NOAA and the Alaska Ocean Observing System

Contributions to the National Backbone and Regional Needs

This article was prepared by Allen Macklin, of NOAA's Office of Oceanic and Atmospheric Research; Gary Hufford, of NOAA's National Weather Service; Bernard Megrey, of NOAA's National Marine Fisheries Service; Rebecca Smyth, of NOAA's National Ocean Service; and Molly McCammon, Executive Director, Alaska Ocean Observing System.

The Alaska Ocean Observing System (AOOS) will improve Alaska's ability to detect changes in marine ecosystems and living resources, predict future changes and their consequences for the public, and enable stakeholders to make better decisions about use of the marine environment. AOOS partners include:

- Federal agencies, such as the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey, the Minerals Management Service, and the U.S. Coast Guard;
- Federal–State agencies, such as the *Exxon Valdez* Oil Spill Trustee Council;
- State agencies, such as the Alaska Department of Fish and Game, and state academic institutions, including the University of Alaska;
- Research organizations, such as the North Pacific Research Board, the Alaska SeaLife Center, the Prince William Sound Science Center, the Arctic Research Commission, and the Barrow Arctic Science Consortium; and
- Industry groups, including fisheries and marine navigation associations.

AOOS is one of 11 regional associations developing across the country to ensure that observing systems meet regional needs as part of the U.S. Integrated Ocean Observing System (IOOS). Nationally, the effort to establish IOOS is led by the Ocean.US Office under the National Oceanographic Partnership Program. Legislation creating the national system and associated regional systems, such as AOOS, is currently pending in the U.S. Congress. IOOS, in turn, is part of the Global Ocean Observing System and ultimately will be the U.S. ocean contribution to the Global Earth Observing System of Systems.

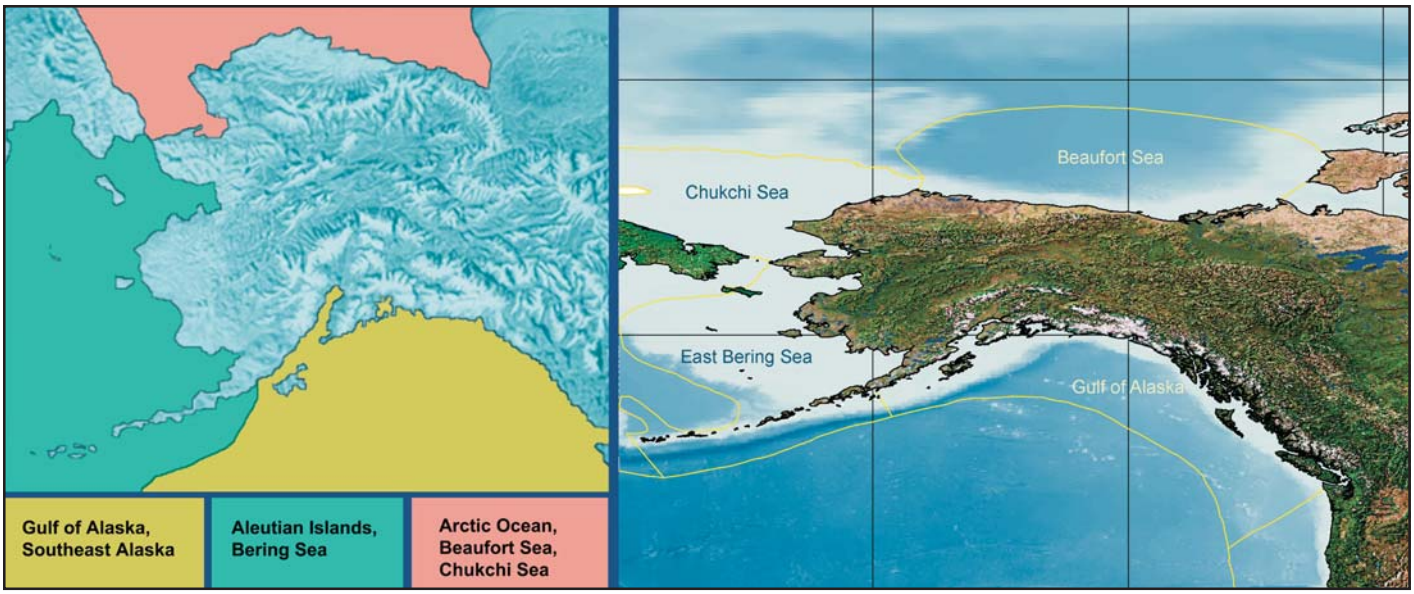
Implementation of AOOS started in 2002. A pilot project, employing elements of the Prince William Sound Ocean Observing System that includes NOAA platforms, will be the first on-line operational element, delivering information this year. When fully developed, AOOS will:

- Serve as the Alaska regional node for the national network of observing systems (IOOS);
- Systematically deliver real-time information and long-term trends about Alaska's ocean conditions and marine life;
- Provide public Internet access to cost-free data and information on coastal conditions; and
- Supply tailored products to meet the needs of mariners, scientists, industry, resource managers, educators, and other users of marine resources.

