT seeks interaction with the newly created IARPC logistics group. In working to improve coordination among ongoing projects, the CBCT hopes to make progress towards meeting the broader milestones of the CBCT.

Improved integration of marine ecosystem research can be achieved through tasking the CBMSG to inform the team about opportunities to direct future investments in areas that address the CBCT members’ interests, and facilitating the organization of an information integration conference.

Glaciers and Fjords Collaboration Team (GFCT)

Accomplishments

Organized to enhance interagency collaborations on land ice loss process studies targeting specific dynamic regimes, the GFCT revised one of its milestones during 2015 to encourage discussion on a variety of processes and parameterizations in addition to Earth system models. NASA began a long-term study, Oceans Melting Greenland, which includes modeling and observations of the impacts of warming ocean waters around Greenland and the degrading ice sheet. NSF initiated a related study of historical data analyses and modeling of the warming oceans around Greenland, as well as an observational and modeling study of plume dynamics in an Alaskan fjord where fjord waters meet a glacier face. With NASA funding, researchers collected side-looking multi-beam echo sounding observations of fjord bathymetry and submerged ice faces of three west Greenland glaciers. The data reveal cavities undercutting the base of the calving faces at sites of subglacial water discharge predicted by a hydrological model. These observations are consistent with models of ice melt in which this discharge transports warm Atlantic waters to the ice faces.

An NSF-funded paleo-study of Petermann Glacier, involving scientists from the United States, Canada, Denmark, Sweden, and the United Kingdom, completed its planned field work based from the R/V *Oden* in September. The Community Earth System Model (CESM) Land Ice Working Group continues to manage collaboration between agencies and academic scientists to develop a community ice sheet model, which incorporates the results of recent process studies, for use in Earth system models. The ice sheet model, CISM 2.0, was publicly released on GitHub in October 2014.

The International Greenland Ice Sheet-Ocean Interactions (GRISO) Network, a self-organized, international, open network of scientists, grew out of the U.S. Climate Variability and Predictability (CLIVAR) working group. GRISO's goals are often commensurate with those of the Study of Environmental Arctic Change (SEARCH) Land-Ice Action Team and GRISO maintains close coordination with that team. The June 2013 U.S. CLIVAR workshop recommended a planning strategy for obtaining long-term time series of critical in situ glaciological, oceanographic, and atmospheric parameters to provide information on the time-evolving relationships between different climate forcings and the glacier flow, called the Greenland Ice-Ocean Observing System (GrIOOS). To further advance discussions regarding the design and implementation of a GrIOOS, the SEARCH Land-Ice Action Team will meet in San Francisco on 12 and 13 December 2015. These activities complete the milestones assigned to the GFCT.

Priorities for 2016

Participation in the GFCT monthly meeting will increase largely through broadened inclusion of members from the non-Federal scientific community. Long-term monitoring of the Greenland ice sheet and its glaciers will continue through NASA's Operation IceBridge. The glacier-fjord collaboration team will endeavor to expand its international linkages both directly and through synergies with the newly formed SEARCH Land Ice/Sea Level Rise Action Team and the expanding activities of the GrIOOS working group. Interagency discussions will continue to look for collaborative opportunities when budgets permit.

Terrestrial Ecosystems Collaboration Team (TECT)

Accomplishments

To better assess the impacts of climate change on Arctic terrestrial ecosystems, the TECT completed two milestones, initiated three, and made significant progress on the remainder.

To enhance potential future coordinated approaches to understanding ecosystem changes in the Arctic, TECT reviewed and summarized 6 administrative, cross-agency and inter-disciplinary documents. These included "The Arctic in the Anthropocene: Emerging Research Questions," and "Collaborative Opportunities," developed by the Alaska Climate Change Executive Round-Table (ACCER). The TECT review is available for comment and updates on the member side of the IARPC Collaborations website.

The TECT completed an assessment of existing tools and methods for measuring and mapping the effects of cryosphere changes on Arctic ecosystems and communities, and posted it to the member side of the IARPC Collaborations website. The spreadsheet includes legacy deep borehole permafrost temperatures and long-term climate (site) data, water related databases, information on terrestrial components, remote sensing imagery, coastal erosion, and geochemical and geophysical surveys.

Due to the importance of the boreal region in providing fresh water and organic inputs to the Arctic Ocean, two new milestones were created to address the completion of a circumboreal vegetation map. The map will provide baseline ecological documentation of boreal watersheds. The TECT added a third milestone to address a pan-Arctic analysis of permafrost dominated Arctic and boreal regions. This milestone will increase our understanding of the magnitude and distribution of permafrost carbon stores, and to identify areas of permafrost that are potentially most vulnerable to carbon loss with continued warming.

