US ARCTIC RESEARCH COMMISSION

REPORT ON THE Goals and Objectives for Arctic Research 2011–2012

FOR THE US ARCTIC RESEARCH PROGRAM PLAN

Front cover photo credit: Gay Sheffield

THE US ARCTIC RESEARCH COMMISSION

The US Arctic Research Commission is an independent federal agency created by the Arctic Research and Policy Act of 1984. It is a presidentially appointed advisory body supported by staff in Washington, DC, and in Anchorage, AK. In addition to establishing the goals in this report, the Commission recommends US Arctic research policy to the President and Congress and builds cooperative links in Arctic research within the federal government, with the State of Alaska, and with international partners. The law also requires the Commission to report to Congress on the progress of the Executive Branch in reaching goals set by the Commission and on their adoption by the Interagency Arctic Research Policy Committee. The Commission plays an active role in the work of several interagency committees, is a statutory member of the North Pacific Research Board and the North Slope Science Initiative, and is a member, a participant, or an observer on various committees, such as the National Ocean Council, Extended Continental Shelf Task Force, Interagency Program Management Committee of the Study of Environmental Arctic Change, Department of the Interior's Arctic Landscape Conservation Cooperative, Civil Applications Committee, Scientific Ice Expeditions Interagency Committee (involving US Navy submarines), UNOLS Arctic Icebreaker Coordinating Committee, State Department's Arctic Policy Group, Alaska Ocean Observing System, Alaska Climate Change Executive Roundtable, International Permafrost Association, and Consortium for Ocean Leadership.

During the last two years, the Commission led special initiatives, gave testimony before Congress and the Alaska State Legislature, authored reports, and contributed articles in peer-reviewed publications, such as the special issue of *Oceanography* on "The Changing Arctic Ocean" and *Marine Policy*. The Commission also writes editorials and "white papers" on a variety of other subjects, which are posted on the Commission's website, http://www.arctic.gov.

HOW THIS REPORT WAS COMPILED

Under the Arctic Research and Policy Act, the US Arctic Research Commission biennially recommends key goals and objectives ("goals report") for the US Arctic Research Program Plan. To prepare this report, the Commission, through public meetings and by other means, sought substantial input from scientific researchers, policy makers, the public in Alaska and throughout the United States, and the growing number of nations with Arctic interests. The Commission also cosponsored a number of scientific meetings and workshops to help define its research goals and policies, including workshops on oil spill response, impacts of an ice-diminishing Arctic on naval and maritime operations, on the provision of safe supplies of water and sanitary facilities in rural Alaska, on Arctic civil infrastructure, and on "Operating in the Arctic: Supporting US Coast Guard Challenges through Research."

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DUTIES OF THE COMMISSION

- Develop and recommend a national Arctic research policy
- Assist the Interagency Arctic Research Policy Committee in establishing a national Arctic research program plan to implement the policy
- Facilitate cooperation in Arctic research among federal, state, and local governments and with international partners
- Review federal Arctic research programs and recommend coordination improvements
- Recommend improvements in Arctic research logistics
- Recommend improved methods for data sharing among research entities

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A MESSAGE FROM USARC CHAIR FRAN ULMER

DEFINING OUR GOALS

As required by the Arctic Research and Policy Act, the US Arctic Research Commission (USARC) recommends goals for the nation's Arctic Research Program Plan. These goals are based on advice we receive from Arctic residents, government agencies, scientists, and citizens who are keenly interested in the Arctic's future.

Although significant progress on these research goals has been achieved by scientists in many organizations, including the Interagency Arctic Research Policy Committee (IARPC), much more investment is needed if we are to improve our understanding of this valuable and vulnerable region. The urgency for this work must be heightened, given the rapidly evolving conditions in the Arctic.

Dramatic changes in the environment and in resource development make it essential that important public and private decisions have the benefit of research, including timely and comprehensive information and a more thorough understanding of Arctic ecosystems, resources, and infrastructure challenges.

Additional research is needed to address national priorities related to energy and climate, ocean policy, health, conservation, national and homeland security, and keeping the United States competitive in the world economy. International investment in research and development has increased significantly in recent years, reflecting global interest in the Arctic. Oil and gas development, shipping, fishing, tourism, communication, and infrastructure construction are of intense interest to many countries, not just Arctic nations. Only with an active Arctic presence, which requires investment, as well as accession to the United Nations Convention on the Law of the Sea (UNCLOS), can the United States help shape new patterns of activity in the Arctic that are consistent with our nation's best interests.

To meet national goals, USARC, IARPC agencies, the National Science Foundation, the White House Office of Science and Technology Policy, the Office of Management and Budget, and Congress must work together to encourage collaboration and the commitment of resources. With regard to Arctic transportation, we encourage prompt decisions, such as on how the nation will obtain the scientific research and maritime mission capabilities previously provided by the nation's polar-class icebreakers, commissioned over 35 years ago, which are currently out of service. With a rapidly changing Arctic Ocean, these capabilities are required for research, law enforcement, environmental protection, emergency response, search and rescue, maritime commerce, and national and homeland security.

Now more than ever, America's Arctic needs increased American attention and investment.

INTRODUCTION

The Arctic is taking center stage both nationally and internationally. Public attention has grown as the media reports on reductions in sea ice, rising sea level, increased threats to communities from coastal erosion, retreating glaciers, thawing permafrost, and diminishing habitats for ice-dependent species such as polar bears and walruses. There has also been a growing interest in Arctic political, commercial, and security issues. Consideration of increased shipping, tourism, and oil and gas development in the Arctic has fueled multiple conferences, research publications, and now even an Arctic-focused investment fund.

Internationally, increased accessibility of the maritime Arctic, and a greater appreciation of the Arctic's potential resource wealth, have increased interest in developing this previously remote region. Infrastructure development, from ice-capable vessels to research stations, from deep-dredged ports to a search-and-rescue agreement, is moving forward, but at a pace that many consider insufficient. At this time of rapid change, what actionable information, ultimately rooted in scientific research, is most needed?

How can research, and data access, analysis, and synthesis, improve the decisions that are being made by both the public and private sectors? Can federal agencies improve the return on their Arctic research investments and increase collaboration among parties with similar interests? How can research results be communicated effectively to those who need answers, and in a timely and scale-appropriate form? Are there new ways of conducting research in this challenging environment to increase understanding and to reduce escalating costs? What kinds of specialized technologies and equipment need to be developed and deployed?

USARC investigates these questions and provides relevant advice to policy makers. Given the challenging budget scenarios that federal agencies are facing, and the mounting pressure to prepare for resource development and greater accessibility in the Arctic, the Commission's work has never been more timely or urgent. For the Commission to successfully fulfill its mission, it consults with and listens to communities of scientists, researchers, decision makers, and Arctic residents. The Commission encourages these groups to share their knowledge and valuable perspectives on these issues.

The following pages of this report have three parts: research goals, communication and coordination, and emerging research topics.