Implementing AOOS presents an enormous challenge because of the vastness of the region. Alaska's nearly 44,000 miles of coastline constitute about two-thirds of the total U.S. coastline and support a wide variety of habitats and user communities. NOAA, with a strong statewide presence in research, monitoring, and forecasting, is well positioned to help establish AOOS.

To make the challenge of implementation more tractable, AOOS's first approach is to organize along three large marine ecosystem boundaries: Arctic, Bering Sea/Aleutian Islands, and Gulf of Alaska. These regional classifications tend to be natural divisions that are differentiated by physical and biological characteristics, management schemes, and use by stakeholders. Even the size of these three regions, however, poses challenges.

Because of Alaska's remoteness and extreme weather conditions (frigid temperatures, precipitation, storms, high sea state, and sea ice), designing, installing, and operating an ocean observing system throughout the three Alaska regions is more difficult than in any other shelf area in U.S. waters. The extremely long distances render any plan for periodic servicing or unscheduled maintenance and repairs of observing arrays very costly and logistically often impractical. The dearth of nearby infrastructure, such as villages or other semipermanent settlements, makes power availability,



AOOS's three regions (left), which are similar to the Large Marine Ecosystems of the area (right).

real-time data retrieval, and routine equipment maintenance extremely demanding for almost every installation. Winter conditions challenge instrument capabilities because of the extreme temperature changes and the high winds and seas, ice, snow, and fog that accompany them. Extensive cloud cover associated with frequent passage of storms also contributes to the lack of ocean color, AVHRR, and other visible remote sensing products that are typically available in other coastal areas.

In spite of the challenges of establishing an integrated ocean observing system in Alaska, the opportunities and needs warrant national attention. Presently, the Alaska fisheries provide more than 40% of the U.S. and about 5% of the world harvest of fish and shellfish; Bristol Bay supports the world's largest sockeye salmon fishery; and the snow crab fishery is currently the largest crustacean fishery (by weight) in the U.S. In addition to supporting a large portion of the nation's fishery production, Alaska waters also support more than 80% of the U.S. seabird population. Another crucial point for implementing AOOS is that greenhouse-gas-related global warming is thought to be amplified in polar regions, making Alaska conditions a harbinger for climate change.

NOAA's Mission

NOAA also shares many of Alaska's concerns. NOAA envisions an informed society that uses a comprehensive understanding of the role of the oceans, coasts, and atmosphere in the global ecosystem to make the best social and economic decisions. NOAA's mission is to understand and predict changes in the earth's environment and conserve and manage coastal and marine resources to meet our nation's economic, social, and environmental needs.

To achieve its mission, NOAA's focus through 2010 will be on four mission goals and a mission support goal:

- Protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management;
- Understand climate variability and change to enhance society's ability to plan and respond;
- Serve society's needs for weather and water information;
- Support the nation's commerce with information for safe, efficient, and environmentally sound transportation; and
- Provide critical support for NOAA's mission.

In an effort to build specific core strengths, NOAA has selected five cross-cutting priorities for the 21st century that it recognizes as essential to support its mission goals. Three that pertain particularly to efforts to develop AOOS are:

- Integrating global environmental observations and data management;
- Ensuring sound, state-of-the-art research; and
- Promoting environmental literacy.

Stakeholders

By partnering, NOAA and AOOS can address common themes and provide benefits to their

stakeholders. The stakeholders cover a broad range of subsistence, commercial, cultural, and economic interests. User groups include a wide array of commercial and recreational fishers; subsistence hunters and fishers; marine transportation interests such as barges, ferries, cruise ships, and oil/gas tankers; oil and gas developers; coastal communities and their residents; and resource managers, including the U.S. Coast Guard performing its full range of regulatory, safety, and security missions.

The user groups have a wide range of needs for data and information products. For example, some of these groups require precise navigation and real-time information, yet others need only rudimentary knowledge of currents and water masses. While these needs exist today, others lie in the future, such as possible Northwest Passage transits under reduced Arctic ice cover. Increased surveillance, security, and safety of transportation and commercial shipping activities (offshore, in ports, and in sea lines of communication between Alaska and the continental U.S.) are recent and emerging areas of concern for the U.S. that will be addressed by many of the proposed AOOS activities. All of the above information needs are closely tied to forecasting weather and oceanographic conditions, as most weather systems, including extreme events, transit across marine waters before entering Alaska.