Priorities for 2016

The TECT will continue to finalize metadata standards for data archiving and to acquire elevation data through the cooperative actions of State and Federal agencies.

The team also will continue to advocate for use of traditional knowledge in ecosystem and climate science, a challenging milestone since traditional knowledge is often proprietary for local inhabitants. The TECT created a proposed process model and initiated discussions to involve six of the IARPC collaboration teams: Terrestrial Ecosystems, Arctic Data, Modeling, Arctic Observing, Arctic Communities, and Chukchi-Beaufort Seas. Discussions will continue, and researchers will focus on past and contemporary knowledge and patterns of use.

The TECT will coordinate with the Permafrost Carbon Network (PCN) to conduct a pan-Arctic assessment that will identify gaps in our understanding of the magnitude and distribution of permafrost carbon stores, and identify permafrost areas potentially most vulnerable to continued warming. The PCN synthesizes and links existing research about permafrost carbon and climate in a format that can be assimilated by biospheric and climate models and that will contribute to future assessments of the Intergovernmental Panel on Climate Change.

Wildfires Collaboration Team (WCT)

Accomplishments

The WCT built on previous analysis, focusing on promoting research that fills in knowledge gaps in Arctic fire science. The team held eight meetings, some of which featured webinars. Laura Bourgeau-Chavez, Ph.D., Michigan Tech Research Institute and Arctic-Boreal Vulnerability Experiment (ABoVE) scientist, presented “Remote Sensing of Subsurface Organic Moisture: State of the Science, Sensors, Potential Application to Fire Danger Index Validation.” Later in the year, USGS Alaska Science Center scientist Rachel Loehman led discussion on the state of knowledge of wildfire emissions in tundra and northern boreal forests. WCT’s milestone progress included the Bureau of Land Management funding a graduate student to study wildfire impacts to indigenous Arctic communities under University of Alaska, Fairbanks’ (UAF) Resilience and Adaptation Program.

WCT added a new milestone to convene an international, interdisciplinary workshop with remote sensing scientists, ecologists, hydrologists, agency fire managers, and decision-makers discussing new opportunities to use remote sensing in boreal/Arctic wildfire management and science. Members of the WCT, with other subject matter experts and lead Alison York from the Alaska Fire Science Consortium (AFSC), developed a proposal for NASA’s Applied Science Program to seek workshop support. One webinar was co-hosted with AFSC: “The Climate Has Changed, Have We? Reflections on 50 Years of Fire Management in Alaska.”

In August 2015, NASA selected 21 proposals for the initial research investigations to begin the ABoVE field campaign—a large-scale study of ecosystem responses to environmental change in western North America’s Arctic and boreal region and the implications for social-ecological systems. Several of the selected proposals focus on topics related to wildfires. In the coming year, this program should begin contributing to progress in achieving several WCT milestones.

Priorities for 2016

The WCT will continue a focus on remote sensing of fires and fire effects in high latitudes and their potential management application as well as modeling efforts to understand climate-fire forcings and their effect on communities and fire management in the North.

If funded, the “Opportunities to Apply Remote Sensing in Boreal/Arctic Wildfire Management and Science Workshop” will be held 9-10 March 2016 at UAF in association with Arctic Science Summit Week.

Atmosphere Collaboration Team (ACT)

Accomplishments

The Arctic Monitoring and Assessment Program (AMAP) recently completed its "Summary for Policy-makers: Arctic Climate Issues 2015," which presents the policy-relevant findings of the AMAP 2015 assessments of short-lived climate forcers (SLCF). Efforts involved new observations and modeling to enlighten the processes by which SLCFs affect Arctic warming, enabling mitigation through policy.

Scientists sampled the Arctic atmosphere during ground and airborne campaigns. DOE's Airborne Carbon Measurements Experiment (ACME) provided transects and vertical profiles of gases, aerosol, cloud, and atmospheric state properties on Alaska's North Slope. DOE also sponsored a campaign to test unoccupied aircraft systems (UAS) platforms. The DOE Atmospheric Radiation Measurement (ARM) facility completed a second year of a long-term deployment of its Oliktok Point, Alaska facility, which complements the Barrow-based DOE/ARM and NOAA observatories to capture the range of variability along the North Slope. The Oliktok Point site also provides FAA-approved special-use airspace so flights with manned or unmanned aerial systems can probe the over ocean atmosphere away from the coast. The DOE has funded an Oliktok Point Site science team to conduct relevant research using these and new measurement approaches.