Photo credit: Gay Sheffield

FIVE PRIORITY RESEARCH GOALS

The US Arctic Research Commission recommends research on five central and crosscutting goals, summarized below. In the following pages, we provide specific and illustrative examples of current and proposed research programs that address these goals.

GOAL 1 | Observe, Understand, and Respond to Environmental Change in the Arctic, Arctic Ocean, and Bering Sea

KEY OBSERVATIONS

- The Arctic is warming at twice the global rate, and the region will likely contribute to further warming through reductions of sea ice cover, forest expansion, and the release of methane, a greenhouse gas.
- The Arctic is experiencing significant increases in shipping, tourism, and natural resource extraction, and greater attention is being paid to its fisheries and ecosystems.

USARC RECOMMENDS...

...greater support for efforts to observe and understand the Arctic environment and climate, how they are changing due to natural and human activities, and how we may better respond to future change. We must do more to synthesize scientific results and translate them into actionable information.

GOAL 2 | Improve Arctic Human Health

KEY OBSERVATIONS

- Marked health disparities exist between US Arctic residents and those who live in the lower 48 states. Similar latitudinal disparities exist in other Arctic nations.
- While Alaskan rates of infant mortality, fetal alcohol syndrome, chronic lower respiratory disease mortality, and accidental injury have decreased, the rates of substance abuse, domestic violence, obesity, diabetes, cancer, and suicide have risen.

USARC RECOMMENDS...

...additional basic biomedical and behavioral research in these areas, continued community health analyses, and a recurring assessment of intervention efforts, on a decadal scale, to help develop research priorities, review results, and guide the scaling up of localized, successful efforts into broader clinical interventions.

LEFT | Thawing permafrost causing land to slump, Selawik, Alaska. *Photo credit: Bruce Molnia* BELOW | Dividing shares after a successful bowhead hunt.

GOAL 3 | Assess Natural Resources

KEY OBSERVATIONS

- The US Arctic is rich in natural resources, such as oil and gas, minerals, fisheries, and wildlife, yet we have not sufficiently assessed their distribution, abundance, and concentration.
- The United States is not yet a party to the United Nations Convention on the Law of the Sea (UNCLOS), thus precluding us from claiming our share of the Arctic beyond 200 nautical miles or contesting the claims of other countries.

USARC RECOMMENDS...

...basic mapping of Arctic lands and charting of Arctic waters to the standards achieved in the lower 48 states. We must also quantitatively assess mineral, energy, and living resources. Concomitant with this assessment, the Commission recommends gaining a greater understanding of the immediate and cumulative environmental, social, and economic impacts of developing these resources. Finally, the Commission continues to urge Senate ratification of UNCLOS.

GOAL 4 | Advance Civil Infrastructure Research

KEY OBSERVATIONS

- Arctic climate change is affecting infrastructure, and the implications for transportation, communication, energy, and community networks are considerable.
- Thawing permafrost affects buildings, utilidors, and roadbeds. Diminished sea ice and stronger storms are eroding coastlines and communities. While marine access increases, terrestrial access decreases (e.g., shorter ice road seasons).

USARC RECOMMENDS...

... a research program on innovative technological and engineering solutions to support civil infrastructure that will withstand environmental change. Focus on building foundations; delivery of utilities, energy, and communication; and a transportation system that addresses land, air, and sea (e.g., deep-draft Arctic ports). Also, if oil spills cannot be prevented, we must be prepared, and the uniqueness of the Arctic requires specialized research.

GOAL 5 | Assess Indigenous Languages, Identities, and Cultural Research Needs

KEY OBSERVATIONS

- Language is one of the most vulnerable, yet important, elements of Arctic cultural identity and heritage.
- When speakers of endangered languages switch from their mother tongue to other languages for communication and education, vast amounts of knowledge and tradition are lost, impacting cultural identity.

USARC RECOMMENDS...

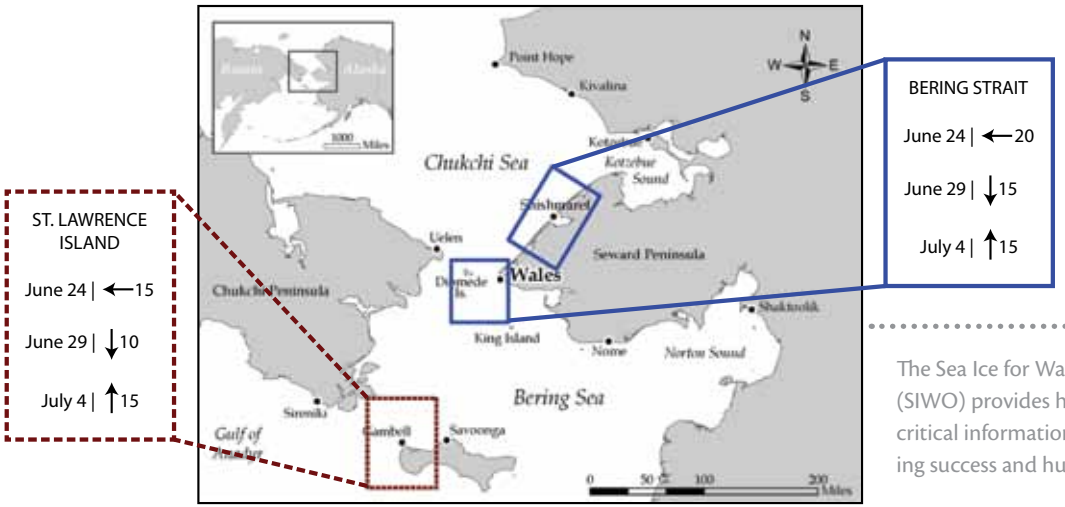
...developing an integrated Arctic indigenous languages research plan that: (1) conducts regular assessments to understand the extent and diversity of languages spoken by Arctic indigenous peoples and the viability of those languages for future generations; (2) documents procedures to ensure that languages and place names spoken and given by Arctic people are recorded and preserved; and (3) defines policy options and processes for language monitoring and preservation.

A RESOURCE FOR WALRUS HUNTERS

By combining research with traditional environmental knowledge, indigenous hunters now have a tool that helps them gauge local and regional conditions, thereby increasing safety during subsistence activities.

Several Arctic wildlife populations, and the subsistence hunters that rely on them, have been forced to adapt to habitat change. The sea ice decline has reduced the size of the platform upon which seals and walruses typically rest between feeding events. Over the past few years, dramatic photos of thousands of walruses hauled out on North Slope beaches have been published in the media. These haulouts are not unprecedented, but what is unusual is their frequency, locations, and the large numbers of animals involved. Hunters are finding it challenging to respond.

