NOAA's ARCTIC VISION and STRATEGY

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National Oceanic & Atmospheric Administration
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NOAA's Arctic Vision and Strategy is a draft report that has been prepared for external review. Once feedback is obtained from partners and stakeholders who will benefit from these enhanced and coordinated efforts in the Arctic region, this report will be finalized.

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NOAA's Arctic Vision & Strategy

Executive Summary

"For centuries annual sea ice has protected the Arctic and its inhabitants. Now the Arctic, both on land and sea, is being transformed by significant warming. The melting of sea ice in the Arctic Ocean is happening at a faster pace than we had predicted, and an ice-diminished Arctic Ocean is creating many new opportunities. These opportunities must be pursued in ways that will ensure our precious ecosystems and Arctic communities remain healthy and resilient, now and for future generations."

The Honorable Dr. Jane Lubchenco,
NOAA Administrator and Under Secretary of
Commerce for Oceans and Atmosphere

The Arctic (Figure 1) has profound significance for climate and functioning of ecosystems around the globe. The region is particularly vulnerable and prone to rapid change. Increasing air and ocean temperatures, thawing permafrost, loss of sea ice, and shifts in ecosystems are evidence of widespread and dramatic ongoing change. As a result, critical environmental, economic, and national security issues are emerging, many of which have significant impacts for human lives, livelihoods, and coastal communities. Though NOAA has numerous and diverse capabilities that support these emerging issues, a strategic approach that leverages NOAA's existing priorities and strengths, as well as those of our national and international partners, is needed. This document provides a high-level framework and six strategic goals to address NOAA's highest priorities in the region. It is based upon assumptions that the region will: 1) continue to experience dramatic change, 2) become more accessible to human activities, and 3) be a focus of increasing global strategic interest.

NOAA envisions an Arctic where decisions and actions related to conservation, management, and use are based on sound science and support healthy, productive, and resilient communities and ecosystems. The agency seeks a future where the global implications of Arctic change are better understood and predicted.

NOAA will focus its efforts on the following six priority goals needed to realize this vision:

1) Forecast Sea Ice
2) Strengthen Foundational Science to Understand and Detect Arctic Climate and Ecosystem Changes
3) Improve Weather and Water Forecasts and Warnings
4) Enhance International and National Partnerships
5) Improve Stewardship and Management of Ocean and Coastal Resources in the Arctic
6) Advance Resilient and Healthy Arctic Communities and Economies

These goals were selected because they represent areas where NOAA can address urgent and timely issues that meet two key criteria: providing the information, knowledge, and policies to meet NOAA mandates and stewardship responsibilities, and providing the information, knowledge, and services to enable others to live and operate safely in the Arctic. Each goal also fulfills international goals and establishes, enhances, or leverages partnerships with other Arctic nations, international organizations, government agencies, and non-governmental organizations, academia, and local communities. The goals are also geared towards generating large societal benefits relative to the resources required and strengthening NOAA's engagement, politically, scientifically, internationally, and publicly.

NOAA will next develop and execute a five-year Arctic Action Plan to achieve these goals. Development and execution of the plan will require coordination across all NOAA Line and Staff Offices and collaboration with local, regional, federal, non-governmental, and academic partners. As a starting point, NOAA will establish a single point of contact within NOAA Senior Executive Leadership who will be accountable for achieving the Arctic goals. The Arctic Action Plan will also include an engagement strategy for reaching internal and external employees, partners, and stakeholders, as well as a detailed budget strategy. NOAA is committed to enhancing its current involvement in research and management programs in the Arctic, and anticipates an initial investment of $10 million towards the implementation of this strategy, recognizing that additional funds will be needed to achieve the goals.

Figure 1. The Arctic: As used in this document, the term "Arctic" means all United States and foreign territory north of the Arctic Circle and all United States 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. For purposes of this document only, this map illustrates the Arctic as defined under the Arctic Research and Policy Act and does not represent or reflect the position of NOAA with respect to the international boundaries and limits depicted therein. Map courtesy of the Interagency Arctic Research Policy Committee.

Introduction

Evidence of a Changing Arctic

There is now widespread and dramatic evidence of overall change in the Arctic region. Many of these observations are highlighted in the annual NOAA Arctic Report Card (www.arctic.noaa.gov):

- **Atmosphere** – Recent Arctic temperature increases are more than double those found at more southerly latitudes. The Arctic's 2008 annual mean air temperature over land was the fourth warmest on record, which continues a long-term upward trend.
- **Sea Ice** – Four of the last five years represent the lowest sea ice extents on record, with open water extending later into the fall prior to freeze-up. Thick multi-year sea ice has decreased 35 percent in the last five years.
- **Ocean** – From the Aleutian Islands to Barrow, Alaska, ocean ecosystems are shifting due to a combination of Arctic warming, large natural variability, and sensitivity to changing sea ice conditions.

These changes in Arctic climate have local to global implications. The Polar Regions, though physically remote from the population centers of the globe, have profound significance for the planet as a thermostat to stabilize the Earth's climate. They act not only as regulators of global temperature, but also as barometers of change. National security concerns are increasing as reductions in sea ice and other climate-induced changes bring increased opportunities for economic development and increased access to Arctic resources. These economic drivers, in turn, can further threaten ecosystems and Arctic inhabitants already impacted by the rapidly changing climate. The risks to national security and sound Arctic stewardship are further intensified because the science that underpins many of the decision-making processes and support services is largely inadequate.

International and domestic interest in the Arctic is increasing in concert with broader discussions regarding climate change, national security, and stewardship. Some examples include:

- The U.S. Government's issuance in January 2009 of a National Arctic Policy (National Security Presidential Directive (NSPD 66)/ Homeland Security Presidential Directive (HSPD 25),
- The November 2009 issuance of the Navy Arctic Road Map, developed by the Navy Task Force Climate Change,
- The Secretary of Commerce's February 2009 approval of the North Pacific Fishery Management Council's Arctic Fishery Management Plan, which prohibits expansion of commercial fishing in U.S. federal waters in the Beaufort and Chukchi Seas,
- Recent decisions on listings of Arctic marine mammals under the Endangered Species Act and Marine Mammal Protection Act,
- Establishment of the Extended Continental Shelf Interagency Task Force to support a potential claim as allowed under United Nations Convention on the Law of the Sea (2007),
- The State of Alaska's move to take immediate actions and plan longer-term research and operations addressing a broad range of impacts (Governor's Climate Change Sub-Cabinet 2007, Joint Alaska Climate Impact Assessment Commission 2007), and
- The Interagency Ocean Policy Task Force's recognition of the Arctic as an area of special emphasis in its interim report (see sidebar).

The *Interim Report of the Interagency Ocean Policy Task Force* (September 2009) identified "Changing Conditions in the Arctic" as an area of special emphasis, calling for the National Ocean Policy to "address environmental stewardship needs in the Arctic Ocean and adjacent coastal areas in the face of climate-induced and other environmental changes." The interim report calls for "better ways to conserve, protect, and sustainably manage Arctic coastal and ocean resources… new collaborations and partnerships to better monitor and assess environmental conditions… improvement of the scientific understanding of the Arctic system and how it is changing in response to climate-induced and other changes." NOAA's strategic Arctic goals were developed to directly support the recommendations identified by the Task Force.

