

# Arctic

NOAA'S ARCTIC ACTION PLAN

SUPPORTING THE  
NATIONAL STRATEGY FOR  
THE ARCTIC REGION





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U.S. DEPARTMENT OF COMMERCE  
National Oceanic and Atmospheric Administration

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NOAA's Arctic Action Plan is available online at:  
<http://www.arctic.noaa.gov/NOAAarcticactionplan2014.pdf>

# EXECUTIVE SUMMARY

The National Oceanic and Atmospheric Administration (NOAA) is actively engaged in the Arctic, providing science, service, and stewardship to this rapidly changing region, its inhabitants, and the Nation. Through its broad range of activities, NOAA is well prepared to make significant contributions, to the extent possible within existing resources, to all three lines of effort in the recently released U.S. National Strategy for the Arctic Region (May 2013) and its subsequent Implementation Plan (January 2014). As described in its 2011 Arctic Vision and Strategy, NOAA has six strategic goals in the Arctic, each of which directly supports the National Strategy.

National Strategy for the Arctic Region — lines of effort —	NOAA's Arctic Vision and Strategy — strategic goals —
<ul style="list-style-type: none"> <li>• Advance U.S. security interests</li> </ul>	<ul style="list-style-type: none"> <li>• Forecast sea ice</li> <li>• Improve weather and water forecasts and warnings</li> </ul>
<ul style="list-style-type: none"> <li>• Pursue responsible Arctic region stewardship</li> </ul>	<ul style="list-style-type: none"> <li>• Strengthen foundational science to understand and detect Arctic climate and ecosystem changes</li> <li>• Improve stewardship and management of ocean and coastal resources in the Arctic</li> <li>• Advance resilient and healthy Arctic communities and economies</li> </ul>
<ul style="list-style-type: none"> <li>• Strengthen international cooperation</li> </ul>	<ul style="list-style-type: none"> <li>• Enhance international and national partnerships</li> </ul>

**Advancing U.S. security interests** in the Arctic requires improved maritime domain awareness, for which NOAA's weather and sea ice forecasts are critically important. NOAA's sea ice research strengthens forecasts of both ice and weather conditions as well as building a better understanding of the direct links between sea ice and climate. As a result of this research, the complicated linkages among melting sea ice, changing climate, and weather patterns in the Arctic and around the globe are becoming more apparent and allow better planning to cope with Arctic change.

NOAA plays a key role in **pursuing responsible Arctic region stewardship**. Foundational science enables better understanding of Arctic ecosystems, the atmosphere, climate, and their dynamic interconnections. NOAA's fisheries research and management programs are likewise vital, particularly for the economically important U.S. Bering Sea fisheries. Research and stewardship of marine ecosystems and protected species like marine mammals promote sustainable use, conservation, and protection from potential impacts of offshore development, increased shipping, and environmental degradation. NOAA provides important services to coastal communities by improving safe Arctic maritime access with mapping and charting as well as increasing preparedness and communities' resilience to intensifying weather. NOAA is also an important partner in hazard response and mitigation (e.g., providing scientific support to the U.S. Coast Guard after oil spills). Research relevant to oil spills, sea ice, and marine ecosystems will help to prepare for and to protect against potential environmental disasters in the Arctic.

All of NOAA's Arctic activities are united in one aspect: leveraging national and international partnerships and collaborating to support common Arctic goals. NOAA **strengthens international cooperation** through the Arctic Council, joint research opportunities, and provision of services. NOAA also has many successful Arctic national partnerships, within and outside the Federal Government. Existing partnerships will be strengthened and new ones developed in the coming years as NOAA continues its work to address the Nation's challenges in the Arctic.



Bowhead whales move through sea ice in the Beaufort Sea. Photo: A. Brower, NOAA.

# I. INTRODUCTION

The Arctic is changing – and those changes will affect us all, no matter which country we live in or region of the world we inhabit. One dramatic change is the loss of sea ice covering the Arctic Ocean and its peripheral seas. The past 10 years have been the 10 years with the lowest Arctic sea ice coverage, and 2012 marked the all-time lowest sea ice extent ever recorded.

Since the 1980s, 75% of Arctic sea ice volume has been lost, and there are consistently more than 300 kilometers of open water north of Alaska every summer. In contrast, 30 years ago 50 kilometers of open water was typical. The ice-free season north of the Bering Strait is projected to increase from 2-3 months at present to about 5-6 months over the next few decades. By 2040, the Arctic Ocean will likely be nearly ice-free during the summer months.

**Table 1.** NOAA’s Arctic strategic goals support the National Strategy for the Arctic Region.

National Strategy for the Arctic Region — lines of effort —	NOAA’s Arctic Vision and Strategy — strategic goals —
<ul style="list-style-type: none"> <li>• Advance U.S. security interests</li> </ul>	<ul style="list-style-type: none"> <li>• Forecast sea ice</li> <li>• Improve weather and water forecasts and warnings</li> </ul>
<ul style="list-style-type: none"> <li>• Pursue responsible Arctic region stewardship</li> </ul>	<ul style="list-style-type: none"> <li>• Strengthen foundational science to understand and detect Arctic climate and ecosystem changes</li> <li>• Improve stewardship and management of ocean and coastal resources in the Arctic</li> <li>• Advance resilient and healthy Arctic communities and economies</li> </ul>
<ul style="list-style-type: none"> <li>• Strengthen international cooperation</li> </ul>	<ul style="list-style-type: none"> <li>• Enhance international and national partnerships</li> </ul>

This rapid loss of sea ice is affecting weather patterns, marine and terrestrial ecosystems, and human activities. Reductions in sea ice cover are changing polar atmospheric circulation patterns, ultimately increasing the frequency and severity of Arctic storms. Furthermore, recent evidence suggests that changes in Arctic atmospheric circulation are reflected in the weather patterns at lower latitudes as well. Weather and climate changes in the Arctic are already affecting the United States and other parts of the world, and these forces are expected to intensify in the coming years.

As Arctic waterways become ice-free and navigable for longer periods, patterns of commerce and industrial activities are also shifting. There is growing interest in oil and gas exploration and development, spurred by estimates of over 23 billion barrels of technically recoverable oil and 108 trillion cubic feet of technically recoverable natural gas within the Outer Continental Shelf of the Beaufort and Chukchi seas. There was a 118% increase in maritime transits through the Bering Strait between 2008 and 2012.<sup>1</sup> Furthermore, ecological shifts in Arctic marine ecosystems are likely to impact commercial fisheries, protected resources such as marine mammals and birds, and Alaska Native subsistence harvests. Arctic climate change and loss of sea ice will influence maritime safety, traditional lifestyles and livelihoods, economies, and associated ecosystems for decades to come.

### National Strategy for the Arctic Region

Recognizing the growing importance of the Arctic, the White House released an overarching National Strategy for the Arctic Region in May 2013 (National Strategy).<sup>2</sup> This strategy establishes priorities for actions to help the United States fulfill its responsibilities as an Arctic nation and to respond effectively to the challenges and opportunities arising from increased Arctic access. It is based on three lines of effort:

- Advance U.S. security interests,
- Pursue responsible Arctic region stewardship, and
- Strengthen international cooperation.

The National Strategy’s guiding principles are to safeguard peace and stability, make decisions using the best available information, pursue innovative arrangements, and consult and coordinate with Alaska Natives. An implementation plan for the National Strategy, released in January 2014, directs federal agencies – including the National Oceanic and Atmospheric Administration (NOAA) – to take action on a number of critical Arctic issues.<sup>3</sup>

<sup>1</sup> For more information, see: [http://www.uscg.mil/seniorleadership/DOCS/CG\\_Arctic\\_Strategy.pdf](http://www.uscg.mil/seniorleadership/DOCS/CG_Arctic_Strategy.pdf)

<sup>2</sup> Available at: [http://www.whitehouse.gov/sites/default/files/docs/nat\\_arctic\\_strategy.pdf](http://www.whitehouse.gov/sites/default/files/docs/nat_arctic_strategy.pdf)

<sup>3</sup> Available at: [http://www.whitehouse.gov/sites/default/files/docs/implementation\\_plan\\_for\\_the\\_national\\_strategy\\_for\\_the\\_arctic\\_region\\_-\\_fi....pdf](http://www.whitehouse.gov/sites/default/files/docs/implementation_plan_for_the_national_strategy_for_the_arctic_region_-_fi....pdf)

## NOAA: Ready for Action

NOAA is well prepared to support the implementation of the National Strategy. NOAA has a long history of Arctic science, service, and stewardship, ranging from biological, physical, and chemical research to weather and climate services to nautical charting, spill response, fisheries management, and marine mammal protection. NOAA issued its Arctic Vision and Strategy in 2011 to define the substantial role that it plays in the region and to provide direction for the future.<sup>4</sup> 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, predicted, and managed.

NOAA's six Arctic strategic goals are to:

- Forecast sea ice,
- Improve weather and water forecasts and warnings,

- Strengthen foundational science to understand and detect Arctic climate and ecosystem changes,
- Improve stewardship and management of ocean and coastal resources in the Arctic,
- Advance resilient and healthy Arctic communities and economies, and
- Enhance international and national partnerships.

Progress in achieving these goals since 2011 shows that NOAA is ready to implement the National Strategy in conjunction with NOAA's sister agencies and other partners. Overall, NOAA's Arctic goals align well with the National Strategy priorities, as illustrated in Table 1. NOAA played a key role in efforts leading up to the National Strategy, including development of the National Ocean Policy Implementation Plan and the Interagency Arctic Research Policy Committee's five-year plan to coordinate federal Arctic research.<sup>5,6</sup> NOAA also contributed significantly to the March 2013 report to

<sup>4</sup> Available at: [http://www.arctic.noaa.gov/docs/NOAAArctic\\_V\\_S\\_2011.pdf](http://www.arctic.noaa.gov/docs/NOAAArctic_V_S_2011.pdf)

<sup>5</sup> Available at: [http://www.whitehouse.gov/sites/default/files/national\\_ocean\\_policy\\_implementation\\_plan.pdf](http://www.whitehouse.gov/sites/default/files/national_ocean_policy_implementation_plan.pdf)

<sup>6</sup> Available at: [http://www.whitehouse.gov/sites/default/files/microsites/ostp/2013\\_arctic\\_research\\_plan.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ostp/2013_arctic_research_plan.pdf)

**NOAA Ship *Fairweather* crew supports Arctic charting operations.**

Photo: T. Smith, NOAA.





the President entitled, “Managing for the Future in a Rapidly Changing Arctic,” prepared under the auspices of the Interagency Working Group on Coordination of Domestic Energy Development and Permitting in Alaska.<sup>7</sup> That report describes social, environmental, and economic trends and challenges in the Arctic, and it promotes adopting an Integrated Arctic Management approach, strengthening key partnerships with the State of Alaska and Alaska Natives, and promoting better stakeholder engagement. In July of 2013, NOAA and its sister agencies on the Committee on the Marine Transportation System submitted a report to the President entitled, “U.S. Arctic Marine Transportation System: Overview and Priorities for Action,” which calls for near- and long-term efforts to develop safeguards for anticipated increases in vessel traffic.<sup>8</sup>

### NOAA’s Arctic Action Plan

NOAA has many diverse and robust programs underway in the Arctic. NOAA’s Arctic Action Plan describes those efforts, how they implement NOAA’s Arctic Vision and Strategy, and how they support and harmonize with the National Strategy for the Arctic Region. This document lays out concrete objectives to set priorities, leverage partnerships, and build upon accomplishments, to the extent possible within existing resources. Specific actions and outcome targets for Fiscal Years 2014 and 2015 are described in the Appendix.