The use of AOOS observations and products for science applications is also important, especially for developing a better understanding of the variability of Alaska's ocean waters and the diverse ecosystem dynamics that produce the nation's most abundant fish and shellfish harvests, as well as important bird and marine mammal populations. Many of the science applications are directed toward the sustainability of commercial and subsistence fishing, especially in the Bering Sea/Aleutian Islands and Gulf of Alaska regions. Other examples of how AOOS products will contribute to scientific understanding include addressing the need to better understand the biophysical processes (for example, wind mixing, upwelling, and eddy formation) that contribute to the sustained high productivity of the shelf and continental slope waters, as well as improved assessment of biota. Weather and climate forecasts will benefit greatly from a much larger set of real-time observations in coastal areas where they are presently missing. Modeling long time series data would result in an improved and more comprehensive understanding of icing phenomena, shelf currents, shoreline erosion, tsunami hazards, and the evolution of catastrophic spill trajectories. In addition, longer-term climate change scenarios will become more "testable" given a more comprehensive and complete set of observations.

Statewide Priority Needs

There is a need throughout Alaskan waters for a system to acquire, process, integrate, and present remote sensing products, some of NOAA origin, that incorporate wind, sea surface height, sea ice cover, ocean color, wave height and direction, water column current, water column salinity, and water column temperature data. An immediate requirement that NOAA will address is the need to obtain a density of data buoys comparable to at least half that along the rest of the U.S. coast.

Additionally, Alaska needs data management and communications systems that provide real-time data for use by Alaska stakeholders. The systems must include the assimilation of data into models that provide information products such as ocean circulation patterns (taking into account waves, eddies, and fronts) and improved nearshore forecasts to minimize impacts of coastal erosion on development. These data systems also must store the data and metadata from the observing network in formats that provide ready access to researchers, regulators, educators, and public and commercial users.

Finally, Alaska must develop:

- Models that assimilate data to simulate circulation, predict wave heights and storm surges, and nowcast/forecast changing sea ice conditions;
- Systems that connect marine data and models with terrestrial data, especially given the importance both of freshwater input into the marine system and anadromous fish such as salmon that rely on both freshwater and marine waters;
- Comprehensive coastal and offshore mapping and charting; and
- Shore-side capabilities to develop, stage, deploy, operate, and maintain observing systems, including AUVs, cabled and moored systems, and ground- and air-based remote sensors throughout Alaska.

Besides these statewide needs, AOOS also will address specific requirements of the Arctic, Bering Sea, and Gulf of Alaska regions. These are documented on the AOOS web site (www.aoos.org).

A NOAA Polar Operational Environmental Satellite (POES), which collects global data on cloud cover; surface conditions such as ice, snow, and vegetation; atmospheric temperatures; and moisture, aerosol, and ozone distributions. They also collect and relay information from fixed and moving data platforms.

NOAA's Role in AOOS

Because of NOAA's long-term involvement in Alaska, NOAA is already a major contributor to the development of AOOS. NOAA efforts range from service on the Governance and the Data Management and Communications committees to provision of funds, observations, and products. Existing and planned activities by NOAA components are detailed in the subsections below.

National Environmental, Satellite and Data Information Service

To properly understand the Arctic environment, an observing system must consist of both space-based and in situ observations. The backbone of present space-based observations is the operational system of polar-orbiting satellites, such as NESDIS's Polar Operational Environmental Satellite (POES) series. The five AVHRR satellite-borne sensors offer a cost-effective means of gaining large-scale information from the synoptic to mesoscale in a systematic, repetitive manner over remote, data-sparse, polar regions. With two operating POES satellites, a pass over a portion of the Arctic can be obtained about every two hours. The POES series of satellites provides a long-term (more than 30 years), consistent database to detect and monitor spatial and temporal variability, necessary for distinguishing climate trends from natural "noise." The POES series will continue until 2012, when a new generation of satellites called the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) will be launched.

NPOESS will consist of a number of advanced sensor arrays to provide higher resolution and

Contributions of NOAA's major line organizations to the Alaska Ocean Observing System. Early, direct contributions are designated by a check. With ongoing commitment, all boxes will eventually be checked.

	AOOS Activity					
NOAA Line Organization	Observations	Modeling and Analysis	Data Management and Communications	Education and Outreach	Governance and Planning	Funding
NESDIS	√					
NMFS	√	√	√		√	√
NOS	√	√	√	√	√	√
NWS	√	√	√		√	
OAR	√	√	√		√	√

more accurate measurements of the atmosphere, clouds, aerosols, the earth radiation budget, clear-air land/water/ice surfaces, sea surface temperature, ocean color, ocean surface wind speed and direction, ocean surface topography, and temperature and moisture profiles. (See htpp://npoess.noaa.gov/index.html for detailed information on sensor type and expected performance.) The major challenge will be to integrate the satellite sensor information with the in situ observations, including calibration and verification of sensor data to the surface observations.