A workshop sponsored by the International Arctic Science Committee (IASC) with support from NOAA focused on the joint observation-modeling issues of understanding the changing composition of the Arctic atmosphere, with an emphasis on identifying the collaborative efforts required to improve critical knowledge in the decade ahead. This group has developed into an initiative called the air Pollution in the Arctic: Climate, Environment and Societies (aPACES) under the auspices of the International Global Atmospheric Chemistry project. This initiative pursues semi-routine vertical profiling in the Arctic atmosphere using UAS. To this end, NOAA has developed several miniaturized ozone and aerosol sampling instruments for UAS.

Through the NSF-supported International Arctic Systems for Observing the Atmosphere (IASOA) radiation working group, scientists developed multi-year datasets of radiation and cloud radiative forcing at Summit Station, Greenland to evaluate the European Center for Medium-Range Weather Forecasting Reanalysis-Interim performance and NCAR's Cloud Earth System Model cloud parameterizations. The IASOA aerosol working group added new products to the World Data Center for aerosols and has also developed a pan-Arctic correction scheme for consistent processing of seven aethalometers. The FAA continues to develop its climate tools to study aviation effects on global and regional climate, including the Arctic.

Priorities for 2016

The ACT will synthesize observations and models for evaluations and cooperation with the newly formed IARPC Systematic Improvements to Reanalyses of the Arctic (SIRTA) working group, and advance aerosol-cloud interaction efforts and observational needs assessments for methane, aerosol, cloud, and atmospheric state properties to provide the spatial and temporal coverage needed to address the most pressing questions regarding the drivers of change in the Arctic.

Arctic Observing Systems Collaboration Team (AOSCT)

2015 Accomplishments

The AOSCT was on hiatus between March and August due to a changeover in agency observing program management. The team reviewed best practices for observing programs and projects that have made progress on sustaining observations or integrating observations in innovative ways. Programs included the Portal for the Arctic Adaption Exchange of the Arctic Council's Sustainable Development Working Group (SDWG), which maps community identified indices onto existing observational resources. The team also reviewed Alaska's Terrestrial Ecosystem Observing Network (TEON) effort to coordinate the design and implementation of a terrestrial environmental monitoring network in northern Alaska, intended to detect and forecast effects of a changing climate, hydrology, and permafrost regime on wildlife, habitat, and infrastructure in northern Alaska. The latter discussion highlighted those aspects of observing network development that can fall through institutional cracks between agencies. In particular, a patchwork of meteorological stations on the North Slope of Alaska maintained by plural agencies was identified as a valuable resource for TEON work, though harmonizing the stations for greater network value falls outside of the responsibility of any agency.

The AOSCT team also focused on developing a pilot "Arctic Observing Assessment" (AOA), led and funded by NSF as a contribution to the joint goals of the IARPC and Sustaining Arctic Observing Networks (SAON). Accessible through the Arctic Hub, the AOA maps relationships between societally significant observing priorities, as defined by northern residents and other stakeholders, to the observing and knowledge resources (or lack thereof) that help them to address those priorities. The AOSCT reviewed initial feedback on the priority areas and also provided information about available products and observations.

Belmont Forum Arctic Observing and Research for Sustainability awards were made by NSF and BOEM in partnership with international funding agencies. Research teams include a breadth of stakeholders, including indigenous communities, local governments, industry, and nongovernmental organizations.

When the AOSCT reconvened under new leadership in August, initial meetings focused on Community Based Observing (CBO) in response to Arctic Executive Steering Committee (AESC) interests in promoting best practices for these networks and enhancing their application, where appropriate, throughout Arctic communities. Through the AESC interests, the AOSCT developed a framework document to guide white paper inputs towards the 2016 Arctic Observing Summit (AOS) in Fairbanks, AK. At this meeting, CBO will be a focus.

Priorities for 2016

The AOSCT will continue to serve as a forum for community engagement and preparation for the AOS. In addition, the Arctic Observing Open Science Meeting (AOOSM) will have ongoing support to develop results and recommendations from their November 2015 meeting. Supporting on-going dialog across CBO groups, in particular communicating best practices, will also remain important. The challenge of developing a true cross-agency vision for an AON will remain part of the evolving conversation. AOSCT will endeavor to identify agency champions to assume leadership on promoting cross-agency observing system harmonization similar to those identified by TEON.

Arctic Data Collaboration Team (ADCT)

Accomplishments in 2015

The ADCT is unique for several reasons. It was the last IARPC collaboration team to convene, and as a result has had just seven meetings, of which the first four were open only to Federal members. Additionally, while some teams started with many, the ADCT had only a single milestone. The Federal only meetings focused on defining what the team could accomplish together, assembling an inventory of Federal Arctic data activities identifying more than 20 activities and investments among 8 agencies.

