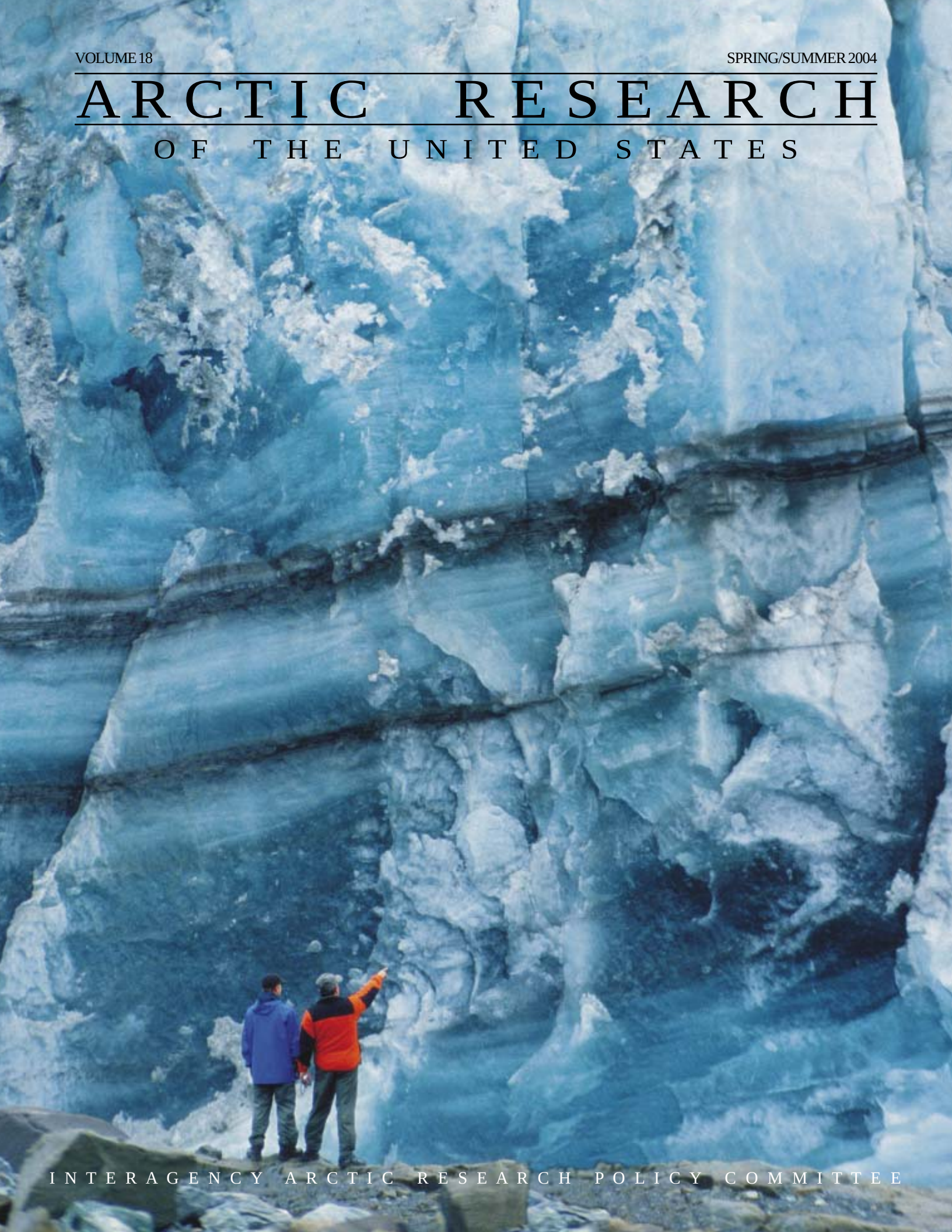
VOLUME 18 SPRING/SUMMER 2004

ARCTIC RESEARCH

OF THE UNITED STATES



INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

About the Journal

The journal *Arctic Research of the United States* is for people and organizations interested in learning about U.S. Government-financed Arctic research activities. It is published semiannually (spring and fall) by the National Science Foundation on behalf of the Interagency Arctic Research Policy Committee (IARPC). The Interagency Committee was authorized under the Arctic Research and Policy Act (ARPA) of 1984 (PL 98-373) and established by Executive Order 12501 (January 28, 1985). Publication of the journal has been approved by the Office of Management and Budget.

Arctic Research contains

- Reports on current and planned U.S. Government-sponsored research in the Arctic;
- Reports of IARPC meetings; and
- Summaries of other current and planned Arctic research, including that of the State of Alaska, local governments, the private sector, and other nations.

Arctic Research is aimed at national and international audiences of government officials, scientists, engineers, educators, private and public groups, and residents of the Arctic. The emphasis is on summary and survey articles covering U.S. Government-sponsored or -funded research rather than on technical reports, and the articles are intended to be comprehensible to a nontechnical audience. Although the articles go through the normal editorial process, manuscripts are not refereed for scientific content or merit since the journal is not intended as a means of reporting scientific research. Articles are generally invited and are reviewed by agency staffs and others as appropriate.

As indicated in the U.S. Arctic Research Plan, research is defined differently by different agencies. It may include basic and applied research, monitoring efforts, and other information-gathering activities. The definition of Arctic according to the ARPA is "all United States and foreign territory north of the Arctic Circle and all United States territory north and west of the boundary formed by the Porcupine, Yukon, and Kuskokwim Rivers; all contiguous seas, including the Arctic Ocean and the Beaufort, Bering, and Chukchi Seas; and the Aleutian chain." Areas outside of the boundary are discussed in the journal when considered relevant to the broader scope of Arctic research.

Issues of the journal will report on Arctic topics and activities. Included will be reports of conferences and workshops, university-based research and activities of state and local governments and public, private and resident organizations. Unsolicited nontechnical reports on research and related activities are welcome.

Address correspondence to Editor, *Arctic Research*, Arctic Research and Policy Staff, Office of Polar Programs, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230.

Front Cover

Researchers observing massive ice calving near the face of the Steller Lobe of the Bering Glacier. This ice face is nearly 100 m high and 15 km long.

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Report from Federal Agencies for 2002–2003

This issue of *Arctic Research of the United States* presents highlights and results of major fiscal year 2002 and 2003 Arctic research programs and selected projects of the Federal agencies. For more information, you may contact the agency staff representatives listed on page 147.

National Science Foundation

National Science Foundation research is concerned with the entire Arctic region, including Alaska, Canada, Greenland, Svalbard, the Arctic Ocean and adjacent seas, the upper atmosphere, and near space. Research falls principally within eight major scientific disciplines: atmosphere, ocean, biology, earth science, glaciology, social science, engineering, and science education.

The NSF supports a formal Arctic research program within the Office of Polar Programs (OPP). Other divisions and programs throughout NSF, primarily in the Directorate for Geosciences and the Division of Environmental Biology in the Directorate for Biological Sciences, support research in and on the Arctic as part of their overall funding. Most research grants are awarded on the basis of unsolicited proposals and are merit reviewed.

In FY 03, NSF awarded funds for 356 Arctic research projects at 136 institutions in 43 U.S. states and the District of Columbia.

The following sections present highlights of several major programs and selected projects. A complete listing of NSF Arctic funded projects can be found in the publication *Arctic Science, Engineering, and Education Awards: FY 2003*, available from the Office of Polar Programs, National Science Foundation, Arlington, VA 22230.

	Funding (thousands)	
	FY 02	FY 03
Arctic Natural Science	11,472	12,200
Arctic System Science Prog	19,093	20,699
Arctic Social Sciences Prog	1,975	2,758
Arctic Education Research	250	300
Arctic Research Support	797	823
Arctic Data/Info/Coord	248	270
Arctic Research Commission	1,017	1,080
Arctic Logistics/Instrumentation	27,580	29,166
Subtotal for OPP	62,431	67,296
Other NSF Science Programs	23,557	25,786
Total	85,988	93,082

Arctic System Science

In 1989 the NSF established the Arctic System Science (ARCSS) program, an interdisciplinary program that examines the interactions within and between the climatic, geologic, biologic, and socioeconomic components of the Arctic system. ARCSS is predicated on the premise that the Arctic system is sensitive to, and important in, global change. The ARCSS goal is to understand the physical, chemical, biological, and social processes of the Arctic system that interact with the total Earth system and thus contribute to or are influenced by global change, in order to advance the scientific basis for predicting environmental change on a decade-to-centuries time scale, and for informing policy options in response to the anticipated impacts of changing climate on humans and societal support systems. The program is coordinated, managed, and supported financially by the OPP, with contributions from other NSF directorates and other Federal agencies where appropriate. NSF/ARCSS has been successful at establishing partnerships with other Federal agencies; considerable cost and in-kind sharing with NASA, ONR, and NOAA on current and past projects has occurred for projects dealing with Arctic climate and ocean processes and modeling research. ARCSS research continues to contribute to the U.S. Global Change Research Program.

ARCSS has employed a series of workshops and interactions with a broad scientific community to develop goals and priorities aimed at understanding the role of the Arctic as a system undergoing change. Planning is focused on three thematic questions: What are the limits of Arctic system predictability? How do human activities interact with changes in the Arctic to affect the sustainability of ecosystems and societies? How will changes in Arctic cycles and feedbacks affect Arctic and global systems? These questions emphasize three concepts fundamental to research on Arctic change: predictability, sustainability, and feedbacks. Focusing the ARCSS program on these concepts reflects the increased ARCSS emphasis

on integrative, interdisciplinary research that weaves disciplinary knowledge into system science. An important assumption underlying these questions is that many changes in the global climate system affect the Arctic system. Changes in the Arctic may, in turn, have impacts on the global system.

ARCSS currently has several components, including Ocean/Atmosphere/Ice Interactions (OAII); Land/Atmosphere/Ice Interactions (LAII); Paleoenvironmental Arctic Sciences (PARCS); the Russian–American Initiative on Shelf–Land Environments in the Arctic (RAISE); and Human Dimensions of the Arctic System (HARC). However, the program is evolving to a more efficient structure, and it is anticipated that these components will change substantially, become woven into a structure more nearly reflecting the questions, and ultimately disappear, and that each of the ARCSS research efforts will contribute primarily to the three thematic questions above. OAII and LAII have long been scheduled to end their planning activities and will do so at the end of 2004. RAISE has been on a trajectory to broaden its scope to a pan-Arctic Land–Shelf Interactions (LSI) effort and has already produced a science plan to provide ideas to the ARCSS process. Similarly, new ideas emerged from the LAII group in the form of a Pan-Arctic Cycles, Transitions and Sustainability (PACTS) plan, which proved to have intellectual content that was highly interdisciplinary and went well beyond terrestrial science.

The ARCSS committee of the Arctic Research Consortium of the U.S. provides recommendations for overall coordination and integration of ARCSS. The committee is actively engaged in the restructuring of ARCSS and in doing so is drawing on ideas emerging from a synthesis effort that explores our knowledge of the linkages and feedbacks within the system. In the past ARCSS had science steering committees and science management offices for each component to facilitate coordination and integration within the component and to provide a focal point for communication with the scientific community. As ARCSS evolves towards a more integrated structure, it is expected that some of this will change as the ARCSS committee engages more in the interdisciplinary, system-wide approach to ARCSS. A mechanism will be identified to maintain the function of community liaison that was provided by these offices.

Paleoenvironmental Studies

Paleoenvironmental research contributes to an understanding of past climate, atmosphere, and ecology of the Arctic, which can give valuable insight towards identifying system interactions. In recent years, PARCS, the principle paleoenvironmental research effort of ARCSS, has been supported through participation in the NSF Earth System History program.

The PARCS program is devoted to reconstructing paleoclimatic history from the sediments of Arctic and sub-Arctic bogs and lakes and from information in tree-ring records and in sediments from the marginal seas, continental shelves, slopes, and abyss of the Arctic Basin. A variety of proxy indicators (such as pollen, diatoms, sediment chemistry, and grain size) in the sediments yield vital information on the responses of terrestrial and marine ecosystems to climate, land use change, and the physical conditions and productivity of the Arctic Ocean.

Contemporary and Process Studies

A current example of a process-oriented ARCSS research activity is the Shelf–Basin Interactions (SBI) effort, begun to improve understanding of the role of the large continental shelf seas for marine biological productivity and the exchange of water, nutrients, heat, and energy with the permanently ice-covered central Arctic basins. Through integrated field and modeling efforts, the SBI project is investigating the effects of global change on production, cycling, and shelf–slope exchange of biogenic matter, both seasonally and spatially. To this end, there are five study objectives deemed both timely and essential to an improved understanding of the effects of global change on productivity as it contributes to shelf–basin interactions within the Arctic Ocean ecosystem, including:

- Understanding the roles of physical processes in the transport and modification of water and biogenic materials across the shelf and into the interior basin;
- Identifying mesoscale oceanographic features that support locally elevated concentrations of benthic and pelagic biota;
- Quantifying upper ocean (water column and sea ice) primary productivity in relation to the biomass and diversity of benthic and pelagic primary and secondary consumers;
- Assessing the relative importance of top-down as compared to bottom-up controls over pelagic–benthic coupling, biotic complexity, and carbon partitioning among different trophic levels; and
- Assessing food web changes consequent to

the impacts of changing ice cover and hydrographic parameters on remineralization of organic matter, recycling efficiency, and biogeochemical fluxes.

Human Dimensions of the Arctic System

Human Dimensions of the Arctic System (HARC) is a collaborative effort with the Arctic Social Sciences Program to integrate natural and social sciences research that will demonstrate the interactions of climate and human development with the use of natural resources. Arctic Native peoples have sustained themselves through hunting, fishing, whaling, and wage employment derived from petroleum revenues. The continued sustainability of their culture and regional development could be affected by global environmental changes that affect vegetation and marine productivity, year-round sea ice maintenance, and construction and land use practices. Research at the interface between natural sciences and human dimensions will increase policymakers' understanding of regional natural and social systems and build linkages between communities in the Arctic. Those linkages will enhance the knowledge base necessary for examining policy choices and risk assessments within the context of global and regional climate changes. So far there is no major research effort within HARC, but numerous collaborative projects have been supported over a period of several years.

Interdisciplinary Research

The first exercise in a new mode of ARCSS research, the Freshwater Cycle research effort, was developed as a thematic interdisciplinary approach that addressed a major part of the Arctic system. This research will address the physical, chemical, and biogeochemical character of the Arctic freshwater system and its interactions with the polar ocean and subpolar seas. It addresses the research planning embodied in the Study of Environmental Arctic Change (SEARCH) program, the Arctic/SubArctic Ocean Fluxes (ASOF) study, and the Arctic Community-wide Hydrological Analysis and Monitoring Program (Arctic-CHAMP) project. Areas of research include:

- Observation systems that take advantage of innovative technological advances and can serve as prototypes for sustained, long-term efforts to document and understand variability in key freshwater, ice, and chemical tracer fluxes and/or processes within the Arctic land, atmosphere, and upper-ocean systems and the teleconnection to the sub-Arctic oceans;
- Synthesis and integration of available data and modeling studies to reveal processes, linkages, and causes of variability in the Arctic terrestrial, atmosphere, and upper-ocean hydrologic cycle; and
- Documentation and assessment of the variability of the Arctic hydrologic freshwater cycle and associated changes in oceanic water-mass properties in the Arctic Ocean on the decade-to-century time scale.

Synthesis in ARCSS

Finally, ARCSS supports the integration of research results across components within ARCSS as well as with any other Arctic research program through a Synthesis, Integration and Modeling Studies (SIMS) effort. This activity is now achieving new prominence in the program, and as ARCSS ventures into its first program-wide synthesis, the program is increasingly interested in efforts that expand on the existing data-oriented SIMS effort and propose to synthesize knowledge of how the Arctic system works, with major emphasis on understanding the linkages between parts of the system and better articulation of the implications for the future.

The Arctic system includes physical, chemical, geological, biological, and cultural factors that may respond to global change. Some models that predict the climatic response to global change show greater change in the Arctic than in any other region. The predicted climatology, however, may not consider the largely unknown interannual-to-centennial variability in the Arctic. The presence of cultural institutions in a region subject to possible large perturbations, however, makes it important that scientists understand better the interactions of the global and Arctic systems. Therefore, the research supported in ARCSS extends beyond purely observational studies to those studies that predict and analyze the consequences of environmental variability and global change important to wise stewardship of renewable resources and the development of decision and policy options for resource managers and residents.

Arctic Natural Sciences

Arctic Natural Sciences (ANS) provides core support for disciplinary research in the following areas: glaciology, atmospheric sciences, ocean

sciences, earth sciences, contaminants, environmental research, and biological sciences.

Glaciology

Glaciology research can focus on the history and dynamics of all naturally occurring forms of snow and ice, including seasonal snow, glaciers, and the Greenland ice sheet. The program also supports mass balance modeling, glacial geology, and remote sensing studies of ice sheets.

To date, the unique paleohistories preserved in Alaska's ice fields have not been tapped and thus have not contributed to this global climate synthesis. The sparseness of high-resolution climate histories from the northeastern side of the Pacific Basin has been a major obstacle to advancing our understanding of the rapid and recent changes in the dynamical state of the Pacific region and its global teleconnections. Ice cores recently obtained from the Bona–Churchill area in the Wrangell–St. Elias Mountains of southeastern Alaska will help fill this void by providing critical new insight into the climate history in this region. Ongoing research is assessing whether the warming of the last 30 years that appears to be amplified at high elevations in the tropics and subtropics extends to northwestern North America, characterizing the most recent "step" change in the dynamics of the Pacific Basin climate regime that occurred in 1976-77, exploring whether similar abrupt transitions have occurred in the past, and if so, determining when, and of what magnitude, were the changes. Ice cores were collected up to 460 m deep, the deepest ice core to be recovered from an alpine ice field. Short cores were recovered to determine the impact of drifting on the various chemical and physical signals preserved in the ice strata and to assess the reproducibility of the records. A light-weight, portable drilling system designed for coring to a depth of up to 700 m was developed for this project. The system was designed to be quickly switched from a dry hole electro-mechanical drill (used to 180 m) to a thermal-alcohol electric drill that collects cores from 180 to 460 m. The core quality ranged from good to excellent. A newly developed, quick-assembly geodesic dome housed all drilling and core processing activities.

The dust and calcium concentrations in the ice cores show distinct annual variations, and the preliminary results suggest that the annually resolved record will cover more than 2500 years. This bodes well for the recovery of a very high-resolution record of past climatic and environmental variability from these cores.

Lake ice studies in Alaska focus on understanding contemporary processes and predicting the consequences of climate variability and change. Ice thickness, ice type (snow ice and congelation ice), ice temperature, snow depth, and snow density are measured at the primary field sites in the vicinity of Poker Flat Research Range 50 km northeast of Fairbanks. In collaboration with a home-school group, a secondary site is maintained at a pond in central Fairbanks. The snow depth and density data are among the inputs used to force a one-dimensional thermodynamic model of lake ice growth and decay. The performance of the model is evaluated using ice thickness and composition data, as well as the dates of freeze-up and break-up. The model simulates contemporary processes well and is being used to investigate the effects of variation in the magnitude and timing of changes in air temperature and precipitation. Precipitation change has a greater effect than air temperature change on ice thickness and composition. The involvement of Fairbanks K-12 teachers and students in the Fairbanks research program has provided the impetus for the development of ALISON (Alaska Lake Ice and Snow Observatory Network), a science research and education program that promotes K-12 scientific inquiry and learning in the local context with those familiar and abundant materials, snow and ice, and that provides data on the variability of lake ice thickness, snow depth, and snow density around Alaska.

Petermann Glacier is the largest and most influential outlet glacier in central northern Greenland. Located at 81°N, 60°W, it drains an area of 71,580 km^2, with a discharge of 12 km^3 of ice per year into the Arctic Ocean. Ground-based, phase-sensitive radar measurements of ice thickness and thinning rates, ice velocity, strain rates, and climatological variables were made near the grounding line of the floating ice tongue of Petermann Glacier during the 2002 and 2003 spring field seasons. Last year's findings have confirmed that large channels, located several hundred meters deep at the underside of the floating ice tongue, are running roughly parallel to the flow direction. These channels were mapped using ground-penetrating radar at 25 MHz frequency and multi-phase radar in profiling mode over half of the glacier's width. NASA airborne laser altimeter and radar data were collected in both field seasons along and across the glacier for accurately assessing the surface and bottom topography.

Remote sensing has shown that 95% of the ice that crosses the grounding line of the Petermann

Glacier melts before it reaches the calving front. The dominant form of this mass loss (55%) has been attributed to basal melting of the ice tongue, with the never-before-measured surface ablation thought to account for about 2–3 m/yr. However, a transmitting automatic weather station on the Petermann Glacier, installed prior to the onset of melt during an extensive field campaign in 2002, allows surface ablation to be described for the first time. Although surface melting does not dominate the mass budget of the Petermann Glacier, field observations lend support to the notion that it may be relevant with regard to weakening and fracturing the floating tongue.