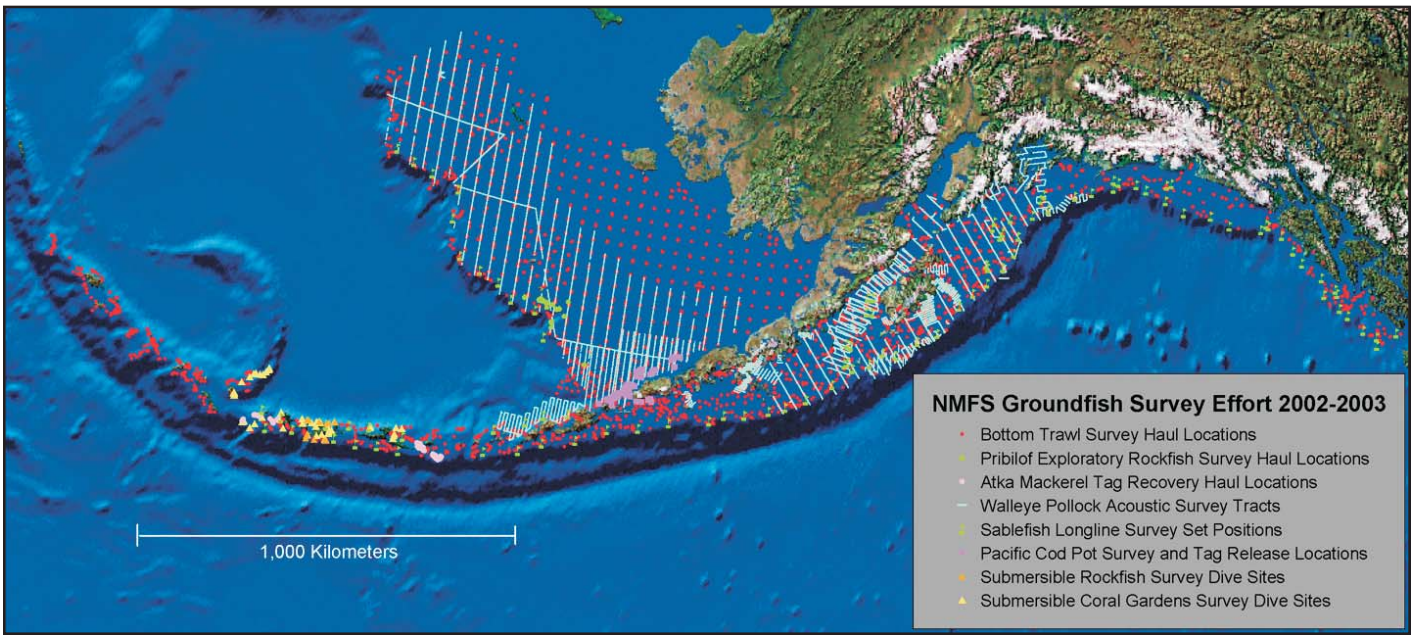
Another area in which NESDIS is committed to AOOS is the implementation of Climate Reference Network (CRN) observing stations across Alaska, including coastal sites. The CRN stations will reduce the uncertainty in the observed climate signal for surface temperature to less than 0.1°C per century and precipitation to less than 1% per century on regional scales. Approximately 29 CRN sites will be located in Alaska, with about 10 sites along the coast. Two sites, at Fairbanks and Barrow, are already operating. Four more sites will be installed during the summer of 2005, and it is anticipated that four sites will be installed each summer until the installation is complete. The coastal CRN sites will provide an important tie to the ocean–land system.

National Marine Fisheries Service

NOAA's National Marine Fisheries Service (NMFS) conducts biological, ecological, and economic research to provide information for the needs of regional fishery management councils, interstate and international fishery commissions, fishery development foundations, government agencies, and the general public.

NMFS, through its research and monitoring activities, seeks to understand and predict changes to marine ecosystems and their subsystems affecting living marine resources, fisheries, habitats, ecosystem condition, productivity, aquaculture, and the generation of net national benefits. NMFS develops the scientific information base required for fishery resource conservation, fishery development and utilization, habitat conservation, protection of marine mammals and endangered species, and the impact analyses and environmental assessments for management plans and international negotiations. It also pursues fisheries oceanographic research from a marine ecosystem standpoint to answer specific needs in the subject areas of population dynamics, fishery economics, fishery engineering, food science, and fishery biology.

The Alaska Fisheries Science Center (AFSC) conducts ecosystem-based research and assessments of living marine resources, with a focus on the North Pacific, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use. Since the early 1970s, the AFSC has conducted annual scientific fishery surveys to measure the distribution and abundance of approximately forty commercially important fish



National Marine Fisheries Service survey of commercially valuable and associated fish, shellfish, and marine mammals in the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands.

and crab stocks in the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands. Surveys in the Bering Sea are conducted annually on a regular sampling grid, while surveys in the Gulf of Alaska occur every other year using a stratified random sampling approach to estimating abundance.