The ADCT identified the Alaska Data Integration working group (ADIwg) as a core activity. Two large NSF-funded data activities, Advanced Cooperative Arctic Data and Information Service and Polar Data Coordination Network, also were of interest, as they will help ADCT explore how large data activities can be leveraged with other agency investments and non-Federal activities. Stan Smith of USGS reported on the completion of a releasable version of the "ISO Metadata Developer's Toolkit" and Peter Pulsifer of the NSIDC provided a brief on the current status of progress on the development of an international polar data coordination network. Both of these activities support ADCT milestones.

In April, the ADCT began evaluating the milestones for clarification, identifying Federal and non-Federal activities to leverage in the near-, mid-, and long-term. One such activity was to assist the Office of Science and Technology Policy in establishing the new Arctic theme within the Climate Data Initiative and Climate Resilience Toolkit resources. IARPC teams provided input to the Arctic theme and sub-themes, created the theme narrative, provided subject matter experts to review narrative content, identified initial new Arctic data set content, provided preliminary review of candidate data content, and recommended new toolkit content. The theme was successfully introduced at the end of August 2015.

Priorities for 2016

Now open to non-Federal collaborators, the ADCT will identify a co-lead from a non-Federal organization and will continue to serve as a forum for data collaborative engagement and building trust among the communities of data providers and users. The ADCT plans to expand the current inventory list of Arctic data sources, assess the lessons learned from current ongoing collaborative projects, and engage in activities such as the Climate Data Initiative and the Climate Resilience Toolkit. In addition, the ADCT will assess several approaches to data management and sharing to identify a set of priorities and strategies. These include the need to improve data sharing, make use of existing resources, and improve sustainable engagement by stakeholders.

Modeling Collaboration Team (MCT)

2015 Accomplishments

Modeling provides two important benefits to scientific research and decision making: it allows the community to capture and evaluate the state of the art in understanding processes and interrelationships, and it provides a mechanism by which current understanding can be used to project future states. As such, modeling crosscuts most topics in IARPC's 5-year plan; as a result, the MCT defined over 25 milestones to improve understanding of regional Arctic climate. In addition to focusing on next-generation models for the Arctic, the MCT contributed significantly to integrating models and observations.

MCT activities contributed to improving individual model components for ice sheets, sea ice, and permafrost. For example, new parameterizations for melt ponds, ice hydrology, and ridging were included in sea ice models. Other examples include the recent efforts in several modeling centers to develop and couple ice sheet models in the global and regional models.

As an example of interagency coordination in Arctic modeling, agencies invested in improvements to the coupled Regional Arctic System Model (RASM). With funding from DOE, ONR, and NSF, RASM, grantees worked on complementary goals that enhance Arctic system understanding holistically.

The MCT identified recent dedicated field campaigns that inform modeling efforts by enhancing knowledge of Arctic processes. PRN and Next-Generation Ecosystem Experiments-Arctic focus on permafrost, to synthesize and link existing research about permafrost carbon and climate in a format that can be assimilated by biospheric and climate models. NASA's ABoVE links field-based, process-level studies with geospatial data products derived from remote sensors to improve the analysis and modeling capabilities needed to understand and predict Arctic ecosystem responses and societal implications.

Further, recent model inter-comparisons have helped to identify improvements in modeling high-priority Arctic processes. The inter-comparison effort for ice sheets (ISMIP6) focuses on evaluating ice sheet models in a common framework. The POLARCAT Model Intercomparison Project evaluated the capability of global and regional atmospheric chemistry and transport models to simulate the chemistry and composition of the Arctic atmosphere. Finally, the SIPN continually analyzes model predictions of sea ice against the observed extent to inform the need for improved processes.

Finally, MCT members organized a session for the fall 2015 AGU meeting titled "Advancing Science of the Arctic System: Exploring the Past and Present to Predict the Future."

Priorities for 2016

The MCT will implement a restructuring of the current milestones, and work to further integrate Arctic modeling activities and progress across the Federal agencies. Recent workshop results and discussion points to a growing need to coordinate our assessment of Arctic system modeling to better understand the sensitivities of these models and improve the representation of coupled processes that are critical to the emerging Arctic environment.

Arctic Communities Collaboration Team (ACCT)

2015 Accomplishments

The ACCT goal of encouraging research on the impact of warming climate on communities and ecosystem services advanced along many fronts in 2015. Per its imperative, the ACCT focused on information sharing and outreach, primarily in Alaska, rather than initiating or coordinating research. ACCT members presented work at several Arctic conferences.

To support the establishment of observing networks, BOEM initiated a social indicators project in coastal Alaska, and NSF funded "Arctic-FROST," an international, interdisciplinary research network aimed at improving health, human development and well-being while conserving ecosystem structures, functions and resources. ACCT identified projects and indigenous local observers for environmental observation and for data record preservation projects. The TECT will address incorporating indigenous knowledge and observing into monitoring environmental parameters.