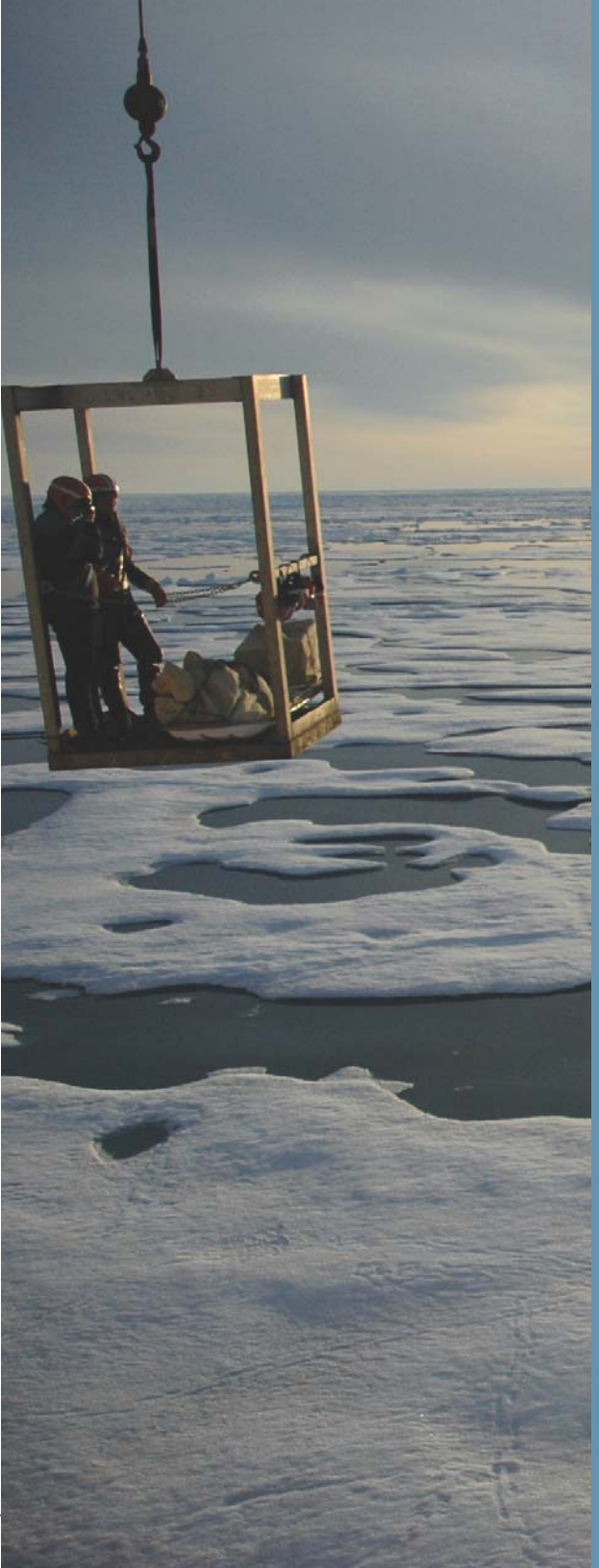
NOAA's Evolving Role in the Arctic:
Providing Critical Science, Services, & Stewardship to the Arctic & Partners

No single region better demonstrates the complex interdependence of communities and changing ecosystem conditions than the Arctic. The breadth and complexity of the cultural, societal, economic, and environmental impacts requires a concerted, systematic, and rapid effort with partners from local to international levels. NOAA provides vital Arctic science, services, and stewardship, including information and products that form a critical foundation for science and management of our trust resources in Arctic oceans and on the coasts—products that are essential for other agencies to succeed in their Arctic missions. However, achieving the Nation's Arctic goals requires strong integrated partnerships at all levels of governance. NOAA is building and continues to advance partnerships with several international, federal, state, and local partners and stakeholders focused on Arctic issues. Interagency and international cooperation should be an element of most of NOAA's Arctic activities and should be included in relevant project plans. Some elements of collaboration have general applications and need to be organized and conducted for the benefit of NOAA as a whole. In this category are participation in interagency working groups such as the Interagency Arctic Research Policy Committee, implementation and development of international agreements, and participation in policy-relevant activities focused on the Arctic.

Given our science, service, and stewardship responsibilities to Arctic residents and to the Nation, NOAA must engage its diverse and unique capabilities to rapidly address the emerging environmental, social, economic, and national security issues in the Arctic. NOAA's scientific capabilities can be deployed to increase our understanding of climate and assess key environmental trends; to predict the ecosystem response to those trends; and to offer the technical expertise needed to develop policy options and planning and management strategies for mitigation and adaptation to the environmental challenges in the Arctic region. NOAA's service capabilities are needed to support safety and security needs for fishing, marine mammal protection, transportation, energy, infrastructure, and mineral exploration in the unique Arctic environment. NOAA's legal and regulatory authorities and operational and international cooperation requirements will set the framework for delivery of our science, services, and stewardship.

Strategic Alignment of NOAA's Priorities

NOAA's Annual Guidance Memorandum, signed August 5, 2009, identified the need to "strengthen Arctic science and service" as one of the agency's five strategic priorities. The other four priorities include: 1) enhance NOAA's climate services and support the establishment of a National Climate Service, 2) support Coastal and Marine Spatial Planning, 3) ensure sustainability of marine fisheries, and 4) sustain satellite-based Earth observations. This Arctic strategy integrates the enhanced capacity provided by implementing NOAA's strategic priorities and positions NOAA to move forward in these areas. Concurrently, it aligns NOAA's Arctic goals to directly support priorities of our federal partners.



NOAA's Arctic Vision

NOAA envisions an Arctic where:

- Conservation, management, and use are based on sound science and support healthy, productive, and resilient communities and ecosystems; and
- The global implications of Arctic change are better understood and predicted.

Guiding Principles

The U.S. and its partners will greatly benefit from enhanced and better coordinated NOAA efforts in the Arctic region. Though NOAA's scientific interests in the Arctic are broad, this strategic framework establishes a limited set of guiding principles that emerged from the strategic planning process. NOAA Arctic activities in the next one to five years will:

1) Provide outcomes critical for other agencies to succeed in fulfilling their responsibilities and support the implementation of the National Ocean Policy,
2) Strive to better understand the linkages between oceans and climate,
3) Advance the implementation of ecosystem-based management and Coastal and Marine Spatial Planning,
4) Concentrate action in the Bering, Chukchi, and Beaufort areas, but be global in scope,
5) Enable, inspire, and engage our partners and stakeholders, both domestic and international,
6) Incorporate the value of traditional and local knowledge,
7) Integrate a coordinated education and outreach program that encompasses formal and informal education and the general public,
8) Incorporate new developments in science and technology, and
9) Anticipate, respond, and adapt to new and emerging issues of importance.

Arctic Goals & Strategy

NOAA's six Arctic goals are both integrated and crosscutting, and are designed to achieve NOAA's Arctic vision. The goals, and initial priorities described within them, were developed based on a set of criteria vetted across NOAA's Line Offices, Staff Offices, and Goal Teams; and derived from the Draft NOAA Strategic Plan for the Arctic. They are intended to support the goals and priorities of our federal and intergovernmental partners and stakeholders.

The goals first provide a foundation for improved research and understanding of the scientific underpinnings, climate changes, and dynamic feedback loops that are needed to support effective stewardship and address national security concerns. Increased scientific understanding and improved service delivery of predictions and forecasts, in concert with increased cooperation and collaboration with national and international partners, will result in more effective management of coastal and ocean resources and resilient and vibrant Arctic communities and economies (Figure 2).

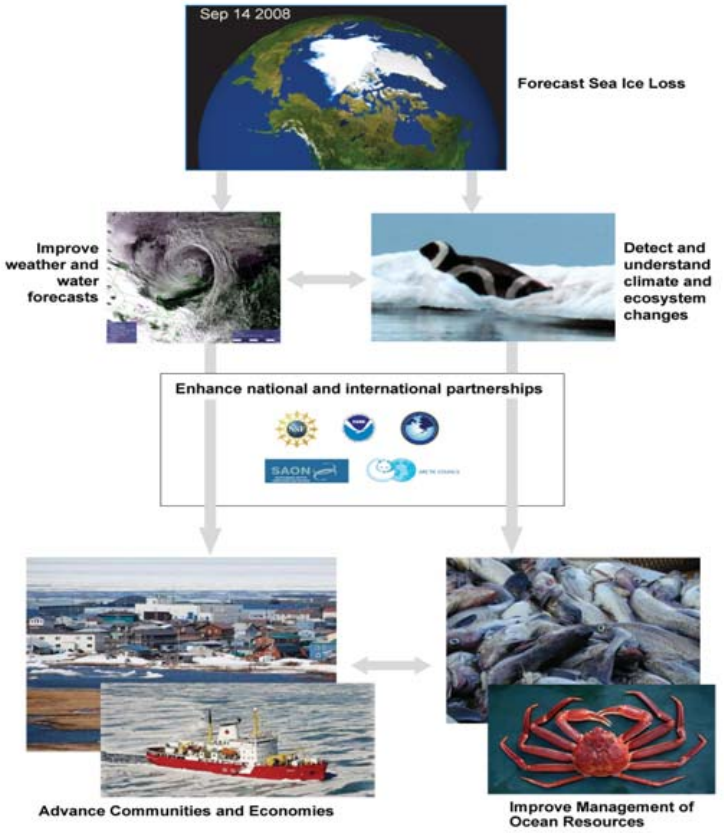


Figure 2. NOAA's Strategic Arctic Goals. This diagram illustrates the alignment and integration of NOAA's Arctic goals.