The movement of glaciers and ice sheets results from the deformation of the ice itself and sliding over the basal substrate. Where sliding occurs, its rate is about equal to that of flow due to internal deformation and therefore doubles the flow speed of a glacier, all else being equal. Under some circumstances, glacial sliding can accelerate rapidly, resulting in a surging glacier where flow speeds reach tens of meters per day before returning to its "normal" flow speed. Under other circumstances sliding may be always fast. In any case, water at the base of a glacier controls, in part, the sliding speeding by reducing the friction against the substrate. For temperate glaciers—those glaciers with temperatures at the melting point throughout the ice mass—water at the base of a glacier comes from surface melt. Streams flowing from glaciers have too great a discharge to be explained by geothermal melting at the glacier bottom. Our fundamental question is: How does the water get from the surface to the bottom of the glacier? Theory suggests that the water flows in naturally formed conduits in the ice. Frictional heating of the flowing water melts a passage into a sizeable conduit, somewhat analogous to solution channels (caves) in karst (limestone and dolomite). This project empirically tested this theory.

In the summers of 2000–2003 scientists traveled to Storglaciären, a small alpine glacier in Sweden and the site of long-term study by the University of Stockholm. Boreholes were drilled into the glacier until areas of hydraulic connection were intersected. A borehole camera was used to investigate the area of intersection, a compass and ruler were used to measure the size and orientation of the connection, and natural and artificial tracers were used to determine flow direction and flow speed. Pressure variations were monitored for the rest of the summer season. High-frequency radar profiles of the glacier subsurface were conducted to image the hydrologic passages that were intercepted in the boreholes.

The results were surprising. Eighty percent of boreholes hydraulically connected to a water-bearing passage inside the glacier. The borehole camera revealed that instead of conduit features with semi-circular cross-sections, all the connections were crack-like features. Water flow in the cracks was quite slow and typically at laminar speeds. Under such conditions it is unlikely that the water produces sufficient heat to significantly alter the geometry of the passage. So instead of creating conduits through frictional heating, the water takes advantage of existing passages formed by cracks. These results profoundly change our way of thinking about how water moves through a glacier. Naturally formed conduits (which can be observed near the margins of a glacier) appear to be special features of the subsurface hydraulic system, and cracks accommodate the bulk of the water flow. With this in mind, the results and conclusions based on the past 30 years of subsurface hydrological measurements will have to be rethought. Cracks exist throughout the entire body of a glacier and are not limited to the more brittle glacier surface. How these fractures originated—through advection from surfaces higher on the glacier or in situ—is not clear. In any case, that such cracks exist at all is interesting and leads us to reconsider the mechanical strength of a glacier. This is important not only to the behavior of alpine glaciers but also to the stability of giant ice shelves around Antarctica, which can catastrophically fail under warming conditions.

Atmospheric Sciences

Atmospheric sciences research focuses on stratospheric and tropospheric processes, climate, and meteorology. Research on past climates and atmospheric gases preserved in snow and ice is encouraged. The program also supports research on atmosphere–sea and atmosphere–ice interactions. In upper atmosphere and space physics, research interests include auroral studies, atmospheric dynamics and chemistry, and magnetosphere–ionosphere coupling.

In the past few years there has been an explosion of scientific interest in the chemical reactions that happen in sunlit snow. Rather than simply acting as the final resting place for pollutants that deposit from the air, snow turns out to be one of the most photoreactive regions on earth. These sunlight-driven reactions in snow release a number of important pollutants to the lower atmo-

sphere, including formaldehyde, nitrous acid, and reactive halogens. In turn, these pollutants alter the composition and chemistry in the lower atmosphere. One of the major effects of snow emissions is that they alter concentrations of atmospheric radicals, highly reactive chemicals that clean the atmosphere. Snow reactions and how they change the amount of pollutants and radicals in the Arctic atmosphere are being explored.

In addition to changing the composition of the atmosphere, these sunlight-initiated reactions also change the make-up of the snow itself and the ice that eventually forms from the snow. Understanding how photochemical reactions influence ice composition will help others use ice cores to reconstruct what the atmosphere used to be like.

There are five major parts of the project: measuring radicals, measuring chemicals that form radicals, characterizing sunlight in the snowpack, determining the physical structure of the snowpack, and putting it all together to create a model of photochemistry in the snowpack.

The northern North Atlantic winter atmosphere is one of the most synoptically active areas of the planet, characterized by frequent cyclone generation and intensification. One reason is that the region lies downstream of the primary eastern North American trough, which provides a favorable environment for storms. But there are important regional processes. Cyclone development is especially preferred in the lee of Greenland and along the sea ice margin, where there are strong horizontal temperature gradients (baroclinicity) that extend rather deep into the atmosphere. This seems to be fostered, in part, by very large heat fluxes from ice-free open waters just south of the sea ice margin, especially in the Norwegian Sea. Associated deep convection mixes heat and water vapor upwards.

Over much of the Arctic, mid-tropospheric temperatures rarely fall below about –45°C. This minimum temperature coincides with that predicted for moist adiabatic ascent of air over a sea surface near its salinity-adjusted freezing point. A primary source region of this heating appears to be winter convection in the Norwegian Sea. Single-column model experiments simulating convective warming of a cold air mass moving over open water and undergoing radiative cooling as it moves again over cold land or sea ice support the hypothesis that the –45°C threshold can be maintained for 10–14 days after the air is convectively warmed.

Cyclone development processes and how they impact the sea ice circulation are being studied in more detail. Initial studies indicate that cyclone variability near the ice margin has a significant impact on the freshwater budget of the Arctic Ocean by modulating the flux of sea ice through Fram Strait.

Ocean Sciences

Ocean science research is concerned with expanding knowledge about the structure of the Arctic Ocean and adjacent seas, their physical and biological interactions with the global hydrosphere, and the formation and persistence of sea ice cover.

The most important subsurface Arctic Ocean transport system is an anticlockwise boundary current, which carries Atlantic (warm, salty) waters and Pacific (fresh, nutrient-rich) waters along the continental slopes and major trans-Arctic ridges. The most complex obstacle the boundary current encounters on its circum-Arctic pathway is the Mendeleev Ridge/Chukchi Borderland. This region, some 350 km northwest of Barrow, is the crossroads for Pacific-origin waters from the south and Atlantic waters carried from the west with the boundary current. The existing data suggest that some of the boundary current and some of the Pacific waters are diverted out into the deep basin in this region and that over the last decade a warming signal is propagating through the area. However, because of the complexity of the region and the paucity of data, we have no clear understanding of the processes that determine the fate of these waters.

In a changing Arctic Ocean, both issues are highly relevant. The sea ice is protected from the warmth of the Atlantic layer by a cold, low-salinity layer originating from the Arctic shelves and from the Pacific, and changes in the pathways or quantities of these waters could thin the sea ice. Similarly, the course and final depth of the nutrient-rich Pacific waters affect the local biological productivity, with implications up the food chain. Changes in the Arctic system over the last decades (the thinner ice cover and the generally warmer climate over both land and ocean) indicate the importance of gaining a clearer understanding of the general Arctic Ocean circulation, especially in complex regions such as the Chukchi Borderland.

A three-year project is investigating the physical and chemical oceanography of this region. Preliminary results show the continued advance of the Atlantic temperature maximum and unexpectedly large variability in temperature structure in the Atlantic core. Temperature and tracer data

indicate the spreading of Pacific halocline waters north across the Chukchi Plateau and Northwind Ridge. Water mass analysis also supports the hypothesis of a "Taylor Cap," an isolated circulation, over the Chukchi plateau. Mooring data reveal a more complex structure to the boundary current than hitherto expected. As the analysis continues, reference to historic data from the region should allow understanding not only of the Chukchi Borderland of today, but also a glimpse of how things have changed in the last decade at this Arctic Crossroads.

Heat and salt exchanges at the ice/ocean interface play a key role in the annual cycle of sea ice growth and ablation. Recent observations of significant change in the extent and thickness of the Arctic ice cover have focused attention on factors that control the mass balance, and treatment of ice/ocean exchanges in numerical models is becoming increasingly sophisticated. Direct measurements of turbulent heat flux under pack ice have shown that the exchange coefficient is an order of magnitude smaller than the corresponding exchange coefficient for momentum. This implies that, unlike momentum flux, heat flux at the interface is rate-limited by molecular processes in thin sublayers adjacent to the surface.

Earth Sciences

Research on earth sciences includes all subdisciplines of terrestrial and marine geology and geophysics. Of greatest interest is a better understanding of Arctic geological processes that are important for improving our ability to interpret the geologic record of environmental change in the polar regions. Also of interest is better understanding and reconstruction of the plate tectonic history of the Arctic Ocean.

Large igneous provinces (LIP) are massive outpourings of mafic igneous rocks that commonly cannot be related to normal plate tectonic processes. A LIP of Cretaceous age, represented by Alpha Ridge, is thought by many to occupy the central Arctic Ocean basin. Given the thick ice cover, remoteness, and sediment overburden, a direct study of Alpha Ridge represents one of the more logistically challenging earth science subjects for the future. However, much can be learned about the nature of this LIP through land-based studies because correlative volcanic rocks are preserved in the stratigraphic sequences of the high Canadian Arctic (specifically on Axel Heiberg and Ellesmere Islands). These sequences also represent a storehouse of geological and geophysical information on topics ranging from the nature of Earth's magnetic field to past Arctic climate.

In a multidisciplinary study of these rocks, it was established that the major pulse of volcanism, which is similar to that typical of continental flood basalt provinces elsewhere, occurred at approximately 95 Ma. However, this volcanism was followed by a less-voluminous episode at 83 Ma (or younger). These ages rely on plume and non-plume models to explain the magmatism. Paleomagnetic studies indicate that the sites of eruption in the Canadian Arctic archipelago (at approximately 71°N) were contiguous with the North American craton, resolving debate concerning potential tectonic motions. Freshwater sediments overlying the volcanic rocks have been found to contain an important fossil fauna, including turtles and champsosaurs (extinct crocodile-like vertebrates). These fossils indicate extreme polar warmth during Late Cretaceous (Turonian) times.

The Arctic region is of special significance for understanding the nature and history of the geodynamo because of its proximity to the tangent cylinder, the imaginary cylinder that is tangent to the solid inner core. Numerical models of the geodynamo have shown that this region is critical in defining the nature of the field. Directional and paleointensity measurements of the Cretaceous Arctic lavas to date show that the field was dipolar, stable, and strong, suggesting that the basic features of the geomagnetic field are intrinsically linked. This conclusion has important implications for our understanding of the past, present, and future geomagnetic field.

Contaminants

ANS supports research in the area of persistent organic pollutant (POP) fate in the Arctic. These compounds are lipid soluble and can bioaccumulate in organisms that are ultimately harvested by the indigenous peoples of the Arctic. These "country" foods constitute a high percentage of the diet of many Native Americans, and as a consequence high levels of POPs may pose a long-term public health threat in the Arctic.

Much of the research conducted to date on POPs in the Arctic have focused on monitoring, i.e., measuring specific levels of POPs in environmental compartments (air, water, soil, biota), but little is known about POP fate in this environment. Recent research supported by ANS has focused on the photochemical transformation of POPs in Arctic surface waters. Many of the lakes, rivers, and nearshore marine environments contain sig-

nificant quantities of dissolved organic matter (DOM), which are naturally derived and ubiquitous substances that are able to act as catalysts (photosensitizers) in the presence of sunlight. Photo-excited DOM releases a number of reactive species that can in turn react with POPS and transform them into other products, a process known as indirect photolysis. Because the Arctic experiences significant irradiance during the boreal summer, indirect POP photolysis maybe an important transformation pathway in waters that contain significant amounts of DOM.

Recent studies at Toolik Lake LTER in the Alaskan Arctic have shown that selective transformation of POPs can occur in sunlit Arctic surface waters. Hexachlorobenzene, a relatively ubiquitous Arctic POP, degrades readily in the presence of DOM and sunlight, while lindane, another commonly detected Arctic POP, does not. These studies demonstrate that in certain water bodies some POPs may be transformed, while others will be conserved and potentially accumulate. Thus, the fate of certain POPs in the Arctic will depend on their structure and the amount of DOM present in the surface waters. Ongoing studies at Toolik Lake will focus on other classes of POPs, such as polychlorinated biphenyls (PCBs), pesticides, and polychlorinated napththalenes (PCNs). All these substances have been detected in the Arctic and can potentially bioaccumulate in the food chain.

Biological Sciences

Biological science research emphasizes understanding the adaptation of organisms; freshwater, marine, and terrestrial biology; organismal biology; ecology; microbiology; ecosystem structure and processes; and the consequences of ultraviolet radiation.

Muskoxen are a relict of the Ice Age. Animals physically identical to modern muskoxen roamed the Arctic along with mammoths, horses, camels, and large cats. Yet muskoxen are one of the few large mammals that survived the end of the Pleistocene and continue to inhabit Arctic regions. Modern muskoxen were close to extinction around 1900 as a result of climate fluctuations and hunting pressure, but they have since recovered, with healthy native populations in Canada and Greenland and re-established populations in Alaska and Siberia. However, these current animals have low levels of genetic variability, which may limit their ability to adapt to future changes in their environment. Numerous Pleistocene-era muskox bones have been collected from the North Slope of Alaska, cataloged, and ^{14}C-dated by the Bureau of Land Management. These ancient bones, which have been frozen in the permafrost for thousands of years, are a good source of DNA for analysis of genetic change over time. DNA from the ancient muskox bones is being investigated to determine whether patterns of genetic change over time can be related to climate change. All DNA from the muskox bones more than 35,00 years old is very similar to that of modern muskoxen, suggesting that muskoxen have lacked significant genetic variability for a long time. Preliminary analysis indicates there is some genetic discontinuity between the muskoxen more than 35,000 years old and all the more recent muskoxen. Genetic analysis of the muskox bones is ongoing to fill in gaps in segments of DNA among individuals and to try to define the genetic change that occurred after 35,000 years ago. NSF and BLM jointly supported this project.

On arrival in the Arctic, migrant birds must adjust their physiology and behavior to unpredictable snow cover, weather, food sources, and predator pressure. In other words, they must cope with environmental perturbations (stress) so that they can migrate to their tundra nesting areas and settle on territories. Breeding must begin immediately when environmental conditions become favorable. They do this partly by using microhabitats where snow depth is low and patches of tundra melt out rapidly (especially near willows). Ground temperatures increase dramatically within hours after exposure to sun, and invertebrate activity begins simultaneously. Wind speeds are attenuated almost completely within 10 cm of the ground in willows and tussock tundra. The combination of these conditions provides an ideal refuge, especially for passerine migrants in early spring. However, if conditions worsen, they can leave. There are adjustments of the adrenocortical responses to stress because Arctic conditions in spring are potentially severe, at least compared with wintering grounds to the south. Secretion of corticosterone in response to acute stress is enhanced at arrival in males, accompanied by a decrease in sensitivity to negative feedback and a change in responsiveness of the adrenal cortex cells to adrenocorticotropin. There is also an increase in corticosterone-binding globulin levels so that the actions of corticosterone are buffered according to the severity of environmental conditions. Regulation at the level of genomic receptors, particularly the low-affinity type-2 receptor for corticosterone in the brain and liver, may be important, and

non-genomic actions of corticosterone may play a major role. In other words, the hormone–behavior system associated with arrival biology is highly flexible.

After arrival on the tundra, migrant birds then begin establishing territories and attracting mates. At this time, circulating levels of testosterone are markedly higher than their congenors at lower latitudes, and adrenocortical responses to stress remain high, especially in populations at the northern edge of their range. Mating, nest building, and egg laying begins quickly, and within days incubation is underway. At this time the adrenocortical response to stress declines rapidly, and birds become resistant to acute stress. It is likely that once Arctic breeding birds commit to reproduction and are on eggs, they become resistant to stresses such as inclement weather because the breeding season is so short and no second nestings are likely. Additionally, these birds become resistant to the effects of high corticosterone levels typical of a stress response. Mechanisms underlying this modulation of the adrenocortical response to acute stress are under investigation.

Another change that occurs as the parental phase of breeding begins is a decline in circulating testosterone, including decreased sensitivity to this steroid hormone. Most songbirds apparently become refractory to testosterone, possibly as a mechanism to avoid distraction from parental care by male–male competition as seen in congenors at lower latitudes. This insensitivity to testosterone is accompanied by a decline in androgen receptor gene expression and reduced levels of aromatase, an enzyme that converts testosterone to an active form (estradiol) in the brain.

Future studies will continue to investigate the cellular and molecular bases of the behavioral ecology of Arctic breeding birds. One promising new area is the regulation of departure from the Arctic breeding grounds, a process about which we know essentially nothing.

In a study on protein conservation and the effects of diet quality, researchers used isotope kinetics to measure changes in the body composition and metabolism of female caribou and reindeer in winter.

Caribou consuming low-energy intakes in late winter apparently recycle carbon from body fat to membranes in other tissues because ^{13}C enrichment of red blood cells increases through winter. A similar redistribution of body protein is probably used to produce a fetus, even when intakes of nitrogen are less than 30% of predicted maintenance requirements for temperate species of deer. The role of dietary nitrogen in fetal growth is not clear because reindeer fed high protein diets during winter gain maternal lean mass as well as fetal tissue even as fat is lost. A close association between the enrichment of ^{15}N in urinary N and that of the diet in caribou suggests that dietary N may be preferentially oxidized over endogenous sources such as muscle. The apparent discrimination between stored and dietary N is unexpected, but it may be a novel adaptation to conserve maternal protein for fetal growth.

Arctic Social Sciences

The Arctic Social Sciences Program was established at NSF in 1990 and is starting a second decade of providing support for social science research across the Arctic. In the last three years, NSF has increased funding to the Arctic Social Sciences Program by 30% to its current level of $3 million, including research support and logistics. The program is unique at NSF in its support for a diverse portfolio of research projects from many social science disciplines, including anthropology, sociology, political science, linguistics, traditional knowledge, archaeology, and interdisciplinary research. In addition, the Arctic Social Sciences Program is unique within the Office of Polar Programs in its funding of stand-alone dissertation research projects. The program is committed to increasing the number of social science researchers from underrepresented groups, particularly rural Arctic Native residents. This commitment is realized by providing funds for unique education projects and workshops, supporting participation of Arctic Native peoples in science forums, and administering a cooperative agreement between NSF and the Alaska Native Science Commission (www.nativescience.org).

The following are highlights of the diversity of Arctic social sciences projects supported by NSF through the Office of Polar Programs in FY 03.

Alaska Natives in Geosciences

Alaska Natives in Geosciences is a project that broadens the participation of Alaska Natives in the geosciences at both the professional level and the community level by increasing geoscience literacy amongst the next generation of Alaska Native leaders. A college-level, field-intensive, introductory geoscience course is designed specifically for the high school juniors and seniors

enrolled at the Rural Alaska Honors Institute (RAHI). This is followed by a community-based one-week field course open to RAHI graduates, as well as other Alaska Native geoscience students. Both classes will introduce Alaska Native students to the geologic issues and concerns relevant to Alaska Natives and their communities.

Alaska Native Science Commission

The Alaska Native Science Commission (ANSC) is funded in part through a cooperative agreement with NSF. ANSC is made up of Alaska Native scholars and scientists who facilitate the connections between rural Arctic communities and NSF-supported research. Through workshops, personal contacts, meetings, and research projects, ANSC has assisted scientists in making contact with Alaska Native communities and facilitated Native peoples' voices in Arctic science. By partnering in this way, scientific research can meet both research goals and the needs of Alaskan rural communities. In addition, ANSC maintains an internship program for Alaska Native students that helps increase the exposure of students to the many disciplines of science and engineering. ANSC publishes a quarterly newsletter to inform Alaskan communities about NSF science projects in their regions and provides a critical link between science, education, and local community concerns.

Northern Science Education Program

The Northern Science Education Program is the continuation of a Research Experience for Undergraduates site that provides a unique science education for urban undergraduate minority (53% of the participating students are women and 33% are from underrepresented minority groups) and non-minority students in Iceland by working on an early human settlement and historical landscape project. Based on the curriculum of interdisciplinary science (e.g., archaeology, zooarchaeology, human osteology, marine mammal necropsy, soil science, geographic information systems, and climate change), the students define and carry out their own research projects under the careful guidance of graduate student mentors and professors.

Dena'ina Archiving, Training, and Access

DATA is a cooperative project between the Alaska Native Language Center at the University of Alaska and the LINGUIST List program at Eastern Michigan University to preserve Arctic languages. The project digitizes existing collections of Dena'ina documentation using the standards and software developed by The LINGUIST List as part of the E-Meld project. The E-Meld project develops and implements recommendations of digital best practice for linguistics data. Through E-Meld the DATA project will create long-lasting archival formats and standardize linguistic data digitization of Dena'ina. In addition, both Native and non-Native students are being trained in linguistic research practices, applied computational linguistics, and linguistic analysis for the future preservation and revitalization of Dena'ina. This project is not only facilitating the preservation of Dena'ina for community members but is also standardizing the linguistics information so as to make it accessible and useful for scientific computational analyses.