Vulnerability research advanced with projects on social indicators for rural Alaska, and studies of how the social sciences inform decision-making. NASA's ABoVE program began studying ecosystem and societal vulnerability and resilience to the changing Arctic. Several Arctic Science, Engineering, and Education for Sustainability programs continued with support from BOEM, EPA, NSF, and USGS.

ACCT's food security work included a North Slope Borough subsistence mapping project and an ICC-Alaska report in collaboration with TECT. Further, Smithsonian research on the history, timing, and causes of animal "crashes" among major subsistence species advanced knowledge as well.

To help preserve indigenous language and heritage, ACCT sponsored a webinar on indigenous Arctic language status and practical steps to encourage use and continuity. The inauguration of the U.S. Arctic Council chairmanship provided an opportunity for IARPC demonstrations of Arctic vitality at the Smithsonian's Arctic Spring Festival in May; several native language programs were featured together with cultural and natural history programs, exhibits, performances, and films. The Alaska State Indigenous Language bill (HB 216) led to efforts to monitor language status and recommend policy. The Smithsonian's "Recovering Voices" programs featured Alaskan topics, and new research on links between oral history, language, archaeology, and climate change were the subject of an NSF-funded Smithsonian research program in Yakutat Bay. The Smithsonian also published a 20th century history of Chukotka. The Arctic Council has also initiated its own Arctic Languages Vitality Project.

The NPS, NSF, Smithsonian, and other agencies have issued publications and new heritage and language programs. However, the bulk of this work is being carried out by or in collaboration with Native organizations, universities, nongovernmental organizations, and others.

Priorities for 2016

Future ACCT activities will expand collaborations with the Arctic Observing and Health teams, and pursue initiatives linked to U.S. Arctic Council chair priorities.

Human Health Collaboration Team (HHCT)

Accomplishments in 2015

With encouragement from the HHCT, the State Department included three health priorities in initiatives framing the United States' approach to the Arctic Council chairmanship (a 2 year appointment that began in spring 2015). HHCT's priorities are behavioral and mental health, and suicide prevention; water sanitation and health; and the merits of taking a "One Health" approach to addressing climate change and health[2]. HHCT also recommended continuing international collaborations and engaging indigenous communities and tribal groups in research.

The International Circumpolar Surveillance and research network published a consensus statement on treatment of *Helicobacter pylori* infections in high-prevalence regions of the Arctic[3].

Priorities for 2016

Arctic Council health priorities will continue to influence activities in 2016. The water and sanitation initiative will be featured at the Alaska Health Summit (2-4 Feb), at the Arctic Science Summit Week in March, and at a special international workshop on innovations in water service delivery to be held in Anchorage in the fall of 2016. The RISING SUN mental health initiative will feature another metrics-defining scientific advisory group meeting in April 2016, followed by further community engagement sessions later in the year. The One Health initiative will undertake a survey of activities and capacities in the Arctic region in anticipation of a presentation to the SDWG in 2017. Additional collaborations for the Alaska One Health group will continue with quarterly meetings to connect partners and to evaluate new events and trends.

The International Circumpolar Surveillance (ICS) network anticipates publication of its summary of Tuberculosis rates and surveillance evaluations. The ICS research network is undergoing similar evaluations of surveillance for potentially climate-sensitive infectious diseases and of viral hepatitis among Arctic nations.

Research on reducing occupational injury risk will be conducted or reported in 2016 for commercial fishermen, commercial pilots, and oil spill response workers.

The Alaska Local Environmental Observer (LEO) network will introduce a new application to facilitate tracking and reporting observations of environmental change; this should expand the reach of the network and facilitate expanded use of the observations. The Maternal Organics Monitoring (MOM) study will continue planned activities; MOM anticipates final analysis of organohalogen results, which will be linked to childhood outcomes and infant Apgar scores.

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[2] Ruscio BA, Brubaker M, Glasser J, Hueston W, Hennessy TW. "One Health - a Strategy for Resilience in a Changing Arctic." .*Int J Circumpolar Health*. 2015 Sep 1;74:27913. doi: 10.3402/ijch.v74.27913

[3] McMahon B, Bruce MG, Koch A, et al., "The Diagnosis and Treatment of *Helicobacter Pylori* Infection in Arctic Regions with a High Prevalence of Infection: Expert Commentary." *Epidemiology and Infection* 2015. doi 10.1017/S0950268815001181

SEARCH Membership in IARPC Collaboration Teams (January 21, 2016)