Goal 1: Forecast Sea Ice

Goal Statement – Accurate, quantitative, daily forecasts to decadal predictions of sea ice are provided to support safe operations and ecosystem stewardship.

Importance: Continued rapid loss of sea ice will be a major driver of large changes across the Arctic (Figure 3). The loss of sea ice affects marine access, regional weather, ecosystem changes, and coastal communities. Food webs are expected to dramatically shift between benthic-focused food webs and pelagic webs as ice cover diminishes. The understanding of ice as a habitat also has implications for oil spill response and damage assessment. As the Arctic Ocean becomes seasonally passable and tourism, oil and gas exploration, and shipping increase, floating sea ice will present a major threat to maritime safety and increase the potential for oil spills in the region.

Projections of a nearly sea ice-free summer by the end of the century, made just three years ago, have been revised recently and now indicate that ice-free summers may occur before mid-century (Figure 4). Arctic change is accelerated by the unique physical properties associated with sea ice loss, which acts to accelerate warming of the Arctic, driven by increasing greenhouse gases in the global atmosphere. Reduction in summer sea ice diminishes reflection

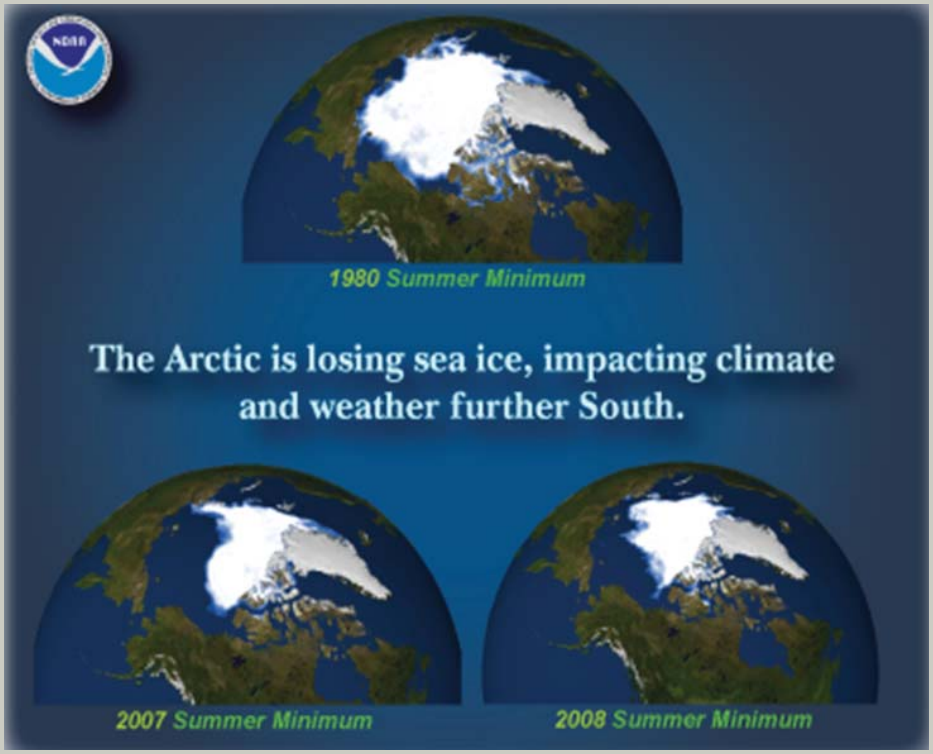


Figure 3. Arctic summer sea-ice cover has decreased over 35 percent over the last 30 years, and the amount of stable long-term multi-year sea ice has decreased by the same amount.

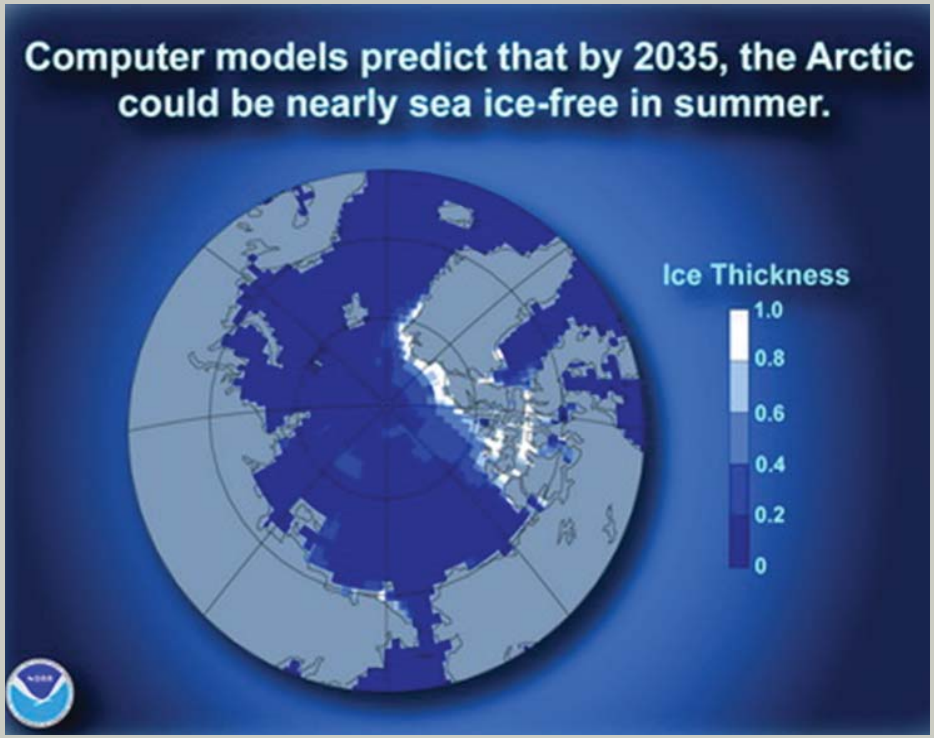


Figure 4. Model projections of sea ice thickness when the Arctic is nearly ice free, in September, within 30 years. Units for sea ice thickness are meters. Figure from Wang and Overland (2009).

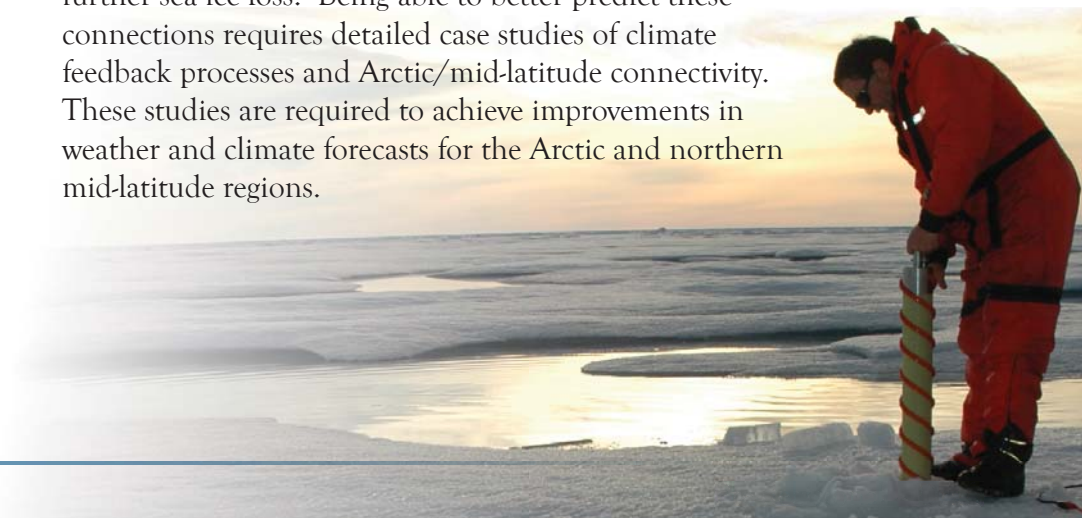
of solar energy and creates additional ocean heat storage in newly formed sea ice-free areas. Further, the additional heat stored in the ocean during summer is given back to the atmosphere the following autumn, causing changes in normal patterns of weather and climate variability with global consequences. The ability to quantitatively forecast Arctic sea ice over varied time scales requires regular observation of Arctic atmospheric and ocean states, circulation, and sea ice characteristics; understanding of the interactions among clouds, radiation, and aerosols; and development of coupled atmosphere-ice-ocean models.