Reducing Land Use Conflict in Arctic Wilderness Areas

This research project is examining public policy and cultural values of stakeholders in land use policy for Arctic wilderness areas. The researcher is comparing three case studies of wilderness areas in Finnish Lapland, Alaska, and the Yukon Territories of Canada in order to understand and explain the variation in conflict between local and non-local groups in these regions. The research will bring a comparative perspective of conflict resolution in cross-cultural as well as national contexts. In addition, it will inform the debate over contested meanings of wilderness between indigenous land users, land managers, and environmental groups.

Education

Objectives for education and outreach at NSF include the broader impacts that researchers perform as part of their projects as well as targeted projects aimed at improving education in science, technology, engineering, and mathematics (STEM). The Arctic Research and Education program, with an FY 04 budget of $250K, supports projects that bridge scientific research with education and public outreach, with emphasis on those that increase participation of underrepresented minorities in science. The approach of the program is to support projects that involve each level along the education continuum from K-12 through graduate school and the public at large. Awards are made as grants, supplements to existing awards, and co-funding to projects receiving primary funding from other directorates.

The programs Teachers Experiencing Antarctica and the Arctic (TEA; 1997–2003) and Teachers and Researchers Exploring and Collaborating (TREC; 2004) provide field research experiences for K-12 teachers to become members of field expeditions as engaged members of the field team. The nearly 40 teachers representing over 20 states who have been part of these programs have brought inquiry-based science to their classrooms, colleagues, and communities. The teachers have networked into a learning community that continues to be involved in polar research.

High school, undergraduate, and graduate students have been supported by the program to participate in research projects, receive mentoring, and participate in workshops and conferences. Through these experiences and the ensuing connection with STEM fields, new generations of scientists and engineers are developed who are familiar with Arctic research. Journalists convey information about science to perhaps the broadest audience through print and visual media. A project providing journalists with Arctic research experience in the lab and field is an important contribution to ensuring that research is reported on by journalists who understand the scientific process. While the scale of the program is small, its reach is increased by involving a broad cross-section of society in Arctic research and through its partnerships with other programs at NSF.

Arctic Research Coordination

NSF supported a program of polar information and advisory services; provided support for the Interagency Arctic Research Policy Committee; provided funds for the Arctic Research Commission; and supported conferences, workshops, and studies to further develop and implement Arctic research planning and policy.

As required by the Arctic Research and Policy Act of 1984, a comprehensive U.S. Arctic Research Plan was prepared by the Interagency Arctic Research Policy Committee and submitted to the President in 2003. The eighth revision to the U.S. Arctic Research Plan included two major sections. The first of these presented the Special Focus Interagency Research Programs:

- Arctic Environmental Change;
- Bering Sea Research and Assessment; and
- Arctic Health Research.

The second major section was Agency Programs, which represents the objectives of Federal agencies, focusing on the period covered by this revision (2004–2008). They were presented in seven major categories:

- Arctic Ocean and Marginal Seas;
- Atmosphere and Climate;
- Land and Offshore Resources;
- Land–Atmosphere–Water Interactions;
- Engineering and Technology;
- Social Sciences; and
- Health.

The Interagency Plan also addressed issues related to logistics support for Arctic research and new opportunities for Arctic research. The biennial revision of the U.S. Arctic Research Plan serves as guidance for planning by individual agencies and for coordinating and implementing mutually beneficial national and international research programs.

NSF supports many other interagency planning and coordinating activities. Coordination with global change programs is an integral part of Arctic program development and implementation. Improved communication at all levels is encouraged through newsletters and journals.

Engineering and Technology

The Engineering, Geosciences, and Mathematical and Physical Sciences Directorates support research in engineering, material sciences, and permafrost. Research has included studies of the mechanical properties of ice, the hydraulic conductivity of frozen soils, metamorphism of dry snowpacks, and three-dimensional analyses of ice.

Research Support and Logistics

NSF is using new resources targeted for Arctic logistics to enhance the U.S. leadership role in Arctic research. The focus on logistics entails:

- Establishment, development, and maintenance of national Environmental Observatories;
- Technology and instrument development;
- Expansion of marine platforms and aircraft support capabilities;
- Integration of research, education, and Arctic community interests; and
- Further international collaboration in the support of research.

The use of the new resources is guided by the Arctic Research Commission's report *Logistics Recommendations for an Improved U.S. Arctic Research Capability* [available from the Arctic Research Consortium of the United States (ARCUS) at http://www.arcus.org]. The general

recommendations of the report are:

- Ensure access to the Arctic over the entire year;
- Increase the availability and use of remote/autonomous instruments;
- Protect the health and safety of people conducting research in the Arctic;
- Improve communications and collaboration between Arctic people and the research community; and
- Seek interagency, international, and bilateral logistics arrangements.

Planning is carried out in partnership with Native groups and other advisory bodies and responds to merit-reviewed proposals.

Another major logistics issue in the Arctic is developing full access and capability to conduct research on all aspects of the Arctic Ocean. NSF facilitates this by funding research use of the new Coast Guard icebreaker *Healy* and supports improved sensors for the Arctic drifting buoy program, moorings, and autonomous underwater vehicles. For both marine and terrestrial research, NSF works to improve basic health and safety by providing access to a pool of emergency beacons, satellite phones, and GPS receivers.

Department of the Interior

The Department of the Interior performs biological, physical, engineering, and social science research; conducts mapping, monitoring, and assessment programs throughout Alaska and its offshore regions; and manages department lands in Alaska. These activities are performed by services or bureaus, each with administrative and technical offices located in Alaska.

Minerals Management Service

The Minerals Management Service (MMS) has the statutory responsibilities to manage the mineral resources located on the U.S. Outer Continental Shelf (OCS) in an environmentally sound and safe manner and to collect, verify, and distribute mineral revenues from Federal and Indian lands.

In support of these responsibilities, MMS conducts two major programs of research that are relevant to activities in the Arctic. One, the Technology Assessment and Research (TA&R) Program, focuses on engineering and technology issues. The other, the Environmental Studies Program, focuses on issues related to assessing and predicting potential environmental and socioeconomic impacts.

	Funding (thousands)	
	FY 02	FY 03
Technology Assessment/Research	400	500
Environmental Studies	4,866	4,273
Total	5,266	4,773

Technology Assessment and Research Program

The MMS supports an active research program to understand the engineering constraints for offshore operations, especially related to the structural integrity of oil and gas facilities and pipelines, the prevention of pollution, and the technologies necessary to clean up an oil spill should one occur. In essence, the program provides an independent assessment of the status of OCS technologies and, where deemed necessary, investigates technology gaps and provides leadership in reaching solutions. The program also facilitates a dialogue among engineers in the industry, the research community, and MMS in dealing with the many complex issues associated with offshore oil and gas operations.

The TA&R Program supports research associated with operational safety and pollution prevention, as well as oil-spill response and cleanup capabilities. It was established in the 1970s to ensure that industry operations on the OCS incorporated the use of the Best Available and Safest Technologies (BAST). The program comprises two functional research activities: Operational Safety and Engineering Research (OSER) and Oil Spill Research (OSR).

The TA&R Program has four primary objectives:

- Technical Support: TA&R provides engineering support to MMS decision makers in evaluating industry operational proposals and related technical issues and ensuring that these proposals comply with applicable regulations, rules, and operational guidelines and standards.
- Technology Assessment: Industry applications of technological innovations are investigated and assessed to ensure that governing MMS regulations, rules, and operational guidelines encompass the use of BAST.
- Research Catalyst: The program promotes leadership in OSER and OSR by acting as a catalyst for industry research initiatives.
- International Regulations: The program provides international cooperation for research and development initiatives to enhance the safety of offshore oil and natural gas activities and the development of appropriate regulatory program elements worldwide.

The TA&R Program operates through contracts with universities, private firms, and govern-

ment laboratories to assess safety-related technologies and to perform necessary applied research. Participation in jointly funded projects with industry, other Federal and state agencies, and international regulatory organizations has become the primary funding mechanism in view of the overlap of issues and challenges. Participation in joint projects is the most effective and efficient means to leverage available funds.

The TA&R Program enhanced its research capabilities in FY 99 through the establishment of a five-year cooperative research program with the Offshore Technology Research Center in College Station, Texas. This cooperative agreement provides direct research support to MMS as well as a forum for identifying and jointly funding research projects with industry on a variety of topics.

For additional information regarding the TA&R Program, please contact Sharon Buffington at 703-787-1147 or sharon.buffington@mms.gov.

The TA&R Program operates Ohmsett—the National Oil Spill Response Test Facility—in Leonardo, New Jersey. This facility provides testing and research capabilities to MMS, other government agencies, and the private sector on topics associated with the prevention and cleanup of oil spills. Ohmsett is the only facility in North America where full-scale response equipment (containment booms, skimmers, etc.) can be tested in a controlled environment, using real oil. (See below for a fuller discussion of Ohmsett.)

In the past the TA&R Program was motivated by the need to acquire basic engineering information necessary to oversee the general development of offshore operations. As a direct result of research funded by the TA&R program, regulatory changes were initiated on:

- The design and operation of diverter systems, well control procedures, and training requirements;
- The need for periodic platform inspections, methodologies for assessing the integrity of older or damaged platforms, and the reduction of exhaust pollution offshore; and
- The development of oil pollution plans to ensure that the proper equipment, personnel, and procedures were available to respond to an offshore oil spill, should one occur.

However, the future has provided new goals and directions for offshore oil and gas research initiatives. This new emphasis is a result of past technology developments, economic constraints within the industry, and a continuing need to ensure that offshore oil and gas operations can be conducted in a safe manner without harm to the environment.

With a sound appreciation for the current state of offshore technology, the TA&R Program will continue to focus its research efforts in the following four areas:

- Frontier areas of operations (both deep water and the Arctic), including safety issues as well as the integrity of structures and pipelines;
- Human and organizational factors and how they can be addressed to mitigate accidents;
- Aging offshore infrastructure, including platforms and pipelines; and
- Spill mitigation measures, including cleanup and containment technologies for an oil spill, should one occur.

The TA&R Program is a contract research program; that is, the research is not performed within the agency but is conducted by academic institutions, private industry, and government laboratories. Studies are performed in cooperation with the offshore industry or with other agencies or governments. This aspect of the program provides an important multiplier of funding support, but probably of equal importance is the discourse it provides with the industry.

The ability to work together to assess a particular technology or the rationale for future technical developments helps both industry and government. Such cooperation and dialogue allow us to understand each other's needs and eliminate possible conflicts or misunderstandings concerning the engineering feasibility of an operational decision. As a result of this dialogue, a valuable exchange of information is provided between MMS and the industry.

Operational Safety and Engineering Research

Arctic offshore operations have been hampered more by the lack of commercially economic discoveries than by technology. The industry has tended to develop onshore resources in the Arctic, with just minimal exploration and development offshore. However, recently there has been an increased interest by the oil and gas industry in Arctic offshore resources.

Sea ice is still the most severe environmental hazard posed by the Arctic relative to future offshore development. Such hazards include the forces that moving sea ice may exert against offshore structures, icing of structures resulting from freezing spray, gouging of the seafloor by sea ice (which could interfere with buried pipelines), and interference with locating or cleaning up a potential oil spill. Engineering data for these hazards will become increasingly important as operations

move from an exploration mode to a production mode and as structures are considered for deeper water, especially within the shear zone or pack ice.

A final report called *Worldwide Assessment of Industry Leak Detection Capabilities for Single and Multiphase Pipeline* summarizes the current issues for pipeline leak detection by identifying the state-of-the-art technologies used in pipeline leak detection, assessing the effectiveness of current leak detection technology, and evaluating the effect of multiphase flow conditions on leak detection technologies. For offshore pipelines operating in the Arctic, leak detection systems are intensely scrutinized for their effectiveness in detecting and locating a leak. The results from this project identify which technologies can work in an Arctic offshore environment and how many redundant and complementary systems can be employed to minimize leak volumes. The final report is available from the MMS web site for TA&R Project 409 at http://www.mms.gov/tarprojects.

The 2003 International Offshore Pipeline Workshop was held during February 26–28, 2003, in New Orleans. The workshop was hosted by the MMS and the U.S. Department of Transportation (DOT) Research and Special Programs Administration and sponsored by major oil and gas companies, offshore pipeline contractors, offshore service companies, and other related entities. Information collected and shared at this successful event will lead to new research projects and updated and new codes and standards, define critical technology needs to maintain the aging pipeline infrastructure and enter frontier areas, and provide critical feedback and background knowledge for the MMS and DOT policymakers. The workshop proceedings also provide ample items that can be used to address a multitude of issues for the Arctic related to design, installation, leak detection, inspection, and repair. The final report is available at http://www.mms.gov/tarworkshops/pipelines.htm.

A project called "Strain-Based Design of Pipelines" had as its objective to develop a best-practice guide for strain-based design of pipelines. It was also jointly funded by MMS and the DOT Research and Special Programs Administration to help fill an industry need for a complete guide on offshore pipeline design. The final report constitutes the first of two efforts to complete this guide, which will cover design, assessment, and testing guidelines for designers of pipelines that may experience high strains in service. Historically, pipelines have been designed to codes that are stress based. This requires a less rigorous detailed engineering analysis to meet acceptable pipeline safety. For offshore pipelines, however, especially those in deep water and in the Arctic, an exacting site-specific analysis including loading conditions and material mechanical properties is needed to maintain the acceptable level of pipeline safety expected. This research project will investigate how the use of strain-based design of pipelines can better assure safe and pollution-free operations, especially in environmentally sensitive areas.

The Banff/03 Pipeline Workshop, held in Banff, Canada, during April 14–17, 2003, was the sixth in a series of workshops that Natural Resources Canada (NRC) has organized to address new pipeline technologies for the Arctic environment. The workshop reviewed the progress achieved from the 2001 workshop and carried out intensive group discussions on such topics as risk assessment/risk management, abandonment issues, strain-based design, and in-line inspections. The workshop was sponsored by NRC and a number of industry participants, including the MMS. Because of the aging condition of existing pipelines and the progression of the industry into deeper water and the Arctic, a need exists to be aware of new managing techniques for pipeline integrity. The workshop discussed such issues and provided a forum for the exchange of information.

Oil Spill Response Research

The MMS is the principal U.S. government agency funding offshore oil spill response research (OSRR). Through funding provided by MMS, scientists and engineers from worldwide public and private sectors are working to address outstanding gaps in information and technology concerning oil spill cleanup. Credible scientific research and technological innovations are considered key elements for improving oil spill response and protecting our coasts and ocean waters against the damage that could be caused by spills.

The MMS research supports the bureau's goal of safe and environmentally sound operations by improving capabilities to detect, contain, and clean up open-ocean oil spills. This research program complies with Title VII of the Oil Pollution Act of 1990 (OPA-90) and is conducted in cooperation with the Interagency Coordinating Committee for Oil Pollution Research, as called for in OPA-90. Oil spill response research is one tool that MMS uses to fulfill its regulatory responsibil-

Test burn with crude oil on frazil ice.

ities mandated by OPA-90. Information derived from the OSRR Program is directly integrated into MMS's offshore operations and is used in making regulatory decisions pertaining to permit and plan approvals, safety and pollution inspections, enforcement actions, and training requirements.

Funds for the OSRR Program are specifically appropriated from the Oil Spill Liability Trust Fund. The fund receives revenues from cost recovery and civil penalties incurred from oil spills and from an oil tax collected from the oil industry (five cents per barrel on domestically produced or imported oil). As intended by OPA-90, companies that produce or transport oil are required to support research and development to improve oil spill response capabilities.

The OSRR Program has funded a variety of projects to develop and improve Arctic oil spill response. The MMS research currently underway focuses on three main types of cleanup technology: in-situ burning, chemical treating agents, and mechanical response.

In-Situ Burning

In-situ burning technology includes the techniques and equipment required to ignite and sustain combustion of oil spills on the water, shorelines, and the marshland environment. In-situ burning is the most promising technique for removing large quantities of oil from the surface of the water as encountered during major and catastrophic spills. It is also effective for mitigating spills on land and in coastal areas. Potential impacts and benefits of developing this technology are high. Burning can be applied in remote areas where other response techniques cannot be used because of distance and lack of infrastructure. In some circumstances, such as when oil is mixed with or on ice, it may be the only option for dealing with an oil spill.

The MMS is designated as the lead agency for in-situ burn research in the Oil Pollution Research and Technology Plan prepared under the authority of Title VII of the Oil Pollution Act of 1990 (OPA-90). The TA&R Program has assembled *In-Situ Burning of Oil Spills: Resource Collection*, which is a comprehensive compendium of scientific literature on the role of in-situ burning as a response option for the control, removal, and mitigation of marine oil spills. All operational aspects of burning are covered in detail. The potential impacts of this technique on the environment and on human health and safety are also addressed. The 2-CD set includes a substantial percentage of the scientific and technical literature on research, development, planning, and implementation undertaken by hundreds of individuals and dozens of organizations. In-situ burning is not necessarily the preferred oil spill response tool for all incidents but is one that is considered by a growing number of responders.

The collection provides a wealth of information in a convenient format that can be used in the planning, response, or research environment. It contains more than 350 documents with over 13,000 pages and nearly an hour of video. For those new to the subject of in-situ burning, the collection includes a 13-minute video developed by the Alaska Department of Environmental Conservation and Alaska Clean Seas.

Publication of this in-situ burn literature collection fulfills MMS's mandate in the Oil Pollution Research and Technology Plan as well as its committment to the Interagency Coordinating Committee for Oil Pollution Research. The MMS distributes this 2-CD collection without charge.

A research project called Mid-Scale Tests to Determine the Limits to In-Situ Burning of Thin Oil Slicks in Broken Ice was designed to investigate the minimum ignitable thickness, combustion rate, residue amount, and effect of waves on thin oil slicks burned in situ on frazil or slush ice typical of freeze-up and on brash ice typical of break-up. The focus was on thin oil slicks, such as those that could be generated by blowouts or subsea pipeline leaks; previous laboratory and field experiments have adequately addressed the burning of thick oil slicks in broken ice. This project consisted of a literature review, small-scale burns in a chilled wave tank in Ottawa, Canada, and mid-scale burns in an outdoor wave tank at Prudhoe Bay, Alaska. A total of 114 burns of 40 cm and 42 burns of 170 cm were completed. Results from this project will be used to propose "rules of thumb" for burning thin oil slicks in broken ice relevant to existing production

For copies of In-Situ Burning of Oil Spills: Resource Collection, *please contact Joseph Mullin at 703-787-1556 or joseph.mullin@mms.gov.*

fields in Cook Inlet and Prudhoe Bay and to proposed fields in Alaska, Norway, and Russia.

Chemical Treating Agents and Dispersants

Dispersants are a specific type of oil spill chemical countermeasure that reduces oil/water interfacial tension so that oil can disperse into small droplets in the water column. Dispersants are an important tool in spill response when it is critical to prevent oil from reaching a sensitive resource. Even though their use is pre-approved in various Area Contingency Plans, so much controversy surrounds dispersant use in the U.S. that it is seldom used. Analysis of tradeoffs between dispersant use and conventional mechanical recovery techniques demonstrates that, in many incidents, dispersant use either in combination with or instead of mechanical recovery could significantly enhance protection of human health and the environment. Potential impacts and benefits of developing this technology are high. Development areas include increasing dispersant effectiveness, reducing the environmental impacts of the chemicals themselves, developing vessel and aircraft application methodologies and equipment, conducting a program of mesoscale and field testing to refine application techniques and procedures, and researching the effects and effectiveness of this technology. Specific focus will be on dispersant use on cold water spills in the Arctic and sub-Arctic environments. The results of this research will facilitate the acceptance and use of dispersants throughout the U.S. and North America.

A project called "Dispersant Effectiveness Testing on Alaskan Crude Oils in Cold Water" studied whether Corexit 9500 and Corexit 9527 dispersants are effective in dispersing Alaskan crude oils in cold-water conditions. Dispersant effectiveness experiments completed at Ohmsett in 2002 demonstrated that Alaska North Slope (ANS) and Hibernia crude oils could be successfully dispersed in cold water. Four Prudhoe Bay crude oils (ANS, Northstar, Endicott, and Pt. McIntyre) and one Cook Inlet crude oil (Middle Ground Shoals) were selected for testing. This project consisted of small-scale dispersant experiments conducted in a chilled wave tank in Ottawa, Canada, and large-scale dispersant experiments conducted at Ohmsett. A total of 64 small-scale experiments were conducted to develop the final test matrix for the large-scale tests. A total of 14 large-scale tests were completed at the Ohmsett facility using various combinations of oil type and dispersant-to-oil ratios.