One example of scientists working with Arctic communities and Alaska Native Organizations, such as the Eskimo Walrus Commission (EWC), to provide a useful, science-based service in response to Arctic environmental change, is the Sea Ice for Walrus Outlook (SIWO) coordinated by the Study of Environmental Arctic Change program (SEARCH) in collaboration with the National Weather Service, NOAA, and the EWC (see http://www.arcus.org/search/seaiceoutlook). Since 2010, SIWO has provided information about weather, climate, and sea ice conditions to Alaska Native subsistence hunters, coastal communities, and other interested groups. This information enables hunters to pursue walruses in a safer and more cost-effective manner, increasing the likelihood of a successful hunt.



The Sea Ice for Walrus Outlook (SIWO) provides hunters with critical information for both hunting success and human safety.

SIWO is a simple, inexpensive, and responsive service that has developed in light of environmental change. Other such services, rooted in research, and responding to change, are needed. These services may be related to improved weather and climate forecasts, marine and sea ice outlooks, river gauging, and fisheries and ecosystem monitoring. The Scenarios Network for Alaska Planning (SNAP, at http://www.snap.uaf.edu) is another example. SEARCH and the International Science Advisory Committee are focusing on these and other means of responding to environmental change.

ARCTIC OBSERVING NETWORK

Interest remains high in developing a sustained and integrated national Arctic Observing Network (AON) and its international counterpart, Sustaining Arctic Observing Networks (SAON), which was endorsed by the Arctic Council in 2011. USARC is a strong supporter of both efforts, but true integration of Arctic observations, and the financial resources necessary to implement these "systems of systems," remain a challenge.

In 2006, the National Academies' Polar Research Board published their findings on AON in *Toward an Integrated Arctic Observing Network* (NRC, 2006). This report was followed by an IARPC publication in 2007 titled *Arctic Observing Network (AON): Toward a US Contribution to Pan-Arctic Observing* (IARPC, 2007). Both reports recommended a dedicated AON program, across the US government. AON, generally envisioned as a system of atmosphere-, land-, and ocean-based environmental monitoring capabilities—from satellites to ocean buoys and even fiber optic cables—would significantly increase observations of Arctic environmental conditions, leading to a better understanding of Arctic change, and ultimately an improved response. Several US agencies are undertaking activities consistent with the AON concept. For example, military organizations, such as the US Navy and Coast Guard, are interested in "Arctic Domain Awareness," which is largely focused on environmental conditions. Given the common interests, USARC recommends greater integration of research- and operational-based efforts in Arctic observing. A simple and cost-effective example would be the consistent collection and release of bathymetric, sea ice thickness, and other data acquired by US Navy submarines that regularly transit beneath Arctic sea ice.

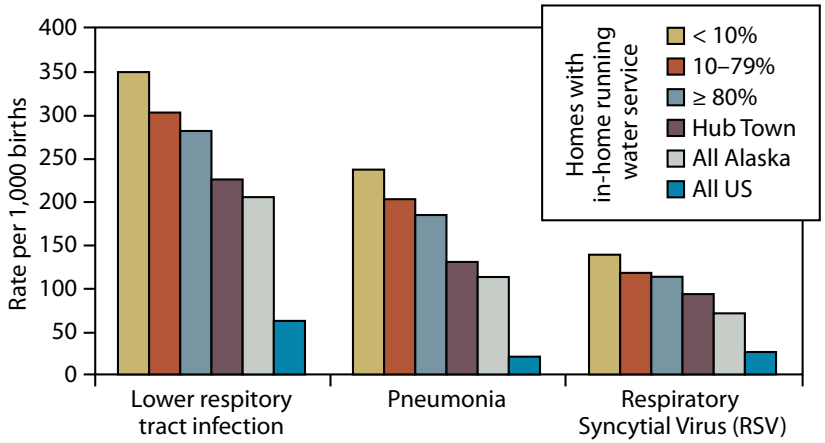
Re-deployment of the North Pole Environmental Observatory (NPEO) mooring in 2004. The hydraulic power pack is seen on the left through the quadrapod legs with hoses connected to the capstan in the lower center. The deployment hole through the ice is covered except when large items are passed through. *From Aagaard and Johnson (2011)*

WATER AND SANITATION NEEDS IN RURAL ALASKA

The health of Alaskan Native communities is often impaired because approximately 23% of rural Alaskan households lack in-home water and sanitation services. Additionally, in terms of the provision of such services, Alaska ranks last among the states.

Medical research demonstrates that the rates of respiratory hospitalizations, skin infections, invasive bacterial infections, and cavities are significantly greater in populations without running water. In Alaska, it has also been rigorously shown that providing villages with adequate supplies of clean water increases washing; improves hand, body, and oral hygiene; and decreases the person-to-person spread of bacteria and viruses, thereby reducing the frequency and severity of infections.

Typical village "haul" system. Water delivery trailer and sanitation holding tank. *Photo credit: Jennifer Dobson*



1999–2004 hospitalization rates for Alaska Native infants according to the percent of homes with in-home running water service. *Centers for Disease Control and Prevention, 2010*

Rural Alaska sanitation funds needed exceed those available. From: *Water and Sanitation Briefing for State of Alaska* available at: http://arctic.gov/publications/soa_briefing.html.

In light of these observations, USARC and the US Centers for Disease Control and Prevention convened a steering committee of health, water, and sanitation experts that have adopted the goal of "maximizing the health benefits of in-home running water and sanitation services in rural Alaska" through the following recommendations:

1. Promote research and development to encourage and test innovations that address the technological challenges of providing rural water and sanitation services.

2. Complete ongoing construction projects to provide first-time water and sanitation services to 11 rural communities, at a cost of $200M, over the next two years.

3. Work with federal and state appropriators to annually set aside 5% of state and federal capital funds to enable communities to follow best practices through operations and maintenance support.

4. Develop specific targets for water-related health indicators: pneumonia and influenza, skin infections, invasive bacterial infections, cavities in children, and diarrheal disease.

USARC is pleased to learn that Alaska's governor has allocated ~$1M in the 2012 budget for a water and sanitation technology development program.