NOAA's current activities: NOAA is currently conducting sea ice analysis and forecasts, evaluation of sea ice projections in Intergovernmental Panel on Climate Change (IPCC) climate models, conducting and analyzing satellite and airborne observations of sea ice freeboard or thickness, improving satellite image analyses, and contributions toward the Arctic buoy program.

Five-year strategy: *Improving daily to weekly sea ice models and forecasts and new seasonal prediction* services will fill a critical gap in marine weather and climate services that will benefit community activities, support the management of protected marine resources, and improve safe operation and navigation through these waters as marine transportation and industry use expands. There is currently no up-to-date sea ice atlas for Alaskan waters, necessary for operational planning. Native communities have noted that not only is the extent and timing of sea ice changing, but its character (floe size, thickness, ridging) is also changing. *Forecast improvements* can be made by enhancing and integrating different types of observations of the atmosphere, sea ice, and ocean, including use of local knowledge, classifying sea ice characteristics, and directly combining data-assimilating sea ice models and climatological information with forecast models. *Seasonal predictions*, particularly the period of open water that defines an extended operations and shipping season, are increasingly in demand. An exploratory Sea Ice Outlook, led by NOAA and the National Science Foundation, in coordination with 20 international contributors, suggests that it is possible to develop seasonal predictions constrained by late spring sea ice conditions and driven by projected weather conditions.

Multi-decadal sea ice projections are required for infrastructure planning, ecosystem stewardship under rapidly changing conditions, and projection of global climate impacts forced by changes first occurring in the Arctic. The most important requirement is to reduce the uncertainty in climate projections forced by anthropogenic gas increases relative to the large natural variability in the Arctic. Current multi-decadal sea ice projections are based on a judicious evaluation of the 24 climate models provided through the IPCC Fourth Assessment Report. NOAA must anticipate a major evaluation of the new model results for application in the Arctic using information that will soon be made available by the IPCC Fifth Assessment Report. Further, special studies using climate and Earth system models need to target Arctic processes. Global models are necessary but not sufficient for regional applications, meaning that development of regional models is also needed.

Retrospective and prospective studies of the linkages between changes in Arctic sea ice and hemispheric weather and climate will lead to new understanding of how these changes affect larger areas. The cold conditions in eastern Asia and the eastern U.S. during winter 2009-2010 highlight the importance of shifts in hemispheric climate patterns to regional weather events, specifically the combination of the two major northern hemisphere patterns of variability—El Nino and the Arctic wind vortex, also known as the Arctic Oscillation. Recent studies support an increased connection between shifts in Arctic climate and increased climate variability in mid-latitudes. Such Arctic/mid-latitude connections can be expected to strengthen over the next decades as the planet experiences further sea ice loss. Being able to better predict these connections requires detailed case studies of climate feedback processes and Arctic/mid-latitude connectivity. These studies are required to achieve improvements in weather and climate forecasts for the Arctic and northern mid-latitude regions.



Goal 2: Strengthen Foundational Science to Understand & Detect Arctic Climate & Ecosystem Changes

Goal Statement – Improved baseline observations and understanding of Arctic climate and ecosystems reduces the uncertainty in assessing and predicting impacts caused by a changing Arctic.

Importance: While sea ice extent can be tracked by satellite sensors from year to year, there is much greater uncertainty in tracking the types and magnitudes of social and ecological impacts caused by Arctic climate changes and economic development. The Arctic will continue to provide short-term surprises as ecosystems move toward new and generally unknown states. Previous data and understanding can provide only minor guidance. For example, the response of marine primary production and the impacts on higher levels of the food chain from additional loss of sea ice are basically unknown. Recent data show that a simple conceptual model of a uniform northward shift of ecosystems as the Arctic warms is too simplistic. Other examples of changes in the Arctic are the warming of permafrost, increased coastal erosion, sea level changes, shifts in land and marine transportation patterns, the recent decrease in the pollock stock of the Bering Sea, and changes in land-based human subsistence resources. Monitoring and understanding climate change in the Arctic is important for other socioeconomic applications as well, including sea level and infrastructure protection, transportation, and community resilience. While the International Polar Year initiated a single intensive observational period in the Arctic, most NOAA missions require an enhanced effort to achieve sustained observations.

NOAA's current activities: NOAA has a variety of ongoing and/or recent Arctic-focused climate and ecosystem projects, but these projects are inadequate to address existing needs. This goal provides necessary baseline ecosystem-level information and identifies four priorities to reduce uncertainties in NOAA provided information: ecosystem responses to sea ice loss, necessary additional climate observations over the Arctic, basic water-level information, and accelerated methane release.

High Arctic Biodiversity

In June/July 2005, NOAA organized an international team of 45 scientists from the United States, Canada, Japan, China, and Russia in a collaborative effort to explore the frigid depths of the Canada Basin, one of the deepest parts of the Arctic Ocean. The expedition focused on assessing the diversity of life and the environment in all three major realms of the Arctic—the sea ice, the water column, and the sea floor. For one month, 35 members of the science party and 75 U.S. Coast Guard crewmembers worked together on board the U.S. Coast Guard Cutter Healy to conduct round-the-clock science operations. Scientists examined the hidden world of life in these extreme conditions with the aid of divers, photographic platforms, and a remotely operated vehicle specially designed to operate under ice and at great depth. More traditional techniques like ice coring, plankton nets, and bottom trawls supported these efforts. Expedition results form much of the basis of the January 2010 special issue of the journal Deep Sea Research.

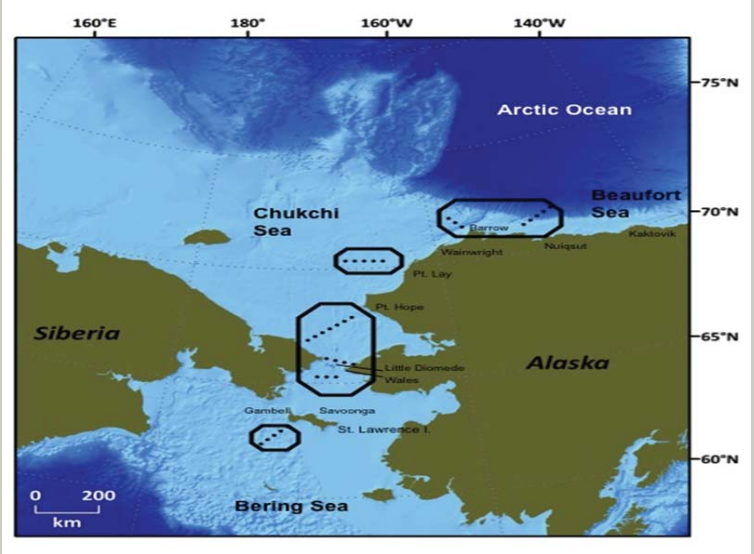


Figure 5. Four possible regional locations of Distributed Biological Observatory transect lines and stations for standard hydrological and biological measurements in the Pacific Arctic sector, including acoustics for marine mammal detection. These stations would include Canadian, Chinese, Japanese, Korean, Russian, and U.S. research vessels, coordinated through the international Pacific Arctic Group, and land-based research from coastal communities using helicopters, small ships, and long-term moorings.

Five-year strategy: An enhanced and integrated set of environmental observations is required to track the new trajectory of Arctic change across land, in the atmosphere, and in the ocean, including physical indicators, biological responses, and social and economic impacts. Rapid organization, interpretation, and dissemination of this information in near real-time is also a necessity, placing it in context with past conditions, natural variability, and model studies. Increased knowledge gained through this process, combined with model forecasts, will further enhance NOAA's capability to project and respond to future change. These enhancements would form the basis for a NOAA Arctic Change Detection System.