SEARCH Role 1	SEARCH Role 2	First Name	Last Name	IARPC Arctic Communities CT	IARPC Arctic Observing Systems CT	IARPC Chukchi & Beaufort Seas CT	IARPC Glaciers & Fjords CT	IARPC Modeling CT	IARPC Terrestrial Ecosystems CT	IARPC Arctic Data CT	IARPC Atmosphere CT	IARPC Distributed Biological Observatory CT	IARPC Human Health CT	IARPC Sea Ice CT	IARPC Wildfires CT	IARPC Arctic Research Support & Logistics CT	IARPC Systematic Improvements to Reanalyses	IARPC Website Member
LIAT		Gordon	Hamilton															1
LIAT		Patrick	Heimbach															1
LIAT		Dave	Sutherland															1
LIAT		Martin	Truffer															
LIAT		Ruth	Mottram															
LIAT		Jakob	Abermann															
LIAT		Andreas	Ahlstrom															
LIAT		Sophie	Nowicki															
LIAT Lead	OCP	Fiamma	Straneo				1											1
LIAT Lead		Ted	Scambos															1
OCP		Philip	Martin		1				1	1								1
OCP		Matthew	Shupe		1						1			1				1
OCP		Carin	Ashjian			1						1						1
OCP		Craig	Fleener															1
OCP		Peter	Pulsifer							1								1
OCP		Ronald	Kwok															1
OCP		Guido	Grosse															
OCP	ARCUS Board	Maribeth	Murray															
OCP		Steven	Oberbauer															
OCP		Eric	Rignot															
OCP		Johannes	Verlinde															
OCP Chair		Craig	Lee		1													1
PAT		Eric	Kasischke					1	1							1		1
PAT Staff		Christina	Schaedel						1									1
PAT	OCP	Cathy	Wilson						1									1
PAT		Dave	McGuire												1			1
PAT		Vladimir	Romanovsky															1
PAT		Kevin	Bjella															
PAT		Antoni	Lewkowicz															
PAT		Merritt	Turetsky															
PAT		Dave	Schirokauer															
PAT		Michelle	Walvoord															
PAT		Scott	Rupp															
PAT Lead		Ted	Schuur					1	1						1			1
SIAT		Martin	Jeffries	1	1	1	1	1	1	1	1	1	1	1	1	1		1
SIAT	SIPN	Lawrence	Hamilton	1														1
SIAT	OCP	Don	Perovich			1						1		1				1
SIAT		Bob	Henson															
SIAT Lead		Henry	Huntington	1	1									1				1
SIAT Lead	OCP	Jennifer	Francis															1
SIAT Staff		Matthew	Druckenmiller	1	1									1				1
SSC		Hajo	Eicken		1	1								1				1
SSC		Betsy	Baker		1	1												1
SSC		Karen	Pletnikoff			1												1
SSC		Dee	Williams			1												1
SSC	LIAT	Robert	Bindschadler				1											1
SSC	SIAT	Marika	Holland					1						1				1
SSC		Caspar	Ammann															1
SSC		Uma	Bhatt															1
SSC	PAT	William	Bowden															1
SSC		George	Kling															1
SSC		Stephen	Vavrus															1
SSC		Courtney	Carothers															
Staff		Brit	Myers	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Staff	SIPN	Helen	Wiggins	1	1	1	1		1	1				1			1	1
Staff		Olivia	Lee	1	1	1				1		1		1				1
Staff		Bob	Rich	1	1				1	1	1	1		1				1
Staff		Lisa	Sheffield-Guy		1	1						1		1				1
Staff	SIAT	Brendan	Kelly			1												1
			Totals:	8	13	12	5	5	9	7	4	7	2	12	4	3	2	41

IARPC Human Health CT	2
IARPC Systematic Improvements to Reanalyses of the Arctic CT	2
IARPC Arctic Research Support & Logistics CT	3
IARPC Atmosphere CT	4
IARPC Wildfires CT	4
IARPC Glaciers & Fjords CT	5
IARPC Modeling CT	5
IARPC Arctic Data CT	7
IARPC Arctic Communities CT	8
IARPC Distributed Biological Observatory CT	7
IARPC Terrestrial Ecosystems CT	9
IARPC Arctic Observing Systems CT	13
IARPC Chukchi & Beaufort Seas CT	12
IARPC Sea Ice CT	12
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SEARCH Data Policy

Last Updated 12 May 2007

The SEARCH Data Policy applies to all data defined as SEARCH data by the participating agencies. An initial list is contained in the SEARCH Implementation Workshop Report (see: http://www.arcus.org/search/resources/reportsandscienceplans.php). The main purpose of the SEARCH Data Policy is to maximize data access, integration, and ultimately long-term preservation. It is intended to complement policies from other associated programs such as International Polar Year (IPY) and those of NSF's Division of Arctic Sciences. The participating agencies in SEARCH should enforce the policy as described below. When SEARCH data are collected as part of a collaborative international effort, they should also be distributed according to the SEARCH Data Policy of free and open access.