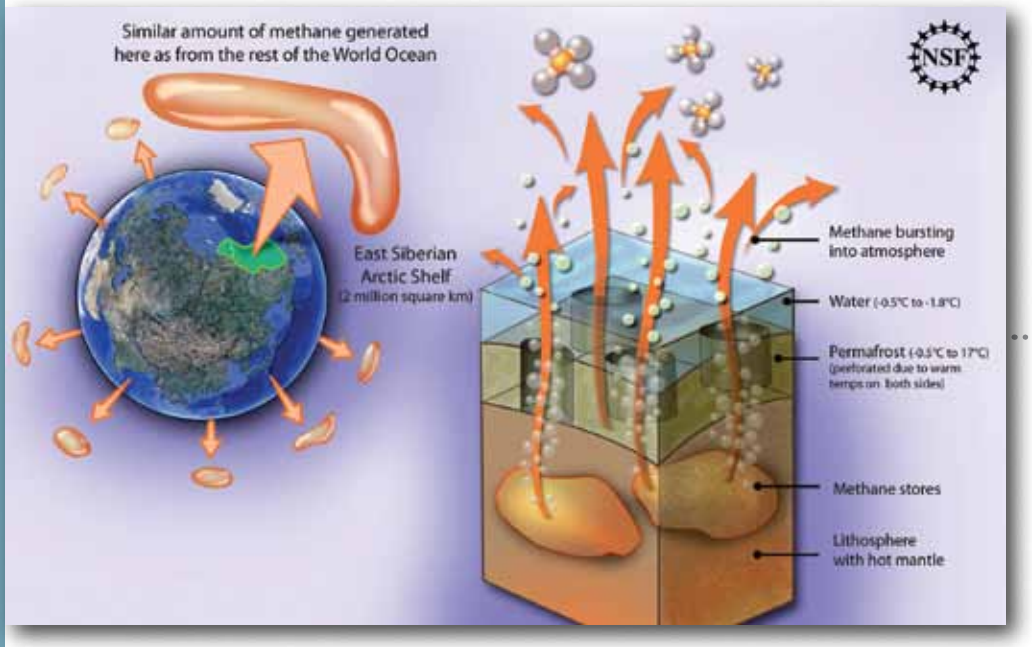
GAS HYDRATES

Arctic permafrost and marine sediment contain large amounts of gas hydrates (frozen solids of methane and water). Although they constitute a large methane reservoir, even on a global basis, an economical way to extract the gas from the hydrate has yet to be developed. Hydrates are a threat to marine infrastructure because they can clog pipes and, when they thaw (and convert to gas), they can destabilize overlying seafloor structures, such as those found in offshore oil and gas fields. If methane escapes to the atmosphere, it is many times more effective in trapping heat than carbon dioxide, another greenhouse gas. Projected estimates of the amount of the total carbon released to the atmosphere from thawing permafrost range from 15 to 35% of today's annual emissions from human activities, a huge, and previously underappreciated, amount. As the Arctic continues to warm, estimates of how much methane will be released, and from where, need to be refined.

As an energy source, gas hydrates are an intriguing possibility. Annually, the United States consumes about 21 trillion cubic feet of natural gas, and in fewer than 10 years, the demand is expected to grow to 32 trillion. Despite the recent availability of "tight gas" from hydrological fracturing efforts ("fracking"), anticipated future demand has been a catalyst for further research on Arctic methane hydrates as an energy resource.

In January 2012, the US Department of Energy (DOE) National Methane Hydrates R&D Program will conduct a 100-day experiment on carbon exchange and methane, harvesting from hydrates in Alaska's North Slope. DOE, US Geological Survey (USGS), and other federal agencies hope to better understand the natural forces that form and destroy gas hydrates, and how they affect the environment.

USARC supports research and modeling of gas hydrates in Arctic environments to better assess the potential use of methane hydrates as an energy source, to understand their flux and climate impacts, and to better understand their threat to civil infrastructure.



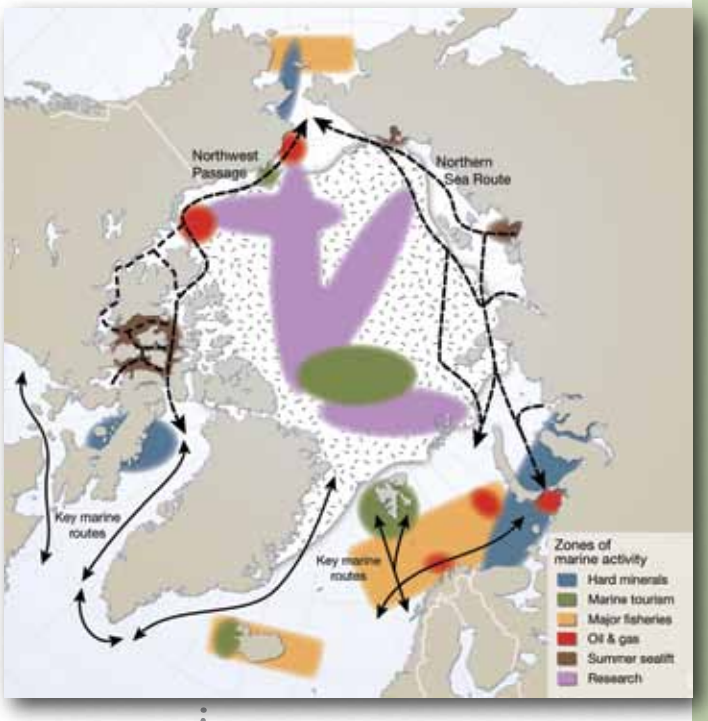
The subsea permafrost of the East Siberian Arctic Shelf (an area of about 2 million square kilometers) is more porous than previously thought. The ocean on top of it and the heat from the mantle below it warm it and perforate it. These pathways allow methane gas stored, under pressure, beneath the permafrost to burst into the atmosphere. The amount leaking from this locale is comparable to all the methane from the rest of the world's ocean put together. Methane is a greenhouse gas 30 times more potent than carbon dioxide. *Credit: Zina Deretsky, National Science Foundation*

ARCTIC MARINE SHIPPING ASSESSMENT

USARC was instrumental in coordinating and drafting the Arctic Council's *Arctic Marine Shipping Assessment 2009 Report* (Arctic Council, 2009), a comprehensive evaluation of Arctic marine activity. The report's main foci are the history and governance of Arctic shipping, current marine use, scenarios of future use, human dimensions, environmental considerations and impacts, and marine infrastructure.

Although several of the objectives in the 2009 report have been achieved, such as the search and rescue agreement signed by the Arctic Council in 2011, a follow-up meeting in 2010 listed outstanding priorities that, to be achieved, will require additional research and funding, as well as both Arctic state and governmental action. These priorities include:

- A mandatory Polar Code for ships operating in polar waters, developed by the International Maritime Organization (IMO), including full tracking and monitoring of Arctic commercial ships (using a mandatory automatic identification system)
- Surveys of indigenous marine use
- Increased hydrography and surveying of Arctic waters to improve navigation charts
- Research on oil spill prevention best practices and responses to oil released in Arctic ice-covered waters
- Enhanced research, including mitigation measures, on shipping impacts on marine mammals and other migratory fauna as Arctic marine operations intensify
- A comprehensive study to identify potential Arctic marine areas, including the central Arctic Ocean, for possible designation as IMO Particularly Sensitive Sea Areas
- Studies on the application of ecosystem-based management to Arctic coastal regions
- Enhanced marine communications systems in the Arctic, including full-coverage satellite communications in the Central Arctic Ocean