The chemically dispersed runs resulted in high percentages (75 to nearly 100%) of oil dispersing into the water column, with the exception of evaporated Northstar and evaporated Endicott. The dispersant effectiveness trends identified in the small-scale testing were mirrored in the large-scale test results. The heavily evaporated Northstar and evaporated Endicott crude oils were resistant to chemical dispersion in both the small-scale and Ohmsett tests. A higher percentage of the fresh Endicott crude oil was dispersed in the Ohmsett tests compared to the small-scale results (74 vs. 20–30%). This may be due to additional mixing energy present in the Ohmsett tests, in the form of breaking waves that do not develop in the small tank tests. Fresh Northstar was the only test where no visible oil was present on the surface at the end of the test. The initial Northstar crude oil slick was thinner (because of its lighter oil characteristics and its tendency to spread faster) than the other oils, so it received a somewhat higher dispersant dosage. The lighter oil characteristics and higher dispersant dosage may account for the complete dispersion and the absence of visible oil on the water surface at the end of this test.

Dispersant experiment in cold water and broken ice at Ohmsett.

Ohmsett: The National Oil Spill Response Test Facility

Ohmsett—The National Oil Spill Response Test Facility—is located in Leonardo, New Jersey. Ohmsett is the only facility in the world where full-scale oil spill response testing, training, and research can be conducted with oil in a marine environment under carefully controlled conditions. It is a vital component of MMS's research program and plays a critical role in developing the most effective response technologies, as well as preparing responders with the most realistic training available before an actual spill. The facility

Preparing Ohmsett for mechanical oil-in-ice experiments.

directly supports the MMS goal of ensuring that the best and safest oil spill detection, containment, and removal technologies are available to protect the U.S. coastal and oceanic environments. Ohmsett is not only vital to MMS's oil spill research program, it is a national asset where government agencies, private industry, and academia can conduct full-scale oil spill research and development programs. Ohmsett is also the premier training site for spill response personnel from government agencies such as the U.S. Coast Guard, the U.S. Navy, the National Oceanic and Atmospheric Administration, and the Environmental Protection Agency.

The heart of Ohmsett is a large outdoor concrete test tank that measures 203 m long by 20 m wide by 3.4 m deep. The tank is filled with 9.84 million liters of crystal clear salt water. There is a wave generator at one end and a moveable beach at the opposite end to reduce wave reflection when regular waves are desired for testing. The tank is spanned by a bridge system capable of towing floating equipment at speeds up to 6.5 knots. The tow bridge is equipped to distribute test oil on the surface of the water several meters ahead of the device being tested so that reproducible thicknesses and widths of oil can be achieved with a minimum of wind interference. The Ohmsett facility features a fully computerized data collection system, above- and below-waterline video capability, and complete oil storage and handling system. Ohmsett is the only facility in the U.S. where full-scale equipment can be easily tested without going into the ocean. If Ohmsett were not available, the only alternative would be at-sea testing, which is very expensive, requires permits, and does not allow reproducible testing conditions. More than 95% of all performance data on offshore oil spill response equipment have been gathered at Ohmsett.

For questions regarding the MMS Oil Spill Response Research Program, please contact Joseph Mullin at 703-787-1556 or joseph.mullin@mms.gov.

To respond to the challenges of testing and evaluating the equipment required to respond to oil spills in ice-infested waters, MMS has upgraded the testing capabilities at Ohmsett to provide a controlled environment for cold-water testing and training (with or without ice). The facility is now able to simulate realistic broken ice conditions. These upgrades will enable the Ohmsett facility to remain open year-round, offering cold-water testing and training during the winter months. Recent testing activities include evaluations of oil spill skimmers for collecting spilled oil in broken ice, cold-water dispersant effectiveness tests, evaluations of viscous oil pumping equipment, basic research on the evaporation of oil and formation of emulsions, cold-water oil spill response training, and evaluations of fast-water oil spill response equipment.

Alaska Environmental Studies Program

As the agency responsible for managing the OCS offshore oil and gas leasing program in Alaska, the MMS Alaska OCS Region has conducted environmental studies since 1974 to obtain information needed to make sound leasing decisions and to monitor the human, marine, and coastal environments. In Alaska, more than $275 million has been spent on studies in 15 OCS planning areas in the Arctic, Bering Sea, and Gulf of Alaska sub-regions. These studies cover a range of disciplines such as physical oceanography, endangered species, living resources, fate and effects, and socioeconomics. The information is used in MMS decision making and monitoring of proposed and existing offshore oil and gas development in Alaska.

A wide variety of interested stakeholders—environmental groups; oil and fishing industry workers; traditional knowledge sources; research contractors; scientists and government personnel from Federal, state, and local agencies; and political entities—help the MMS to identify environmental issues and information needs. Information Transfer Meetings and workshops are convened to bring together information from key sources. The pooling of shared knowledge results in a synthesis of information that identifies those studies most needed to meet the current focus on post-lease and monitoring information requirements. Information regarding these studies can be found in the Alaska Region's Annual Study Profiles list available at http://www.mms.gov/alaska/ess/essp/

SP.HTM. As final reports become available, they will be added to the Environmental Studies Program Information System (ESPIS) web site at http://mmspub.mms.gov:81/search.html.

Coastal Marine Institutes (CMIs) were initiated by MMS to take advantage of the expertise of highly qualified scientifists at local levels and to achieve cooperative research goals in key OCS regions. In 2003 the MMS renewed funding of the CMI at the University of Alaska Fairbanks (UAF) to benefit from its scope and depth of scientific expertise. Under a recently extended cooperative agreement, the MMS committed $1 million per year for studies to be conducted by the CMI if matching state funds were available. The institute conducts research focused on environmental, social, and economic studies relevant to both Federal and state offshore oil and gas and mineral resource management issues. The internationally renowned UAF School of Fisheries and Ocean Science manages the CMI. The Institute creates an opportunity for the MMS and the State of Alaska to jointly accomplish research that could not otherwise be carried out. In addition to 22 ongoing studies, 8 new studies are being evaluated for funding through the CMI in 2004.

Endangered and Protected Species

The bowhead whale, an endangered marine mammal of high importance to Native cultures in the Arctic, migrates through areas of oil and gas exploration and development, including the Northstar offshore production site. Efforts to monitor the fall migration of bowhead whales and related environmental factors will continue through 2004 under the MMS-conducted Bowhead Whale Aerial Survey Project (BWASP) (OCS Study MMS 2002-061 is available at http://www.mms.gov/alaska/reports/BWASP/2002_061adobe6test.pdf) and the MMS-funded study called "Analysis of Covariance of Human Activities and Sea Ice in Relation to Fall Migrations of Bowhead Whales."

Northstar, the first offshore oil development in the Alaskan Beaufort Sea.

The BWASP results indicate that fall bowhead whale sightings tend to be farther offshore in heavy ice years across the central Alaskan Beaufort Sea (142–155°W longitudes). While factors other than sea ice may have localized effects on site-specific distributions, broad-area distributions of bowhead whales in the central Alaskan Beaufort Sea apparently are related to overall sea ice severity. The fall 2001 report showed a greater relative occurrence of feeding and/or milling behaviors of bowhead whales in six different years near the mouth of Dease Inlet, Alaska. It showed similar activity in four of those years near Cape Halkett, Alaska. The analysis of covariance study was funded in early 2003 and will further test hypotheses regarding the relative degree to which various human activities and sea ice may explain variance in observed bowhead whale distributions.

A multi-year study, "Bowhead Whale Feeding in the Eastern Alaskan Beaufort Sea: Update of Scientific and Traditional Information," has been unique in the extent of its coordination with area whale hunters (http://www.mms.gov/alaska/reports/BowheadWhaleFeeding/2002_012.pdf). Residents of Kaktovik assisted in the study design, field implementation, report review, and knowledge sharing needed to determine the importance of the eastern Alaskan Beaufort Sea area to feeding bowheads. Other study components included aerial photography, behavioral observations, isotopic analysis of baleen and muscle tissue, stomach content analysis, and energetics modeling. The results of the study provided important information that was used in the environmental assessment for OCS Lease Sale 186.

Beluga whales are an important species for Native subsistence, with more than 300 harvested annually in Alaska. The movements of beluga whales were documented using satellite telemetry under the MMS/CMI study entitled "Satellite Tracking of Eastern Chukchi Sea Beluga Whales in the Beaufort Sea and Arctic Ocean." From 1998 to 2002, 23 whales were instrumented with the help of Native subsistence hunters in Kasegaluk Lagoon near the village of Point Lay. Data from this and a previous MMS-funded study suggest that female belugas may not move as far north in the Beaufort Sea as male belugas do. Belugas of all ages and both sexes were found most often in water deeper than 200 m and beyond the continental shelf break. Tagged females remained within about 60 km of shore and quite near the continen-

tal shelf break in the Beaufort Sea. Conversely, all instrumented males tended to travel north of latitude 75°N, past the shelf break over waters exceeding 3,000 m in depth. Belugas rarely used the inshore waters within the OCS lease sale area of the Beaufort Sea.

Another MMS-supported study, "Use of Sea Ice Habitat by Polar Bears in the Southern Beaufort Sea," correlated seasonal polar bear locations for the years 1998 through 2001 with sea ice and bathymetry data.

Ringed seals are the primary prey of polar bears and a significant source of food for Natives living in the Arctic. The MMS funded two studies during 2001–2003 addressing the distribution, abundance, and/or behavior of the species in order to evaluate potential effects from OCS development. An MMS/UAF CMI project entitled "Timing and Reinterpretation of Ringed Seal Surveys" began in 2001, building on the results of a previous study: "Correction Factor for Ringed Seal Surveys in Northern Alaska." During these studies, 60 ringed seals have been monitored with radio transmitters. The proportion of seals visible during aerial surveys has been found to vary as a function of snow conditions on the surface of fast ice. A correction factor has been developed, and density estimates derived from previous surveys are being re-analyzed.

Harbor seals, another important subsistence species, are abundant in the Gulf of Alaska region, including Cook Inlet. In 2003 the MMS funded two new studies of harbor seals through an interagency agreement with the National Marine Fisheries Service, National Marine Mammal Laboratory. The first of these, "Distribution and Abundance of Harbor Seals in Cook Inlet: Seasonal Variability in Relation to Key Life History Events," supports repeated, seasonal aircraft surveys of seals at haulouts. The second, "Development of Remote Sensing Survey Techniques for Marine Mammals and Birds in the Arctic: Assessing Variation in Harbor Seal Haulout Patterns," makes use of remote cameras for continuous monitoring of harbor seals at selected haulouts. The latter study will provide insight into factors causing variation in the observations of the aircraft surveys.

Two other studies of marine mammals were funded by the MMS through interagency agreements with the U.S. Fish and Wildlife Service. The first, "Demography and Behavior of Polar Bears Feeding on Stranded Marine Mammal Carcasses," began in 2002 and focused on polar bear use of bowhead bone piles left by Native whalers near the village of Kaktovik (in the Arctic National Wildlife Refuge) and near a traditional whaling camp on Cross Island (near Prudhoe Bay). Increasing numbers of bears have aggregated and fed on whale remains at these locations, with concurrent risks to the resident human populations and to the bears. This study is expected to yield data on the patterns of use of these sites by individual bears and on other bear behaviors in order to establish better estimates of bear mortality in the event of an oil spill. The second study, "Development of Remote Sensing Survey Techniques for Marine Mammals and Birds in the Arctic: Development of Airborne Thermal Remote Sensing for Survey of Pacific Walrus," provided funds for the development of high-altitude thermal remote sensing for use in surveys of walrus. Survey flights were completed near St. Lawrence Island in the Bering Sea during April 2003, and data are being analyzed.

Eiders (a species of sea duck) are harvested for subsistence by Alaska Natives, who have expressed concerns that the abundance of all four species living in the Alaskan Arctic may be declining. From 2001 to 2003, the MMS funded five new studies through the MMS/UAF CMI that address issues related to the population biology of eiders and the potential risks from offshore oil and gas development. The study entitled "Importance of the Alaska Beaufort Sea to King Eiders," funded in 2001, was designed to provide information about how king eiders make use of the OCS waters or adjacent near-coastal areas. A total of 33 adult eiders were implanted with satellite transmitters. The investigators discovered that king eiders staged in the Beaufort Sea before migrating southward to molt along the Chukotsk Peninsula and Kamchatka Peninsula of Russia and in U.S. waters off St. Lawrence Island and the Alaska Peninsula.

Three eider studies were funded in 2002. The study titled "Breeding Biology and Habitat Use of King and Common Eiders on the Coastal Plain of Northern Alaska" will examine and compare the nesting timing, clutch size, reproductive success, and habitat use between a relatively undisturbed site at Teshekpuk Lake (in the National Petroleum Reserve–Alaska) and an area with considerable activity in the Kuparuk oil field. Another study, "King and Common Eider Migrations Past Point Barrow," repeats a count of those species that has been conducted periodically for several decades. Results of previous surveys suggested that populations of king and common eiders had declined by about 50% between 1976 and 1996. Preliminary

results of this study suggest that those populations have not declined further and may have increased since 1996. The third study, "Population Structure of Common Eiders Nesting on Coastal Barrier Islands Adjacent to Oil Facilities in the Beaufort Sea," is designed to use molecular genetic markers to examine the level of population structuring among common eiders breeding on coastal barrier islands along the Beaufort Sea coastline. Results of this study will include a test of the discreteness of genetic stocks of common eiders inhabiting the Beaufort Sea region and an analysis of the risks posed to maintain those stocks by potential oil spills.

A study entitled "Foraging Ecology of Common Ravens (*Corvus corax*) on Alaska's Coastal Plain" was initiated during 2003. This study is expected to provide information on the predator–prey relationships between ravens and waterfowl breeding near the developed areas of Alaska's North Slope. Among the questions this study will address are whether industrial infrastructure is advantageous to ravens, and the extent to which proximity to such infrastructure increases raven depredation of eider nests and ducklings.

Physical Oceanography

Knowledge of predominant weather patterns and wind/current dynamics in the Beaufort Sea enables us to evaluate better the potential effects of an oil spill and to develop precautionary oil spill response strategies. A recently completed MMS/UAF CMI study that examined the seasonal and interannual variability of the Arctic Ocean and Beaufort Sea found that there has been a decadal cycle between wind-driven anticyclonic (ACCR) and cyclonic circulation regimes (CCR). Higher Arctic atmospheric pressure, lower wind speed, and lower winter temperatures characterize the ACCR compared with cyclonic summer winds, precipitation increases over the ocean, and decreases over land during the CCR. The cyclonic summer wind produces more openings in the sea ice, allowing upper ocean heat accumulation. The ice melt season lengthens, increasing freshwater content and leading to generally thinner ice. Anomalous weather patterns in recent years will receive additional scrutiny to determine whether a new pattern is emerging.

The study entitled "Synthesis and Collection of Meteorological Data in the Nearshore Beaufort Sea" completed over two and half years of meteorological data collection from five stations along the Beaufort Sea coast. A new station was added on Cottle Island in August 2002. This study will provide a completed time series of wind data to MMS ocean circulation modelers and researchers for use in their ongoing modeling of the nearshore Beaufort Sea. A project web site (http://www.resdat.com/mms) provides up-to-date project information, station locations and pictures, data downloading, and quarterly graphical data results. This information will assist MMS in improving oil spill trajectory modeling and is available to the general public.

An MMS/UAF CMI study completed three years of moorings, including the first successful winter-long measurements of currents directly under the ice in the nearshore Beaufort Sea. Three upward-looking acoustic Doppler current profilers were moored on the sea bottom within the barrier islands near the Northstar and Liberty offshore development prospects, and a fourth profiler was added offshore of the barrier islands in the third year. The project collected data on water and ice velocity, temperature, salinity, and water clarity (transmissivity) from August 1999 to August 2002. Once landfast ice formed and blocked the wind, current speeds dropped drastically, with less than 1% of current speeds exceeding 20 centimeters per second. A new study, "Beaufort Sea Nearshore Currents," will deploy three similar moorings for three years, starting in 2004, over a greater length of coastline, extending across most of the U.S. Beaufort Sea coast.

An MMS/UAF CMI study entitled "A Nowcast/Forecast Model for the Beaufort Sea Ice–Ocean–Oil Spill System" has developed a new 3-D coupled ice–ocean model with links to a regional mesoscale atmospheric model. The resolution of the model is currently being increased to 1 km or less to resolve coastal barrier islands. This model will be used by the MMS to improve oil spill risk analysis.

In Cook Inlet the MMS/UAF CMI study "Water and Ice Dynamics of Cook Inlet" is using a combination of global positioning system (GPS)-equipped ARGOS drifters, satellite remote sensing, and oceanographic modeling to enhance understanding and to improve the predictability of water and ice dynamics. A parallel MMS/UAF CMI study, "High-Resolution Numerical Modeling of Near-Surface Weather Conditions over Alaska's Cook Inlet and Shelikof Strait," will provide a high-resolution meteorological model that can capture low-elevation wind jets known to occur in Cook Inlet and Shelikof Strait. This model will provide high-resolution grid wind fields to the oceano-

graphic modelers, ultimately enhancing the MMS environmental assessment of the potential effects of oil spills, which, although very unlikely, may occur after OCS development.

Fate and Effects

One of several MMS/UAF CMI laboratory studies documented synergistic effects of weathered North Slope crude oil and ultraviolet light on zooplankton. Establishment of a correlation coefficient between total lipid content and polycyclic aromatic hydrocarbon (PAH) uptake will allow estimates of the PAH load of predominant plankton on the basis of abundance data and their lipid profile. The possibility of further distribution of PAHs into the ecosystem through zooplankton feces is also being evaluated. Another study looks at the kinetics and mechanism of slow PAH desorption from sediments in the lower Cook Inlet and the Beaufort Sea. This study will lead to better capability for predicting the environmental fate of PAH in Arctic sediments. A third and related CMI study examines petroleum-degrading bacterial communities in Beaufort Sea sediments and will compare the current community to that existing at the onset of coastal Beaufort Sea development in the late 1970s.

In the first of four modeling studies, "Revision of the OCS Weathering Model, Phases II and III," the MMS is participating in a consortium to advance the state of the art in oil weathering models, including additions of Alaska-specific oils and ice conditions and the development of an experimental and observational spill database suitable for model validation. In the second and third studies, the MMS is investigating "Alternative Oil Spill Occurrence Estimators for the Beaufort/Chukchi Sea OCS" with parallel fault-tree and statistical engineering approaches. These latter studies include analyses of differences in potential spill causes in these Arctic areas versus elsewhere in the U.S. OCS, primarily in the Gulf of Mexico. In the fourth study, "Persistence of Crude Oil Spills on Open Water," the MMS is developing empirical statistical relationships among environmental and response factors related to the persistence of crude oil slicks at sea.

Research Monitoring

A multi-disciplinary, site-specific Beaufort Sea monitoring study, "Arctic Nearshore Impact Monitoring in the Development Area (ANIMIDA)" was initiated in June 1999. This study examines impacts associated with the first Federal oil development on the Alaskan OCS at Northstar and the anticipated Liberty prospect near Prudhoe Bay. Phase I of ANIMIDA reported the results of measured changes in ambient noise, resuspension of sediments, and sediment quality.

Designed to provide long-term continuity beyond what could be expected through industry-sponsored studies alone, ANIMIDA Phase II expanded monitoring in 2000–2002 by measuring:

- Partitioning of contaminants between dissolved and particulate water phases;
- Trace metals, hydrocarbons, persistent organic pollutants, and biomarkers in fish;
- Effects on kelp in the Boulder Patch (an area of Special Biological Concern); and
- Perceived effects on Native subsistence whaling.

The Phase II studies were reported in a special session at SETAC in November 2003, with the final reports expected in January 2004. A third phase, cANIMIDA (Continuation of ANIMIDA), is being procured in 2003 and will start field work in 2004.

An MMS/UAF CMI study recently examined and reported on the historical changes in trace metals and hydrocarbons in the inner shelf sediments of the Beaufort Sea. The study used a combination of dated sediment cores, freshly collected surface sediment, 30 years of prior analytical measurements by the investigator, and data from prior MMS Beaufort Sea monitoring projects. Of multiple metals, only vanadium and barium levels were possibly elevated in more recently collected and analyzed sediments. The levels of vanadium and barium found were still low and well below harmful levels. The hydrocarbon analyses primarily found natural compounds indicative of decayed marine plankton and peat from onshore. No petroleum signal was found. The study concluded that the nearshore Beaufort Sea has remained a relatively clean environment as far as trace metals and hydrocarbons are concerned, despite the adjacent petroleum-related industrial activities during the past 30 years. A follow-up CMI study continues the documentation of trace metals and hydrocarbons in sediments across the Beaufort Sea from Elson Lagoon near Barrow, to Prudhoe Bay, to Beaufort Lagoon in eastern Alaska.