The research surveys utilize a wide range of sampling techniques, mensuration equipment, and fishing gear, including underwater video systems, autonomous submersibles, hydroacoustic technology, and midwater, bottom trawl, ichthyoplankton, longline, crab pot, and pot sampling gear, as well as tagging studies. Often physical oceanographic measurements are taken concurrently with biological samples.

Data derived from these surveys and other sampling programs are analyzed by AFSC scientists, and the results and outcomes from these activities are supplied to fishery management agencies and to the commercial fishing industry, where they are used in making resource management decisions.

National Ocean Service water level observing station at Valdez. Stations such as this one are located at 18 sites in Alaska, and six new stations are planned.

NMFS and the AFSC, through their regular execution of large-scale fisheries surveys, will be an important source of biological information for AOOS. In turn, AOOS will provide much of the physical and chemical information needed by NMFS for ecosystem-based fisheries management.

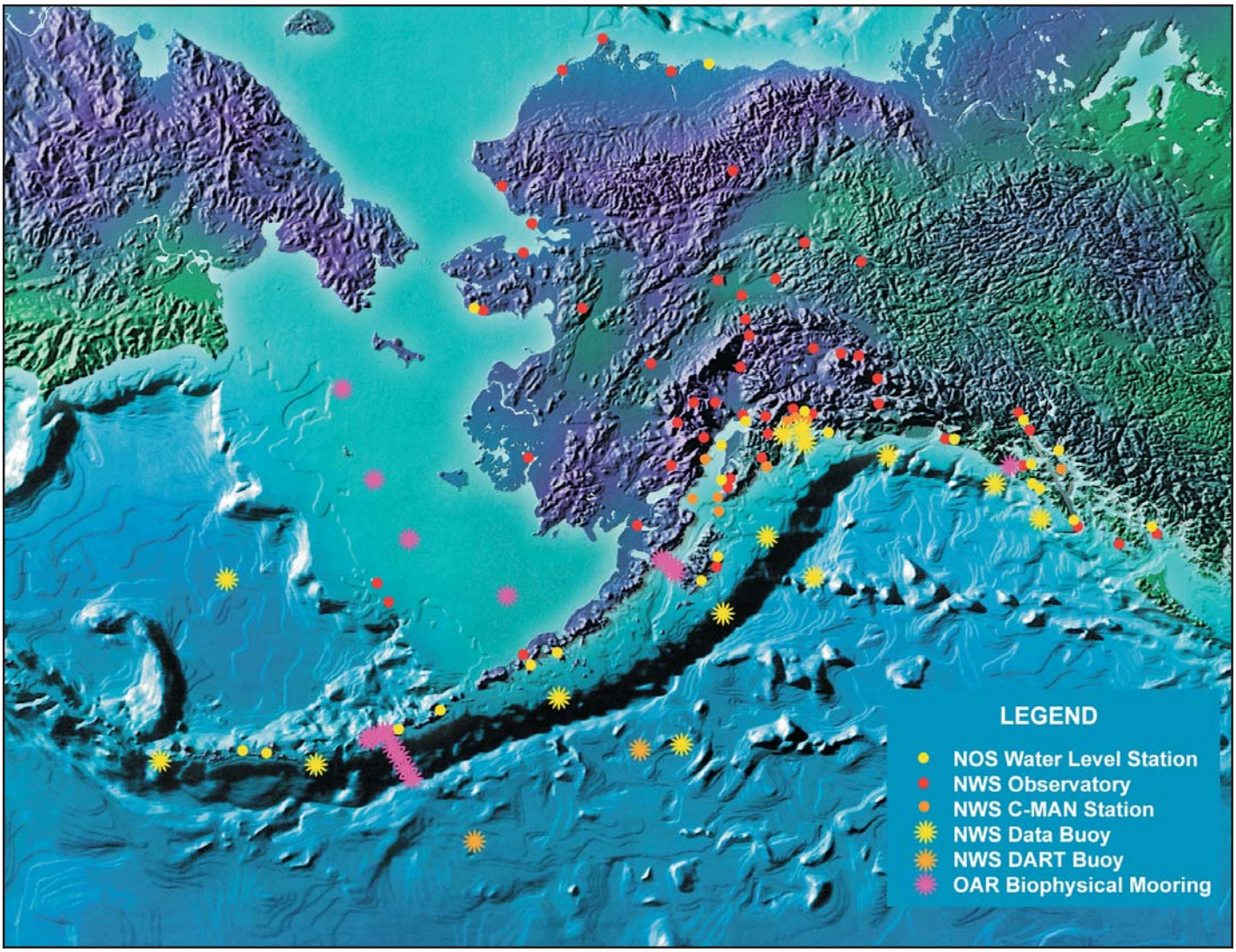
Besides the valuable survey information that NMFS will provide to AOOS, NMFS is a major partner in the development of AOOS, providing funds and personnel who serve in governance and data management capacities.