Such a system also includes a *marine Distributed Biological Observatory* (DBO) in the U.S. Arctic for consistent monitoring of biophysical responses in four pivotal oceanographic areas along a north-south latitudinal gradient (Figure 5). Each area exhibits high biological productivity, biodiversity, and gradients in ecosystem properties and direct linkages to subsistence-based coastal communities. All areas are projected to experience increased commercial use with the loss of sea ice. The Bering Strait region represents potential conflicts between commercial shipping and resource exploration, subsistence hunting, and management of biological resources. As sea ice retreats, the DBO will track the rate of ecosystem change and sample currently unknown impacts. The DBO was the central recommendation from a NOAA-sponsored workshop in May 2009 on the biological impacts of loss of sea ice. The DBO integrates biological and physical sampling, including both mooring and dedicated repeat ship occupations using a collaborative international network of logistical support. Efforts such as the Russian-American Long-term Census of the Arctic (RUSALCA) should be expanded to improve the exchange of information about near and far-field changes in the Arctic.

The science community was surprised by the rate of loss of summer Arctic sea ice from 2007 through 2009, as well as the magnitude of its impact on the regional and potentially hemispheric ocean and atmosphere. Current observing systems are inadequate to track and understand such changes. New in-situ, airborne, and satellite observing technologies are needed to fill gaps in meteorological and oceanographic fields. While satellites provide vertical profiles of air temperatures, they are less reliable in the lower layers of the Arctic atmosphere. For example, three areas of enhancement can improve analysis products, which in turn are the basis for understanding current Arctic change and improving forecasts. First, *in situ atmospheric profiles* across the Arctic Ocean are needed to stabilize the satellite data in reanalysis products and initial conditions. Second, *increase the number of drifting buoys and long-term moorings*. It is imperative to know upper ocean temperatures at the beginning of the summer melt and fall sea-ice freeze-up seasons to project future sea ice conditions. Long-term biophysical moorings at key locations in the Arctic are essential for tracking influx of heat to the Arctic. Third, NOAA should work to *maintain real-time access to NOAA and other national and international satellites* to fill critical gaps in observations, including the European CryoSat, the Canadian RadarSat, and Indian satellites. In addition, NOAA needs to continue and enhance research on integration of satellite data into regional products and scientific analyses to make the best use of these expensive systems.

Water-level information and forecasts are necessary for coastal community hazard resilience. NOAA is limited in its ability to meet this goal due to insufficient resources and outdated historical data sets. Increased sea-ice-free areas in fall allow a completely new wave and storm surge regime to develop. Deficiencies in information include accurate elevations based on new and updated gravity data and a geodetic framework tied to a new Arctic tide gauge network. Traditional tide gauges have difficulties in freezing and sea ice areas, but these difficulties can be overcome. More effort is needed to conduct circum-Arctic sea level analyses using all in situ and satellite data available from national and international sources.

Recent research has shown that methane is being released from thawing permafrost on land and in shallow coastal seas. The amount of methane potentially available for release is very large, but there are no data sets that allow an estimate of the current rate of methane release throughout the Arctic and how this rate may be changing over time. *New synoptic observations over large regions of the Arctic, coupled with modeling and process research* are needed to determine if methane release from Arctic permafrost will be another positive, and powerful, feedback to the global climate system.

Goal 3: Improve Weather and Water Forecasts and Warnings

Goal Statement – Advanced, accurate forecasts and warnings are provided to ensure society can prepare for and respond appropriately to weather-related routine and extreme events.

Importance: Major stakeholders and partners, including the U.S. Coast Guard and the State of Alaska Division of Homeland Security and Emergency Management, require more useful weather and water information for planning and decision making to protect lives, property, and manage the region's many resources. Arctic weather also plays an important role in global weather; understanding this role is essential to improving global forecasts as well.

Arctic populations rely on aviation and marine systems for transportation and access to goods and services. A 2006 study by the National Institute of Occupational Safety and Health reported that the accident rate for commercial pilots in Alaska was five times higher than the national average. Additionally, Alaska's $4 billion fishing industry is one of the most dangerous in the Nation. Improvements in weather and water information will lead to increased safety and efficiency in these important sectors. Environmental observations and studies supporting weather and ice forecasts are highly limited in both geographic scope and frequency. For example, there is inadequate real-time meteorological data in U.S. Arctic waters to support accurate forecasting of fall sea storms, which threatens marine transportation, offshore oil and gas operations, and the Arctic coastal communities. In 2008, the U.S. lost access to satellite data that detected sea ice, river ice, and ocean surface winds. This information was critical in forecasting and warning of events such as rapid sea ice formation, river ice jams, and hurricane force winds.

Climate change is also affecting the Arctic environment, as evidenced by changing precipitation patterns, later freezing and earlier thawing of snow and ice, and changing sea level. People living along rivers and inland waterways face increasing disruption due to more frequent and devastating flooding. Still others face drought, straining municipal water supplies and putting the sustainability of entire businesses and communities at risk. Alaska's strategic location and waterways present both challenges and opportunities in terms of marine transportation, homeland security, and economic development.

NOAA's current activities: NOAA provides forecasts, warnings, and information for surface, marine, and aviation weather interests, with emphasis, when possible, on high-impact events such as extra-tropical storms and polar lows, storm surge and other coastal hazards such as tsunamis, heavy precipitation, floods, droughts, volcanic ash, and space weather. Services are delivered through a number of media from Internet to high frequency radio broadcasts.

Updating Alaska's Precipitation Frequency Estimates

NOAA is using a team of experts, and a set of global best practices, to update the 40-year-old Precipitation Frequency Estimates (PFE) for the State of Alaska. The PFE data are commonly used to reduce the risk of runoff-related loss of life and property and to prevent pollution. The data provide rainfall-related criteria used extensively by the engineering and environmental communities for the design of structures such as sewers and drainage systems, for environmental studies and design, and for sediment control. The criteria are used by the Federal Emergency Management Agency to update National Flood Insurance rate maps and by the Environmental Protection Agency's National Pollution Discharge Elimination System Program to regulate pollution control in streams. Results from climate change investigations in Alaska suggest the seasonality, amount, and type of precipitation are changing in many locations. NOAA uses these criteria for comparison during rainstorms that could produce flash flooding. NOAA expects to complete this task in September 2010.

Five-year strategy: Predictive services are generally not of the same accuracy, resolution (temporal and spatial), and reliability as similar products in mid-latitude regions. Forecasts of weather and water conditions lack detail beyond 60-72 hours and lose reliability considerably thereafter. A primary reason for this discrepancy is the relative coarseness of the observational fields to support meteorological and oceanographic modeling. New in-situ, airborne, and satellite observing technologies are needed to fill gaps in meteorological and oceanographic datasets, with then intent of improving both local and global weather forecasts. NOAA must expand services by addressing greater needs for observations, modeling, and forecasts while incorporating new techniques for ensuring this information leads to the best possible decisions and associated response. Science and technology will need to be leveraged based on advanced numerical models, including ranges of uncertainty. Improved Earth system models will include coupling of atmosphere, ocean, land and ice at local, regional, and global scales.

NOAA *must improve Arctic marine weather, sea ice, and storm surge forecast services* by addressing greater needs for observations, modeling, and forecasts while incorporating new techniques for ensuring this information leads to the best possible decisions and associated response. Improved forecast services will ensure the safety and security of marine transportation, mineral (oil and gas) exploration, and tourism activities, and *protect northern and western Alaska coastal communities from storm surge, inundation, and erosion hazards*. The operational marine weather service infrastructure in the National Weather Service will enable NOAA to provide regular forecasts and on-demand support for the Arctic Ocean to meet the NOAA mandate to protect life and property as well as enhance the economy and fulfill NOAA's obligations under international treaties.

Goal 4: Enhance International & National Partnerships

Goal Statement – National and international partners are engaged to promote cooperation and sharing of data, observational platforms, and intellectual resources to enable more rapid and comprehensive attainment of NOAA's Arctic science and ecosystem-based management goals.

Importance: The Arctic is comprised of the northern regions of eight countries and adjacent marine areas. As the Arctic climate continues its warming trend, sea ice in the Arctic continues to recede and freshwater entering the Arctic from rivers is increasing. These changes in the Arctic environment are likely to impact the globe, making it urgent that NOAA builds on its abilities to observe, understand, predict, and respond to these Arctic changes. Both national and international partnerships are needed to help fill data gaps; improve analyses, models, and forecasts; and apply ecosystem-based management.