The MMS/UAF CMI study "Seabird Samples as Resources for Marine Environmental Assessment" collects and curates seabird tissues in cooperation with the University of Alaska Museum to provide further resources for contaminant and other scientific researchers. Loans and tissue samples from this collection have already been made

available to scientists for contaminant and oil-spill-related studies. The MMS/UAF CMI has also arranged for the University of Alaska Museum to archive high-quality surface sediments and dated sediment cores from the MMS study "Sediment Quality in Shelikof Strait and Outermost Cook Inlet."

A greater knowledge of Arctic fishes is important to protecting subsistence and biological resources while developing offshore oil and gas resources. Very little documentation exists on the actual locations of overwintering habitat of Beaufort Sea anadromous fish. The potential of remote sensing applications, such as synthetic aperture radar, is being investigated to reduce the high cost of locating and evaluating overwintering habitats. Native Alaskans are concerned that a major subsistence species in the Colville River, Arctic cisco, has been less abundant during the last few years than in preceding years. An effort to quantify interannual variation in their abundance and estimate which environmental factors contribute to observed variation will provide better predictions, which will allow adjustment to natural cycles and help avoid potential development effects on this important resource.

Socioeconomics

Since its formation the MMS Alaska Region Environmental Studies Program has been unique in its emphasis on social and economic studies relating to the potential effects of offshore oil and gas development. Because of the distinctive nature of subsistence activities and sociocultural attributes throughout rural villages and coastal communities in Alaska, MMS social research goes well beyond conventional economic considerations.

In response to recommendations of community leaders of Alaska's North Slope, MMS initiated a study in 2001 entitled "Quantitative Description of Potential Impacts of OCS Activities on Bowhead Whale Hunting and Subsistence Activities in the Beaufort Sea." The study, to be completed in 2004, focuses on Native perceptions of the acute and cumulative effects of oil industry operations on bowhead whale hunting. The study will collect information from residents of Nuiqsut, Kaktovik, and Barrow through survey instruments and will consider both beneficial and detrimental potential effects.

Another North Slope project aims to develop and implement a GIS mapping system to describe subsistence hunting and fishing activities for selected species, including bowhead whales, ringed seals, caribou, Arctic cisco, broad whitefish, Arctic char, and various waterfowl. The project focuses on collecting and describing contemporary subsistence patterns while accommodating the addition of past and future harvest data to enable analyses of pattern changes over time. A sample of hunters in each community will be selected using systematic social networking methods. In addition, the project will document the locations of harvest campsites and travel routes.

In Cook Inlet the prospect of OCS oil and gas development presents some potential for spatial conflict with local fishing operations, especially the commercial driftnet fishery. Drift gillnet fishermen often focus their efforts near turbulent rip tides because salmon are known to concentrate in these areas. The presence of an oil platform in favorable fishing areas could pose a navigational hazard, with potential consequences of diminished access, loss of harvest resulting from premature net release, or gear entanglement. A study entitled "Mitigation of Oil Industry Operations on Driftnet Fishing in Cook Inlet," begun in 2003, intends to explore and define specific ways to mitigate these potential conflicts and to analyze the significant tradeoffs of reasonable alternative proposals.

On Kodiak Island a new study is underway to collect and analyze data on the major socioeconomic consequences of the *Exxon Valdez* oil spill litigation settlement for local residents. The project will investigate and document key secondary social and economic impacts from the litigation and settlement experiences that follow the primary impacts of the original spill event. It will also attempt to formulate general recommendations pertaining to the effective management of potential future oil spills and related litigation settlement procedures, even though the spill event did not occur under MMS jurisdiction or even within imaginable MMS offshore spill scenarios.

To document the extent of social research in Alaska and the substantial information accumulated over the past 20 years, MMS initiated a book project in 1998 that will enhance the accessibility of research products and summary findings for all interested parties. When completed, the project will produce a peer-reviewed book that will explain and synthesize the results of more than 160 MMS-funded studies.

A study entitled "North Slope Economy, 1965 to the Present" will provide detailed information on local government revenues and expenditures, including capital projects of North Slope commu-

nities (both prior to and after the formation of the North Slope Borough), as well as property tax and other categories that merit analysis. The study will:

- Classify local government services by departments and other major categories;
- Describe how the revenues and expenditures have been a component and shaping force of the North Slope economy;
- Describe the structure of the North Slope economy, including employment, income, and their fluctuations;
- Describe how quantifiable, non-cash economic factors for households have changed from 1965 to the present in relation to the greater availability of salaried jobs;
- Describe the role of the Arctic Slope Regional Corporation, the Ukpeagvik Inupiat Corporation, and other village for-profit corporations in the North Slope economy; and
- Describe how individual and household economies have responded to changes in the regional economy.

Some of the empirical measures will include income and changes in quality of life, such as housing and sewer and water facilities. A draft of the study report was submitted in 2003 and is now under review.

GIS Databases

The study entitled "Evaluation of Sub-Sea Physical Environmental Data for the Beaufort Sea" was completed in 2002. It integrates all Federal Beaufort Sea OCS site-specific geological and high-resolution geophysical data results and similar data sets into a geographical information system (GIS) database in support of exploration and development projects. The GIS database includes spatial and attribute data on the location of strudel scour, ice gouge, and drain racks, in addition to data on bathymetry, faulting, near-surface stratigraphy, seismic anomalies, boulder patch, and earthquakes. The documentation is available at http://www.mms.gov/alaska/reports/SubseaGIS/evaluation_of_sub.htm.

An ongoing MMS/UAF/University of Alaska Anchorage CMI study is in the process of completing an updated sea ice atlas for Arctic and sub-Arctic Alaska marine waters. A web site (http://holmes-iv.engr.uaa.alaska.edu/), which is under construction, will provide statistical and GIS output of National Ice Center and National Weather Service sea ice data for the Alaska OCS, including Cook Inlet. This web site will contain a unique set of tools to query and graph historical meteorological data from first-order weather stations located throughout Alaska.

Information Transfer

An Information Update Meeting was convened by the MMS Alaska OCS Region in Barrow in March 2003. The MMS and officials of the North Slope Borough scheduled this meeting in Barrow, Alaska, so that residents would have better access to information on key MMS studies. Principal investigators presented information on 11 ongoing studies at the one-day event. Also, MMS held its Ninth Information Transfer Meeting in Anchorage, Alaska, in March 2003. Principal investigators presented information on 37 ongoing studies in the Beaufort Sea and Cook Inlet regions. It was attended by a diverse audience drawn from local communities, industry, other Federal agencies, and state and local governments.

In cooperation with the U.S. Fish and Wildlife Service, the MMS also supported a 2003 workshop in Anchorage entitled "Polar Bear Population Monitoring Workshop." Management issues were identified, and recommendations for future research and monitoring were made by individuals representing a variety of organizations.

In 2003 the MMS Alaska OCS Region also sponsored two international workshops designed to produce recommendations regarding future Arctic oceanographic research needs. The MMS/UAF CMI "Workshop on Small-Scale Sea-Ice and Ocean Modeling (SIOM) in the Nearshore Beaufort and Chukchi Seas" brought together international sea-ice modelers and researchers to develop strategies to advance the state of the art in Arctic ice modeling. Following recommendations from this workshop, MMS and the National Aeronautics and Space Administration signed an Interagency Agreement in 2003 to research "Sea-Ice Modeling in Nearshore Beaufort and Chukchi Sea in the Arctic Ocean." The MMS Physical Oceanography of the Beaufort Sea Workshop brought together international experts in Arctic oceanography to review the state of knowledge concerning Beaufort Sea physical oceanography and to recommend long-range goals for oceanographic research to meet MMS needs.

Reports of MMS-sponsored information transfer meetings and MMS studies are available from the MMS Environmental Studies Information System (ESPIS) at http://mmspub.mms.gov:81/.

Fish and Wildlife Service

The U.S. Fish and Wildlife Service (FWS) conducts research in the Arctic to help accomplish its mission to conserve and manage migratory birds, threatened and endangered species, certain marine mammals, and anadromous fish, as well as all biota inhabiting nearly 77 million acres within 16 National Wildlife Refuges in Alaska.

	Funding (thousands)	
	FY 02	FY 03
Migratory Birds	3,884	3,800
Fisheries	4,068	4,300
Marine Mammals	1,768	2,255
CAFF	200	200
U.S.–Russia Environ. Agreement	150	350
Total	10,070	10,905

Fisheries and Ecological Services

Fisheries

Fishery research in the Arctic by the FWS continues to focus on Yukon River salmon shared by the United States and Canada in support of the U.S.–Canada Treaty. The FWS continues to develop enumeration techniques for Yukon River salmon to quantify abundance, apply genetic stock identification techniques to assess genetic diversity, and determine what portion of the U.S. harvest is of Canadian origin. These studies also generate data needed for in-season management of Canadian-origin salmon. Research includes a mark–recapture study of fall chum salmon at Rapids/Rampart and the use of video technology to determine marked-to-unmarked ratios of fall chum salmon and catch-per-unit-effort for chinook and fall chum salmon. To manage U.S. stocks of salmon, the FWS uses resistance board weirs to enumerate summer chum and chinook salmon on the Gisasa River and summer chum, chinook, and coho salmon on the Andreafsky River. Split beam sonar is used to count fall chum salmon on the Chandalar River. The information from these monitoring studies is used to schedule fishery openings and ensure stock conservation on National Wildlife Refuges.

Although salmon are extremely important to subsistence users and ecological productivity, the importance of other species is becoming apparent. Whitefish are used seasonally in areas with salmon fisheries and are used extensively in areas with no salmon runs. Studies indicate that whitefish in certain river systems are as abundant as salmon, and they may be critical to food webs and nutrient cycling. Radiotelemetry has identified important habitats and migration corridors of inconnu (sheefish), broad and humpback whitefish, and least cisco in several National Wildlife Refuges. Also, electron probe microchemistry has identified several anadromous stocks and indicates that these fish rival salmon in the distances traveled during their migration. These long-distance movements make these stocks vulnerable to fisheries as they travel to their spawning areas.

Fish stocks of Alaska's North Slope in the Arctic National Wildlife Refuge have also received considerable attention recently. One study being conducted in the coastal lagoons near the village of Kaktovik is designed to determine the relative abundance of Arctic cisco and Dolly Varden. Catch results, length frequencies, length–weight relationships, and fish condition will be compared to baseline data collected on these species between 1988 and 1991. A second study will use dual-frequency induction sonar to estimate the number of Dolly Varden that return to spawn in the Hulahula River and provide the first quantitative information about population size of these fish on the North Slope. A third study focuses on locating the overwintering areas of Dolly Varden in the lower Canning River. These studies will provide valuable information to use for conserving viable populations should the area be available for oil and development.

The FWS's Conservation Genetics Lab continues to study Yukon River chinook and fall chum salmon and has collected both species from a number of drainages in the U.S. and Canada. A recent study concluded that genetic diversity of chum salmon in the Yukon River is widely distributed over a broad geographic area, whereas coho salmon populations are small and discrete. This has important implications for management of these species and suggests that the genetic diversity of coho salmon is at higher risk from habitat degradation than chum salmon.

Environmental Contaminants

The FWS and its partners have actively pursued scientific studies and management solutions concerning complex contaminants problems in the Arctic for several decades. International research programs such as the Arctic Monitoring and Assessment Program (AMAP) have shown that pollutants are a circumpolar, and indeed global, issue. The FWS conducted a number of contaminant-related studies during FY 2001–2003.

Chinook and Chum Salmon. In 2001 the FWS began collecting baseline data on contaminants in chinook and chum salmon from the Yukon and Kuskokwim Rivers. Runs of these salmon have declined in recent years, and subsistence users are concerned about the presence of environmental contaminants in their food. Analyses for heavy metals and persistent organochlorine compounds indicate that these fish have relatively low contaminant concentrations, and the State of Alaska recommends unlimited subsistence consumption of these stocks.

Spectacled and Steller's Eiders. Environmental contaminants specialists are investigating lead concentrations in threatened spectacled and Steller's eiders and other waterfowl from Alaska. Exposure to lead in breeding areas, presumably from ingestion of lead shot, can contribute to population declines. Recent research compared isotopic "signatures" in eider blood to known lead sources, including samples of lead shot and various wetland sediments. Initial results indicate that shot is the primary source of lead for eiders with high blood lead levels, while eiders with low lead levels have signatures that match the sediments in their breeding areas. Work is ongoing to further characterize these sources and determine thresholds for exposure to lead shot in eiders. Positive identification of shot as the lead source will contribute to ongoing FWS efforts to reduce lead shot use through education and enforcement.

Steller's eiders.

Wood Frog. The wood frog is the only amphibian that occurs across most of Alaska, including areas within the Arctic. Since 2001, surveys for abnormal wood frogs have been conducted on several National Wildlife Refuges in Alaska. Low numbers (<3%) of abnormal frogs have been found in Arctic areas of Alaska, with the most prevalent anomalies being missing hind limbs and digits. Initial sampling suggests that the dramatic abnormalities seen in frogs in more temperate climates, such as additional appendages and misplaced eyes, are not commonly observed in localized areas of northern and western Alaska.

Marine Mammals

Pacific Walrus. Research on Pacific walruses continues to focus on monitoring haul-outs in Bristol Bay, monitoring the spring subsistence harvest to collect information on the size and demographics of the harvest, and developing techniques to estimate the size and trend of the Pacific walrus population.

The size and trend of the Pacific walrus population remain unknown. Several approaches are under investigation for developing an accurate estimate, including genetic fingerprinting in a mark–recapture study. Computer simulations indicate that for a modeled walrus population of 300,000, even relatively large sample sizes (15,000–30,000 samples annually) produce poor population estimates. However, incorporating age into the mark–recapture analysis dramatically increased the efficiency and precision of the estimate and simulated sampling rates as low as 1,500 animals. The successful application of mark–recapture techniques to estimate the size and trend of the Pacific walrus population will require the ability to determine age and gender and identify individual animals with negligible error rates, but collecting representative samples from free-ranging animals across a wide-ranging, dynamic habitat presents significant logistical challenges.

The FWS is also evaluating remote sensing tools for use in developing a population estimate. Techniques under evaluation include high-resolution aerial photography and satellite imagery. Previous studies demonstrated the capability to detect and enumerate walruses with appropriate satellite imagery; additional work refined the technique for use in counting walruses on terrestrial haul-outs. Imagery of walruses on ice is currently under analysis. The results suggest that a walrus survey could potentially be flown with an airborne thermal scanner from a height of 3,500 m. The advantages of this technique are that a high-altitude, scanner-based survey would cover more than four times the area per survey hour compared to traditional visual-based observation methods. Also, a high-altitude, scanner-based survey would produce a permanent data record that could be re-examined, eliminate observer bias in estimating numbers of animals in groups, minimize disturbance to walruses, and increase safety for flight crews by eliminating low-altitude flights over open ocean and pack ice.

Northern Sea Otter. The FWS continues to focus its efforts on the stock-wide population decline of sea otters in southwestern Alaska. Abundance estimates for some areas have declined by as much as 93% since the surveys in the mid-late 1980s and early 1990s. Rates of decline have varied from 6.7% per year at Kodiak Island since 1989 to 17.5% per year in the Aleutian Islands. Sea otter population declines are similar among survey areas in the Aleutians, along the Alaska Peninsula, and in the Kodiak Archipelago in terms of severity and timing, and severe declines of pinniped populations have occurred in the same areas. The results of broad-scale aerial surveys prompted the FWS to designate the southwest sea otter population stock as a candidate species under the Endangered Species Act; the FWS published a proposal to list this stock as threatened under the Endangered Species Act on February 11, 2004. Site-specific surveys at representative islands in the central and western Aleutians in 2003 indicate that the decline is continuing, with an estimated 63% decline between 2000 and 2003 at these sites.

Polar Bear. The FWS, in cooperation with the North Slope Borough, the Alaska Nanuuq Commission, and the Native villages of Kaktovik and Nuiqsut, initiated a polar bear feeding ecology study during September 2002. In the southern Beaufort Sea, polar bears tend to migrate to nearshore coastal areas during the fall to look for dens and feed on seals and whale carcasses. In recent years the number of bears using the coastal habitat in the fall has increased. The objectives of the three-year study are to determine the number, sex, and ages of the bears and their behavior and habitat use at Cross and Barter Islands during the fall open-water period. These locations were chosen because of the presence of subsistence-harvested bowhead whale remains that attract numbers of polar bears. The maximum number of bears seen at Barter Island at one time was 51. A maximum of seven bears were observed at one time at Cross Island. The majority of bear use at both the Barter Island and Cross Island feeding sites was by single adult bears (41% and 76%, respectively) and by family groups of adult females with dependent cubs (26% and 13%, respectively). At both locations, all age/sex classes of bears fed predominantly at night. During the day the majority of bears were inactive. The study was continued in 2003–2004.

The FWS, in cooperation with BP Exploration and LGL Research, completed four years of weekly aerial surveys along the coastline and barrier islands of the Beaufort Sea (2000–2003). During the first three years, there were 706 polar bear observations. The number of observations between the fall open-water period and freeze-up was quite variable among years, with the greatest number of observations in fall 2002 (five surveys, 377 observations). A greater number of bears used coastal habitat during years when the pack ice remained farther offshore for extended periods of time. Adult females with dependent young comprised 45.5% of the observations. Habitats used by polar bears most frequently during the study were barrier islands and shore-fast ice.

Threatened and Endangered Species

Spectacled and Steller's eiders. In 2002 and 2003 the FWS continued to participate in a long-term study of the threatened Steller's eider in the vicinity of Barrow in cooperation with the North Slope Borough. The study focuses on documenting abundance and distribution and identifying the primary influences on survival and reproduction. Nesting effort and success of Steller's eiders vary tremendously from year to year. Predation is considered to be the main cause of Steller's eider nest failure near Barrow. Management strategies to improve nesting success may be necessary to maintain the population. Research projects in support of this objective include video monitoring of Steller's eider nests to identify predators that are responsible for egg loss and collaborative efforts with the Alaska SeaLife Center to develop artificial incubation techniques.

Satellite telemetry was used to determine that Alaska-breeding individuals of both Steller's and spectacled eiders spend part of their annual cycle (molt or pre-molt staging) in northeast Russia. Recognizing that effective wildlife conservation efforts must reach across the border, the FWS has sponsored several projects in northeast Russia. Aerial and boat surveys were conducted in western Chukotka in the summer of 2002 to locate key areas being used by both species. Large numbers (approximately 14,000) of Steller's eiders were observed there in 2002 and 2003 during the pre-molt period.

Virtually the entire Pacific population of Steller's eider molts and spends the winter in the nearshore waters of southwestern Alaska. This population is estimated at roughly 100,000 individuals and appears to be declining at over 6% annually. Currently the Alaska-breeding population includes, at most, 2,500 individuals. The FWS, in coopera-

tion with the Corps of Engineers, has conducted boat surveys of wintering eiders in a number of coastal areas where development may occur that could impact the protected lagoons and productive, shallow areas that eiders depend on for their over-winter survival.

In 2003 a nesting biology and survival study of spectacled eiders in the Chaun River Delta, Chukotka, was initiated. The long-term goal of this project is to compare the productivity and survival of spectacled eiders in Russia and Alaska. The FWS also sponsored a pilot subsistence harvest survey in villages in the Yakutia and Chukotka regions in 2002 and 2003. Data from 2002 indicated that hunting pressure on eiders may be greater than previously thought and that local knowledge of waterfowl conservation issues, such as the effects of lead shot, is very low.

Short-tailed albatross. Once numbering in the millions, the short-tailed albatross was driven to the brink of extinction by feather hunters. Today, fewer than 1,800 individuals exist, and they nest on only two islands in the western Pacific. Japan's Torishima Island, home to 80% of the world population, is an active volcano, with the albatross colony located in the caldera's fluvial outwash plain. The short-tailed albatross is listed as endangered throughout its range. Since 1990 there have been five documented takes of this endangered seabird in Alaska's longline fisheries. Recently the FWS has undertaken, funded, and cooperated in a number of projects aimed at understanding the birds' movements and threats.

As a joint conservation initiative, the FWS and Japanese Ministry of Environment began a satellite tracking study of post-breeding short-tailed albatrosses in 2001. Since 2001, tracks lasting between 50 and 140 days have been obtained from 17 albatrosses, for a total of over 6,000 at-sea locations. In an effort to further define where short-tailed albatrosses are foraging, the FWS undertook a study to track adult and sub-adult birds at sea. All of these data will be used in conjunction with oceanographic data (collected via satellite remote sensing) and fishing effort and bycatch data to identify important marine habitats for the short-tailed albatross and environmental factors that affect their potential interaction with longline fishing fleets.

Previous studies conducted by the Washington Sea Grant Program indicated that paired streamer lines, towed behind longline fishing vessels, are very effective at reducing seabird attacks on bait (thus reducing potential bird hookings and drownings). Current research will help determine whether proposed streamer line performance standards are appropriate for small vessels and on vessels using snap-on gear. Additionally the FWS is funding Washington Sea Grant to study whether integrated-weight groundlines, with their faster sink rates, are effective in reducing seabird bycatch by the longline fishery.