National Ocean Service

NOAA's National Ocean Service (NOS) works to balance people's use of the coast with conservation of the nation's coastal and ocean resources. Thus, NOS's mission is to manage society's uses of coastal ecosystems to sustain their natural resources and services. This mission is undertaken in a variety of ways: supporting commerce and marine transportation navigation; protecting, restoring, and managing coastal and marine resources; and building the capacity of regional, state, and local partners to undertake both these activities. A key component of these activities is to observe coastal and ocean conditions and resources, either directly or by building the capacity of regional, state, and local partners.

NOS is conducting or has planned a number of activities that will expand or enhance IOOS-related activities in Alaska. NOS will expand the multimission National Water Level Observation Network (NWLON) in Alaska (18 existing locations) with six new NWLON stations, primarily to help strengthen the U.S. Tsunami Warning System. NOS will continue to conduct tidal current surveys in Cook Inlet and southeast Alaska to update tidal current predictions, as well as hydrographic surveys using in-house and contract capabilities. NOS also will deploy a high-frequency surface current mapper during the summer of 2005 to complete its data collection requirements in the Cook Inlet area.

NOS also provides financial and technical assistance to Alaskan partners to aid in the development of regional observing capabilities. Grants to AOOS have helped fund the development of the regional governance needed to establish the regional association, including outreach and data management. Additional grants starting this fall will aid the Alaska region in implementing data management, visualization, and pilot observing systems around the state and in developing edu-



Locations of nearly 115 land and marine stations operated by NOS, NWS, and OAR. The observations from these stations represent NOAA's primary contribution to AOOS. In addition, about 150 more stations (not shown) operated by the Federal Aviation Administration, the Department of Defense, and commercial interests report through the NWS network.

cation, outreach, and business plans. Over the past two years, NOAA has provided resources to aid in developing coastal observations along the Gulf of Alaska. The system-wide monitoring program of the National Estuarine Research Reserves, part of the national backbone, which includes long-term data on water quality and weather at frequent time intervals, provides resources for the Kachemak Bay Reserve to participate in the system-wide program and the regional efforts. In addition, NOS is working with other parts of NOAA and with their partners, including AOOS, to coordinate and provide technical assistance for data management.