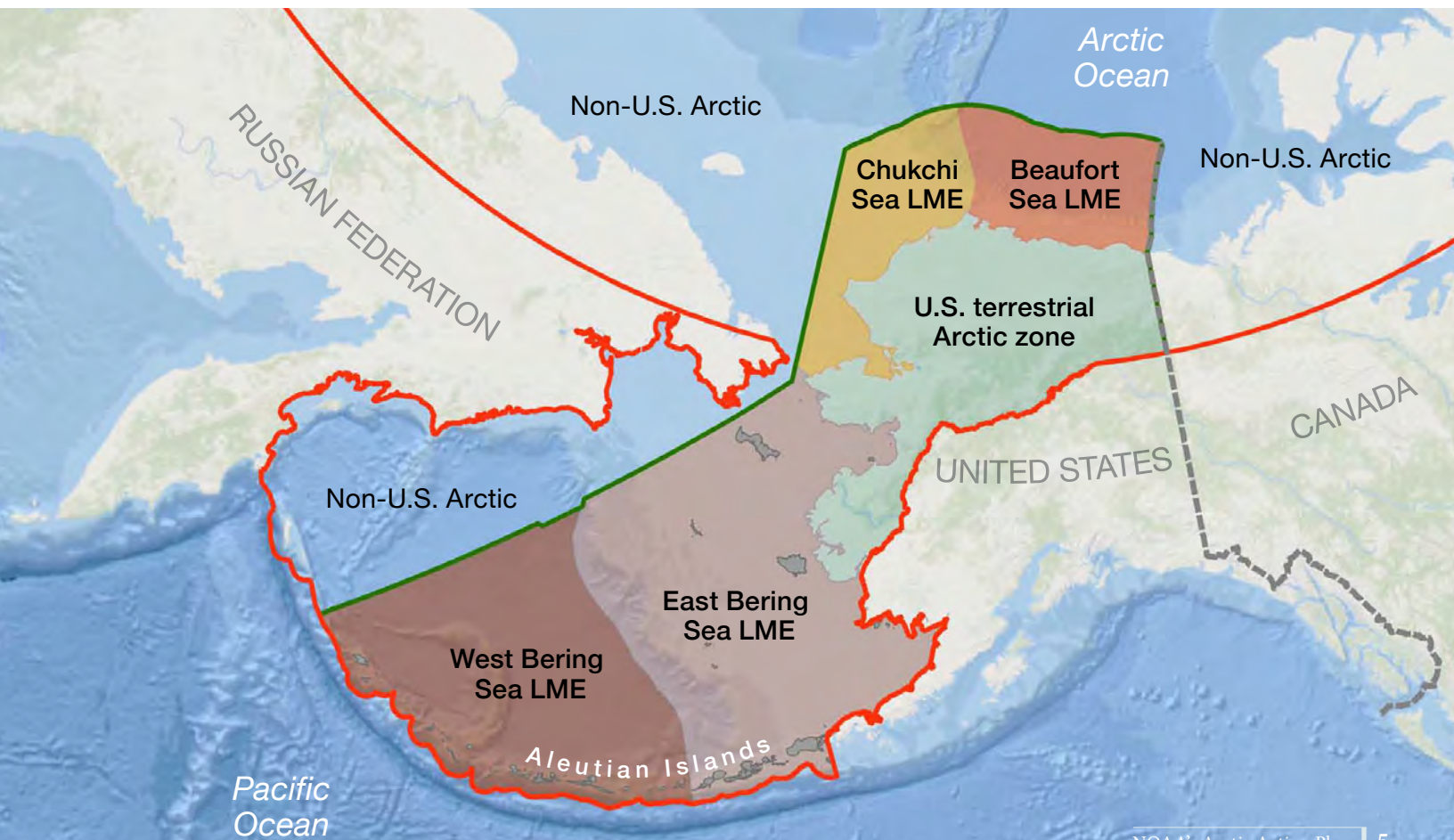
The geographic scope of NOAA’s Arctic Action Plan includes all of the areas defined by the Arctic Research and Policy Act of 1984 (i.e., the zone within and to the north of the red line in Fig. 1).<sup>9</sup> For the United States, that area includes four large marine ecosystems (West Bering Sea, East Bering Sea, Chukchi Sea, and Beaufort Sea) and the terrestrial portions of northern and western Alaska (Fig. 1). NOAA currently has active programs in all of these Arctic geographic subareas.

<sup>7</sup> Available at: [http://www.afsc.noaa.gov/publications/misc\\_pdf/IAMreport.pdf](http://www.afsc.noaa.gov/publications/misc_pdf/IAMreport.pdf)

<sup>8</sup> Available at: <http://www.cmts.gov/downloads/CMTS%20U%20S%20Arctic%20MTS%20Report%20%2007-30-13.pdf>

<sup>9</sup> The Arctic Research and Policy Act of 1984 defines the Arctic as all U.S. and foreign territory north of the Arctic Circle and all U.S. 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 Islands chain (Fig. 1)

**Figure 1.** As defined by the Arctic Research and Policy Act of 1984, the U.S. Arctic includes the Aleutian Islands, Bering Sea, Chukchi Sea, Beaufort Sea, and vast terrestrial areas of northern and western Alaska. The marine areas in the U.S. Arctic comprise four discrete large marine ecosystems (LME). [Basemap courtesy of Esri Ocean Basemap.]





NOAA Ship *Oscar Dyson* maneuvers through sea ice in the Bering Sea. Photo: J. Jansen, NOAA.

## II. National Strategy Line of Effort 1: ADVANCE U.S. SECURITY INTERESTS

NOAA's sea ice and weather services directly support the National Strategy's aim to advance U.S. security interests. This line of effort has four objectives:

- 1) Evolve Arctic infrastructure and strategic capabilities,
- 2) Enhance Arctic domain awareness,
- 3) Preserve Arctic region freedom of the seas, and
- 4) Provide for future U.S. energy security.

NOAA contributes to all of these objectives, particularly through its activities supporting its strategic goals to "Forecast Sea Ice" and "Improve Weather and Water Forecasts and Warnings." NOAA's forecasts, warnings, and research on weather and sea ice inform decision-making for all stakeholders in the Arctic. These services are critical for safe Arctic operations and enhanced maritime domain awareness.

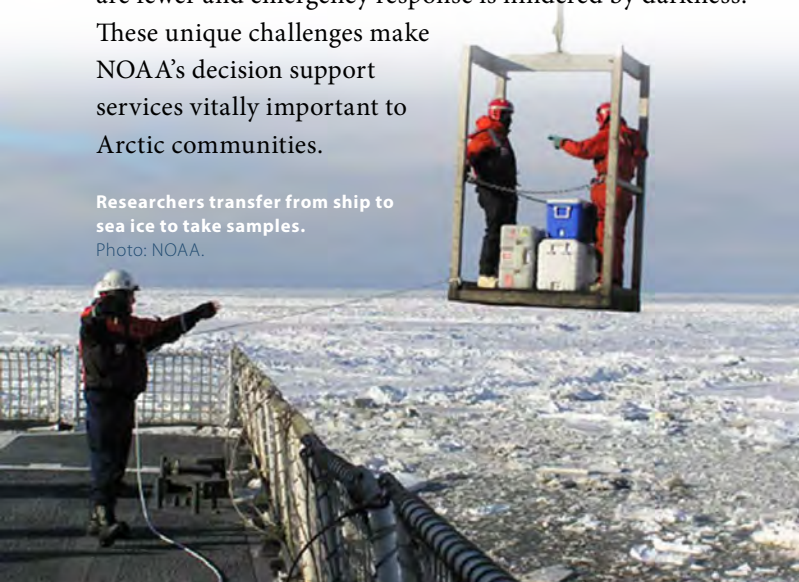
## Weather and Sea Ice Forecasts

NOAA provides forecasts, warnings, and information for marine, aviation, and other weather interests, which are critical for maritime domain awareness in the Arctic. NOAA's National Weather Service provides forecast services to protect life and property, to enhance the national economy, and to fulfill NOAA's obligations under international treaties for the safety and security of maritime shipping, energy exploration, and tourism activities. Major stakeholders and partners, including the U.S. Coast Guard and the State of Alaska, require weather, water, and sea ice information for planning and decision-making to serve communities and to manage the region's many resources. People in the Arctic rely heavily on aviation, marine weather, and sea ice information for safe transportation and access to goods and services. Forecasts and warnings are delivered through a number of media, from the Internet to high-frequency radio broadcasts.

Increasing air and ocean temperatures, thawing permafrost, loss of sea ice, and ecosystem shifts are evidence of widespread and dramatic change. Critical environmental, economic, and national security issues are emerging, many of which are having significant impacts on human lives, livelihoods, and coastal communities. Meeting the information needs for Alaska, with its vast size, remote population, and cultural diversity, presents NOAA with unique challenges. Partners, emergency managers, and communities in the Arctic deal with extremes in temperature, darkness, and sea ice, further complicating decisions and possible actions.

For example, a decision to deliver heating fuel to a coastal community in the Arctic may require weather and sea ice outlooks weeks in advance to ensure safe navigation. Evacuation of coastal communities that might take several hours in Connecticut, for example, may take several days in remote Alaska during the winter, when daylight hours are fewer and emergency response is hindered by darkness. These unique challenges make NOAA's decision support services vitally important to Arctic communities.

Researchers transfer from ship to sea ice to take samples.  
Photo: NOAA.



Weather and sea ice forecasting are closely linked, and forecasts are often provided together. Weather conditions affect the development and movement of sea ice, and the loss of sea ice in the Arctic impacts the weather and climate. The present rate of sea ice loss, with its regional and global impact, creates an urgency to improve sea ice predictions at all time scales, from the short term (i.e., daily to weekly) to seasonal and decadal time scales. Some of NOAA's sea ice services and forecasts are described below.

- NOAA provides Arctic sea ice analysis and forecast services from local to regional scales through the National Weather Service, and at basin to global scales through the U.S. National Ice Center in collaboration with the U.S. Navy and Coast Guard.
- Accurate weekly sea ice information is important for many stakeholders to operate in the marine environment, including the U.S. Coast Guard, Arctic coastal communities and Alaska Native populations, the oil and gas and fishing industries, first responders to emergencies, and scientific researchers. Current sea ice forecasts are based primarily on satellite data, simple sea ice drift calculations, and Arctic weather models. Generating timely forecasts depends on the ability to collect basic observations and rapidly process the information. To improve weekly sea ice forecasts, NOAA is developing and refining higher spatial resolution regional sea ice models for Alaska waters that can assimilate both weather and sea ice observations.