National Wildlife Refuges

The National Wildlife Refuge system in Alaska encompasses 16 refuges and approximately 77 million acres. Staff of each refuge conduct a variety of research, monitoring, and inventorying studies, ranging from long-term ecological monitoring to more narrowly focused intensive studies of specific plant, fish, and wildlife species. Research highlights are included for several refuges in Alaska.

Yukon Delta National Wildlife Refuge

The bar-tailed godwit is the most abundant large shorebird in the East Asian–Australasian Flyway. Each fall, approximately 100,000 godwits migrate from the coast of western Alaska to Australia and New Zealand. This 11,000-km flight is apparently the longest non-stop bird migration in the world. Since 1999, refuge staff in collaboration with the USGS have studied flocks of godwits staging on the coast of the refuge to determine the wintering grounds, migration routes, and racial identity of godwits staging on the Yukon–Kuskokwim Delta and determine the proportion of juveniles in the staging flocks in order to estimate annual reproductive success. By reading site-specific color-flags on the godwits' legs, field crews have been able to identify godwits that have wintered in northeastern and southeastern

Bar-tailed godwit with leg bands at the Yukon Delta National Wildlife Refuge.

Braids at the Yukon Delta National Wildlife Refuge.

Australia, as well as on the North and South islands of New Zealand. Godwits banded on spring migration in both China and Japan have also been observed in Alaska. The proportion of juveniles in the fall staging flocks has been consistently low, never exceeding 3% since the study began and averaging considerably lower than age ratios among small samples of birds captured on the wintering grounds. Therefore, refuge scientists, along with researchers from Australia and New Zealand, are evaluating hypotheses to explain this discrepancy. A population model to assess the impact of chronically low productivity on population growth is being developed in collaboration with the USGS. The refuge plans to initiate a pilot study of godwit breeding biology in 2004 to begin exploring the factors contributing to the apparently low reproductive success.

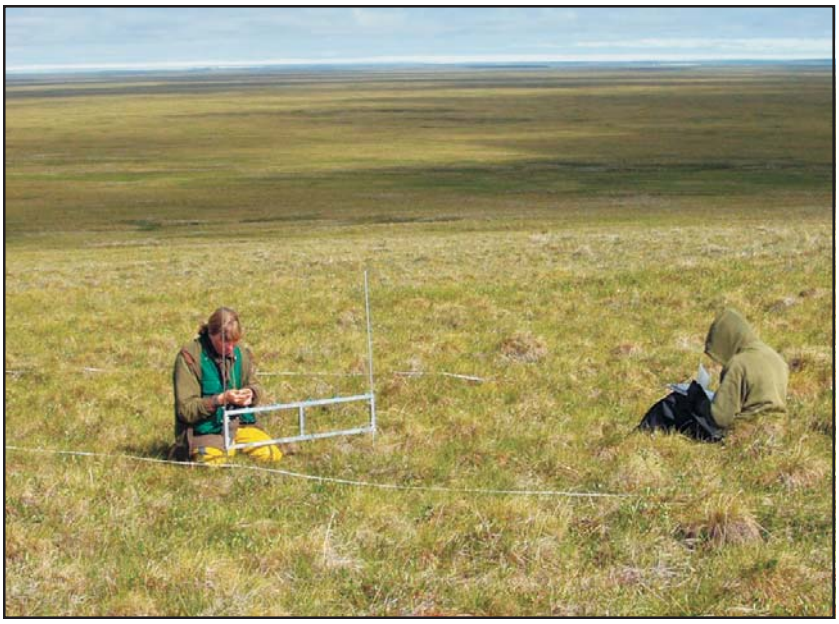
About 42,000 pairs of black scoters, or 47% of the western North American breeding population, nest on the Yukon Delta National Wildlife Refuge. Black scoters remain the least known of all waterfowl species. Because of a steady decline in Alaska's breeding population, refuge staff and USGS researchers initiated a multi-year study of black scoter breeding ecology. The study, designed to identify nesting habitat and timing, has found more scoter nests than any previous research effort. Preliminary results indicate that black scoters are one of the latest-nesting waterfowl species, with onset of nesting occurring between late June and early July. Nests contain an average of eight eggs and are difficult to find. They are often situated far from large water bodies in dense thickets of knee-high (or taller) dwarf birch and willow along the sides of pingos, drainages, and dry lake basins. Researchers have only found about 40 nests per year, despite several weeks of intensive searching in areas identified as having high concentrations of pairs. Black scoters are sought by subsistence hunters in late May and early June on large lakes and along rivers of the refuge as they migrate to breeding areas. They are heavily harvested on the refuge, averaging about 6,000 birds per year. Ultimately the results of the study will assist refuge staff with the management and conservation of this little-known species.

Black scoter research at the Yukon Delta National Wildlife Refuge.

Arctic National Wildlife Refuge

Temperatures in northern Alaska have warmed over the past 30 years. To determine whether tundra vegetation has changed, botanists from the refuge in northeastern Alaska examined data from 26 plots that were sampled 5–6 times each between 1984 and 2002. The plots represented all of the major vegetation types on the coastal plain of the refuge. The investigators used point sampling to estimate percent cover of all plant species, measured the depth of thawed soil above the permafrost, took photographs from permanent photo points, and measured the height of willows at four plots. They used linear mixed-effects regression models to test for changes over time in plant species cover, willow height, and active-layer depth. The investigators detected small but significant decreases in cover of nonvascular plants (i.e., mosses, liverworts, and lichens) but no trend in vascular plant cover or willow height. The depth of thawed soil increased over the 18-year period. Refuge staff plan to continue monitoring the permanent vegetation plots every five years to develop a long-term record of changes in plant cover and active-layer depth and will examine relationships between observed changes and climatic conditions in the region.

The Arctic coastal plain of northern Alaska provides important breeding habitat for over 70 species of birds, including shorebirds, waterfowl, loons, and passerines. The coastal plain is also increasingly influenced by human activities, especially oil exploration/development and growth of Native villages. Human food sources may enhance populations and alter the distributions of preda-



Vegetation sampling at the Arctic National Wildlife Refuge.

tors such as arctic foxes, common ravens, glaucous gulls, and grizzly bears. Predator populations may also be influenced by man-made structures that are used for nesting, denning, or surveillance. Increased numbers of predators in the vicinity of human developments could negatively affect the productivity of breeding birds via increased predation on eggs and young. The FWS, Wildlife Conservation Society, BP Exploration (Alaska), Inc., ConocoPhillips Alaska, Inc., ExxonMobil Corporation, and Manomet Center for Conservation Sciences initiated a project in 2002 to investigate the effects of development on populations of nest predators and productivity of shorebirds on the coastal plain. Study sites were established across the North Slope. At each site, investigators are collecting data on nest density, nest fate (hatch vs. fail), and causes of nest failure. They are also investigating the relationship between nest survival, predator abundance, and proximity to human developments.

A rope drag being used to find nests of birds on the coastal plain of the Arctic National Wildlife Refuge.

Yukon Flats National Wildlife Refuge

Breeding scoter populations have declined over 50% in North America since 1955. The Yukon Flats National Wildlife Refuge (NWR), the largest interior wetland basin in Alaska, supports the largest breeding population of white-winged scoters in Alaska. Refuge staff, in collaboration with the University of Alaska, initiated a study in 2002 to estimate nesting success, nest habitat selection, and duckling survival for white-winged scoters. They captured female scoters with mist nets prior to breeding and marked them with prong and suture radios to locate nests. They performed nest searches and extensive brood surveys. Preliminary data suggest low nesting success, high adult female mortality, and earlier nest initiation dates than previously estimated. Nesting habitat ranged from densely vegetated shrubby areas near lakeshores to sites up to 400 m inland in black spruce forest. Brood surveys showed that large numbers of scoter arrive on the brood-rearing lakes in late July and August. This study will provide information essential for modeling the population dynamics of this species and making sound management decisions.

White-winged scoter study at the Yukon Flats National Wildlife Refuge.

The Yukon Flats NWR and the USGS are collaborating to develop a baseline earth cover inventory of the Yukon Flat NWR using Landsat thematic mapping (TM) imagery that meets the requirements for the National Land Cover Database (NLCD) 2001 project administered by the USGS. The refuge's goal is to produce an integrated GIS database that can be used to improve natural resources planning. The field effort has focused on purchasing, classifying, field verifying, and producing high-quality, high-resolution, digital and hard copy resource-based maps. Over 800

ground-truthed points have been archived. A draft map, which will include 35–40 earth cover types, will be constructed in the winter of 2004. An accuracy assessment is scheduled for the summer of 2004.

Migratory Bird Management

The Migratory Bird Management Program is responsible for conducting research, monitoring, and surveys of migratory bird populations throughout Alaska in support of the management of migratory birds. In Arctic Alaska, efforts are concentrated on sea ducks and other waterfowl that inhabit areas undergoing exploration and development by the oil and gas industry.

Breeding Population Surveys of Waterbirds on the North Slope of Alaska

Since 1992 the FWS has conducted systematic aerial surveys of waterbirds on the North Slope of Alaska. One of the objectives of the study is to determine the breeding range and relative abundance of the threatened spectacled eider on the North Slope. To date, significant positive growth rates have been observed for Arctic terns, red-breasted mergansers, greater scaup, king eiders, snow geese, and black brant, while a significant negative growth rate was observed for red-throated loons.

Program for Regional and International Shorebird Monitoring

The goals of PRISM are to estimate the size of breeding populations of 74 shorebird taxa in North America; describe the distribution, abundance, and habitat relationships for each of these taxa; monitor trends in shorebird population size; monitor shorebird numbers at stopover locations; and assist local managers in meeting their shorebird conservation goals. PRISM has four main components: Arctic and boreal breeding surveys, temperate breeding surveys, temperate non-breeding surveys, and neotropical surveys. Arctic PRISM has three components: an extensive survey of the entire Arctic region of North America, using random sampling and methods that permit estimating abundance (not just an index to it); annual or semi-annual surveys at 10–20 non-randomly selected permanent shorebird sites using either index or density methods; and collection of checklist data, using a standard protocol, at as many sites and as often as possible. Taken together, these components will provide essentially unbiased estimates of actual population size and thus of change in size since the last major survey.

To date, most of the focus has been placed on developing and testing methods to accomplish the first component. The extensive surveys use a combination of GIS methods to select plots and double sampling to collect the bird information. Stratified sampling is used to separate the good and less good habitat so that sampling effort can be concentrated in the higher-quality areas. Full implementation of the program awaits additional funding.

International Activities

Because of its strategic location in the North and its wealth of diverse and productive habitat, Alaska shares populations of wildlife with many other countries. To successfully achieve its conservation mission, the Fish and Wildlife Service frequently participates in international cooperative research, management, and conservation activities.

Arctic Monitoring and Assessment Program

FWS contaminants data figure prominently in the latest round of assessment reports published by the Arctic Monitoring and Assessment Program. In particular, a long-term peregrine falcon monitoring study was highlighted in recent reports on heavy metals and persistent organic pollutants. Long-term contaminants data sets are rare, both in the Alaskan Arctic and within the United States. The FWS also contributed Alaskan polar bear tissue data, which fill a significant data gap identified in the first AMAP assessment report. In addition to helping complete the circumpolar database for contaminants such as PCBs, DDT, and mercury, the FWS cooperated with researchers at Michigan State University to investigate some "new" compounds of concern, including perfluorooctane sulfonate (PFOS) and brominated flame retardant chemicals, both of which have recently been identified as emerging issues for Arctic wildlife.

Conservation of Arctic Flora and Fauna

The Fish and Wildlife Service is the designated Federal agency for participation in the Arctic Council's CAFF program. For the period 2002–2004, FWS employees are chairing CAFF as well as its Flora Group and the Circumpolar Seabird Working Group. CAFF recently produced two significant products. The vegetation map of the cir-

cumpolar Arctic was published in 2003. CAFF also published a major review of the status and conservation of Arctic fauna and flora.

Area V

Under Area V of the U.S.–Russia Conservation Agreement, the FWS continues to support scientific exchanges with Russia to promote research and monitoring of key Arctic species and small grants to Russian colleagues to further scientific inquiry and conservation of species of mutual concern in Russia.

U.S.–Asia Activities

The FWS became a part of the Asia–Pacific Migratory Waterbird Committee. Under the auspices of the APMWC, the FWS is participating in a study of the migration and wintering of four Arctic-nesting subspecies of dunlin. The FWS is also participating in the South Pacific Regional Environment Program. Under the auspices of this program, the FWS participated in an expedition to document the wintering range of the bristle-thighed curlew, as well as the ranges of several shorebird species endemic to south Pacific islands.

National Park Service

NPS Goals

The National Park Service (NPS) preserves unimpaired the natural and cultural resources and values of the National Park system for the enjoyment, education, and inspiration of present and future generations. The NPS cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout the U.S. and the world.

The NPS's goals for Arctic research stem from the specific authorizing legislation that established Arctic parks, preserves, monuments, and programs and from strategic planning and management policies. An overarching goal is to ensure that management of units of the National Park system is enhanced through a broad program of high-quality science and information.

The NPS's Natural Resource programs in Alaska emphasize four priorities: preserving Alaska's ecosystems, visitation and access, balancing preservation and consumptive uses, and building a scientific foundation for park management. The natural resource Inventory and Monitoring program is intended to provide consistent databases of information about natural resources, including species diversity, distribution, and abundance and to determine the current condition of park resources and how they change over time. The NPS's Cultural Resource programs in Alaska are focused on preserving Alaska's cultural resources and contributing to knowledge about cultural resources and human populations. The Shared Beringian Heritage Program recognizes and celebrates the contemporary and historic exchange of biological resources and cultural heritage shared by Russia and the United States on both sides of the Bering Strait. The Beringia program seeks local resident and international participation in preserving and understanding natural resources and protected lands as well as working to sustain the cultural vitality of Native peoples in the Central Beringia region. All projects address Interagency Arctic Research Policy Committee (IARPC) program areas of natural ecology and cultural resources.

	Funding (thousands)	
	FY 02	FY 03
Cultural Resources	1,400	1,296
Natural Ecology	2,486	2,810
Inventory and Monitoring	0	3,500
Total	3,886	7,606

Biological Inventory Program in Alaska's Arctic Network

What is Inventory and Monitoring in the National Park Service?

The NPS established the Inventory and Monitoring Program in 1992 to provide a consistent database of information about our National Parks' natural resources, including species diversity, distribution, and abundance, and to determine the current condition of these resources and how they change over time. Inventory and monitoring are two key strategies of the Natural Resource Challenge, a multi-year funding initiative begun in FY 2000 to revitalize and expand the NPS's resource management program.

For administrative purposes, parks have been organized nationally into 32 ecosystem-based networks. Alaska has four such networks: the Southeast, Southwest, Central, and Arctic Networks.

The Arctic Network (ARCN) consists of five parks: Gates of the Arctic National Park and Preserve (GAAR), Noatak National Preserve (NOAT), Kobuk Valley National Park (KOVA), Cape Krusenstern National Monument (CAKR), and Bering Land Bridge National Preserve (BELA). The Arctic Network spans much of the Brooks Range ecosystem. To the east, the network encompasses a large expanse of mostly mountainous Arctic ecosystems at the northern limit of treeline. To the west, the network extends to the coast and has strong biogeographic affinities to the Beringian subcontinent, the former land bridge between North America and Asia.

Why Inventory?

The Alaskan Arctic represents some of the least biologically documented ecoregions in our country. Covering approximately 21 million acres, the ARCN alone represents about 25% of all of the National Park Service land in the country.

Understandably this huge area of remote land, which contains no publicly maintained roads, provides a logistical challenge for systematic and rigorous scientific investigation. These challenges have resulting in significant geographic and taxonomic gaps in knowledge of species occurrence, distribution, and abundance. The Biological Inventory Program represents an important step in filling these large gaps in knowledge. The true extent of these gaps, and the success of the inventory program in beginning to fill them, is demonstrated by the large proportion of new species and range extensions revealed through this effort.

Beach ridge flowers at Cape Krusenstern National Monument, part of the vascular plant inventory.

NPS's Approach

Initial work involved compiling a bibliography of research conducted within the ARCN and developing lists of species known, or suspected, to occur within the ARCN boundaries. These lists serve as a baseline to help direct inventory efforts in the field and are a starting point for data collection. This information is stored in a species database (NPSpecies) and bibliography (NatureBib). These are being updated with new information as the Biological Inventories progress. The current emphasis for inventory fieldwork in the ARCN is on vascular plants, montane-nesting birds, and small mammals. NatureBib and NPSpecies will ultimately be made available to the public. Inventory fieldwork is complete, and final products will be completed in 2005.

Interesting Finds

Vascular plant inventories in the ARCN during the 2001 and 2002 field seasons resulted in many new plant records for each of the five parklands, including many rare species, and five species new to Alaska or North America. In CAKR, which was floristically understudied prior to the surveys, 305 species were documented as new to the monument. New species included the first record of *Dupoa labradorica* in Alaska, and the documentation of six other rare plants (listed as rare to critically imperiled by the Alaska Natural Heritage Program). In KOVA, 131 species were documented as new to the park, including five new rare species and a second population of *Saussurea triangulata*, recently found to be new to North America during a previous survey. In BELA, 32 new species were documented for the park, including one new rare species and additional populations of *Dupoa labradorica*. In NOAT, 151 new species were documented for the park, including 11 new rare species. In GAAR, 168 new species were documented, including 12 new rare species and *Draba pauciflora* and *Festuca edlundiae*, both new to Alaska. Range extensions (more than 150 km) within Alaska were also documented for numerous rare and widespread species.

Small-mammal inventories of the ARCN during the 2001–2003 field seasons have resulted in major range extensions for several small mammals. The tiny shrew, one of the most poorly documented small mammals in North America, only recently discovered in Alaska, was found in BELA, GAAR, and CAKR, extending its range by 300 km. Major range extensions of 200–300 km were also documented for the barren ground shrew, which was

Approximately one square meter of late-successional lichen tundra dominated by Cladina stelaris, *BELA lava beds. This area has not been grazed in hundreds of years because of natural landscape barriers. A one-acre plot is likely to have more than 60 lichen species.*

collected for the first time in BELA, CAKR, NOAT, GAAR, and KOVA, and the pygmy shrew, which was found in CAKR. In total, 12 small mammal species were documented for the first time in one or more of the ARCN parks through this effort.

Inventories of montane-nesting birds were conducted in all of the parks except BELA during 2001–2003. Initial examination of the survey results provides documentation of 115 bird species, at least 17 of which were previously undocumented in one or more of the four ARCN parks surveyed. Of these, three are shorebirds considered to be of high regional and national conservation concern: the bar-tailed godwit in GAAR, the pacific golden plover in NOAT, and the surfbird in GAAR and NOAT.

Looking Forward

As these biological inventories are completed, the Arctic Network turns to designing a program to monitor the status and long-term trends in the condition of the ecosystems under National Park Service stewardship. This program will identify and monitor indicators of ecosystem condition, or "vital signs," to develop scientifically sound information for use in management and research. The results of the biological inventories provide a much needed foundation for this important next step.

Other Arctic Projects

Reindeer Impacts to Lichen Ecosystems

Reindeer grazing was established as a Native industry on the Seward Peninsula in 1892 to help Natives overcome food shortages caused by overhunting of marine mammals by international fleets. The enabling legislation of BELA requires the National Park Service to continue to permit reindeer grazing according to sound range management practices without allowing damage to preserve resources. All of BELA (2.8 million acres) is included in active reindeer grazing allotments. This project will provide data needed for a comprehensive, scientifically based reindeer management plan focused on protecting sensitive lichen habitats. The major objectives were to assess and model the condition of lichen communities for each landscape stratum and to quantify the relationship between condition class and grazing intensity. During FY 2003, fieldwork consisting of range assessment and non-vascular plant collections was completed. Data analysis, voucher identification, and overall synthesis are ongoing. A publishable, peer-reviewed manuscript describing lichen community gradients and their relationship to major environmental variables and successional state is estimated to be completed in FY 2005.

Alaska Park Science *Publication*

During FY 2003, 2500 copies of the first two issues of *Alaska Park Science* were produced and distributed. Both issues can also be viewed online at http://www.nps.gov/akso/AKParkScience/index.htm. The purpose of *Alaska Park Science* is to provide information about scientific investigations within and relevant to Alaska's National Parks. Articles were contributed by scientists from several agencies and institutions. An editorial board recommended content, and the Alaska Natural History Association designed, edited, and produced the publication.

Population Ecology of Wolverines in Northwestern Alaska

Wolverine ecology has been studied within Noatak National Preserve and Kobuk Valley National Park, Alaska, since 1996. The project was initiated to gather baseline population parameters for evaluating the impacts of harvest by hunting and trapping. Specific project objectives include

Veterinarian holding anesthetized wolverine after surgery.