NOAA's current activities: NOAA currently cooperates with other governments through broad Science and Technology (S&T) Agreements and NOAA-specific agreements, as well as through international institutions and organizations. S&T Agreements and Memorandums of Understanding with Russia, Norway, Sweden, Finland, Canada, and Denmark support NOAA's work with these Arctic countries in areas such as weather, climate, aviation, and marine observations, forecasts, and services; ecosystem management; fisheries; and ice monitoring. . These agreements allow us to cooperate on sea ice forecasts, as well as better understand and predict changes in the Earth's environment by observing the Arctic atmosphere and cryosphere from manned observatories in places such as Summit, Greenland and Tiksi, Russia.

NOAA is also an active participant in numerous international organizations such as the World Meteorological Organization, International Maritime Organization, International Hydrographic Organization,

Enhance International and National Partnerships: Arctic Council

NOAA has played a key role in major products of the Arctic Council and is now providing leadership on future products. By enhancing and institutionalizing its support for the Council, NOAA can exert stronger leadership on the Council's science-based activities and offer greater support to U.S. Arctic policy goals. The Arctic Council is the only intergovernmental group that focuses solely on the Arctic. By engaging through the Council with the other seven Arctic countries, permanent participants, and the several observer countries, the goals outlined in this plan can be more readily achieved.

and the Arctic Council. NOAA serves in leadership roles in two Arctic Council working groups (Protection of the Arctic Marine Environment and Arctic Monitoring and Assessment Program), while providing expertise to others. Current Arctic Council work includes assessing the effects of pollutants in the Arctic, reviewing the comprehensiveness of governance mechanisms for the Arctic, and understanding the status of biodiversity in Arctic ecosystems.

Five-year strategy: Modeling climate change at the regional and global levels is an enormous task, best accomplished by *sharing data at multiple levels* – with universities and researchers, with other Arctic countries, and with non-Arctic countries possessing satellite and observation capabilities in the Arctic. NOAA must continue and expand these relationships through partnerships and formal bilateral arrangements. Understanding and predicting how ice cover and consistency will change in the Arctic will necessitate cooperation. NOAA should increase both its interagency and international partnerships to increase the accuracy, timeliness, and coverage of its sea ice forecasts – ensuring seamless transitions across jurisdictional boundaries and enhancing safe navigation.

With reduced sea ice comes opportunities for trans-Arctic shipping, increased oil and gas exploration and extraction, tourism, and other uses that increase regional vessel traffic, as well as associated threats such as oil spills, transport of invasive species, and collisions with species or small craft. NOAA, working through the interagency process, should *expand Arctic protection mechanisms* at the international level (e.g., the International Maritime Organization), including developing a mandatory Polar Code, Particularly Sensitive Sea Areas, vessel routing measures and sea lanes (in particular for choke points such as the Bering Strait). NOAA also should increase hydrographic charting and cooperation in the region (e.g., via the International Hydrographic Organization).

These changes in climate and sea ice are also driving changes in marine ecosystems, species abundance, and composition, in ways not yet fully understood. NOAA should *provide leadership and additional resources to support Arctic governance and science organizations*. Specifically, NOAA should support the Arctic Council and its working groups, which monitor and assess biodiversity, climate, and the health of humans and ecosystems and contribute to international approaches to ecosystem and protected area management, and management of shipping. The International Arctic Science Committee and the Pacific Arctic Group identify science priorities across countries and build trusted and lasting relationships among scientists.

The Sustaining Arctic Observing Networks (SAON) activity co-sponsored by the Arctic Council and the International Arctic Science Committee aims to become an effective mechanism for sharing data among the Arctic countries and for identifying critical observing systems that should be maintained for long periods. The success of SAON will make achievement of NOAA Arctic science goals more likely and NOAA should *support development of an effective international SAON process*.

Continued coordination across federal entities, such as that provided by the Interagency Arctic Research Policy Committee, will be needed to implement overarching U.S. Arctic Policy goals, particularly those identified by the U.S. Arctic Policy (NSPD 66/HSPD 25) and the Interagency Ocean Policy Task Force. Scientific research and discovery will proceed in collaboration with the National Science Foundation, and other federal, state and local partners, academia, non-governmental organizations, and private entities. Due to the interconnected nature of Arctic ecosystems, the U.S. will also need to continue to improve collaboration and engagement with other Arctic nations through international mechanisms, such as the Arctic Council and our bilateral relationships, to better understand, observe, research, and manage Arctic resources.

Goal 5: Improve Stewardship & Management of Ocean & Coastal Resources in the Arctic

Goal Statement – Conservation, management, and use of ocean and coastal resources are based on sound science and support healthy, productive, and resilient ecosystems and communities.

Importance: As the Arctic Ocean becomes more accessible with the retreat of sea ice in summer months, cascading consequences must be anticipated. Biophysical and chemical changes in the ocean, combined with increasing human uses will impact the Bering, Chukchi, and Beaufort Seas. Currently commercial harvest of groundfish, shellfish, salmon and other resources, primarily in the Bering Sea, constitute almost 50 percent of marine fish landings in the U.S. Further, these same resources, plus various species of marine mammals, seabirds, and other marine life are critical to the maintenance of the subsistence lifestyle of over 40,000 indigenous people who inhabit small towns and villages on Alaska's Arctic coastline. It is therefore critical to both the U.S. economy and the coastal inhabitants of the U.S. Arctic that NOAA, in cooperation with Federal, state, and local partners and stakeholders, expand its capabilities to understand and predict the full spectrum of changes associated with climate change in the Arctic, with the intended outcome of improving the stewardship of Arctic marine resources.

NOAA's current activities: NOAA currently conducts population assessments and ecological process studies to meet its living marine resource management mandates. However, data in the Arctic are insufficient to make adequate assessments, and it is currently beyond the scope of existing ecosystem models to provide reliable indications of how loss of sea ice, increased ocean acidity, and increasing ocean temperatures will impact key fish and mammal species. NOAA will need to expand aspects of its current Arctic ecosystem research program and the regional Alaska Ocean Observing System, as well as implement better data collection, analyses, and models to provide reliable predictions of the changes coming to marine ecosystems in the U.S. Arctic.

Extended Continental Shelf Mapping

Since 2001, NOAA activities have been critical to U.S. efforts to gather and analyze data to determine the outer limits of its extended continental shelf (ECS) including the Arctic region. The primary goal these efforts is to establish the limits of the areas of seabed beyond 200 miles where the United States can exercise sovereign rights over seabed and sub-seafloor continental shelf natural resources. NOAA is a co-vice chair on the State Department-led interagency task force established in 2007. To date, U.S. data collection efforts have provided a wealth of bathymetric and seismic information. Though beyond the scope of ECS, collecting the baseline ecosystem-level data would enhance the existing information and provide the U.S. with a better understanding of the nature, extent, and economic value of these resources, as well as insights into issues such as climate variability; marine ecosystems; and undiscovered or unconventional energy, biological, and mineral resources.

Five-year strategy: At present, the biggest limiting factor in providing managers with the information they need regarding the impact of climate change on Arctic living marine resources off Alaska is access to survey vessels and aircraft during the ice-free summer months and support for over-wintering sampling tools including autonomous sea gliders, passive acoustic recorders, and satellite-linked tags. Specifically, very few surveys have been conducted to assess the status of living marine resources in the northern Bering, Chukchi, and Beaufort Seas. Additional Arctic surveying capability is proposed in NOAA's Fleet and Aircraft Recapitalization plans, which include state-of-the-art replacements of aging NOAA survey vessels and planes. Additional charters are required to meet capacity shortfalls. Also, resources are needed to conduct ecological process studies on how loss of sea ice, increased acidity, and sea surface temperature warming will change the productivity and composition of Arctic marine resources in waters off Alaska.

Because of fiscal limitations, it is beyond the capability of NOAA to address all of these deficiencies in the next five years. Therefore, in this strategy, NOAA is proposing to expand two existing programs, while *continuing on-going assessment programs on marine mammals, fish, and shellfish*: 1) the Bering-Aleutian Salmon International Survey (BASIS) and the RUSALCA (Figure 6), which are cooperative international research programs in the northern Bering and Chukchi Seas, and 2) NOAA's *ocean acidification* program. The former will provide critical information on the biodiversity of this region and a baseline for assessing how biodiversity will respond to climate change and loss of sea ice. The latter activity will result in greater attention given to the *impact of more corrosive waters on the ecology and life history of key Arctic species* such as king crab. The geographic scope of this proposal is therefore limited to the northern Bering and Chukchi Seas. This is a critical region because of the connectivity of the high Arctic marine ecosystems with the Bering Sea through the Bering Strait. Further, the expansion of existing research programs in this area is a cost-effective way to address critical information needs. Expansion of the existing research program in the Beaufort Sea will be dependent on the availability of funding between 2015 and 2020.