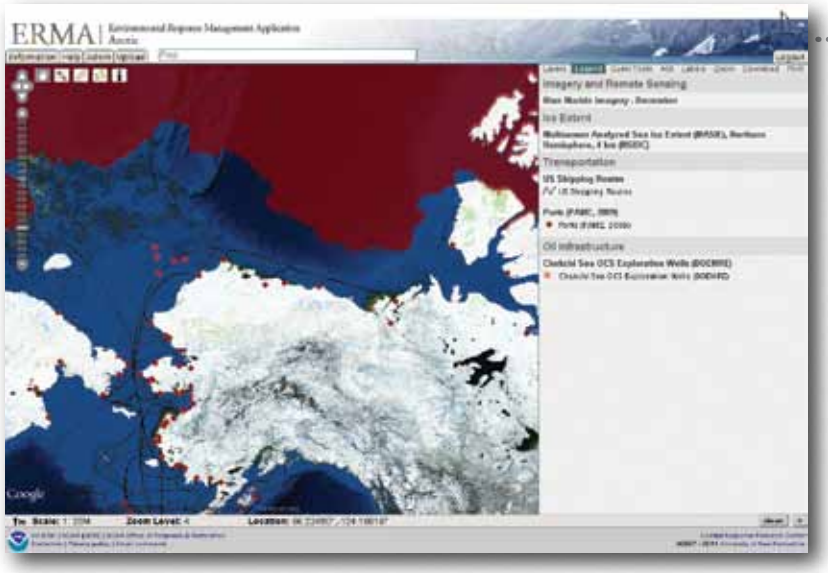


Current marine shipping uses in the Arctic. *From: Figure 7.1 in CAFF International Secretariat (2010)*

USARC supports the efforts of many entities that continue to work toward these priorities in both national and international forums.

A MANAGEMENT TOOL FOR OIL SPILLS

The possibility of oil spills in Arctic waters will increase as climate change, the demand for resources, and improved technology lead to increased Arctic shipping and greater exploration and development of offshore oil and gas resources. An extended open-water season likely means more ship traffic, though ice hazards remain. Thawing permafrost in areas supporting pipelines and oil exploration infrastructure, and an increase in oil and gas exploration and development, also increase spill risk. For these reasons, the National Oceanic and Atmospheric Administration (NOAA), the University of New Hampshire, and other federal, state, and local entities are taking a proactive position to prevent, plan for, and mitigate future losses related to these risks. One example is incorporation of synthesized Arctic data into NOAA's geospatial decision-support tool, Environmental Management Response Application (ERMA™), that is being developed in the Office of Response and Restoration.



The goal of NOAA's Arctic Environmental Management Response Application (ERMA™) is to provide information and tools to support decision making for oil spills in Arctic and sub-Arctic waters.

ERMA™ is a web-based Geographic Information System tool designed to assist both emergency responders and environmental resource managers facing incidents that may adversely affect the environment. ERMA™ integrates and synthesizes incoming data, provides a common operational picture for all individuals involved in an incident (such as an oil or fuel spill), improves communication and coordination among responders and stakeholders, and provides resource managers with the information necessary to make faster and better-informed decisions. USARC supports the efforts that NOAA and others are making to reduce risks and improve response coordination with respect to Arctic spills. USARC has been active in the development and support of ERMA™ and continues to encourage the data synthesis needed to feed into projects such as this in order for them to achieve success.

LANGUAGES

Yup'ik elder Simeon Agnus sharing *qanruyutet* (instructions) during a trip with youth and elders around Nelson Island, July 2007. *Photo credit: Ann Fienup-Riordan*

The significance of indigenous languages, cultures, and identities has been garnering greater attention, importance, and prominence throughout the Arctic. While a positive development, it reveals the need to better understand, preserve, and revitalize the indigenous languages and cultures of the Arctic.

Language is the distillation of many aspects of culture and identity that allows a people to relate to a common past while they move toward the future. When language use or cultural activity dramatically decline, the probability of language extinction increases. This was the case for the Eyak language, whose last living native speaker died in 2008.

Due to the increased frequency of endangered languages becoming extinct, USARC promotes the revitalization and preservation of Alaska Native languages, cultures, and identities, and recommends social science research in these areas, both at the federal level and through international circumpolar initiatives, such as one being considered by the Arctic Council. To this end, USARC recommends that due consideration be given to:

- Assessing languages by undertaking regular censuses to document linguistic diversity and the number of fluent speakers of each language
- Assessing place names and efforts to record Alaska Native nomenclature and the availability of language materials and documents
- Developing, approving, and disseminating language policy options and processes to improve language revitalization efforts in Alaska and across the Arctic

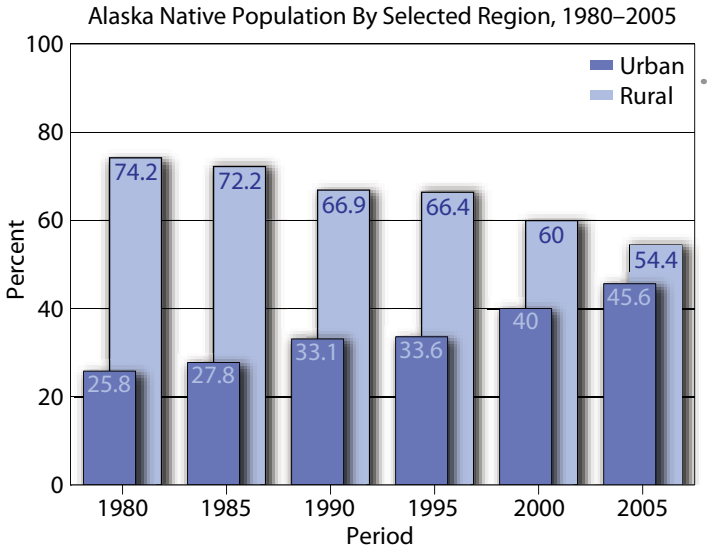
RURAL EMIGRATION

The 2010 US census reveals that Anchorage hosts the largest Yup'ik and Inupiat communities in Alaska, and has a total Alaska Native population of 23,130, constituting one out of every 13 Anchorage residents.

Migration from rural Alaska to urban centers has significantly increased over the last decade due to cost-of-living differences, impacts of climate change on communities and traditional lifestyles, and insufficient economic and educational opportunities in villages. According to recent studies (Martin et al., 2008; State of Alaska, Department of Administration, 2009), a sustained spike in oil prices has resulted in cost-of-living increases in interior and rural Alaska that are twice that of Anchorage. Federal, state, and local governments are struggling to respond. Traditional adaptation strategies are unable to buffer communities from these cost disparities.

Additional research, using data collected after the most recent sustained increase in fuel prices, is needed to more fully understand and detail these phenomena. These emerging trends raise many important social, economic, and cultural questions worthy of partnership with Alaska Native communities.