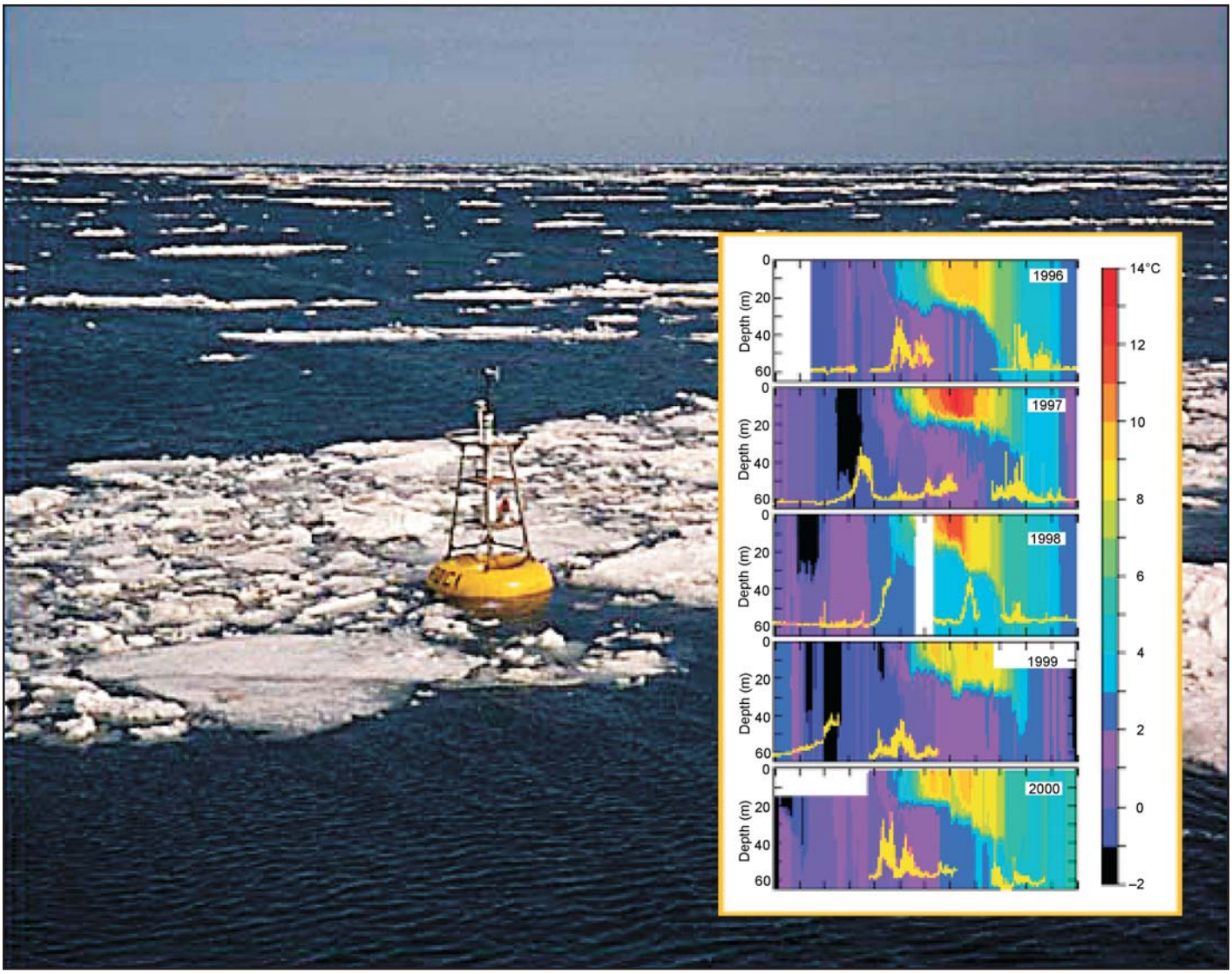
National Weather Service

The National Weather Service (NWS) has nearly 100 land observation stations across Alaska that report hourly. NWS also has over 150 cooperative observation sites (many near the coast) that provide daily minimum and maximum temperatures and total precipitation. In addition, Coastal-Marine Automated Network (C-MAN) stations are being installed along the coast, especially in the Gulf of Alaska. C-MAN was established by the NWS in the early 1980s to continue meteorological observations previously made by the U.S. Coast Guard until automation of many Coast Guard navigational aids ended that practice. Over the last few years, the number of fixed ocean data buoys has increased from 3 to 13, providing new information in data-sparse areas. Several of these buoys will be instrumented with subsurface ocean instruments in the coming year as part of a national effort to increase the data generated by this system. The data from all these sites form the backbone for the long-term surface observations in Alaska.

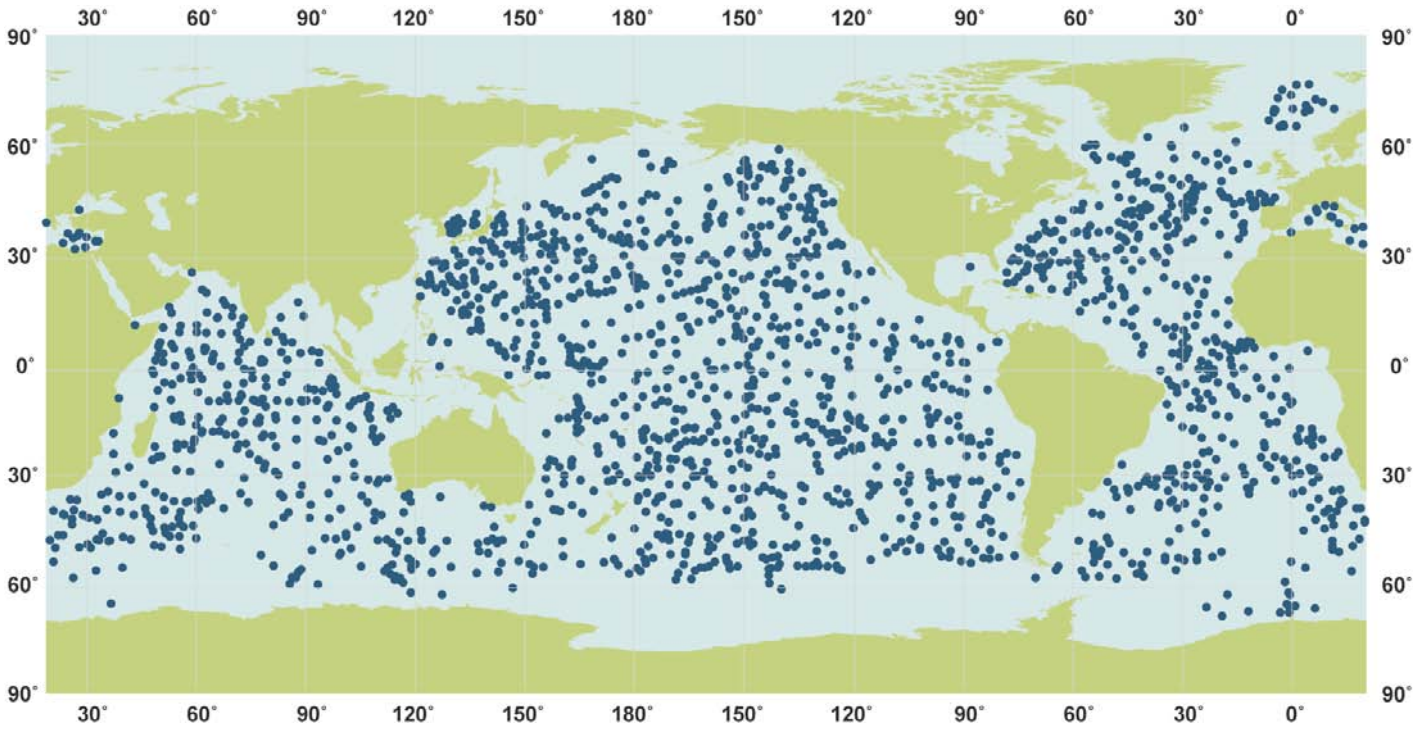
As funding becomes available, NWS will continue its efforts to expand marine observational sites, especially for the northern waters of the Bering and Chukchi Seas and the Arctic coast, as technology provides a buoy that can withstand sea ice conditions. With climate change occurring around Alaska, forecasters are observing increasing frequencies and intensities of ocean storms, shifts in storm track, and more formation of storms in the Arctic. The recession in sea ice cover is producing larger areas of open water, which is resulting in greater air–sea interaction. Large waves from these storms are not only affecting vessels at sea, but they are also creating increased coastal erosion and coastal flooding. In addition, subsistence activities are being disrupted. Longer lead times are required for short-term forecasts and warnings so that affected towns and villages can prepare the best they can. There is a need for more and better Arctic atmospheric and oceanic observations, both in situ and remotely sensed, and improved numerical weather and ocean prediction models that will incorporate the observations and better handle advances in high-latitude meteorology and oceanography.