The data produced by the continuation and expansion of these two on-going research programs will provide a subset of the information needed to develop models that will allow resource managers to better assess the risk of action or inaction, as well as the relative benefit of specific actions. Integrated ecosystem assessments and operational ecosystem modeling will ultimately require further investments in human and facility infrastructure in the Arctic (e.g., real-time sea-ice monitoring at the appropriate scale for safe maritime operations). Through conservation, research, and response to environmental threats, NOAA will assist the part of the U.S. that is already impacted by climate change in developing risk-averse strategies to maximize the resilience of marine ecosystems in the Arctic, and develop strategies to mitigate and adapt to adverse impacts.

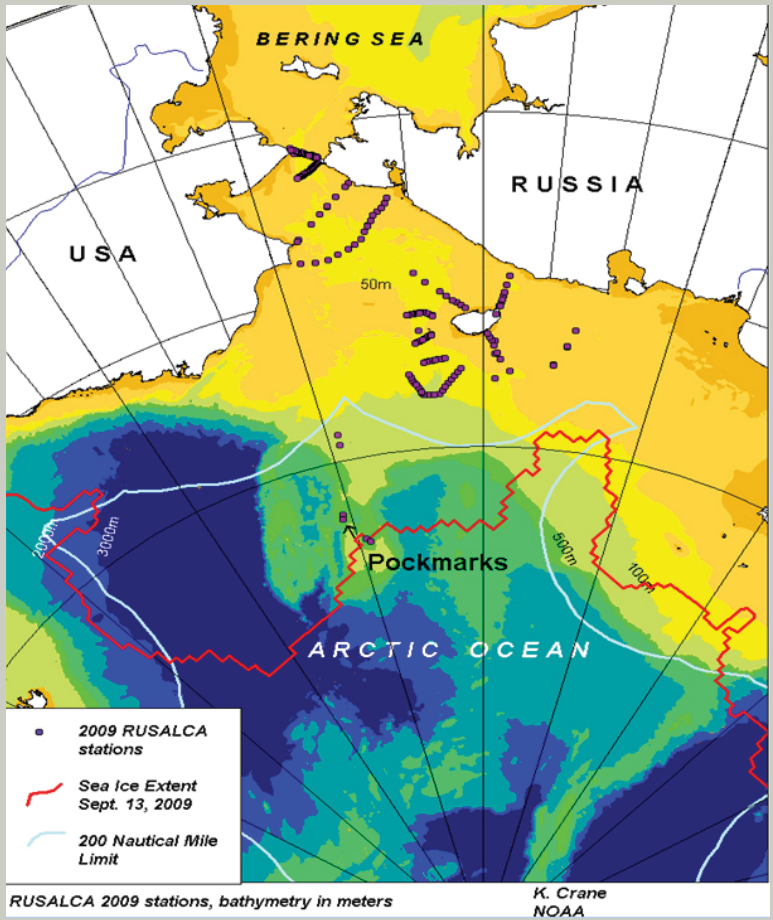


Figure 5. RUSALCA Ecosystem stations taken in 2009 from the Bering Strait north to 77°N on the Chukchi Plateau.

Goal 6: Advance Resilient & Healthy Arctic Communities & Economies

Goal Statement - Resilient and healthy Arctic communities and economies through improved geospatial infrastructure, safe navigation, oil spill response readiness, and climate change adaption strategies.

Importance: We measure the well-being of our Nation through the health of our communities and economies. The condition of the Arctic can be gauged by the health of the people living and working in this unique environment, and by the impact of increased economic activity on it. Indigenous people have long depended upon the unique characteristics of the Arctic for food, livelihoods, cultural heritage, and protection. However, climate change in the Arctic is altering the foundations of their communities and challenging indigenous ways of life. At the same time, the loss of sea ice creates opportunities for commercial enterprises such as oil and gas development, cruise and cargo shipping, fishing, and other economic sectors. This creates tension between the traditional and the new, and argues for a measured approach to Arctic resource utilization.

As the ice barriers that protect Arctic coastal communities diminish, the State of Alaska and its people must make critical decisions based on threats from stronger storms, increasing erosion, thawing permafrost, changing animal migration patterns, and sea level changes. Shorter freeze periods and weak ice impact transportation and can result in loss of life. The potential economic effects of these changes in the Arctic are also enormous, as retreating sea ice opens access to economic development. Oil companies are investing in exploration, private interests are anticipating an open Arctic trade route, and pressure is increasing on our defense and security assets to maintain a presence in the region in a "response-ready state" because of the increased risks.

NOAA's current activities: NOAA has a variety of mandates relating to resilient communities and economies. The agency has the U.S. government lead for hydrographic surveys, nautical charts, and the National Spatial Reference System. NOAA is also responsible for administering the Coastal Zone Management Program. During oil spills, NOAA is legally responsible for providing scientific support to the U.S. Coast Guard and conducting natural resource damage assessments following those incidents. In addition, people who live in, work in, and visit the Arctic rely on NOAA and the Search and Rescue Satellite System to rescue them in an emergency.

Environmental preparedness, response, and recovery: NOAA and the University of New Hampshire's Coastal Response Research Center are partnering to expand Environmental Response Management Application (ERMA) coverage to one or two key areas of concern in the Chukchi and Beaufort Seas. The demonstration will show how the ERMA tool can benefit Arctic stakeholders, including coastal communities, Alaska Native villages, the State of Alaska, NOAA, Federal agencies, and industry. ERMA is a web-based map tool designed to assist both emergency responders and environmental resource managers who deal with incidents that may adversely impact the environment. The data within ERMA also assist in resource management decisions regarding hazardous waste site evaluations and restoration planning. ERMA includes human use and human dimension data components and, for the Arctic, will include sea-ice conditions. Federal, State and Tribal governments would be able to use this information and the ERMA interface to address not only oil spill planning and response, but also to access sea-ice/shoreline erosion information.

The Arctic is severely deficient in many of the capabilities that NOAA extends to the rest of the Nation. The region currently has virtually no geospatial infrastructure for accurate positioning and elevations; sparse tide, current, and water-level prediction coverage; obsolete shoreline and hydrographic data; poor nautical charts; insufficient weather and ice forecast coverage; inadequate oil spill response capacity; and poor understanding of baseline conditions for existing ecosystems. There are large gaps in the information that NOAA does have, illustrated by empty white space on nautical charts of the region and limited capabilities for modeling spills in ice conditions. Most Arctic waters that are charted were surveyed with obsolete technology, some dating back to the 1800s, before the region was part of the United States. Most of the shoreline along Alaska's northern and western coasts has not been mapped since 1960, if ever, and confidence in the nautical charts of the region is extremely low.

Five-year strategy: NOAA can make the highest positive impact to Arctic communities and sustainable economic growth by providing products and services for safe navigation and security, oil spill response readiness, post-incident resource restoration efforts, and climate change adaptation strategies.

The Arctic region needs accurate land and tidal elevations to build flood protections, harden infrastructure, ensure safe and efficient marine transportation, model storm surge, and monitor sea levels. Good weather and navigation tools, building the capacity to respond to spills when they occur, and research to improve Arctic spill response and restoration capabilities are essential. Arctic communities also need a reliable source for information on climate in Alaska to support decisions on moving communities and other adaptive strategies. By building on the capabilities noted in other strategic priorities such as marine weather, sea ice forecasts, and increased observing capacity, NOAA can act to support navigation safety, maritime security, and environmental protection from oil spills and other hazardous events. NOAA's geospatial framework, products, and services will also provide the foundation for all other NOAA activities in the Arctic, including effective climate adaptation, community resilience, coastal resource, and marine spatial planning strategies in the region.