Rural communities, while rich in culture, may lack the educational and job opportunities found in urban areas. *Top photo credit: Gay Sheffield*



"Urban" includes Anchorage, Mat-Su, Fairbanks, Juneau, and Kenai Boroughs. Sources: US Census Bureau and Alaska Department of Labor and Workforce Development, Research and Analysis Section. *From Hunsinger (2008)*

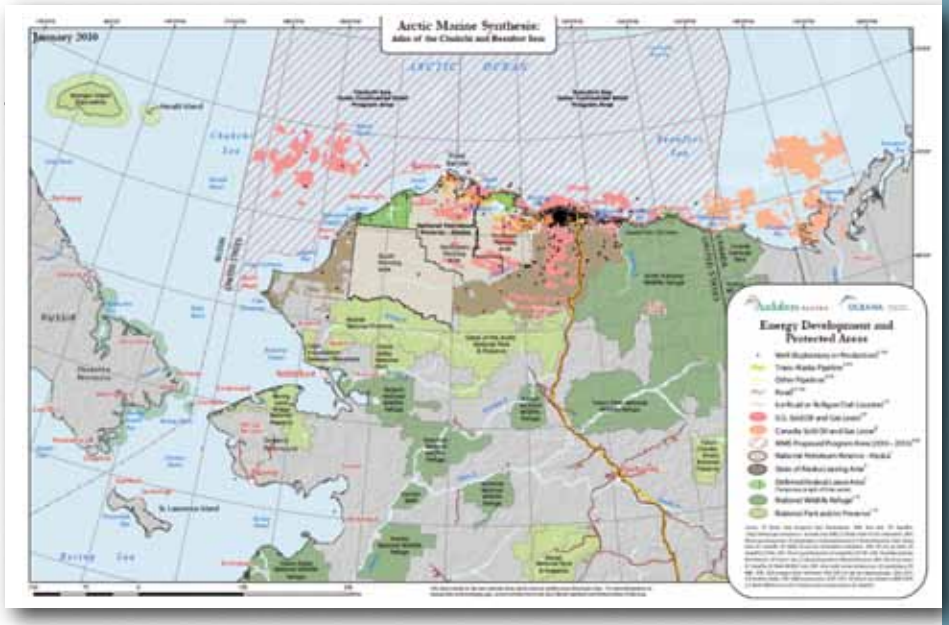
COOPERATIVE RESEARCH: INDIGENOUS USE PROJECT

Conservation and indigenous organizations, along with local governments, are working together to identify Important Ecological Areas (IEAs) in US Arctic marine waters. This collaboration links local and traditional knowledge (LTK) with research scientists to identify areas important for subsistence use, marine mammals, seabirds, fish, and other important ecological processes. Once identified and mapped, IEAs will be used to help inform and guide management decisions about Arctic resources. USGS noted the lack of IEAs as a major gap in the report, *An Evaluation of the Science Needs to Inform Decisions on Outer Continental Shelf Energy Development in the Chukchi and Beaufort Seas, Alaska* (Holland-Bartels and Pierce, 2011). This report is a comprehensive review of Arctic science needs that now must be taken to the next level: assessing which additional gaps are of primary importance and the most appropriate organization(s) to address them.

Projects investigating IEAs have been initiated in four regions: waters off the North Slope of Alaska, the southern Chukchi Sea and Kotzebue Sound (Northwest Arctic Borough region), the northern Bering Sea and Bering Strait, and the Aleutian Islands. Funding for the work has been obtained for each region, and available scientific information has been gathered in all regions and published for the three northern regions in *Arctic Marine Synthesis: Atlas of the Chukchi and Beaufort Seas* (Smith, 2010). Conservation and indigenous organizations and government entities are currently working together to document additional LTK, which is being obtained directly from subsistence users in each of the regions. IEA atlases for all regions will be completed by 2014, with the regional atlas for the waters off the North Slope of Alaska and Aleutian Islands scheduled for completion in early 2012.

USARC supports efforts to incorporate indigenous knowledge into research efforts and recognizes IEAs as relevant to land use and natural resource managers.

The collaborators on the project are Oceana, Inuit Circumpolar Council-Alaska, North Slope Borough, Northwest Arctic Borough, Kawerak Inc., Aleutian Pribilof Islands Association, and Audubon Alaska. Funding for this project is provided in part by the Oak Foundation, Packard Foundation, the National Science Foundation, and the Coastal Impact Assistance Program.



INTERNATIONAL EFFORTS

UNCLOS

Eight nations have Arctic territory. Several key Arctic maritime boundaries between nations need to be resolved, such as between the United States and Canada in the Beaufort Sea, and between Canada and Denmark in Baffin Bay. Progress was made recently when Russia and Norway resolved their 40-year boundary dispute in the Barents Sea. Furthermore, the sovereign rights over each Arctic nation's "extended continental shelves" (beyond the 200 nautical mile exclusive economic zone) depend upon adjudication by the parties to the United Nations Convention on the Law of the Sea (UNCLOS). Several Arctic nations (including Russia and Canada) are completing their delimitation efforts. Unfortunately, and to the detriment of the United States, we are not yet a party to this treaty. USARC strongly favors Senate ratification of UNCLOS, which has significant Arctic security and economic ramifications.

US Coast Guard icebreaker *Healy* and the Canadian Coast Guard icebreaker *Louis S. St-Laurent* side by side. *Credit: USGS; http://continentalshelf.gov/gallery.html*

INTERNATIONAL RESEARCH COOPERATION

Arctic scientists have long realized the value of interdisciplinary and international research, and have focused attention and resources on collaboration and cooperation. This effort, in the study of environments and ecosystems, human populations, flora, and fauna, as part of a globalized system, has emphasized the importance of current research into climate change, weather, pollution and contamination, adaptation, fisheries, infrastructure requirements, resource development and extraction, and the health and culture of indigenous people. To this end, USARC continues its support of international research initiatives and partnerships. A sampling of cooperative efforts over the last year include:

The Agreement on Cooperation on Aeronautical and Maritime Search and Rescue (SAR) in the Arctic. SAR is an international treaty agreed upon among the member states of the Arctic Council in 2011 to coordinate international search-and-rescue and response activities in the Arctic and establish areas of SAR responsibility for each party to the agreement.

Collaboration of Canadian and US Coast Guard icebreakers in multiple missions to explore and map the Arctic Ocean. Over the past several years, the crews of the US icebreaker *Healy* and the Canadian icebreaker *Louis S. St-Laurent* worked together to map the Arctic Ocean.

Russian and US scientific studies of methane gas emissions in the eastern Arctic Ocean. Russian and US scientists joined forces to measure the scale and nature of the methane emissions in the Laptev Sea, the East Siberian Sea, and the Russian part of the Chukchi Sea.

INTERNATIONAL SCIENTIFIC ACCESS

USARC recognizes that scientists need to access and study the Arctic region and its processes without regard to national boundaries. Russia has over half the Arctic land mass and perhaps significant sovereign rights in the Arctic Ocean seabed as well, depending on the outcome of extended continental shelf claims. As such, study of the Russian Arctic is critical to understanding the pan-Arctic system.

Researchers sometimes face challenges in attempting to gain scientific access to Arctic lands and exclusive economic zones of the Arctic nations. Access to the Russian Arctic can be particularly challenging, given political uncertainties, changing rules, and barriers to communication. Problems range from obtaining visas and exporting samples and data, to language barriers and the availability of qualified Russian scientists to assist and/or collaborate with on scientific projects. USARC has encouraged greater scientific access to the Russian Arctic, and is developing a white paper that details challenges, previous successes, best practices, and recommendations that we hope will result in a more cooperative and productive Arctic scientific relationship with Russia.