Launching a radiosonde at Summit Station, Greenland.  
Photo: M. Shupe, NOAA & Univ. Colorado.



## National Ocean Policy: NOAA's Role

*A decade ago, the final reports of both the U.S. Commission on Ocean Policy and the Pew Oceans Commission recognized that lack of federal coordination was a major impediment to improving the Nation's ocean and coastal policy. The National Ocean Policy and its accompanying Implementation Plan are designed to specifically address this issue by streamlining and integrating federal oceans policy to benefit the U.S. economy, sustain ocean health, and strengthen national security. Addressing environmental stewardship needs in a changing Arctic is one of the National Ocean Policy's priority objectives, and NOAA plays a primary role in implementing milestones related to both the Arctic and maritime security.*

### Key areas that emerge for NOAA are:

- Improving Arctic weather and sea ice forecasting,
- Strengthening scientific research of Arctic ecosystems,
- Supporting science-based management and conservation of natural resources,
- Improving Arctic mapping and charting, and
- Improving Arctic environmental incident prevention and response.

- The ability to provide accurate advanced sea ice predictions of the seasonal timing of the freeze-up and melt-out of sea ice has direct implications for U.S. commerce and industry. For example, in 2012, the Bureau of Ocean Energy Management asked NOAA to assist in reviewing an oil and gas industry request to extend the drilling season in the Chukchi Sea based on the possibility of a late freeze-up of sea ice. NOAA provided a probability-based sea ice forecast indicating an unusually rapid freeze-up. The resulting decision to deny the extension request mitigated risks for offshore drilling operations.
- On a decadal scale, sea ice loss is a major index of global climate change and represents an important time horizon for community, industrial, and environmental management. NOAA has contributed key input to several national and international climate reports that illustrate trends in sea ice loss and climate, including the 5th Assessment Report of the International Panel on Climate Change.

Weather analysis and prediction capabilities are currently poorer in the Arctic than in other parts of the United States. Major challenges for long-term modeling being addressed by NOAA include the lack of good physical data regarding winds

and clouds. Although accurate forecasts and models depend upon the availability of observations, existing observations in the Arctic are very limited in both geographic scope and frequency. The ability of NOAA and its partners to deploy a variety of sensing devices to collect observations, from buoys and other in situ technologies to airborne and satellite sensors, is key to improving weather and sea ice forecasts. Real-time satellite data are critical for accurate forecasting and warning of events, such as rapid sea ice formation and frequent storms that pose major hazards to life, property, and economic activities in the Arctic.

NOAA will continue to improve Arctic marine weather, storm surge, and sea ice forecast services. Improved sea ice and marine weather forecasting would assist the energy, maritime shipping, and transportation industries as well as infrastructure planning, economic development, and ecosystem stewardship. Forecast improvements will be made by enhancing and integrating different types of observations of the atmosphere, sea ice, and ocean (including use of traditional and local knowledge) and by directly combining sea ice and climate models with weather forecast models.



## Sea Ice Research

NOAA conducts sea ice research to better understand the drivers and associated impacts that cause ice to form and melt. Sea ice research is especially important due to the high impact of sea ice distribution on transportation, marine ecosystems, resource development, search and rescue operations, national security, and global climate. NOAA's research efforts are focused on improving sea ice predictions and models as well as understanding the consequences of increased sea-ice-free areas on Arctic ecosystems and mid-latitude weather.

- Currently, researchers are exploring the direct connection between melting Arctic sea ice and weather extremes in the mid-latitude United States, which has broad implications for NOAA's stewardship and environmental prediction missions.
- NOAA is meeting the growing challenges of Arctic change and the impact of those changes in other regions by launching a five-year science initiative on predicting Arctic weather and climate connections with mid-latitude zones.
- Future goals include leveraging and expanding observation, modeling, and forecast capacity, as well as improving models that couple atmosphere, ocean, land, and ice at local, regional, and global scales.

Arctic services are best accomplished by sharing data at multiple levels – among universities and researchers, commercial ventures, other Arctic countries, and non-Arctic countries possessing Arctic capabilities. NOAA intends to expand these relationships through partnerships and formal bilateral/multilateral arrangements, increasing both its interagency and international partnerships to improve the accuracy, timeliness, and coverage of forecasts.

Panoramic view of the flight deck of NOAA WP-3D aircraft conducting aerial surveys of Arctic sea ice.  
Photo: K. Wood, NOAA.



## NOAA Provides Essential Decision Support Services

- Forecasts and warnings for high-impact events, such as extra tropical storms, tsunamis, floods, droughts, volcanic ash, fires, and space weather, are particularly critical in Alaska communities.
- Storm surge and inundation hazards threaten northern and western Alaska coastal communities. Water-level information and forecasts are necessary to help protect these communities and improve coastal community hazard resilience.
- An enhanced and integrated set of environmental observations is required to track changes to the Arctic across the land, in the atmosphere, and in the ocean, including physical indicators, biological responses, and social and economic impacts. Rapid integration, interpretation, and dissemination of this information in near-real time are required to support decision-making.
- Accurate sea ice charts and forecasts are critically important for the maritime shipping, commercial fishing, and offshore energy industries, as well as for safe navigation, successful search and rescue operations, and other emergency response efforts.

Scientist measures the temperature of a recently drilled ice core.  
Photo: J. Potter, NOAA.





Bering Sea pollock fleet prepares to depart Dutch Harbor, Alaska, for another season of the largest commercial fishery in the U.S. Photo: S. Zmolek, NOAA.

## III. National Strategy Line of Effort 2: PURSUE RESPONSIBLE ARCTIC REGION STEWARDSHIP

As described in the National Strategy, the U.S. Government will pursue four objectives to achieve responsible stewardship in the Arctic region:

- 1) Increase understanding of the Arctic through scientific research and traditional knowledge,
- 2) Protect the Arctic environment and conserve Arctic natural resources,
- 3) Use Integrated Arctic Management to balance economic development, environmental protection, and cultural values, and
- 4) Chart the Arctic region.

The following goals under NOAA's Arctic Vision and Strategy strongly support the National Strategy objectives noted above:

- Strengthen foundational science to understand and detect Arctic climate and ecosystem changes,
- Improve stewardship and management of ocean and coastal resources in the Arctic, and
- Advance resilient and healthy Arctic communities and economies.

Strengthening foundational science to detect climate and ecosystem changes increases understanding of the Arctic through observational networks and research. Baseline characterizations provide a unique window into the Arctic and are the basis for monitoring future change. Improving stewardship and management of ocean and coastal resources promotes sustainable use, conservation, and protection of Arctic natural resources. Advancing resilient and healthy Arctic communities and economies supports the National Strategy by protecting the Arctic environment, charting the Arctic for safe navigation, and providing products and services to coastal communities. NOAA will also continue to be an active leader in developing and implementing Integrated Arctic Management, as called for in the National Strategy.

### Foundational Science

NOAA's Arctic observing programs investigate sea ice processes, ecosystem processes, atmospheric patterns, and climate feedbacks. These programs strengthen the foundational science and research necessary to detect and understand the climate and ecosystem changes that are now occurring throughout the Arctic. NOAA also leads important synthesis activities, such as the Arctic Report Card.<sup>10</sup> Issued annually since 2006, the Arctic Report Card is a peer-reviewed source of clear, reliable, and concise environmental information on the current state of the Arctic relative to the historical record. The Arctic Report Card is intended for a wide audience, including scientists, teachers, students, decision-makers, and the general public interested in the Arctic environment and science.

**Ice-Ocean-Ecosystem Observations:** NOAA implements and participates in many observation programs in the Arctic to better understand connections between the ocean, sea ice, and ecosystems. These observations are critical to advancing foundational research in the Arctic, with implications for future research, management of resources, and an overall understanding of changes occurring in the Arctic region.

- NOAA is part of a multi-agency effort called the Distributed Biological Observatory, a mooring- and ship-based observation program which aims to understand the impacts of rapid physical changes on biological processes in the Pacific Arctic.<sup>11</sup> The overarching goal is long-term standardized sampling of physical and biological parameters in five oceanographic regions that exhibit high

biological productivity, biodiversity, and strong gradients in ecosystem properties.

- NOAA scientists participate in the Russian American Long-term Census of the Arctic, a multi-disciplinary observation program operating collaboratively with international partners in the Bering Strait region and the Chukchi Sea. Major goals are to track changes in fluxes of heat, fresh water, nutrients, and marine life in the Pacific Arctic.<sup>12</sup>
- NOAA provides leadership and contributes to the U.S. Interagency and International Arctic Buoy Programs, including support for the Ice-Mass Balance Buoy Program to better understand the sources of heat causing the thinning of the Arctic sea ice cover.
- NOAA is exploring new methods of estimating snow and ice properties, such as sea ice thickness, from visible/infrared and microwave imagers and altimeters. NOAA's National Environmental Satellite Data and Information Service provides access to over 30 years of ice and atmosphere properties from satellite data that are used in climate studies.
- The Alaska Ocean Observing System (AOOS) is the "eye on Alaska's coasts and oceans."<sup>13</sup> AOOS, which is a part of the NOAA-led Integrated Ocean Observing System program, represents a network of critical ocean and coastal observations, data, and information products that promote understanding of the status of Alaska's marine ecosystem.

Scientist retrieves bongo nets and samples in the Bering Sea.  
Photo: E. Acuna, NOAA.



<sup>10</sup> Available at: <http://www.arctic.noaa.gov/reportcard>

<sup>11</sup> For more information, see: <http://www.arctic.noaa.gov/dbo>

<sup>12</sup> For more information, see: <http://www.arctic.noaa.gov/aro/russian-american>

<sup>13</sup> For more information, see: <http://www.aos.org>

## Interagency Arctic Research Policy Committee (IARPC): NOAA's Role

*In February, 2013, the National Science and Technology Council released a five-year Arctic Research Plan, outlining key areas of study where the Federal Government will focus to better understand and predict environmental changes in the Arctic. This plan provides a roadmap for extensive collaboration between agencies on high-impact research activities to provide a solid scientific basis for decisions in the Arctic.*

- The IARPC five-year plan encourages interagency collaboration within the Federal Government, as well as with Alaskans and other Arctic residents and indigenous leaders. NOAA was engaged in developing the plan and is very involved in implementing it. The plan's focus is to develop accurate and understandable science-based information of value to a wide range of users, and it is closely aligned with NOAA's research mission.
- NOAA is actively engaged in the IARPC research areas related to sea ice and marine ecosystems, observing systems, regional climate models, and adaptation tools for sustaining communities. NOAA's commitments to these areas can be seen throughout this Action Plan, particularly in activities related to the National Strategy goal of "pursuing responsible Arctic region stewardship."