Office of Oceanic and Atmospheric Research

The major contributors to AOOS from NOAA's Office of Oceanic and Atmospheric Research (OAR) are the Pacific Marine Environmental Laboratory (PMEL) in Seattle and the Arctic Research Office. PMEL helped fund early planning for AOOS and has provided representation and leadership to the AOOS Data Management and Com-



Biophysical mooring, operated jointly by OAR and NMFS, that measures a suite of environmental variables (pressure, wind, radiation, humidity, air and sea temperature, current, salinity, nutrients, and indicators of primary and secondary productivity), some of which are reported in real time.



Locations of Argo floats, which provide a new source of data from the top 2 km of the ocean. There were 1894 active floats as of June 13, 2005. The robotic floats spend most of their lives at depth but surface regularly to make temperature and salinity profile measurements. Many countries contribute the floats, and all data are freely available. A challenge for the Argo program will be the deployment of floats in Arctic waters. NOAA funds the U.S. Argo component.

munications Committee. The Arctic Research Office also has been instrumental in planning AOOS and is represented on the Governance Committee. OAR marine observations and products will come largely from PMEL. PMEL, together with the Alaska Fisheries Science Center, is a leader in the deployment of biophysical moorings in continental shelf and slope waters of the Arctic and subarctic. Several of these are planned for AOOS, including moorings in Cross Sound (southeastern Alaska), Shelikof Strait (western Gulf of Alaska), across the Alaska Stream south of the Aleutian Islands, in passes of the Aleutian Islands, and in the eastern Bering Sea. Biophysical moorings measure a suite of environmental variables (pressure, wind, radiation, humidity, air and sea temperature, current, salinity, nutrients, and indicators of plankton biomass), some of which are reported in real time. These observations may be reported directly by AOOS or incorporated into marine products that are disseminated through AOOS. PMEL also is working cooperatively with AOOS to plan and produce ocean circulation models of coastal Alaska.

NOAA funds the U.S. portion of the Argo Project. The Argo Project is building an array of 3,000 profiling CTD floats that, when completed, will measure the temperature and salinity of the upper 2 km at a spacing of roughly 3° latitude by 3° longitude and at 10-day intervals. The U.S. is presently contributing about half of the floats for the array, which was over 60% complete as of mid-June 2005. North of 45°N and east of 180°W in the Pacific at that date, there were about 49 Argo floats, and about 15 of these were U.S. floats. No floats have been deployed in the Pacific Arctic region. OAR's PMEL and Atlantic Oceanographic and Meteorological Laboratory are key contributors to the U.S. Argo effort.

Summary

NOAA and AOOS is a strong partnership. NOAA's line organizations are present and operating in each of the three AOOS regions, offering a rich mixture of marine and atmospheric measurements. AOOS and its constituents benefit from the information and services that NOAA supplies. Many of these will now be delivered to and disseminated by AOOS, as well as through existing NOAA channels. NOAA benefits from AOOS through the enriched flow of Alaska marine information that NOAA scientists and managers will have at hand for formulating analyses and decisions concerning regional marine issues. Moreover, discussions and exchanges between NOAA and AOOS foster an increased understanding of mutual problems and aspirations that can further improve cooperation between the organizations. Because of ongoing cooperation, NOAA and AOOS will be stronger and better able to serve the region and nation.