SEARCH investigators must describe their plan and timing for making data available as part of their proposals to announcements of opportunity that are designated as part of SEARCH.

Data policy actions for SEARCH Principal Investigators (PIs) are:

- Make all SEARCH community project data fully, freely, and openly available as quickly as possible after collection and quality control, subject to procedures approved in the proposal. Timely data availability will be part of SEARCH proposal review criteria.
- Follow guidelines for the preparation and submission of data, metadata, and documentation as described in the SEARCH Data Management Plan (in development). Standard metadata are required to achieve the program goals of maximum data integration and synthesis, broad community usage, and long-term preservation. Make sure all project related data sets are submitted to an appropriate data archive. These archives are generally defined as national archive centers and/or SEARCH project specific repositories.

In keeping with the IPY data policy, the only exceptions to this policy are some instances with human-dimensions data where respect for confidentiality, intellectual property rights, or proprietary information sources might take precedence; or in other cases where data release might cause harm (for example, locations of nests of endangered birds or of sacred sites).

All SEARCH data users are obligated to properly recognize the data providers. Attribution should credit both the data provider or author and the data center or publisher. In a scientific publication, attribution should take the form of a formal citation, such as for a journal article or book, or as described by the publication. General acknowledgement may be more appropriate in other situations such as instrument development, field applications, or logistics planning.

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

Draft version: 12 November 2015

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

Overview

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

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

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

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

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

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

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

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

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

An Arctic Information and Services Framework as an organizing structure

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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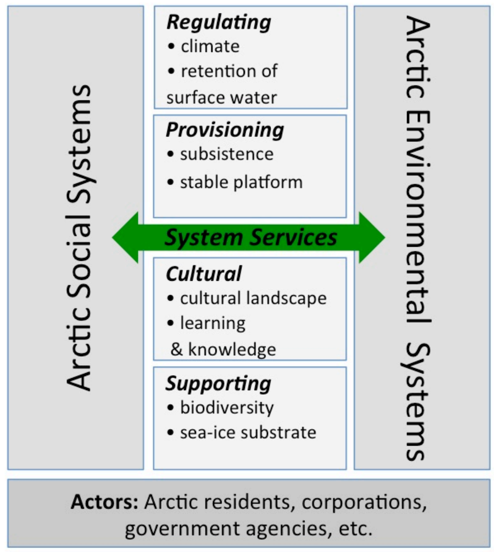

Fig. 1a: Schematic providing an example of services provided by Arctic social-environmental systems, here specifically for the example of terrestrial permafrost and sea ice.