**Atmosphere-Climate Observations:** NOAA's Office of Oceanic and Atmospheric Research observes the Arctic atmosphere from a number of manned observatories. Whereas weather stations are only able to measure how the environment is changing, observatories collect additional measurements that help determine why the environment is changing.

- NOAA's Barrow, Alaska, Observatory has operated since 1974 as a premier Global Atmosphere Watch Station. It is colocated with a Department of Energy Climate Research Facility.
- NOAA is also active outside the U.S. Arctic through direct investment and partnerships with Russian, Canadian, and U.S. National Science Foundation collaborators at facilities such as Tiksi Observatory in the Russian Far East, Eureka Observatory in the Canadian Archipelago, and Summit Station in Greenland.

Ground-based remote sensors monitor clouds and atmospheric structure at Summit Station, Greenland.  
Photo: M. Shupe, NOAA & Univ. Colorado.

- NOAA has led the effort to develop a pan-Arctic consortium of Arctic Observatories through the International Arctic Systems for Observing the Atmosphere, which conducts observations on surface radiation, cloud properties and changes, and atmospheric composition via eight observatories encircling the Arctic Ocean.

Looking to the future, it is clear that NOAA's Atmospheric Observatory Program will be closely aligned with the science questions driving the World Meteorological Organization/World Weather Research Programme's Polar Prediction Project, which seeks to determine linkages between polar and lower-latitude weather and climate. Atmospheric observations will also be improved by deploying autonomous and other instrumentation packages aboard ships and aircraft of opportunity to provide valuable atmospheric data across broad areas of the Arctic Ocean. For example, atmospheric, ocean, and sea ice data can be collected from NOAA aircraft while monitoring the marginal ice zone.





## Stewardship and Management

NOAA is keenly focused on the stewardship and management of Arctic living marine resources. Through its many marine research programs, NOAA provides the information necessary to support management decisions that are based on a strong scientific foundation. NOAA also plays key management and regulatory roles in the Arctic, working to ensure that natural resources are utilized sustainably and that marine ecosystems are protected.

**Living Marine Resource Surveys and Assessments:** NOAA's National Marine Fisheries Service is responsible for research on marine species and their habitats in the coastal oceans of the Arctic region. These waters support some of the most important commercial fisheries in the world, as well as rich, productive ecosystems. Living marine resource surveys and assessments include:

- Fishery stock assessments, incorporating fishery-dependent and fishery-independent data collection, to support groundfish and shellfish management,
- Economic and socio-cultural information for resource managers, commercial and subsistence fishers, and other stakeholders, and
- Marine mammal stock assessments incorporating state-of-the-art survey design, telemetry, passive acoustics, and other technologies to support management.

NOAA conducts annual research and stock assessments in the Arctic to guide decisions for sustainable management of Alaska/Arctic fisheries under the Magnuson-Stevens Fishery Conservation and Management Act. Annual assessments of Arctic marine mammals are also underway.

Researchers recover trawl net during Bering Sea fisheries assessment cruise. Photo: NOAA.



- NOAA's scientific research on groundfish, salmon, and crab provides essential information to sustainably manage the largest commercial fisheries in the United States.
- In the Arctic, NOAA operates the nation's largest fishery observer program to meet science and fishery management demands. This program annually deploys about 40,000 observer days on commercial fishing vessels in the Bering Sea and near the Aleutian Islands.
- NOAA conducts research on Arctic marine mammals, including evaluations of their abundance, population trends, vital rates, feeding ecology, habitat use, and ecosystem interactions. Stock assessments of Arctic marine mammals are published annually.
- Key species being investigated by NOAA in the Arctic include 29 stocks of groundfish, salmon, and crabs; deep-water corals; Steller sea lions; northern fur seals; harbor seals; four species of ice-dependent seals; western Arctic bowhead whales; beluga whales, North Pacific right whales; and other endangered whales.
- Applied research on marine mammals, fish, and shellfish in the Arctic also supports management and regulatory decisions regarding energy development and other industrial activities, status reviews and determinations under the Marine Mammal Protection Act and Endangered Species Act, and protection of marine mammal subsistence harvests by Alaska Natives.
- Sampling technologies employed include trawl and longline gear, acoustic profilers, environmental monitors, archival tagging, satellite telemetry, multi-spectral aerial survey sensors, genetic stock identification, bycatch reduction devices, electronic monitoring devices, and underwater video systems. In the future, NOAA will continue its innovative approaches and investments in advanced technology for improved assessment surveys.

Biologists sort, measure, and sample fish caught in Bering Sea research trawl. Photo: NOAA.



**Ecosystem and Habitat Research:** NOAA conducts integrated ecosystem-level observation and process studies to understand Arctic marine ecosystems. These programs address fish recruitment processes, ecological processes, contaminant impacts, and marine mammal-fisheries interactions.

- The overall goal of recruitment process research is to examine linkages among fish, oceanographic conditions, and climate change (e.g., ocean warming, loss of sea ice, ocean acidification) to understand the mechanisms that affect fish survival. NOAA conducts this research to reduce uncertainty in stock assessment models of commercially important species in the Arctic.
- Integrated ecosystem research programs address diverse ecological processes, spanning physical oceanography, plankton, fish, shellfish, bottom-dwelling communities, mammals, and birds. This research includes efforts to assess and mitigate, as needed, potential impacts of bottom trawling on marine life.
- Studies of marine mammal-fisheries interactions evaluate the effects of commercial fishing on marine mammals near the top of the food chain, such as Steller sea lions.
- NOAA conducts bioeffects studies in coordination with the State of Alaska and others to provide comprehensive assessments of environmental contamination and toxic impacts in regional water bodies, ranging from small bays to large sounds to the coastal ocean. This program is nationwide, allowing data from all coasts to be compared.

Measuring crabs caught during Bering Sea research survey.  
Photo: R. McConnaughey, NOAA.



Where possible, NOAA strives to incorporate traditional knowledge and community-based research into its Arctic science enterprise. Traditional knowledge is an evolving body of practical environmental knowledge based on the observations and personal experience of local residents over successive generations. Alaska Native ways of knowing reflect a holistic understanding of biology, ecology, meteorology, and physical processes that help to shape and contribute to NOAA's stewardship mission in the Arctic. For example, NOAA's longstanding partnerships with Alaska Native marine mammal organizations rely on traditional knowledge to assist with research, subsistence harvest monitoring, and biological sampling. NOAA has also sought out traditional knowledge to identify and evaluate potential resource development conflicts in the Beaufort and Chukchi seas.

**Management and Regulatory Activities:** NOAA's National Marine Fisheries Service protects Arctic living marine resources and their habitats under the Magnuson-Stevens Act, the Marine Mammal Protection Act, and the Endangered Species Act.

- NOAA is committed to furthering the goals of fishery sustainability, including taking a precautionary management approach where necessary. For example, in 2009, under the Magnuson-Stevens Act, the Secretary of Commerce approved the Arctic Fishery Management Plan, which covers U.S. federal waters of the Chukchi and Beaufort seas. The plan prohibits commercial fishing north of the Bering Strait until more information is available to support sustainable fisheries management.
- Under the Magnuson-Stevens Act, federal agencies such as the Department of Interior's Bureau of Ocean Energy Management (BOEM) consult with NOAA on actions in the Arctic that may adversely affect essential fish habitat, including oil and gas activities.

Scientists measure and collect samples from a young spotted seal in the Bering Sea, supported by the NOAA Ship *McArthur II*.  
Photo: M. Cameron, NOAA.



- Under the Marine Mammal Protection Act, NOAA issues incidental take authorizations for marine mammals affected by oil and gas activities, including seismic surveys and exploratory drilling activities in the Beaufort and Chukchi seas. In collaboration with BOEM and other partners, NOAA is developing an environmental impact statement for oil and gas activities in the Arctic Ocean that will be used to support future authorization decisions.
- NOAA routinely works with stakeholders to solicit feedback on oil and gas activities and how activities planned for the upcoming year may affect subsistence uses of marine mammals. NOAA has Marine Mammal Protection Act co-management agreements with Alaska Native organizations focused on species that are important for subsistence, including ice seals, harbor seals, Steller sea lions, northern fur seals, beluga whales, and bowhead whales. NOAA also conducts National Environmental Policy Act analyses related to the subsistence harvest of bowhead whales.
- NOAA is responsible for Endangered Species Act listing and recovery actions in the Arctic, including bowhead whales, humpback whales, North Pacific right whales, fin whales, Steller sea lions, ringed seals, and bearded seals. Under Section 7 of the Endangered Species Act, NOAA consults with federal agencies that authorize, fund, or undertake actions that may affect threatened or endangered species, including oil and gas exploration, coastal construction, commercial fishing, and other activities. NOAA has designated “critical habitat” in the Arctic for North Pacific right whales and Steller sea lions, and is currently in the process of doing the same for ringed and bearded seals.

**Concrete island drilling system in sea ice.** Photo: Dept. of the Interior.



## NOAA Provides Science-based Management of Commercial Fisheries

- Consistent with the Magnuson-Stevens Act and other applicable laws, NOAA and the North Pacific Fishery Management Council oversee the management of the prolific Bering Sea/Aleutian Islands fisheries.
- Annually, these groundfish and shellfish fisheries account for approximately 40 percent of all commercially harvested seafood from U.S. waters, making these the largest fisheries in the United States.
- NOAA has established additional cooperative management relationships with the State of Alaska and international partners. This collaborative management approach ensures productive and sustainable fishery harvests, consideration of fishery-dependent communities, effective monitoring and enforcement, and ongoing success in reducing the impacts of fishery bycatch of non-targeted species.

- Under both the Marine Mammal Protection Act and the Endangered Species Act, NOAA’s goals and objectives over the next five years include improving understanding of the distribution and abundance of marine mammals as well as mitigating both the effects of increasing human activities and the impacts of environmental change that threaten these species.

**Endangered Steller sea lions haul out in the Aleutian Islands, Alaska.** Photo: K. Sweeney, NOAA.



## Managing for the Future in a Rapidly Changing Arctic: NOAA's Role

*NOAA played a key role in developing the 2013 report to the President entitled "Managing for the Future in a Rapidly Changing Arctic." That report introduced the concept of Integrated Arctic Management and its goal of balancing environmental, cultural, and economic needs and objectives.*

- NOAA supports the report's recommendations, which include adopting an Integrated Arctic Management approach when making stewardship and development decisions affecting the U.S. Arctic, ensuring ongoing high-level White House leadership on Arctic issues, strengthening key partnerships with the State of Alaska and Alaska Natives, improving engagement between the Federal Government and stakeholders, and coordinating and streamlining federal actions in the Arctic.
- Key management tools that will be emphasized by this approach include ecosystem-based management, adaptive management, and scenario planning. Integrated Arctic Management is a specific objective of the National Strategy for the Arctic Region, and NOAA intends to continue working with its partners to develop and implement this new approach in the Arctic.
- Next steps may include establishing a stakeholder forum for effectively incorporating input and participation of non-government stakeholders, coordinating efforts to employ ecosystem-based management approaches to help integrate ecological, social, economic, commerce, health, and security goals, and addressing the Arctic-related milestones of the National Ocean Policy Implementation Plan.