Muskoxen group exhibiting defensive behavior, which makes them particularly vulnerable to hunting.

survival estimation, harvest assessment, reproductive performance, and testing of prototype satellite-transmitting radiocollars. Nine VHF radiocollars, 12 VHF implants, and 9 satellite transmitters have been deployed on 17 male and 8 female wolverines. Wolverines fitted with VHF radiocollars or implants have provided over 130 locations, but distance to the study area and inclement weather have inhibited consistent efforts to obtain radiotelemetry locations at regular intervals. Satellite transmitter performance has been variable but has provided accurate locations; however, transmissions have been intermittent because satellite signals are impeded when wolverines are presumably in snow or rock caves or dens.

Home range and habitat use data have been analyzed. Eleven animals (44%) have died because of predation, harvest, starvation, or unknown causes. As expected, the harvested wolverine sample is male biased (66% of 137 individuals). Fifteen of 17 females harvested were more than two years old. Examination of stomach contents from harvested wolverines indicate that caribou are an important diet item. Preliminary isotope analyses of liver, muscle, and femur samples from harvested wolverines indicate seasonal variation in diet.

North and West Alaska Cooperative Ecosystem Studies Unit

The North and West Alaska Cooperative Ecosystem Studies Unit (CESU) was established in August 2003. This CESU, which is administered through the University of Alaska Fairbanks, will focus on providing research, education, and technical assistance for Federal agencies in studies of high-latitude ecosystems. The NPS, along with the Geological Survey, Bureau of Land Management, and USDA Forest Service, demonstrated their support for the proposal developed by the University of Alaska System, University of New Hampshire, and Alaska SeaLife Center by joining the CESU. During early 2004, the cooperating agencies and institutions met to develop a role and mission statement, first-year work plan, and multi-year strategic plan. Future activities will include the development of specific research, education, and technical assistance projects involving university faculty, students, and cooperators.

Cape Krusenstern Muskoxen Range Use

Muskoxen were extirpated from Alaska in the late 1800s. In 1935–1936, 27 animals from Greenland were reintroduced to Nunavak Island, and from that stock, 70 were brought to northwest Alaska in 1970 and 1977. The muskoxen population within the monument is an extension of the latter. Fieldwork was done in 2002, and will be completed in 2004, on a study of the muskoxen population composition and behavior in Cape Krusenstern National Monument The objective is to determine conditions necessary to maintain the NPS-mandated "natural and healthy" population and to assess the feasibility of providing an opportunity for local Eskimo hunters to harvest these muskoxen as a subsistence resource. A final report and Ph.D. dissertation are due in FY 2004.

Nutritional and Contaminant Assessment of Lynx and Snowshoe Hare

The area of the Brooks Range near Wiseman, Alaska, is the location of a project investigating the presence of heavy metals in lynx and hare. It will also assess the nutritional status of lynx and analyze hare forage. Post-mortem analysis will be preformed on carcasses acquired from local trappers, and samples will be collected. Analysis will be directed at determining if there is a link between hare and lynx body condition. Lynx in the Wiseman area appear to exhibit unhealthy characteris-

Selection of spear points from the Caribou Crossing site. All but one of the over 150 points found at the site are basal fragments like these, which would remain hafted in spears after the tips were broken. The bases were discarded when re-arming spear shafts with new points. This is an activity hunters probably engaged in at these hilltop locations while watching for game.

tics while the hare population is at its peak. Tissue will be examined to determine levels of heavy metals, nutritional status, reproductive status, and the presence, abundance, and significance of potential pathogens. The study will provide the NPS with information regarding the park's dynamic ecosystem where the populations of hare and lynx exhibit unique characteristics absent in neighboring populations.

Ancient Hunters of the Western Brooks Range

In 2002 NPS archaeologists from Western Arctic National Parklands, along with students and researchers from Washington State University, Brown University, University of Alaska Anchorage, and the Russian Academy of Sciences, conducted test excavations at the Caribou Crossing site in northwestern interior Alaska. The site, estimated to date to approximately 10,000 B.P., has contributed key information to a multi-year project aimed at understanding the lifeways of the early inhabitants of eastern Beringia at the end of the last ice age. More than 150 large spear points were recovered at Caribou Crossing, more than at any other site of this age in Beringia. It seems that people were visiting this location repeatedly, perhaps on a seasonal basis over the course of several years, and were harvesting animals in fairly large numbers. However, despite the site's name, there is no direct evidence for caribou hunting, and the prey targeted at the site remains an open question.

Excavations at the Caribou Crossing site.

Bureau of Land Management

Mineral Assessments

BLM Solid Minerals has completed its second year of a mineral resource assessment of the Delta River Mining District and has began a four-year mineral resource assessment of the Aniak Mining District. Mineral assessment objectives are to identify the nature, extent, and development potential of mineral resources; perform mining feasibility studies, using hypothetical mine models on mineral deposits that have economic potential; and fund geophysical investigations of areas having the potential to contain concealed mineral deposits. Bureau work includes locating, sampling, mapping, and evaluating historic mines, prospects, and occurrences and investigating newly discovered mineralization. This assessment is part of BLM's mining district evaluation program authorized under the Alaska National Interest Lands Conservation Act (ANILCA), which has been ongoing since the early 1980s.

The Delta Mining District study area encompasses approximately 2.9 million acres in east-central Alaska. BLM geologists have collected and analyzed approximately 960 samples since the beginning of the study. In addition, 264 U.S. Geological Survey stream sediment samples have been re-analyzed. Fieldwork during 2002 consisted of a five-week field season, focusing on property examinations and sample collection

The Aniak Mining District study area encompasses approximately 27 million acres in southwestern Alaska and includes parts of the adjacent Anvik, Iditarod, Innoko, Marshall, and McGrath mining districts. The area contains over 405 mineral sites, including those located in the historic mining areas of Iditarod–Flat, Nyac, Crooked Creek–Donlin Creek, Candle Creek, Ganes Creek, Nixon Fork, Illinois Creek, and Red Devil, to name a few.

	Funding (thousands)	
	FY 02	FY 03
Natural Ecology	2,700	2,500
O&G Minerals Research	1,000	1,100
Solid Minerals Assessments	720	580
Cultural Resources	210	160
Pipeline Monitoring	600	600
Fire Control	380	380
Total	5,610	5,320

Minerals field assistant exposing mineralized bedrock at the Red Knob Occurrence.

Placer gold has been the main commodity produced from the area since the late 1900s. Placer platinum and mercury, as well as lode gold and mercury and its byproducts silver and antimony, have also been mined. Placer gold production totals nearly 2.6 million ounces of gold, along with minor amounts of mercury and platinum. Lode production totals nearly 197,000 ounces of gold and over 35,000 76-pound flasks of mercury and byproduct antimony between 1902 and 1967. Other commodities prospected in the region include barite, copper, lead, molybdenum, silver, tin, tungsten, uranium, and zinc.

Fieldwork during 2003 consisted of a seven-week field season, focusing on property examinations and sample collection in the eastern third of the district. Bases of operation were McGrath and Farewell Lake. BLM geologists collected 351 rock, stream sediment, pan concentrate, soil, and placer samples from the Ganes Creek–Beaver Mountains and Nixon Fork areas southeast to the headwaters of Windy Fork and the Post River area.

Shallow Unconventional Hydrocarbon Resources

The Alaska North Slope (ANS) contains enormous potential in the form of unconventional oil and gas (viscous oil, gas hydrates, and coalbed methane). As production of conventional oil and gas resources declines, unconventional resources take on a more important role in supplying energy needs. Large onshore viscous oil and gas hydrate deposits exist beneath the current ANS infrastruc-

ture. Estimates of in-place shallow gas resources on the ANS are 590 TCF (trillion cubic feet), with 100 TCF or more beneath the existing development infrastructure. In-place shallow viscous oil resources exceed 18 billion barrels. Research has focused on:

- Assessing known ANS unconventional oil and gas resources, which promotes BLM understanding for potential unconventional resources leasing and permitting;
- Reviewing and evaluating existing best-production methods for shallow resource extraction;
- Developing technology to encourage ANS shallow unconventional resource development;
- Identifying shallow drilling and completion methods applicable on ANS; and
- Identifying existing, emerging, and new technologies to enable economically viable production of the vast shallow ANS unconventional resources, with a focus on economy of scale, low impact, and low cost. Technologies may include highly portable, lightweight rigs and simple shallow well completions, with options to consider complex horizontal and multi-lateral well completions.

Alaska Rural Energy

BLM Alaska partnered with U.S. Geological Survey, the State of Alaska, the University of Alaska Fairbanks, and the Department of Energy in evaluating the potential of exploring for and developing coal bed methane (cbm) resources for rural Alaska villages. These villages currently rely on expensive diesel fuel for transportation, heating, and electricity. In places, this fuel costs up to $3.50 per gallon. This high cost deters development of other resources that would help generate income for the villages. This fuel is transported to these villages on prime fish-spawning rivers and streams, where a spill would be a disaster.

Weed Management

BLM joined as a lead agency with 31 other agencies and organizations in 2000 to form the Alaska Committee for Noxious and Invasive Plants Management (CNIPM). In December 2001 CNIPM published the *Strategic Plan for Noxious and Invasive Plants Management in Alaska*. Much has been accomplished by CNIPM and the partner agencies and organizations. During 2002 and 2003, through a National Fish and Wildlife Foundation matching grant awarded to the Northern Field Office, BLM was successful in developing preliminary weed awareness programs targeting citizens and agency managers. BLM was able to pool resources and work across agency boundaries to initiate weed inventories on public and private lands. Through the project, BLM also developed a statewide weed database, housed in a central clearinghouse. A Plant Management Area (PMA) was established by CNIPM partners in Juneau, driven by the invasion of such plants as garlic mustard. A research needs assessment was developed and prioritized and will be published in the journal *Agroborealis*.

BLM initiated an invasive plant inventory on BLM-managed lands in 2002, completing a survey of 20,000 acres of the Steese National Conservation Area. During 2003, an inventory was conducted in the White Mountains National Recreation Area and in the Glennallen area (40,000 acres).

Biologists and other specialists in BLM Alaska continue to work actively with CNIPM and contribute to the education and outreach efforts, database development, coordination with other agencies and groups in Alaska, identification of research needs and procurment of funds, and development of management options and tools, such as a certified weed-free forage and mulch program.

Fortymile Caribou Herd Recovery

During 1994, BLM joined state and Federal agencies and concerned citizens to begin planning for the recovery of the Fortymile Caribou Herd (FCH). This effort was triggered by requests from subsistence hunters throughout Alaska and Yukon, Canada, to develop a broad management plan by all agencies and organizations. The FCH management plan was completed in 1995, and implementation began in 1996 and was completed in June 2001. Results of the implementation have been monitored in 2002 and 2003.

Important to subsistence hunters throughout the ages, the FCH once occupied 220,000 square kilometers of Alaska and Yukon, and based on estimates by the biologist Olas Murie in 1935, it numbered about 568,000. In 1994 the FCH occupied less that a quarter of its original range and numbered 22,104. Years of research showed that wolf predation was the primary factor limiting the survival of calves and thereby the growth of the FCH. The management plan included actions to

increase calf survival. Today the herd is growing because of the recovery efforts and has begun to expand west and south into former ranges, including the highlands of the Steese National Conservation Area, and east into former ranges in Yukon. During the winter of 2002, Fortymile caribou crossed the Yukon River in Yukon, Canada, for the first time in 30 years. Calf/cow ratios have improved from 22 calves per 100 cows in 1994 to 38.7 calves per 100 cows in 2002, and the herd has grown by about 10% annually since implementation of the management plan began (22,104 in 1994 to 43,373 in 2003). Harvest bag limits have increased, beginning in regulatory year 2001–2002, and will continue to increase modestly over the next few years based on herd growth.

The management plan was carefully crafted by subsistence and sport hunters, wildlife enthusiasts, animal rights advocates, environmental advocates, ecotourism representatives, and agency representatives from Alaska and Yukon. Implementation of the plan included reduced harvest, monitoring of land use within the FCH range, fertility control of alpha wolves, and translocation of subordinate wolves. The BLM has formed a partnership with the Alaska Department of Fish and Game to continue to monitor calf survival and population growth.

Neotropical Migratory Bird Surveys

BLM Alaska wildlife biologists continued to participate in the Neotropical Migratory Bird (NTMB) Conservation program during FY 2002 and 2003. The program is better known as Partners In Flight.

In an effort to monitor trends in North American bird populations, 11 breeding bird surveys and 7 off-road breeding bird surveys were conducted annually in northern and northwestern Alaska. Survey routes were initiated in 1992 and 1993. Many species detected on these routes are identified by Boreal Partners in Flight, the working group for Canada and Alaska, as species of conservation priority. These include the olive-sided flycatcher, Hammond's flycatcher, gray-cheeked thrush, varied thrush, Townsend's warbler, blackpoll warbler, and white-winged crossbill.

Breeding bird surveys were also conducted along the Unalakleet and Anvik Rivers in western Alaska, adapting standard protocols to a river, rather than roadside, setting. Thirty-five species have been recorded on the Unalakleet route and 42 on the Anvik survey since the routes were established in 1996.

The surveys provide a source of standardized data on populations of breeding birds throughout the U.S. and Canada. Breeding habitats in Alaska are largely intact and provide an opportunity to clarify the importance of breeding habitat versus migration and wintering habitats for many species of long-distance migrants.

All survey data are reported to the Biological Resources Division (BRD) of USGS. A trend analysis statistical procedure is used to estimate the population change for every species or trend each year.

Three bird banding stations were established to inventory breeding landbirds in 1998 and continued to be run in FY 2002 and 2003. In June of each year, birds were banded at the Old Woman public use cabin on the Old Woman River, a tributary to the Unalakleet River that drains into Norton Sound. An off-road breeding bird survey was also established in 1998 on Old Woman Mountain to supplement the banding efforts. Bird banding stations were also established on the upper reaches of the Anvik and Bonasila Rivers, which drain into the Yukon River near the village of Anvik. The northern waterthrush was the primary species captured, followed by Swainson's thrush, Wilson's warbler, and myrtle warbler. Banded birds have returned to the stations in subsequent years. These recaptures provide information on breeding site fidelity and longevity. The BLM bander conducted a demonstration for local children at the Unalakleet site this summer, taking advantage of the project to teach about migratory birds.

Forest Age Profiles

A study to gather baseline data on the fire history of the Steese National Conservation Area and White Mountains National Recreation Area in the Yukon–Tanana Uplands of interior Alaska was begun in 2001. In addition to documenting current forest stand age profiles of this area, the study attempts to examine the relationship between spruce stand age and lichen abundance. During late July and early August 2001 and 2002, 225 randomly selected sites were visited, resulting in more than 1,100 tree samples (disks or increment cores). With University of Alaska Fairbanks cooperators, these samples are being dated. Also in cooperation with UAF scientists, sediment cores were collected from two lakes in the study area to examine past changes in vegetation (pollen) and fire frequency (charcoal). Sample dating and data analysis continue. Congress directed in ANILCA

that caribou habitat was a special value to be considered in the management of the Steese National Conservation Area. Because fire can impact caribou habitat, this study and similar studies will provide an improved basis for caribou habitat management.

Fuels Reduction

Recent large wildfire events have captured the nation's attention and caused many communities, homeowners, and agencies to seek methods to reduce wildfire risks to homes and property at the urban interface. Cleared fuel breaks or prescribed burns have been employed, but sometimes less dramatic treatments are desirable for ecological, aesthetic, or engineering reasons. The BLM Alaska Fire Service (AFS) and Tanana Chiefs Conference, Inc. initiated a three-year Fuels Treatment Demonstration project in 2001, with funding from the national interagency Joint Fire Science Program. This study was intended to compare degrees of fuel reduction by thinning with or without pruning in boreal black spruce with the concomitant risk reduction, visual impact, environmental effects, and cost/benefit ratio.

Preliminary results after two years of monitoring the treated and control sites have demonstrated changes in live moss cover, shrub and seedling development, microclimate, permafrost, and forest floor moistures. Attempts to predict changes in fire behavior indicated tradeoffs between increased rates of spread due to higher average wind speed in thinned and pruned treatments versus an increase in the fire intensity threshold required for sustaining a crown fire.

Fire Management of Landscape

The University of Alaska Fairbanks (UAF) is leading an effort along with AFS, U.S. Geological Survey, and several Federal and state partners to develop a computer model for landscape-level analysis of fire–human interactions, vegetation change over time, and prediction of regional fire risk in interior Alaska's boreal forest. The interagency Joint Fire Science Program granted funding of $442,000 for this project for 2002–2004. The goal is to build a model that will provide land managers with thematic representations spanning years to centuries into the future of how forest cover and the probability of large fire events respond to different scenarios of fire management and climatic change. The model utilizes physical, biological, and human thematic layers and simulates boreal forest ecosystem dynamics that influence wildlife, hydrology, and soil processes. UAF field crews have been systematically sampling trees to establish stand age and fire regimes across interior Alaska in 2002–2003.

Student Conservation Association volunteer measuring duff moisture in a research plot that demonstrates thinning and pruning for mitigation of fire hazard in boreal black spruce forest (Delta, Alaska, July 2003).

Fallen, shallow-rooted black spruce along a monitoring transect at Chena Lakes Prescribed Fire. Deep burning into the dry moss/duff from a low-intensity surface fire caused the spruce to topple (July 2003).

Fire Effects Research

The USFS Pacific Northwest Research Station (PNW) is determining how weather and fuel dryness affect the reduction in moss/duff forest floor during fire. This question is integral in targeting revegetation with desired plant species in many wildlife habitat improvement projects, as well as in determining erosion potential and the extent of smoke pollution during wildfires and prescribed fires. In June 2003 the Joint Fire Science board granted funding for a proposal by PNW, AFS, the National Park Service, and the U.S. Fish and Wildlife Service entitled "Forest Floor Consumption and Smoke Characterization in Boreal Forested Fuelbed Types of Alaska." Fuel consumption and smoke emissions data were collected on active wildfires and prescribed fires in June–August. The data will be used to develop forest floor fuel consumption models (i.e. how much bare soil is exposed by burns under various conditions) and to develop emission rate equations for boreal forest types. Because of the thick layer of moss and organic material in boreal forests, large quantities of pollutants can be released by fire; this issue is only beginning to be understood, thanks to ongoing research.

Forest Service researchers from the Fire and Environmental Research Applications team in Seattle and Missoula Fire Lab preparing to measure smoke emissions and duff consumption on a wildfire near the Arctic Circle along the Dalton Highway (June 2003).

NASA approved a proposal by the Veridian Systems Division to fund a project entitled "Remotely Monitoring Plant and Soil Fuel Moisture for Wildfire Danger Assessment using Satellite Radar Data." The proposal will study the relationship between the Fire Weather Index and Alaska fire occurrence and soil moisture as detected by synthetic aperture radar.

Fire Monitoring Studies

The BLM Alaska Fire Service and field offices have established long-term vegetation monitoring plots at several prescribed fire or fuel treatment sites to look at vegetation changes that may impact land users and wildlife. Partners include the State of Alaska, the Army Corps of Engineers, and the Tanacross Village Corporation. An interagency Fire Effects Task Group meets regularly to exchange information on fire research and monitoring studies and to look at means of standardizing some data collection on certain types of studies.

National Petroleum Reserve—Alaska

In April 2003 the BLM, in cooperation with the Alaska Department of Fish and Game, conducted a study of the effects of vibroseis (seismic exploration) on fish overwintering in lakes. In two trials, one or five vibroseis trucks were operated over lake ice while arctic char (from a hatchery near Anchorage) were suspended beneath the ice in traps. Two control trials, with no vibroseis trucks operating, were also run with fish placed under the ice either for a brief exposure to lake water or for the same period of time as for the fish that experienced vibroseis. None of the fish (108 in each of four trials) was observed to suffer any adverse effects from the experiments. All were alive and apparently healthy after removal from the lake. None had ruptured gill filaments prior to euthanasia, and subsequent necropsy revealed no ruptured blood vessels in their eyes and no ruptured swim bladders.

Another series of vibroseis trials, conducted over wild, free-swimming broad whitefish in a nearby river, was conducted while the fish were

The 120,000-acre Erickson Creek fire looming over the Dalton Highway, which follows the Alaska pipeline along its track to the North Slope oil fields. This fire provided good access for research teams to study smoke emissions and fire effects in the northern boreal forest (June 2003).