Arctic Boundary as defined by the Arctic Research and Policy Act. All US and foreign territory north of the Arctic Circle and all US territory north and west of the boundary formed by the Porcupine, Yukon, and Kuskokwim Rivers; all contiguous seas, including the Arctic Ocean and the Beaufort, Bering, and Chukchi Seas; and the Aleutian Chain (the Aleutian Chain is demarcated by the "contiguous zone" limit of 24 nautical miles). *Funding for this map was provided by the National Science Foundation through the Arctic Research Mapping Application and Contract #0520837 to CH2M HILL for the Interagency Arctic Research Policy Committee. Map author: Allison Gaylord, Nuna Technologies, May 27, 2009*

Ancient domicile made of sod and whalebones, Whalebone Alley, Chukotka, Russia..

THE ARCTIC IN NATIONAL OCEAN POLICY

USARC supports the US National Ocean Council's effort to develop a strategic action plan, "Changing Conditions in the Arctic," to improve understanding of the marine environment and to better prepare for the significant changes in the Arctic. The Plan, part of a larger implementation strategy, is a useful mechanism to focus attention and resources on the most important topical areas. USARC has chaired (along with the US Navy) the Arctic strategic planning process. Although still in draft form, the essential elements include:

Improve Arctic environmental response management. Developing new management systems and tools will help protect ecosystems, local communities, and subsistence resources from the effects of accidents associated with resource extraction and marine transportation.

Observe and forecast Arctic sea ice. Observing and predicting the extent, thickness, and age of sea ice will improve daily forecasts and decadal predictions to help support safe, secure, and reliable marine operations and ecosystem stewardship.

Establish a distributed biological observatory. Integrating biological and other data from a network of observatories in the Pacific Arctic will improve understanding of how climate and environmental change affects marine ecosystems and the communities that rely on them.

Improve Arctic communication. Improving marine communication networks and communication architecture will support research, reduce accidents, contribute to safe navigation, and facilitate emergency response, search, and rescue.

Advance Arctic marine mapping and charting. Developing accurate hydrographic surveys and biological/shoreline mapping of US Arctic waters and the Alaskan coastline will improve the Arctic marine transportation system.

Improve coordination on Arctic issues. Clarifying the responsibilities of federal agencies and policy groups will achieve greater governmental efficiency by reducing duplicative efforts and increasing the sharing of resources, knowledge, and information.

INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

Significant progress has been made over the last two to three years in revitalizing the Interagency Arctic Research Policy Committee (IARPC), which was established by the Arctic Research and Policy Act. The increasing importance of the Arctic region among national priorities has certainly been a factor in this development. President Obama's July 22, 2010, memorandum to his science advisor, Dr. John Holdren, assigned to the National Science and Technology Council the responsibility of coordinating activities assigned to IARPC. This action elevated the significance of this committee and improved coordination of interagency efforts through closer contact with the White House Office of Science and Technology Policy and the Office of Management and Budget. In 2011, the principal members of the IARPC member agencies met twice, and approved the themes and outline for a five-year Arctic Research Program Plan, as required by law. This plan, to be released in early 2012, is based on the goals and objectives put forward by USARC, and includes the following seven research initiatives as well as a section on Arctic research infrastructure:

1. Understand factors impacting human health in the Arctic, including infectious and noncommunicable diseases, environmental contamination, and behavioral and mental health disorders.
2. Integrate and continue to deploy a national Arctic observing system and promote international cooperation to create a circumpolar observing system.
3. Understand ecosystem processes, ecosystem services, and climate feedbacks in the Beaufort and Chukchi Seas and the contiguous Arctic Ocean.
4. Understand high-latitude terrestrial ecosystem processes, ecosystem services, and climate feedbacks.
5. Coordinate and improve integrated understanding of Arctic atmospheric processes.
6. Assess vulnerabilities of Arctic communities to impacts of climate change and develop adaptation strategies and tools to maximize sustainability, well-being, and cultural and linguistic heritage.
7. Integrate Arctic regional models.

EMERGING TOPICS

Recognizing the rapid rate of Arctic change, the eight Arctic nations are striving to better understand and more accurately forecast future conditions and to anticipate the challenges that lie ahead. Most of these nations have adopted comprehensive national policy statements to guide their strategic investments and manage their resources. In order to do so, they are investing in scientific research, which provides information to decision makers. While not attempting to be fully comprehensive, USARC highlights several emerging topics of interest.

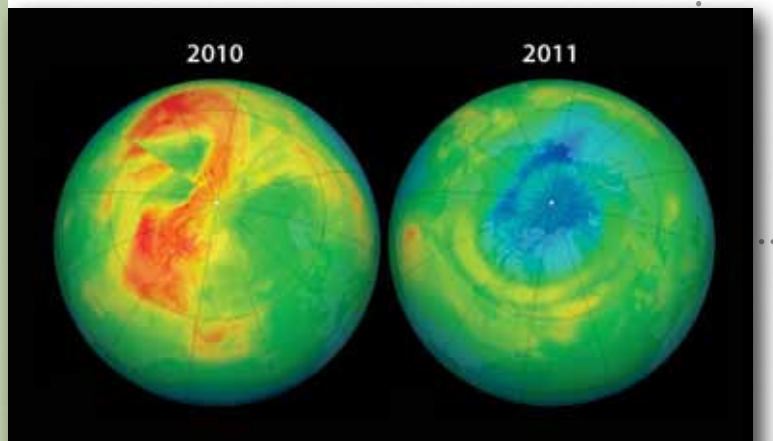
BLACK CARBON

Black carbon changes Earth's surface reflectivity when it settles on snow and ice. *Photo credit: Terry Whitledge*

Many researchers believe that black carbon (or "soot") is a strong contributing factor to climate change in the Arctic and that emissions should be cut to prevent global temperatures from crossing a dangerous threshold. In 2011, China, Germany, Italy, Norway, Russia, and the United States announced a collaborative effort (the Coordinated Investigation of Climate-Cryosphere Interactions) that will track black carbon in order to develop fast and effective strategies to mitigate its impact on climate. Scientists need to better understand the behavior of black carbon in the Arctic to provide accurate measures of how much of it is being deposited in the Arctic, its source, its impact on ecosystems, and its relationship to climate warming.

OZONE LAYER

Although ozone holes are characteristically associated with the Antarctic, a NASA-led study documented an unprecedented depletion of Earth's protective ozone layer above the Arctic in winter 2011. Eighty percent of the ozone was lost in the stratosphere, about 21 km above the ground. The cause was an unusually long spell of cold weather aloft, which enabled chlorine chemicals (from man-made chlorofluorocarbons [CFCs]) to destroy the ozone (see Manney et al., 2011). The Stockholm Convention on Persistent Organic Pollutants has targeted some CFCs for discontinuation, however, it will be decades before they are fully phased out.