### Communities and Economies

Climate change in the Arctic is altering many important features of communities and challenging indigenous ways of life. The State of Alaska and its people must make critical decisions based on threats from stronger and more frequent storms, increasing erosion, thawing permafrost, changing animal migration patterns, ocean acidification, and sea level changes. They must consider immediate and future impacts of these changes on existing infrastructure, adaptation plans, new construction and development; their lifestyles; and their livelihoods. The potential economic, environmental, and

cultural impacts of these changes are enormous, including both potentially beneficial and adverse impacts. NOAA partners with the State of Alaska, Alaska Sea Grant, the Alaska Center for Climate Assessment and Policy, and others to work with coastal communities to develop planning tools for understanding how climate change will affect their health and welfare. Building on the tools and services described below, NOAA's National Ocean Service helps Arctic communities and sustains economic growth by providing products and services to support climate change adaptation strategies and coastal resilience.



## NOAA Partner Builds Arctic Coastal Ocean Observing System

**Charting the Arctic:** NOAA provides foundational services that are needed to chart Arctic waters. Essential for mariners' situational awareness, these data also serve many other purposes, such as coastal ocean science, maritime heritage protections, management of living marine resources, habitat characterizations, emergency response, climate adaptation strategies, and coastal zone management. NOAA also provides tools to support geospatial activities and services in the Arctic.

- NOAA conducts hydrographic surveys, maps the shoreline, measures water levels and currents, and supplies the geospatial framework for determining accurate positions and elevations. NOAA plans to survey annually at least 500 square nautical miles (1,700 square kilometers) of the navigationally significant 240,000 square nautical miles (823,000 square kilometers) in the U.S. Arctic and map 390 linear miles (630 kilometers) of shoreline each year for nautical chart updates and navigation safety. Leveraging partnerships with agencies such as the U.S. Coast Guard, the U.S. Geological Survey, and the U.S. Army Corps of Engineers is critical to this effort.
- To accurately measure land elevations, NOAA uses gravity data to correct current substandard measurements, which can be off by as much as one or more meters, to an improved accuracy of approximately two centimeters. NOAA collects airborne gravity data across Alaska as the most cost-effective way to establish vertical geodetic control.

Community members sing and dance during the Nalukataq Festival at Wainwright, Alaska.  
Photo: J. London, NOAA.

- Despite the ongoing efforts of agencies and private industry, information gaps remain in Arctic observing. The Alaska Ocean Observing System (AOOS) attempts to fill this gap by providing easy access to a network of critical ocean and coastal observations, data, and information products.
- AOOS' primary activities include hosting centralized data with web-based tools and products, working with marine users to fill gaps in ocean monitoring, and fostering collaborations to meet multiple stakeholder needs.
- There are four focus areas for AOOS: safe marine operations, coastal hazard mitigation, tracking ecosystem and climate trends, and monitoring water quality.

- NOAA operates and maintains nine long-term National Water Level Observation Network stations in the Arctic that provide real-time water level data and the vertical reference for tidal datums along coasts. NOAA is focusing its efforts on improving water level datum coverage as well as obtaining better data on currents. Short-term water level gauges are being deployed to support hydrographic surveying and the NOAA VDatum modeling project to seamlessly transfer between tidal and geodetic datums.



## Report on U.S. Arctic Marine Transportation System: NOAA's Role

*The Committee on the Marine Transportation System (CMTS) released a report in 2013 entitled, "U.S. Arctic Marine Transportation System: Overview and Priorities for Action." The report described the actions required to develop a Marine Transportation System in the Arctic capable of meeting the Nation's maritime safety, economic, security, and environmental protection needs now and in the future.*

- Many of NOAA's services are critical to establishing a U.S. Arctic Marine Transportation System, including marine weather and sea ice forecasts, oil spill response, and hydrographic surveying and mapping to update nautical charts.
- NOAA's nautical chart coverage is particularly important to the U.S. Marine Transportation System, but in the Arctic, charting data are inadequate or nonexistent. For example, the U.S. Coast Pilot describes the Bering Sea area as "only partially surveyed, and the charts must not be relied upon too closely, especially near shore. The currents are much influenced by the winds and are difficult to predict; dead reckoning is uncertain, and safety depends upon constant vigilance." Updating NOAA's Arctic nautical charts with modern shorelines, depths, hazards, and recommended routes throughout the region would improve maritime safety and efficiency.

NOAA is working with partners to augment its capacities to provide a stronger geospatial foundation and the data needed for safe navigation, science, and more-informed coastal decision-making. This approach will leverage existing coordination by agencies involved in Integrated Ocean and Coastal Mapping and the Alaska Mapping Executive Committee.

- Partners with survey-capable vessels such as the U.S. Coast Guard, U.S. Navy, the academic fleet, and private industry may be able to collect survey data en route between Dutch Harbor and the Arctic Ocean for analysis and charting by NOAA. These efforts will aim to accelerate and enhance the acquisition and processing of U.S. Arctic bathymetric data. The highest priority focus of this effort will be 40,000 square nautical miles (137,000 square kilometers) in need of surveys to delineate a safety corridor from the Aleutian Islands to the Beaufort Sea, which would otherwise take 50-80 years to

accomplish at the current level of effort. Employing this integrated mapping concept will result in more accurate data and charts along the most-utilized Arctic open water routes, allowing NOAA to focus its resources on the more challenging coastal areas for harbors of refuge, port access, and coastal community resilience.

- During the past decade, NOAA and its federal partners have gathered and analyzed data and samples to determine the outer limits of the U.S. extended continental shelf in the Arctic. The data collected to make these shelf extension determinations will provide a rich baseline for understanding the diversity of this maritime zone and for setting future exploration, research, and resource management priorities.

Hydrographic survey crew installs a horizontal control station at Little Diomed Island, Alaska.  
Photo: D. Neander, NOAA.



## NOAA Provides Scientific Support for Oil Spill Response

**Hazard Assessment and Response:** Decreased summer sea ice is already leading to growth in Arctic commerce, tourism, and oil and gas exploration. The chances of oil spilling from either a vessel or exploratory drilling facility are likely to increase in the future, and NOAA is concerned over the readiness and effectiveness of spill response capabilities in the Arctic. NOAA is responsible for delivering scientific support to the U.S. Coast Guard for marine hazards, including oil spills and marine debris. In addition, the Oil Pollution Act of 1990 established NOAA as a trustee for natural resources and outlined a framework for conducting natural resource damage assessment and restoration of natural resources that have been contaminated by the discharge or threatened discharge of oil. The Comprehensive Environmental Response, Compensation and Liability Act provided similar authorities for hazardous substances, pollutants, or contaminants that could endanger human health and/or the environment.

- Under the National Oil and Hazardous Substances Pollution Contingency Plan, NOAA is responsible for providing scientific support in chemistry, trajectory modeling, natural resources at risk, and data management to the Federal On-Scene Coordinator for oil and hazardous material spills. In addition to spill response software and mapping tools, NOAA provides standard techniques and publishes guidelines for observing oil and assessing shorelines.
- NOAA participates in interagency cross-training exercises for emergency responders, including response to oil in sea ice. NOAA is involved in joint training and workshops with other Arctic nations on oil spill response activities in the Arctic, such as the use of mechanical recovery, dispersants, and in situ burning following transboundary spill events.

- In 2012, NOAA launched the Arctic Environmental Response Management Application (Arctic ERMA). ERMA is a web-based tool that assists both emergency responders and environmental resource managers in dealing with incidents that may harm the environment. This system integrates and synthesizes data into a single interactive map, providing quick geo-spatial visualizations and improving communication and coordination.
- ERMA brings together all of the available information needed for an effective emergency response in the Arctic's distinctive conditions, such as the extent and concentration of sea ice, the locations of ports and pipelines, and the presence of vulnerable environmental resources.

- To support preparedness for spill response and natural resource damage assessment in the Arctic, NOAA has been compiling and developing baseline information on natural resources in the Arctic and preparing Arctic injury assessment sampling guidelines. NOAA has also engaged Alaska communities in preparing for spill response and natural resource damage assessment and restoration.
- Going forward, NOAA will work with the Department of the Interior to ensure that NOAA's expertise is applied in reviewing oil spill response plans and applications for drilling permits.



Biologists haul in a beach seine to sample coastal marine life near Barrow, Alaska.  
Photo: NOAA.



Atmospheric scientists arrive at Summit Station, Greenland. Photo: M. Shupe, NOAA & Univ. Colorado.

## **IV.** National Strategy Line of Effort 3: **STRENGTHEN INTERNATIONAL COOPERATION**

NOAA's many international and national partnerships provide excellent support to the U.S. overall strategy on Arctic cooperation. As stated in the National Strategy for the Arctic Region, the United States will focus its efforts to strengthen international cooperation by:

- 1) Pursuing arrangements that promote shared Arctic state prosperity, protect the Arctic environment, and enhance security,
- 2) Working through the Arctic Council to advance U.S. interests in the Arctic region,
- 3) Acceding to the Law of the Sea Convention, and
- 4) Cooperating with other interested parties.

NOAA engages directly in international partnerships through the Arctic Council, other bodies such as the World Meteorological Organization and the International Maritime Organization, and through bilateral discussions and agreements with Canada, Russia, and others. National partnerships with federal agencies, tribal organizations, the State of Alaska, academia, the private sector, and non-governmental organizations provide great strength for achieving NOAA's science, service, and stewardship missions in the Arctic region. NOAA is always seeking to improve existing partnerships and foster new ones for the benefit of and service to the Arctic region.



## National Partnerships

Through regional partnerships in the U.S. Arctic, NOAA actively coordinates Arctic science, policy, and regulatory activities. NOAA participates in many groups that unite various stakeholders around common causes in Alaska and the Arctic.

- NOAA contributes to the scientific research plans and activities of the Interagency Arctic Research Policy Committee, which establishes federal research priorities and pursues integrated Arctic research initiatives.
- To better inform lands and resource management efforts, NOAA plays a role in working groups such as the Alaska Climate Change Executive Roundtable, the North Slope Science Initiative, the Arctic and Aleutian Bering Sea Islands Landscape Conservation Cooperatives, the North Pacific Research Board, and the Alaska Ocean Observing System.
- For policy and regulatory issues, NOAA is an active member of both the national and regional components of the Interagency Working Group on the Coordination of Domestic Energy Permitting in Alaska. This group leads federal agency coordination on permitting for energy in Alaska, including offshore oil and gas drilling and renewable energy efforts.

NOAA works closely with several of its sister agencies on Arctic issues. NOAA's relationship with BOEM and its predecessor agencies has evolved over the years into an especially strong partnership to conduct scientific research of mutual interest in the Arctic, particularly with respect to marine mammals. Today NOAA and BOEM are coordinating

with increasing efficiency on environmental reviews and permitting as well as on collaborative environmental studies. NOAA and the U.S. Coast Guard have also improved ties on common mission areas relating to navigation safety, pollution prevention and cleanup, and fishery enforcement.