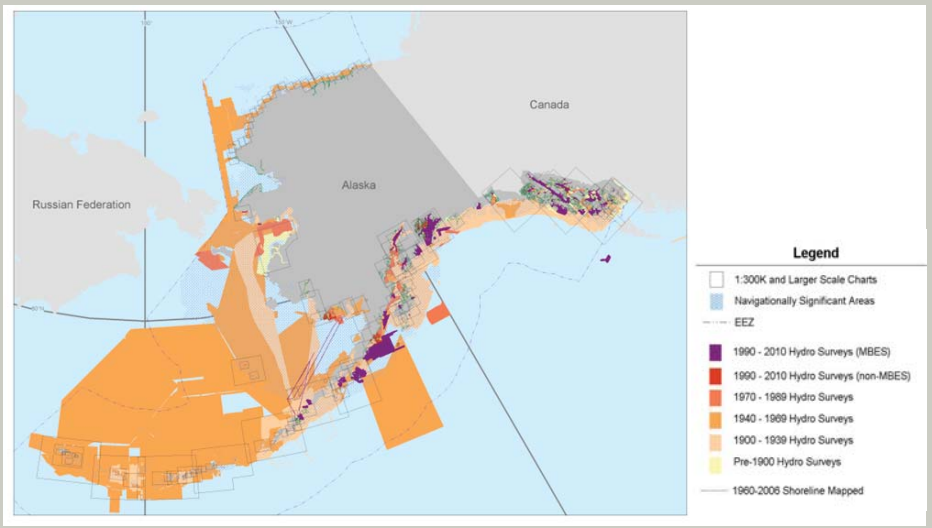


Figure 7. Age and quality of NOAA nautical charts in Alaska.

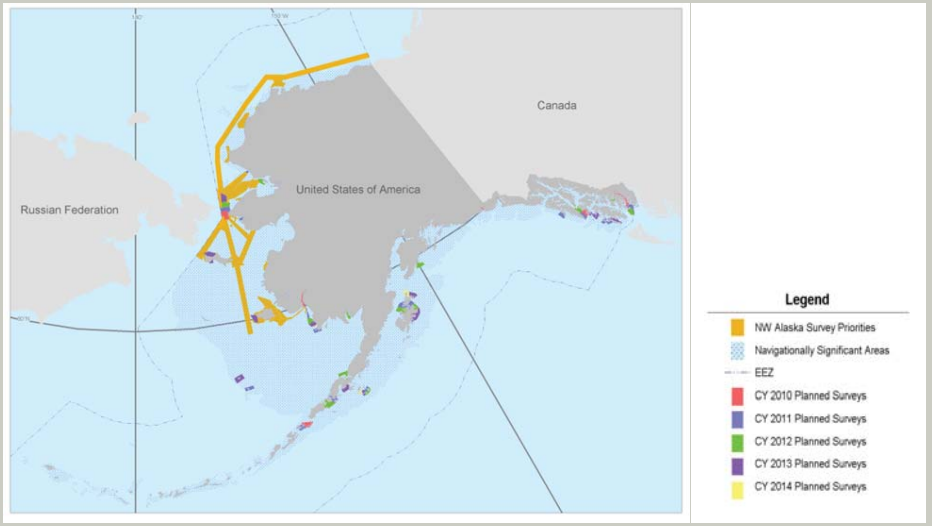


Figure 8. NOAA Arctic hydrographic survey priorities (2010 – 2014)

Overhauling the Arctic Geospatial Framework of geodetic control and water levels will correct meters-level positioning errors and enable centimeter-level measurements to support such critical needs as marine transportation, sea level rise monitoring, understanding of erosion and permafrost thaw impacts to infrastructure, oil/gas resource exploration, and storm surge modeling. *Delivering scientific support for Arctic pollution response* such as contingency plans, place-based drills and community workshops, and spill trajectory modeling to decision makers will help to reduce risk of accident and injury to protected resources and ecosystems as commercial vessel traffic in and through the Arctic increases. *Surveying and mapping Arctic waters and shoreline* for accurate coastal maps and nautical charts will benefit navigation and national security, sea level change impact assessments, and habitat characterizations (Figure 8). NOAA will work with partners to prioritize and survey likely shipping lanes in the North Bering and Chukchi Seas and around coastal communities. This effort will help address the Bering Strait chokepoint in particular, and reduce the risk of accidents and environmental impacts in Arctic waters more broadly.

Finally, by working with local, State and Federal health agencies such as the Alaska Native Tribal Health Consortium and the Centers for Disease Control, NOAA will *support coastal communities with adaptive strategies and planning tools* and contribute to the understanding of how the changing climate is affecting health and welfare. NOAA will assist Arctic communities on this issue by leading the development of a regional climate service partnership. This climate center will serve as a one-stop shop for information on climate in Alaska. NOAA will also work with other agencies, the State, and tribal entities to implement coastal and marine spatial planning to improve the management and coordination of human activities in the coastal zone and U.S. Exclusive Economic Zone.

Conclusion & Next Steps

As the Nation's only Arctic state, Alaska and its communities are the first to be impacted by climate change. Observations have shown that Alaska has warmed at over twice the rate of the rest of the Nation. The average annual temperatures in Alaska have increased by 3.4 degrees Fahrenheit and the winter time average temperatures have increased by 6.3 degrees. This means Alaska is already experiencing early snow melt, changes in sea ice, wide-spread glacial retreat, and permafrost thawing.

The Arctic is a particularly vulnerable system, which is prone to rapid change. It is also a primary driver for global weather patterns. Initial predictions from global climate change models underestimated the rate at which the Arctic would lose sea ice. This has led to an underestimate of global warming. Understanding global climate change and providing reliable predictions regarding changes in worldwide weather patterns will require an improved understanding of the impacts of Arctic climate change.

NOAA has diverse capabilities that can and should be brought to bear on the emerging environmental, economic, and national security issues in the Arctic. NOAA envisions an Arctic where:

- Conservation, management, and use are based on sound science and support healthy, productive, and resilient communities and ecosystems; and
- The global implications of Arctic change are understood and predicted.

In support of this vision and in order to fulfill NOAA's missions and responsibilities that are critical for other agencies to succeed in fulfilling their responsibilities, NOAA intends to undertake the following four steps:

Step 1 – In the next five years, implement, through a NOAA five-year Arctic Action Plan, actions to achieve the six primary goals that are identified and described in this document in support of the Arctic vision.

1) Accurate, quantitative, daily forecasts to decadal predictions of sea ice are provided to support safe operations and ecosystem stewardship,
2) Improved baseline observations and understanding of Arctic climate and ecosystems reduces the uncertainty in assessing and predicting impacts caused by a changing Arctic,
3) Advanced, accurate forecasts and warnings are provided to ensure society can prepare for and respond appropriately to weather-related routine and extreme events,
4) National and international partners are engaged to promote cooperation and sharing of data, observational platforms, and intellectual resources to enable more rapid and comprehensive attainment

of NOAA's Arctic science and ecosystem-based management goals,

5) Conservation, management, and use of ocean and coastal resources are based on sound science and support healthy, productive, and resilient ecosystems and communities, and

6) Resilient and viable Arctic communities and economies through improved geospatial infrastructure, safe navigation, oil spill response readiness, and climate change adaption strategies.

Step 2 – In order to accomplish these goals, coordination across all NOAA Line and Staff Offices and collaboration with local, regional, federal, academic, and non-governmental organizational partnerships will be required.

Step 3 – Develop an engagement strategy to reach internal and external employees, partners, and stakeholders. As a starting point, establish a single point of contact within NOAA Senior Executive Leadership that is accountable for implementation of this strategy.

Step 4 – Include the formalization of a detailed budget strategy as part of the NOAA Arctic Action Plan. NOAA is committed to enhancing its current involvement in research and management programs in the Arctic, and anticipates initial investment of $10 million towards the implementation of this strategic plan, recognizing that additional funds will be needed to achieve these goals.

No single region better exemplifies the complex interdependence of communities and changing ecosystem conditions than the Arctic. The breadth and complexity of the cultural, societal, economic, and environmental impacts requires a concerted, systematic and rapid effort with partners from international to local levels. NOAA's scientific capabilities can be deployed to increase understanding of climate and other key environmental trends, to predict the ecosystem response to those trends, and to offer the technical expertise needed to develop policy options and management strategies for mitigation and adaptation to the environmental challenges in the Arctic region. NOAA's service capabilities are needed to support safety and security needs for fishing, marine mammal protection, transportation, energy, infrastructure, and mineral exploration in the unique Arctic environment. The choices we make today can have pivotal impacts on the future state of the Arctic.

UNDER SECRETARY OF COMMERCE FOR OCEANS AND ATMOSPHERE AND ADMINISTRATOR, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION - NOAA

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