Recent observations from satellites and ground stations suggest that atmospheric ozone levels for March in the Arctic were approaching the lowest levels in the modern instrumental era. *Credit: NASA image by Rob Simmon, with data courtesy of Ozone Hole Watch. From http://visibleearth.nasa.gov/view.php?id=49874*

RENEWABLE/GEOTHERMAL ENERGY

Increasing demand for energy resources and rising heating costs have placed greater emphasis on developing renewable energy resources, particularly in remote Arctic environments. Iceland gets one-third of its electric power and 95% of its home heating from steam and hot water that are derived naturally from volcanic rocks. Iceland's biggest energy company, Landsvirkjun, is planning to construct the world's longest underwater electric cable so that the country can sell its vast geothermal and volcanic energy to the rest of Europe. Further research is needed on the potential of renewable technologies in polar regions, such as wind, hydroelectric, microhydro, hydrokinetic, and geothermal power.

Steam rising from the Nesjavellir Geothermal Power Station in Iceland. *Photo credit: Gretar Ívarsson.*

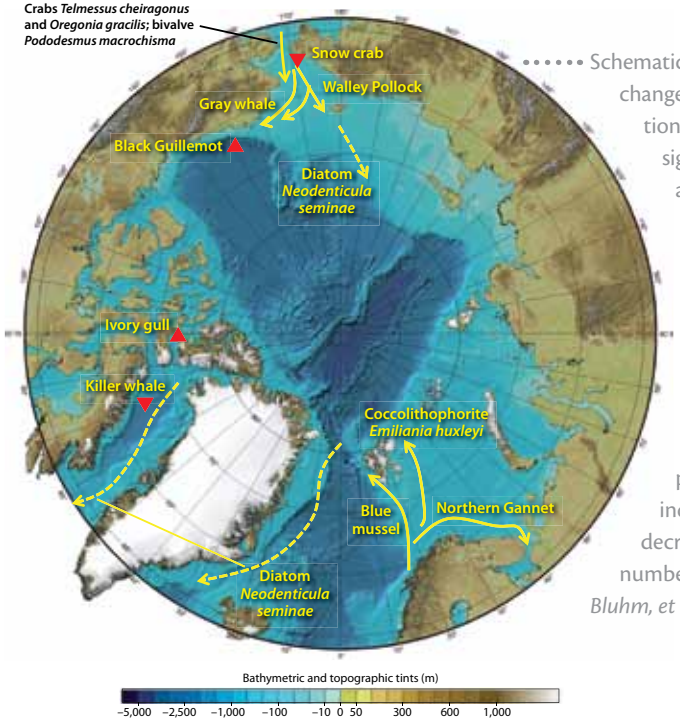
Applied Physics Laboratory-University of Washington team members launch a Seaglider from R/V *Knorr* into Davis Strait in 2008. *Photo credit: Craig Lee.*

UNMANNED AUTONOMOUS VEHICLES (UAVs) AND AUTONOMOUS UNDERWATER VEHICLES (AUVs)

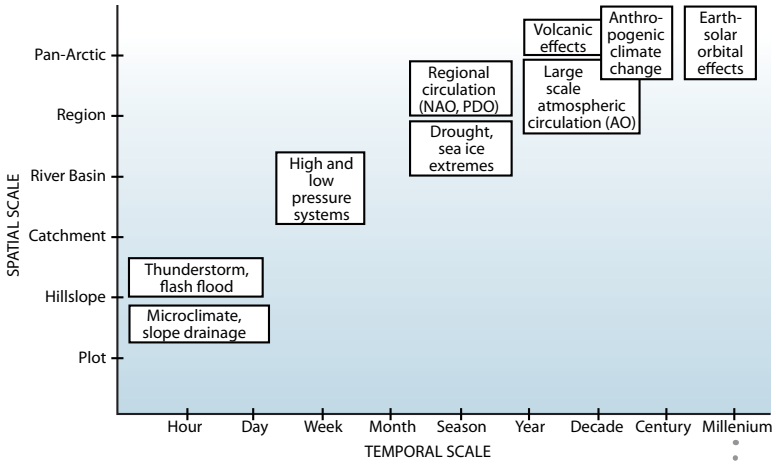
Application of aerial and marine technologies hold great promise in the Arctic given the region's remoteness and the difficult and dangerous operating environment. Specific Arctic applications include monitoring of sea ice, marine mammals, roads, bridges, vehicles, oil and gas pipelines, and power transmission lines. UAVs and AUVs can also aid rescuers who are engaged in disaster management associated with floods, fires, earthquakes, and technological disasters. These unmanned systems may be equipped with aerological sensors to gather information on temperature and humidity, and to measure the density of black carbon in the air as well as other atmospheric parameters. They can also conduct topography and ice reconnaissance and monitor radioactive characteristics of the environment without putting humans in danger. Russia, Canada, the United States, and European countries are increasing use of unmanned systems to conduct research in the Arctic.

ARCTIC FISHERIES

Will commercial fisheries expand further and to a greater degree into the Arctic? University of British Columbia researchers estimated that fisheries catches in the Arctic (Russia, Alaska, Canada) totaled 950,000 tons between 1950 and 2006. This amount is almost 75 times what was reported to the United Nations Food and Agriculture Organization, signaling a far greater fishing pressure in the Arctic region than was previously recognized (Zeller et al., 2011). Some research indicates a trend of fish stocks moving poleward due to climate change. This trend, along with the increasing accessibility of Arctic areas due to seasonal melting of sea ice, results in the potential for immense pressure on the region for future large-scale fisheries. Recognizing the importance of seafood as a source of the world's food, there is a need for additional research on Arctic fish migration, fish stocks, and the health of these stocks to ensure sustainable fisheries.



Schematic of examples of recent change in species distributions or population size or sightings that have been attributed to global climate change. The yellow arrows show the general direction of the species range change and end in the general area of the new occurrence, but are not meant to suggest exact pathways. Red triangles indicate increases (▼) or decreases (▲) in population numbers or sightings. *From Bluhm, et al. (2011)*



Spatial and temporal scales related to weather and climate dynamics. NAO = North Atlantic Oscillation. PDO = Pacific Decadal Oscillation. AO = Arctic Oscillation. *From USARC (2010)*

SCALING ARCTIC RESEARCH

The scientific community has a rich legacy of studies focused on local, place-based research. Although these studies are an important foundation for scientific understanding of the Arctic, there are a growing number of techniques and approaches that enable researchers to observe, simulate, and analyze trends over extremely large spatial scales, including the full pan-Arctic domain. Tangible strategies to bridge scales, and to ensure a consistency of conclusions obtained from studies cast over often disparate temporal and spatial domain scales, will be necessary before a comprehensive understanding of the behavior of the full Arctic system can be achieved. In 2010, USARC released the report *Scaling Studies in Arctic System Science and Policy Support: A Call-to-Research*, which emphasized the importance of this research (USARC, 2010).

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