NOAA's partnerships in the Arctic region with the private sector are also improving. An excellent example is the recent data-sharing Memorandum of Agreement between NOAA, Shell, ConocoPhillips, and Statoil. This precedent-setting document is advancing Arctic science and improving operational safety by making valuable data on weather, sea ice, ocean, and environmental studies available to researchers, planners, and industry operators through the AOOS Arctic Data Portal funded by NOAA.

NOAA is always seeking productive ways to strengthen its partnerships with the State of Alaska and the Alaska Native community. NOAA values its long-standing partnerships with Alaska Native groups such as the Indigenous People's Council for Marine Mammals, the Alaska Eskimo Whaling Commission, the Alaska Beluga Whale Committee, the Ice Seal Committee, the Aleut Marine Mammal Commission, and the tribal governments of St. Paul and St. George to co-manage marine mammals in support of the long-term sustainability of these populations and subsistence harvests. NOAA and the State of Alaska are working together on oil spill response logistics and education, water quality and contaminants surveys, Bering Sea bottom-trawl surveys for crabs, Steller sea lion research, and research and harvest monitoring of ice-associated seals.

NOAA scientists conduct collaborative research with Alaska Native partners.

Photo: M. Cameron, NOAA.



## International Partnerships

**Intergovernmental and operational:** NOAA is engaged in many activities with its international partners, ranging from enhancing science and fostering a greater understanding of climate change and its impacts to promoting safe navigation and emergency response.

- NOAA is involved in several important marine shipping issues, such as working with the International Maritime Organization to negotiate improved protections related to maritime shipping, participating in the Aleutian Islands Risk Assessment working group, coordinating with the Arctic Regional Hydrographic Commission to increase uniformity among charts, and determining feasible next steps for shipping and port access in the Bering Strait region.
- NOAA plays a leadership role in the 88-nation International Whaling Commission, which is responsible for international conservation and management of whales, as well as issuing subsistence harvest catch limits for bowhead whales in the western Russian-American Arctic. NOAA co-chairs the U.S.-Russia Marine Mammal Working Group, which promotes scientific cooperation and effective marine mammal management and conservation, and which has fostered long-standing research partnerships with several Russian institutes.

- Monitoring ice internationally is critically important, and NOAA participates in the International Ice Charting Working Group to coordinate operational ice services supporting maritime navigation. NOAA is also part of the North American Ice Service, a partnership between the Canadian Ice Service, the International Ice Patrol, and the U.S. National Ice Center.
- Through a Memorandum of Understanding with the Russian Federal Service for Hydrometeorology and Environmental Monitoring, NOAA cooperates in the areas of meteorology, hydrology, and oceanography. NOAA also works through a Memorandum of Understanding with Environment Canada to collaborate on Arctic weather, climate, hydrology, geodesy, and marine forecasting. Finally, NOAA scientists play key roles in the World Meteorological Organization's Expert Panel on Polar Observations, Research, and Services; the Global Cryosphere Watch; the Polar Prediction Project; and the Polar Space Task Group.
- NOAA scientists collaborate internationally on several other marine research programs: with the Norwegian Institute of Marine Research on the Arctic Ocean Ecosystem initiative; with Russian partners on the Bering-Arctic-Subarctic Integrated Survey through the North Pacific Anadromous Fish Commission; and with scientists from Japan, Canada, and the United Kingdom on plankton surveys of the Bering Sea and Aleutian Islands region.

**U.S. Coast Guard Cutter *Healy* and Canadian Coast Guard Cutter *Louis S. St. Laurent* work jointly in support of NOAA scientists' mapping efforts as part of the Extended Continental Shelf Project.**  
Photo: NOAA & Univ. New Hampshire.



## NOAA's Leadership Within the Arctic Council

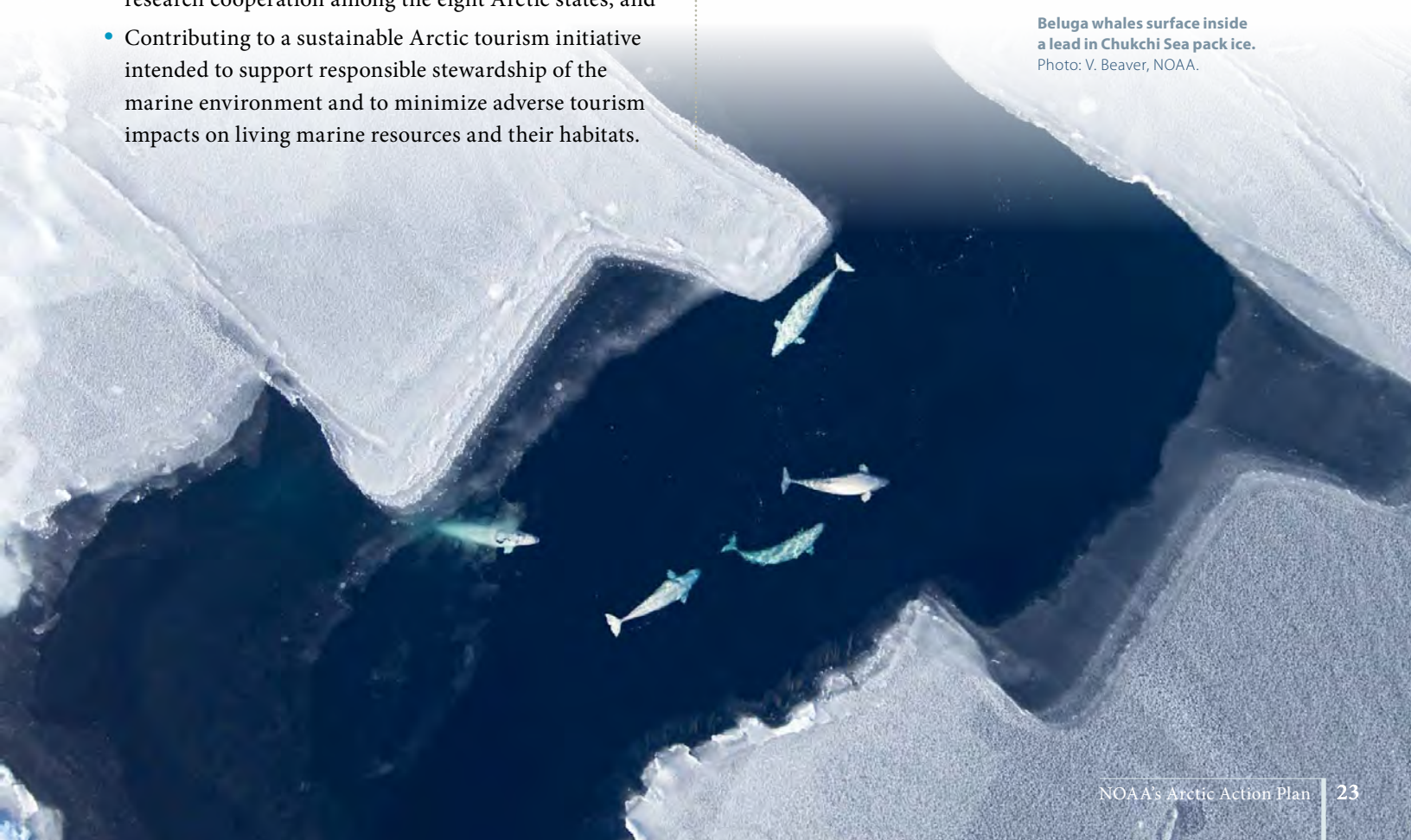
- NOAA is the head of the U.S. delegation to, and the Vice-Chair of, the Arctic Council's Working Group on the Protection of the Arctic Marine Environment (PAME).
- NOAA co-leads the PAME Shipping Expert Group that, among other projects and initiatives, is working to identify options for mitigating the risks associated with the use and carriage by vessels in the Arctic of heavy fuel oils and to recommend measures to protect ecologically significant areas within the Arctic high seas from the potential adverse impacts of international shipping activities.
- NOAA co-chairs PAME's Ecosystem Approach Expert Group and NOAA is active in the international initiative, "Implementing the Ecosystem Approach to Management in the Arctic."
- NOAA chairs the U.S. expert team to the Circumpolar Biodiversity Monitoring Program's Marine Implementation Plan.

**Arctic Council:** The Arctic Council is the predominant intergovernmental forum addressing international Arctic issues for the eight Arctic nations. NOAA provides substantial leadership and expertise to several of the Arctic Council working groups on diverse subjects such as oil spill response, safe shipping, ecosystem-based management, and biodiversity monitoring. These efforts help the United States to sustainably use and manage its resources, protect the environment, and advance U.S interests in the Arctic Council and the circumpolar Arctic.

NOAA will continue its leadership role in the Arctic Council, which the U.S. will chair from 2015 to 2017. NOAA's contributions to the Arctic Council's ministerial mandates issued in 2013 will include:

- Participating in future national, binational, and multinational contingency plans, training, and exercises to develop effective measures for oil spill preparedness and response,
- Developing an Arctic Council action plan on oil pollution prevention,
- Encouraging Arctic states to implement Arctic Council recommendations regarding ecosystem-based management,
- Working toward arrangements to improve scientific research cooperation among the eight Arctic states, and
- Contributing to a sustainable Arctic tourism initiative intended to support responsible stewardship of the marine environment and to minimize adverse tourism impacts on living marine resources and their habitats.

Beluga whales surface inside a lead in Chukchi Sea pack ice. Photo: V. Beaver, NOAA.

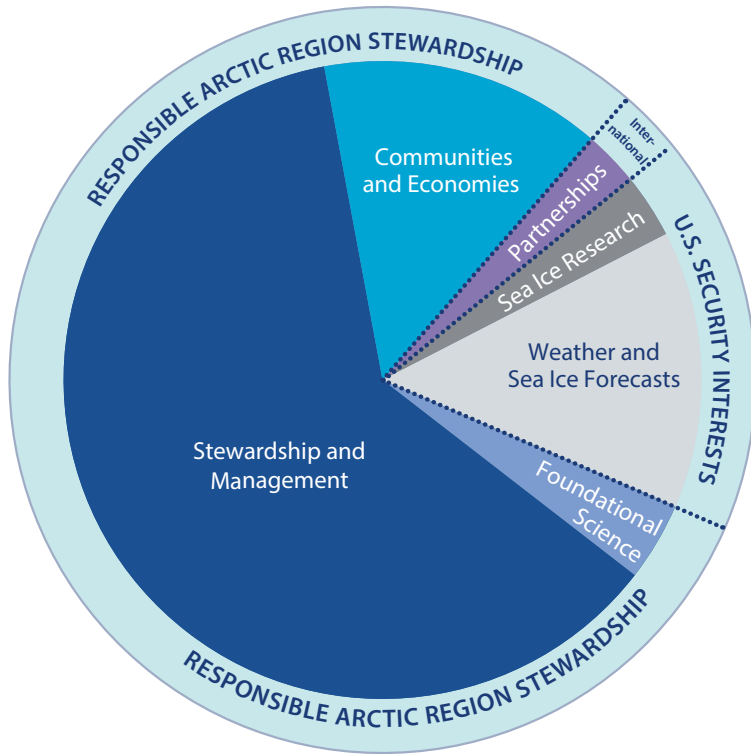




Scientists traverse sea ice en route to their sampling site. Photo: NOAA.