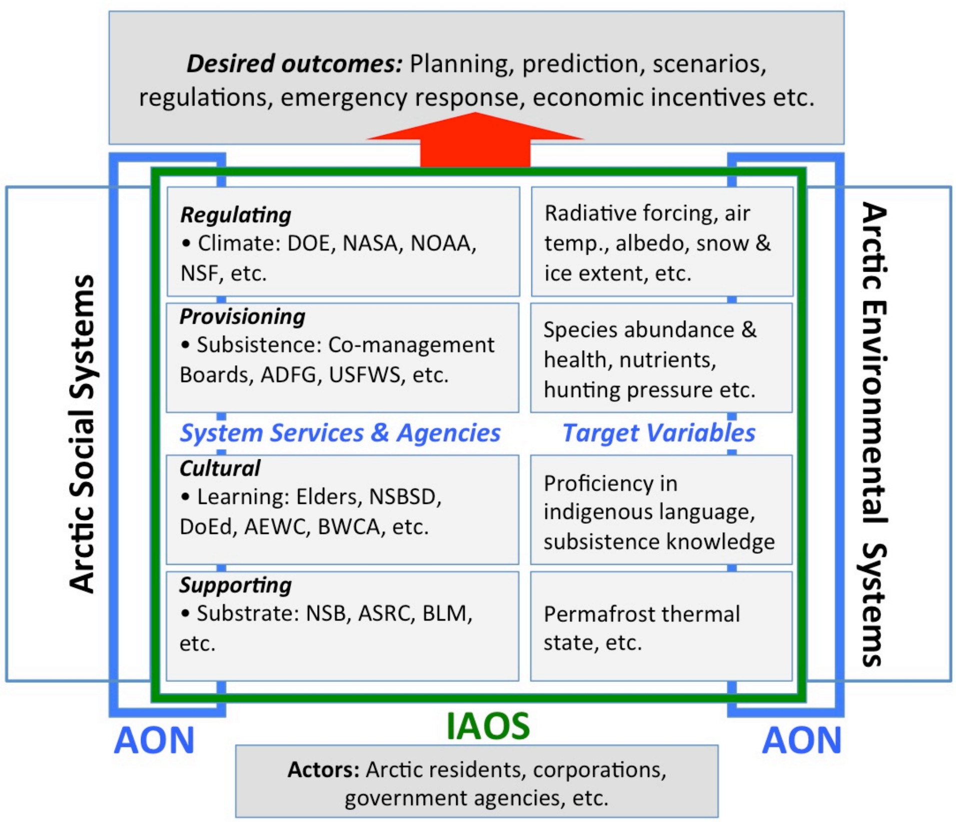

Fig. 1b: Schematic illustrating how example services shown in Fig. 1a map onto agency sustained observing activities and relate to specific target variables.

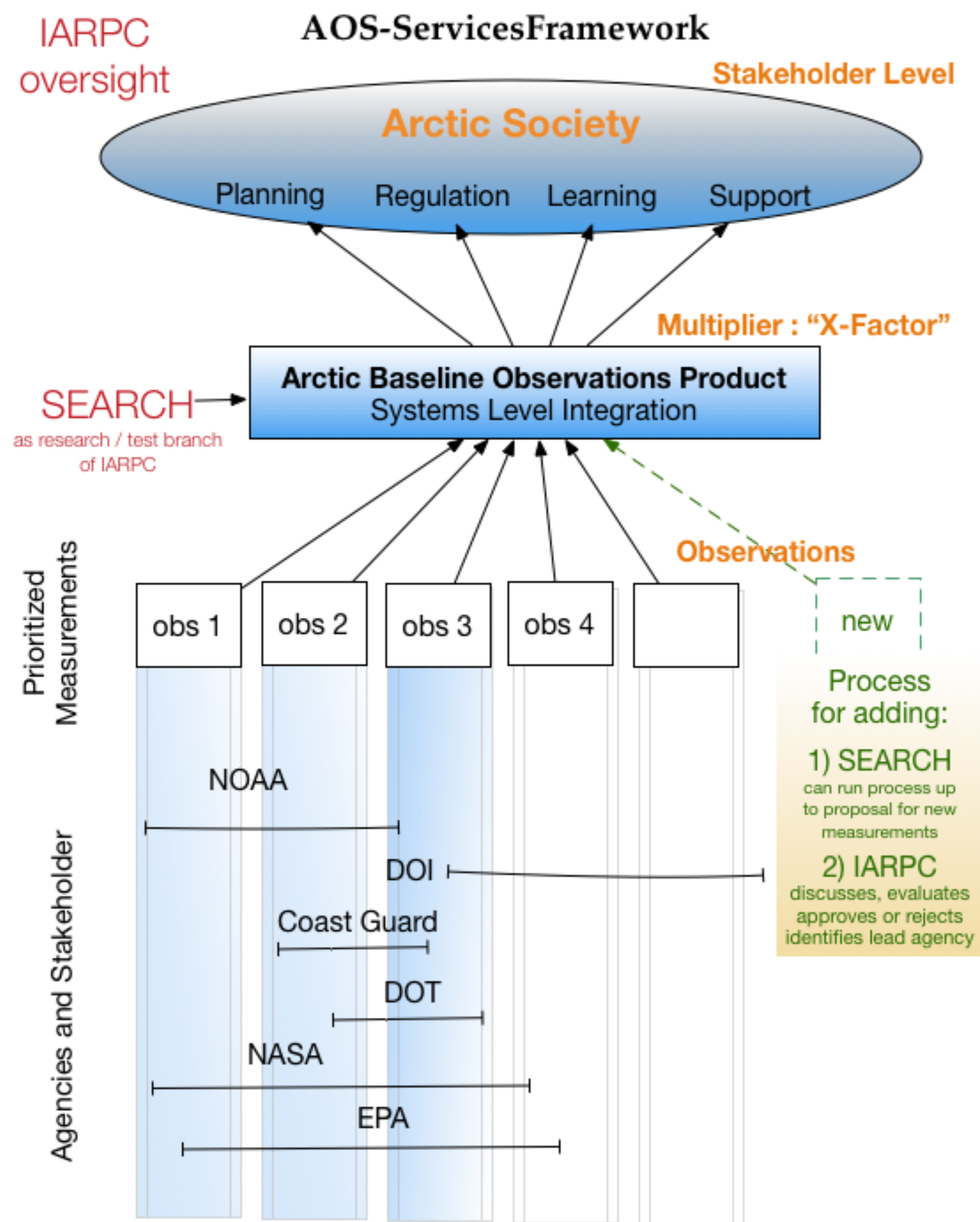

Figure 2. Schematic illustrating broader IAOS Framework.