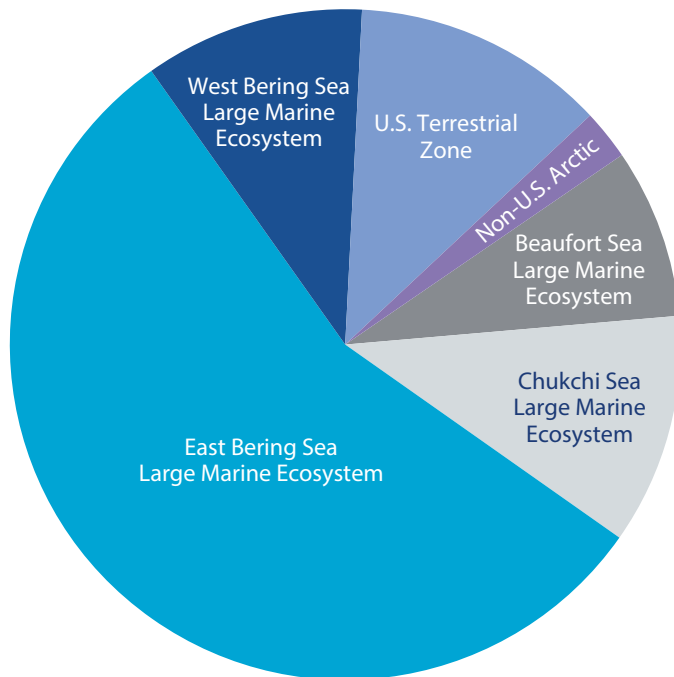
## V. NOAA'S INVESTMENTS IN THE ARCTIC

Looking ahead, NOAA will continue to conduct a strong and dynamic Arctic program in support of the National Strategy for the Arctic Region, to the extent possible within existing resources. In 2013, NOAA invested approximately \$125 million to develop products and services in support of all of its Arctic strategic goals (including funding transferred to NOAA for research needed by external partners). The largest share of NOAA Arctic funding is directed to supporting Arctic region stewardship, with substantial investments also being made to advance U.S. security interests and partnerships (Fig. 2). NOAA's Arctic program is geographically broad, topically diverse, and rich in talent. As evident in Figure 3, NOAA's activities are distributed across all geographic areas in the Arctic, both within and outside U.S. boundaries (see Figure 1 for definitions). NOAA's unique capabilities and expertise enable it to provide critically important support to the Nation as it implements the U.S. National Strategy for the Arctic Region.



**Figure 2.** NOAA 2013 Arctic funding by NOAA Arctic goal and National Strategy line of effort.

- National Strategy for the Arctic Region lines of effort
- Sea ice research (3.3%)
- Weather and sea ice forecasts (14.0%)
- Foundational science (4.0%)
- Stewardship and management (61.6%)
- Communities and economies (14.3%)
- Partnerships (2.8%)



**Figure 3.** NOAA 2013 Arctic funding by geographic area.

- Beaufort Sea LME (8.2%)
- Chukchi Sea LME (11.1%)
- East Bering Sea LME (55.5%)
- West Bering Sea LME (10.6%)
- U.S. terrestrial zone (12.2%)
- Non-U.S. Arctic (2.4%)



Arctic cod swimming inside sea ice. Photo: E. Siddon, NOAA & Univ. Alaska.

## APPENDIX – NOAA’S ARCTIC MILESTONES FOR 2014 AND 2015

This Appendix presents specific action-oriented milestones associated with Arctic programs, products, and services that NOAA is committed to supporting in Fiscal Years 2014-2015. These actions cover the range of NOAA missions across each of its six Arctic strategic goals and relate directly to several broader Administration policy initiatives including the National Strategy for the Arctic Region, the Interagency Arctic Research Policy Committee Research Plan (2013-2017), and the National Ocean Policy Implementation Plan. This list of milestones is considered to be a living document that will evolve with Administration budgets, Congressional appropriations, and national priorities.

Bracketed letters at the end of each milestone indicate the NOAA line offices with lead responsibility for each milestone – followed by the relevant national goals as described below:

### NOAA offices with lead responsibility for Arctic milestones

<b>NESDIS</b>	National Environmental Satellite and Information Service
<b>NMFS</b>	National Marine Fisheries Service
<b>NOS</b>	National Ocean Service
<b>NWS</b>	National Weather Service
<b>OAR</b>	Office of Oceanic and Atmospheric Research
<b>OIA</b>	Office of International Affairs
<b>OMAO</b>	Office of Marine and Aviation Operations

### National goals supported by NOAA milestones

<b>NOP</b>	National Ocean Policy
<b>NSAR</b>	National Strategy for the Arctic Region
<b>IARPC</b>	Interagency Arctic Research Policy Committee

# ADVANCE U.S. SECURITY INTERESTS

## Weather and Sea Ice Forecasts

Issue routine sea ice analyses, forecasts, advisories, and outlooks 5-days per week in a variety of formats to be useful from the community level to the federal stakeholders and partners; continue to provide non-routine tactical support services as needed for core partners. **[NWS – NOP, NSAR]**

Advance our sea ice services through the addition of more observational data sets to our analysis and forecasting techniques, evaluations of coupled model output from Environment Canada and the Naval Research Laboratory, and the expansion of product suites with new and more frequent services. **[NWS – NOP, NSAR, IARPC]**

Produce and disseminate routine weather forecasts and non-routine alerts of hazardous conditions (high winds, winter storms, thunderstorms, wildfire conditions, floods) across Alaska 365 days a year. **[NWS – NOP, NSAR]**

Address weaknesses in our communications infrastructure to ensure more reliability/redundancy in forecast and warning dissemination. **[NWS – NOP, NSAR]**

Continue to modernize and make more efficient our observational networks through the installation of hydrogen generators; automated marine, aviation, and river observing platforms; and in leveraging partnerships for infrastructure and data sharing wherever possible. **[NWS – NOP, NSAR, IARPC]**

Establish foundational components of a Regional Operations Center and Arctic Test Bed to strengthen NOAA's ability to be responsive to emerging service requirements in the Arctic and leverage new science and technology capabilities. **[NWS – NSAR, IARPC]**

Produce and disseminate routine aviation weather forecasts and non-routine alerts of hazardous conditions (turbulence, icing, fog, wind shear, volcanic ash) for the airspace in and around Alaska 365 days a year. **[NWS – NSAR]**

Produce and disseminate routine weather forecasts and warnings of hazardous conditions (high winds, waves, freezing spray, fog, thunderstorms) for the coastal and offshore waters around Alaska 365 days a year. **[NWS – NSAR]**

Develop an implementation plan for seamless marine weather services across the Arctic and in accordance with World Meteorological Organization standards. **[NWS – NSAR]**

Lead the effort to validate the requirements for climate-scale Arctic-specific forecasts for weather and sea ice to inform and prioritize NOAA's research and observing investments. **[NWS – NOP, NSAR, IARPC]**

Integrate new satellite-derived sea ice information into National Ice Center operations, such as ice thickness, ice concentration, and size of leads (fractures) in ice. **[NESDIS – NOP, NSAR, IARPC]**

Improve snow depth, snow cover, ice cover, and ice thickness analysis for operational model initialization or assimilation. **[NESDIS – NOP, NSAR, IARPC]**

Coordinate with national and international partners to broaden geographic coverage of Arctic sea ice analysis and forecasting by calibrating single-point buoy/mooring data with satellite data. **[NESDIS – NOP, NSAR, IARPC]**

## Sea Ice Research

Collect observations to enable modeling and analyses of Arctic sea ice to provide the necessary information and understanding required to support sea ice forecasts and advisories. **[OAR – NOP, NSAR, IARPC]**

Continue research to analyze and synthesize in situ, remote sensing, and model data for Arctic Ocean seasonal sea ice and the tropospheric impacts of loss of sea ice. **[OAR – NOP, NSAR, IARPC]**

Undertake research and model-based analyses that investigate the current status, future changes, and interactive processes related to sea ice drift, sea ice thickness, and snow cover on ice. **[OAR – NOP, NSAR, IARPC]**

Conduct coordinated calibration and validation of satellite measurements of the cryosphere through in-situ and airborne missions in collaboration with national and international partners. **[NESDIS – NOP, NSAR, IARPC]**

# PURSUE RESPONSIBLE ARCTIC REGION STEWARDSHIP

## Foundational Science

### ICE-OCEAN-ECOSYSTEM OBSERVATIONS

Conduct sustained observations in key regions of the Chukchi Sea, Beaufort Sea, East Siberian Sea, and Pacific Arctic Ocean with inter-agency and international partners to support the Russian-American Long-term Census of the Arctic (RUSALCA) Program and other research initiatives. [OAR – NSAR, IARPC]

Implement and expand the Distributed Biological Observatory in the Pacific Arctic to monitor changes in the physical environment and species' distribution, abundance, biomass, composition, and ecological processes in marine ecosystems to assess potential socioeconomic and ecosystem impacts of climate change. [OAR – NOP, NSAR, IARPC]

### ATMOSPHERE-CLIMATE OBSERVATIONS

Maintain, strengthen, and enhance atmospheric climate observatories and monitoring sites around the Arctic Rim to capture measures of variability and change; continue to improve data management to support analyses to understand the causes and implications of those changes both in the Arctic and in the Northern Hemisphere. [OAR – NOP, NSAR, IARPC]

Develop and update meaningful products for delivering findings and information concerning key climate features. [OAR – NOP, NSAR, IARPC]

## Stewardship and Management

### LIVING MARINE RESOURCE SURVEYS AND ASSESSMENT

Improve the frequency and quality of assessments for key fish stocks, prepare a baseline monitoring report for all managed fish stocks, and add next-generation assessments for selected stocks with high sensitivity to ecosystem conditions. [NMFS – NOP, NSAR, IARPC]

Conduct upper continental slope trawl surveys biennially to estimate the distribution and abundance of Alaska groundfish resources in the eastern Bering Sea. [NMFS – NOP, NSAR]

Conduct crab and groundfish bottom trawl surveys annually to estimate the distribution and abundance of fisheries resources in the eastern Bering Sea. [NMFS – NOP, NSAR]

Conduct comprehensive bottom trawl surveys of the Chukchi Sea to monitor the effects of loss of sea ice. [NMFS – NOP, NSAR]

Collect fisheries and oceanographic survey data from the Bering-Arctic-Subarctic Integrated Survey (BASIS) in the Bering and Chukchi seas. [NMFS – NOP, NSAR, IARPC]

Conduct fisheries surface trawl and acoustic surveys in the Chukchi Sea as part of the Arctic ecosystem integrated survey. [NMFS – NOP, NSAR, IARPC]

Continue to develop advanced technologies to enhance data collection for stock assessments. [NMFS – NSAR]

Continue to provide observer coverage in the groundfish and halibut fisheries in the Bering Sea and near the Aleutian Islands. [NMFS – NSAR]

Update the web-based Interagency Electronic Report System that enables landings and production data to be reported by shoreside processors to accommodate catch share fisheries such as Bering Sea crab and flatfish. [NMFS – NSAR]

Partner with state agencies and fishing commissions, as appropriate, to expand collection of economic and socio-cultural information for resource managers, commercial and subsistence fishers, and other stakeholders. [NMFS – NOP, NSAR, IARPC]

Conduct marine mammal stock assessments to support management, incorporating state-of-the-art survey design, telemetry, passive acoustics, and other advanced technologies. [NMFS – NOP, NSAR]

Conduct surveys to assess the abundance and trends of the endangered western stock of Steller sea lions. [NMFS – NOP, NSAR]

Assess the vital rates of the western stock of Steller sea lions in Alaska and Russia. [NMFS – NOP, NSAR]

Conduct research on the food habits of Steller sea lions and northern fur seals in the Bering Sea. [NMFS – NOP, NSAR]

Conduct annual assessments in the Bering Sea of northern fur seal population abundance and trends. [NMFS – NOP, NSAR]

Evaluate the age-specific rates for reproduction, growth, and survival of northern fur seals. [NMFS – NOP, NSAR]

Analyze the results of joint U.S./Russia aerial surveys of the abundance and distribution of ribbon, spotted, ringed, and bearded seals in the Bering and Okhotsk seas. [NMFS – NOP, NSAR]

Continue studies of the distribution, abundance, ecology, and behavior of cetaceans in the Chukchi and Beaufort seas. [NMFS – NOP, NSAR, IARPC]

Provide at-sea vessel support for living marine resource surveys, studies of protected species, and ecosystem research. [OMAO – NSAR]

### ECOSYSTEM AND HABITAT RESEARCH

Increase understanding of the effects of climate variability on Alaska's four Arctic Large Marine Ecosystems. [NMFS – NOP, NSAR, IARPC]

Maintain Bering Sea climate and marine ecosystem observing networks and distribute data to decision-makers and stakeholders. [NMFS – NOP, NSAR, IARPC]

Develop and evaluate environmental indicators for improving stock assessments and integrated ecosystem assessments. [NMFS – NOP, NSAR, IARPC]

Conduct long-term observations of climate-related impacts on Bering Sea ecosystems through integrated ecosystem assessments. [NMFS – NOP, NSAR, IARPC]

Deliver Bering Sea ecosystem forecasts to help living marine resource managers incorporate climate-related impacts into management decisions. [NMFS – NOP, NSAR, IARPC]

Increase information regarding climate-related impacts on early life history stages of key Bering Sea fisheries. [NMFS – NOP, NSAR, IARPC]

Evaluate ecosystem impacts of oil and gas development and the toxicity of oil and chemical dispersants used in response to oil spills on the early life history stages of Arctic cod, a keystone species in Arctic marine food webs. [NMFS – NOP, NSAR, IARPC]

Conduct captive experiments to investigate the potential impacts of ocean acidification on the early life history stages of commercially important king crab stocks. [NMFS – NOP, NSAR, IARPC]



Undertake a research cruise to investigate the distribution, stock structure, diet, and ecology of spotted and ribbon seals in the Bering Sea in relation to the loss of sea ice. **[NMFS – NOP, NSAR, IARPC]**

Conduct research integrating information on cetaceans, zooplankton, and oceanography in the Chukchi Sea. **[NMFS – NOP, NSAR, IARPC]**

Plan and conduct synoptic bioeffects sampling studies for baseline sediment chemistry, benthic community assessment, and sediment toxicity in the Bering, Chukchi, and Beaufort seas. **[NOS – NSAR, IARPC]**

## MANAGEMENT AND REGULATORY ACTIVITIES

Manage the Alaska groundfish fisheries to avoid exceeding annual catch limits. **[NMFS – NOP, NSAR]**

Prepare annual regulations for governing the Pacific halibut fishery under jurisdiction of the International Pacific Halibut Commission. **[NMFS – NSAR]**

Publish in the Federal Register fisheries management rules and harvest specifications for Bering Sea groundfish, halibut, and crab fisheries. **[NMFS – NOP, NSAR]**

Inspect and certify shoreside processor catch monitoring plans and certify at-sea processor scales so that catch estimates are accurate and harvests of Alaska crab, Pacific halibut and groundfish are consistent with allocations of total allowable catch. **[NMFS – NOP, NSAR]**

Update the Alaska Region catch accounting system to meet fishery information needs for management of the North Pacific groundfish fisheries. **[NMFS – NOP, NSAR]**

Provide industry training and user support of the Interagency Electronic Reporting System which provides the Alaska fishing industry with a consolidated means of electronically reporting halibut and sablefish, groundfish, salmon, and shellfish landings to multiple agencies. **[NMFS – NOP, NSAR]**

Compile and synthesize existing information on red king crab habitat in the federal waters of Norton Sound. **[NMFS – NOP, NSAR]**

Complete interagency consultations for federal actions that may adversely affect Essential Fish Habitat. **[NMFS – NSAR]**

Develop a Draft Programmatic Essential Fish Habitat Consultation with the Bureau of Ocean Energy Management for oil and gas activities in the Chukchi Sea. **[NMFS – NOP, NSAR]**

Assist the Environmental Protection Agency in completing the Bristol Bay Watershed Assessment. **[NMFS – NOP, NSAR]**

Complete the Steller sea lion protection measures for the Bering Sea and Aleutian Islands Groundfish Fisheries Environmental Impact Statement. **[NMFS – NOP, NSAR]**

Complete a new Biological Opinion on the effects of the Alaska groundfish fisheries on Steller sea lions. **[NMFS – NOP, NSAR]**

Determine whether to modify the current designation of Steller sea lion critical habitat. **[NMFS – NSAR]**

Continue strong partnerships with Alaska Native organizations to support co-management of marine mammal subsistence harvests and to utilize traditional knowledge to complement information obtained through scientific research. **[NMFS – NOP, NSAR, IARPC]**

Publish proposed and final rules to revise northern fur seal subsistence harvest regulations on St. George Island. **[NMFS – NSAR]**

Complete the Final Environmental Impact Statement evaluating the effects of seismic and drilling exploration on marine mammals in the Arctic. **[NMFS – NOP, NSAR]**

Complete a new Biological Opinion on the effects of the Alaska groundfish and crab fisheries on ringed and bearded seals. **[NMFS – NOP, NSAR]**

Work together with other federal agencies, State of Alaska and Alaska Native partners, and Arctic stakeholders to develop and implement an Integrated Arctic Management approach to addressing natural resource issues. **[NMFS – NOP, NSAR, IARPC]**

## Communities and Economies

### CHARTING THE ARCTIC

Update nautical charts, environmental sensitivity index maps, and other Arctic feature maps with data acquired through annual field seasons. **[NOS – NOP, NSAR]**

Build hydrodynamic models, vertical datum transformation tools, and digital elevation models for U.S. Arctic coasts. **[NOS – NOP, NSAR, IARPC]**

Collect airborne gravity data over the State of Alaska (including the Aleutian Islands) and refine the experimental Alaska geoid model to help correct errors in Arctic. **[NOS – NOP, NSAR]**

Develop prototype Arctic-capable water level gauges to fill gaps in NOAA water level observations for tidal determinations and to support charting and mapping efforts. **[NOS – NSAR, IARPC]**

Continue efforts to develop force-multiplying survey technologies (e.g., autonomous platforms and technologies, LIDAR, IFSAR, satellite sensors) capable of collecting high quality Arctic survey data. **[NOS – NSAR, IARPC]**

Develop a plan for an integrated maritime heritage mapping project to find the lost whaling fleets of the western Arctic and implement when feasible. **[NOS – NSAR]**

Provide at-sea vessel capability to support charting and research operations in the Arctic. **[OMAO – NSAR]**

### HAZARD ASSESSMENT AND RESPONSE

Continue compiling and refining the data sets provided by the online data portal Arctic ERMA (Environmental Response Management Application). **[NOS – NOP, NSAR, IARPC]**

Participate in interagency research and data integration to improve Arctic natural resource maps that feed scenario development and risk assessment; strengthen models for oil spill trajectory as well as the weathering and fate of oil. **[NOS – NOP, NSAR, IARPC]**

Improve oil spill prevention, containment, and response infrastructure, plans, and technology for use in ice-covered Arctic seas, using all available sources, such as federal agencies, industry, academia, and international partners. **[NOS – NOP, NSAR, IARPC]**

Finalize and test contingency plans to ensure adequacy of response equipment, trained personnel, and nearshore protection strategies using existing response preparedness efforts, such as the Aleutian Island Risk Assessment. **[NOS – NOP, NSAR, IARPC]**

## STRENGTHEN INTERNATIONAL COOPERATION

### National Partnerships

Coordinate with regional groups such as the Alaska Climate Change Executive Roundtable, Interagency Working Group on the Coordination of Domestic Energy Permitting in Alaska, North Slope Science Initiative, Landscape Conservation Cooperatives, and the Alaska Ocean Observing System. **[All – NOP, NSAR, IARPC]**

Continue working with the State of Alaska and the Alaska Native community to promote environmental protection, sustainable development, and thriving coastal communities. **[All – NOP, NSAR, IARPC]**

Leverage partnerships with other federal agencies, academic collaborators, and private industry to advance scientific initiatives, improve operational efficiency, and share environmental data. **[All – NOP, NSAR, IARPC]**

### International Partnerships

#### INTER-GOVERNMENTAL AND OPERATIONAL

Coordinate with international partners to facilitate scientific collaboration, participation in international organizations, and cooperation on other cross-boundary issues such as conservation and management, navigation and emergency response, and climate change. **[OIA – NOP, NSAR, IARPC]**

Work with international partners and organizations to enhance the provision of services such as weather, sea ice, and climate forecasts; environmental monitoring; and the information needed for science-informed decisions. **[All – NOP, NSAR, IARPC]**

Continue to work with the International Maritime Organization to develop safe and secure shipping, to prevent marine pollution by ships in the Arctic, and to finalize the Polar Code. **[OIA – NOP, NSAR, IARPC]**

#### ARCTIC COUNCIL

Maintain leadership roles and active engagement in the Arctic Council and its subsidiary working groups such as Protection of the Arctic Marine Environment (PAME) and Conservation of Arctic Flora and Fauna (CAFF). **[OIA – NSAR, IARPC]**

Support the development of an Arctic Council Arctic Science Cooperation arrangement. **[All – NOP, NSAR, IARPC]**