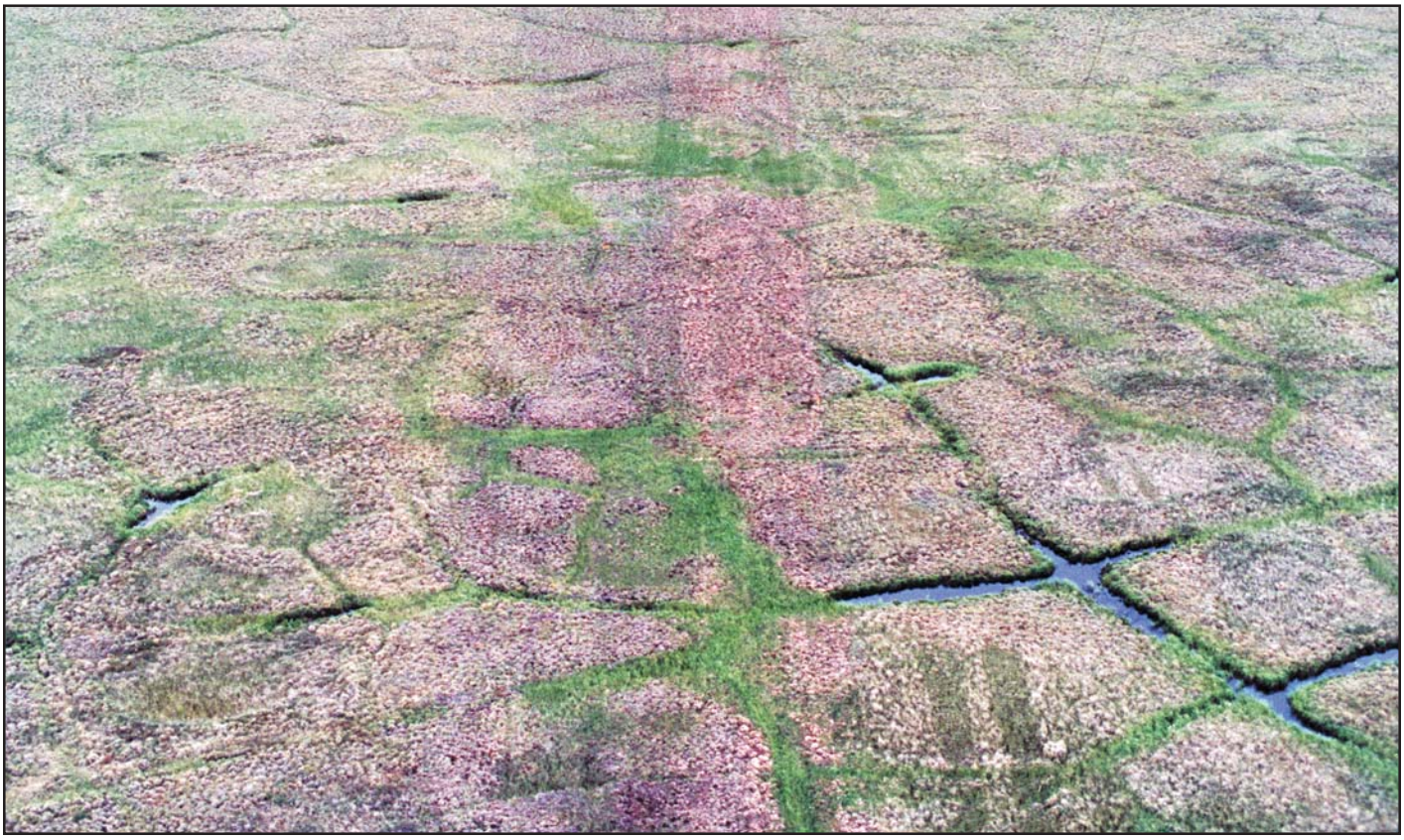
observed by underwater cameras. In each trial the fish were observed to swim slowly away from the vibroseis source and then to slowly return. By the sixth trial, little response to the vibroseis application was observed. Apparently seismic exploration using vibroseis over lake ice has no adverse impact on overwintering fish, nor does it cause displacement from preferred areas of the waterbody on more than a temporary basis.

A study by the BLM of the effects on tundra vegetation of overlapping, multi-winter ice roads was begun in 2002 and continued in 2003. This was intended as a pilot study, and the sample size (5) was limited by the availability of overlapping ice road paths in suitable vegetation cover types. The resulting power of statistical tests was low. The four treatments in the study were control, ice road path from 2001 only, ice road path from 2002 only, and overlapping ice road paths from both winters. The characteristics measured were the depth of thaw (late summer distance between the tundra surface and the permafrost layer), the proportion of tussocks that were scuffed or crushed, and the percent cover of each of eight vegetation cover types.

No statistically significant differences in thaw depth were observed among the four treatments, but the overall depths were significantly greater when measured in 2003 than when measured in 2002. This could be caused by a warmer summer in 2003, or a cumulative effect of greater sunlight absorption by impacted vegetation over two summers, or both. Weather records for the two summers have not yet been investigated.

Tussock damage was significantly greater in all three manipulated treatments than in the control, greater in the "2002 only" treatment than in the "2001 only," and significantly less overall in the second summer of data collection. The difference between 2001 and 2002 treatments may indicate that ice road construction techniques or snow cover differed between the two years. The overall difference between measurements in each of the two summers indicates that recovery is occurring regardless of treatment.

The percent cover of eight vegetation types was the only measure that showed a significantly greater effect in the overlap treatment than in either single-season treatment. In a comparison of the ratio of live versus dead vegetation, especially among shrubs and forbs, the control had the highest ratio, the single-year treatments had an intermediate level, and the overlap treatment had the lowest ratio of live to dead vegetation. This



Vehicle effects on tundra in the National Petroleum Reserve–Alaska, July, 2003. BLM is studying the effects on tundra vegetation of overlapping, multi-winter ice roads to determine whether it may be beneficial to construct the roads over new paths each year, increasing the area affected but decreasing the intensity of the effect per unit area.

implies that the effects of ice road construction are additive over multiple years. It may be beneficial to construct ice roads over new paths each year, increasing the area affected but decreasing the intensity of the effect per unit area.

In 2003 the BLM continued its cooperative effort with the Alaska Department of Fish and Game and the North Slope Borough's Department of Wildlife Management to monitor the population dynamics, movements, and range use of the Teshekpuk Caribou Herd, which calves in the northeastern NPRA. Both traditional satellite telemetry and GPS collars have been deployed to document large- and small-scale movement patterns. The importance of this information increases as plans progress for the first oil development in the northeastern NPRA.

A river trip was conducted along the Colville River in 2003 to assess the occupancy of cliff-nesting raptors. Peregrine falcons, gyrfalcons, and rough-legged hawks were the targeted species, although information was also collected on common ravens. The trip was conducted in June and July, and all suitable cliff-nesting raptor habitat along the Colville River, beginning just below the mouth of the Etivluk River and ending at Ocean Point, was surveyed, a distance of 347 km. The survey team detected 56 territorial pairs of peregrine falcons, 63 of rough-legged hawks, and 13 of gyrfalcons. A total of 41 nests were located for peregrine falcons, 57 for rough-legged hawks, and 12 for gyrfalcons. This 2003 survey was a continuation of a long-term data set documenting the presence of cliff-nesting raptors on the Colville River. Surveys were first conducted along the Colville River in 1952. After that first survey, efforts were sporadic until 1978, after which surveys have been conducted yearly. This valuable data set has documented the decline and subsequent recovery of the peregrine falcon population along the Colville River, with a low of 14 pairs detected in 1973 and a high of 62 pairs in 1998. The U.S. Fish and Wildlife Service (USFWS) has taken the lead on conducting this survey for the past 15 years, with some financial and personnel help from BLM. In 2003 the USFWS was unable to participate, so BLM conducted the survey with the assistance of a consulting raptor biologist.

BLM-USGS Bering Glacier System Program

The BLM and the U.S. Geological Survey (USGS) have carried out complementary physical

and biological inventory and research programs at Bering Glacier, Alaska. The synthesis of results from these studies, which range from glaciology to ecology, show that the Bering Glacier system is very dynamic, a system that is undergoing profound changes. To better address the short- and long-term management of the Bering Glacier region, BLM, in cooperation with USGS, has created a public/private partnership between Federal, state, local, academic, and non-governmental organizations (NGOs), as well as commercial Bering Glacier stakeholders. The successful operation of the Bering research facility, populated by the stakeholders each summer conducting investigations in geology, glaciology, paleontology, plant biology, animal biology, oceanography/water quality, remote sensing, and GIS decision support, is testimony to the public/private partnership.

The Bering Glacier is the largest and longest glacier in continental North America, with an area of approximately 5175 square kilometers and a length of 190 km. It is also the largest surging glacier in America, having surged at least five times during the twentieth century. The last great surge occurred in 1993–1995. Bering Glacier alone covers more than 6% of the glacier-covered area of Alaska and may contain 15–20% of Alaska's total glacier ice. The entire glacier lies within 100 km of the Gulf of Alaska. The rapid ongoing retreat of the glacier and the expansion of Vitus Lake at the glacier terminus has provided opportunities for establishment of new habitat and new flora and fauna. The post-surge retreat of Bering Glacier has created a dynamic landscape of reticulated and fluted surfaces with subtidal invertebrate fossils, lake sediments, and previously overrun forests.

The BLM/USGS's coordinated investigations of the Bering Glacier system have suggested that the site is biologically and environmentally significant. Paleontological research has documented a diverse assemblage of invertebrate species, preserved forests, and ancient peats, and preliminary botanical studies have identified more than 350 vascular and non-vascular species. The forelands are also known to support a highly diverse vertebrate community: fresh and anadromous fishes, three rare subspecies of geese, genetically distinct populations of wolf and goat, and a previously undocumented harbor seal haulout. The diversity of fauna and flora in the area around the margins of the Bering Glacier is likely due to the dynamic physical habitat. In contrast to the forelands of most retreating glaciers, in which distance from the glacier reflects both habitat age and climate, the pattern of surges and retreats has created a landscape where local climate and time since glacial cover have effectively decoupled. Within this relatively small region, the impact of habitat age, climate, and physical properties on community structure can be studied independently over a broad range of habitats. In the limited area around the glacier, habitats vary from newly exposed rocks at close to sea level to 10,000-year-old moraines at elevations above 5,000 m, and from wet fens to relatively dry subalpine forests. Outcrops and corings reveal sediments that record the interactions of climate, sea level, and earthquake-induced land movements over the past few thousand years.

BLM personnel are currently developing a new land use plan for the Glennallen District, which includes the Bering Glacier region. This plan is referred to as the East Alaska Resource Management Plan. The current guiding document is the *Southcentral Management Framework Plan of 1980*. This plan is outdated, and the only reference to Bering Glacier is to "provide opportunities for development of coal reserves in the Bering planning block." A set of decisions will be made in the East Alaska Resource Management Plan relative to the Bering Glacier. These include vegetation resource management, special status species management, state role in fish and wildlife management, recreation use, off-highway vehicle use, land use planning, and oil, gas, coal, and mineral management.

In addition to the formidable task of creating a new land use plan for the Bering Glacier region, there are three scientific reasons for research on Bering Glacier. First, because the Bering Glacier landscape is being created by the dramatic and catastrophic disintegration of a piedmont ice lobe, it will likely be substantively changed as the glacier continues to retreat. Second, understanding the interactions between the physical habitat and the biological communities in this region will help scientists understand how glacial retreats (now occurring world-wide) are likely to impact local biotic communities. And third, because human activities at the site are increasing because of growing interest by commercial and recreational users, it is likely that there will be impacts on the fragile ecosystems in the area.

To address the Bering Glacier research and land use issues, the BLM, in cooperation with USGS, operates the Bering Glacier field camp each summer. The field program typically starts in early July and runs through the end of August. The camp is

located on the edge of Vitus Lake on a former terminal moraine. The camp, complete with refueling airstrip, kitchen and mess tent, command center, and restrooms can comfortably host 25 scientists at a time. The scientists and their staff sleep in tents or wooden-floor huts.

BLM-invited investigators, representing other Federal, state, academic, and non-government organizations, address a variety of scientific and observational issues, including:

- Bering Glacier observations (terminus, ice movement, ablation, thickness, berg calving rate, ice depth, and sub-glacial geology);
- Vegetation studies (mapping communities surrounding the glacier);
- Water properties of Vitus, Berg, and other Bering Glacier lakes (bathemetry, conductivity, temperature, density, O_2, pH, turbidity, oxidation–reduction potential, and total dissolved sediments);
- Paleontology and paleoseismology (fossil and plant analysis in estuarine, lake, and glacial outwash areas);
- Geology, geomorphology, and sea level studies (moraine deposits, thermokarst, and coastal and lake sediments);
- Seal population studies (count, behavior, and food source);
- Fish population (species, count, and size);
- Remote sensing (mapping) of the Bering Glacier area;
- Hazard modeling and mitigation; and
- Environmental monitoring.

These specific investigations all aid the BLM in managing this wilderness area.

To support the ongoing Bering Glacier science and observational investigations, the BLM has incorporated the use of National Technical Means (NTM). NTM contributions, along with the use of civil and commercial satellite remote sensing data, are being used to specifically support hazard and risk mitigation issues at the glacier, as well as to support the environmental characterization and monitoring. The NTM contributions are coordinated through the Civil Applications Committee (CAC). The lessons learned at the Bering Glacier are being used by BLM and other civil agencies at other sites such as the Alaskan North Slope.

The BLM Bering field camp is a good example of leveraging resources. BLM provides logistical support to invited investigators, while salaries, equipment, analysis, and reporting are the responsibility of the participating investigators.

To encourage and facilitate collaboration across the various science disciplines, the BLM has created a web-based portal (http://quickplace.erim.org/bering) as a repository for the field observations and reports. A part of the portal is a comprehensive geographic information system (GIS) that includes the geological, glacier, oceanographic, and water properties, as well as the biological surveys. The BLM also conducts an annual Bering Glacier workshop, where previous findings are reported and planning for future field activities occurs.

Wildlife Project Work on the Dalton Highway

In cooperation with the Alaska Department of Fish and Game, the BLM performed a herd composition count of the Ray Mountains Caribou Herd. During this study three new animals were radio-tagged in this herd, bringing the number of collared caribou in the Ray Mountains to 12. In addition, the BLM also cooperated on a herd composition count of caribou inhabiting the Dalton Corridor in the vicinity of the Hodzana Hills southeast of Bettles, Alaska, and also radio-tagged four of these animals.

The BLM surveyed five Areas of Critical Environmental Concern (ACEC) for important Dall sheep habitat in 2003. Sheep use by season and the presence of sheep licks were noted during this work.

In FY 2003 the BLM cooperated with the Kanuti National Wildlife Refuge and the Alaska Department of Fish and Game in a moose trend count in the northern part of Game Management Unit 24 near and in the Dalton Highway Corridor.

BLM personnel and a volunteer conducted three 25-mile breeding bird survey routes along the Dalton Highway in 2003.

BLM personnel began a nest box monitoring study for raptors along the Dalton Highway in the Brooks Range in 2002. In 2003 the BLM checked these boxes and found five active nests of American kestrels and five of boreal owls. Prey remains and unhatched eggs were collected from each nest for later food habits and contaminant analysis, respectively.

The BLM funded a cooperative study with the University of Alaska Herbarium to search for rare plants in the Toolik Lake Research Natural Area. This project was begun in 2002, and 8000 acres have been surveyed.

U.S. Geological Survey

Biological Resources Discipline

	Funding (thousands)	
	FY 02	FY 03
Marine Mammals	1,660	1,560
Migratory Birds	2,390	2,250
Fisheries Research	360	360
Cooperative Research	330	330
Terrestrial Ecology	1,130	1,060
Park Research	1,140	1,070
Total	7,010	6,630

The U.S. Geological Survey (USGS) Biological Resources Discipline (BRD) conducts research in the Arctic to generate information that will help Department of the Interior agencies and other partners in Alaska meet their resource management responsibilities. These responsibilities include conservation of migratory birds, certain marine mammals, endangered species, anadromous fishes, and all biota inhabiting National Wildlife Refuges and National Parks and Preserves. Research is designed to address the effects of development, disturbance, hunter harvest, and natural environmental cycles on fish and wildlife populations. Other research will help develop improved census and survey methods that will better detect trends in populations. All research has the ultimate goal of providing information that will lead to better management decisions and actions to promote conservation of living resources in the vast ecosystems of the Arctic. Fish and wildlife populations in the U.S. Arctic are extensively shared with Canada and Russia, and a portion of the research effort is directed toward treaty and other international requirements to jointly manage shared resources.

Most Arctic research of the BRD is conducted from the Alaska Science Center (ASC), Anchorage, and the Cooperative Fish and Wildlife Research Unit at the University of Alaska Fairbanks. Some additional research is performed by others of the 15 national research centers or the more than 50 cooperative research units, each of which has special capabilities that may be applicable to problems in Arctic research.

Ecological research in Arctic ecosystems is difficult, given the harsh conditions, frequently inaccessible habitats, and often wide-ranging movements of Arctic biota. It is also very costly. Since it has often been necessary to develop new methods of obtaining information, some of the most advanced technologies have been developed for, or first applied to, research in the Arctic. Satellite-linked biotelemetry and heavy metal tracers are but two of many new techniques that have been successfully applied to the problems of fish and wildlife conservation in the Arctic.

Fisheries

Fisheries biologists from the Alaska Science Center are conducting several studies in the region dealing with a broad range of aquatic resource issues. These studies range from detailed ecological investigations to determination of the genetic population structure within species. Current research projects in the region focus on chum salmon, chinook salmon, sockeye salmon, rainbow trout, and blackfish.

The USGS and the National Park Service share a collaborative study of microevolution looking at genetic and phenotypic differences in sockeye salmon in Albert Johnson Creek and the recently colonized Surprise Lake, Aniakchak National Monument and Preserve, Alaska. Aniakchak caldera was formed by a massive eruption 3500 years before the present (BP). The caldera filled with water and subsequently breached the caldera wall roughly 1800 BP. Additional sizable eruptions occurred in the caldera 500 and 72 BP. Sockeye salmon populations in Aniakchak caldera were established naturally by colonization following the collapse of the caldera wall, and they perhaps re-established following the eruptions 500 and 72 years ago. In comparison, most other sockeye salmon populations in southwest Alaska were established 10,000 years ago following glacial recession. Sockeye that spawn in Surprise Lake, inside the caldera, exhibit the typical lake-type life history, with juvenile access to a lake for one to two years of rearing before the seaward migration. The likely colonizing population at the base of the volcano exhibits a river-type life history, with no juvenile lake access. The juveniles of this life history must rear in the less-productive river. This study will determine if the populations have genetically diverged with respect to nuclear microsatellite markenjrs. It will also determine if divergence in juvenile body shape has occurred, and if so, the role different food and foraging tactics play in these local adaptations.

The USGS Global Change Initiative funded recent research on non-linear systems and sockeye salmon growth in the Bering Sea, 1955–2002. Non-linear systems present a challenge to conceptual thinking in reductionist science. When the rate of change of one or more variables is a non-

linear function of one or more states or conditions, we find evidence of unexpected thresholds beyond which change occurs much more rapidly and qualitative changes in behavior that can lead to cyclic extremes in abundance and diversity. There are few biological models that cross as many thresholds and follow such divergent life-history trajectories as Pacific salmon. The dynamics of non-linear systems is an essential part of understanding how and where this culturally and economically important group of fishes will be modified by global change.

Most research on Pacific salmon has focused on freshwater growth and marine harvest. However, the interactions among important ecosystem components for Pacific salmon are not proportional and therefore are non-linear. The transitions salmon make between freshwater and marine environments are critical times during which fish undergo physical, behavioral, and morphological changes. These changes are a response to challenges associated with water ion balance, food requirements, diseases, parasites, predators, and the shift between riverine and pelagic ecosystems. The timing of these transitions is regulated by climate, hydrology, oceanography, development rate, growth, and genetics. Changes in ecosystem conditions, including nutrients, food distribution and abundance, predators, currents, and temperature, are important factors that interact to support salmon at these critical stages of their life history. All of these non-linear factors are subject to extreme shifts and discontinuities with global change. The degree that changes in ecosystem condition in both freshwater and marine habitats are non-linear will impact the survival of salmon populations adapted to a particular schedule or sequence of change.

Salmon live in the ocean as pelagic fish for various lengths of time and return with unique fidelity to their stream of origin to reproduce and create subsequent generations. Human-induced changes to both freshwater and marine environments have greatly complicated this relationship. The impacts of marine harvest, habitat destruction, and development on salmon stocks have been well documented in the scientific literature. Hatchery production and supplementation of salmon stocks were linear fixes for a complex system that have not worked out as expected. Recent studies of Alaskan sockeye salmon in the Bering Sea, 1955–2001, showed a strong negative relationship between late marine growth in sockeye and Asian hatchery releases of odd-year pink salmon. Pink salmon have a distinct two-year life history, and hatchery production originating from northern Japan and wild pink salmon production from streams in eastern Kamchatka are especially abundant in odd-numbered years. These populations overlap both temporally and spatially with wild Alaska sockeye in the Bering Sea. Density dependence for Alaskan sockeye in the ocean appears to result from prey reduction caused by large numbers of hatchery pink salmon feeding in the Bering Sea in June and July before they migrate back to Asian coastal waters. This results in a sharp reduction in prey availability for Alaska sockeye salmon because of mortality and ontogenetic vertical migrations of some prey during the summer. Subsequently Alaskan sockeye, in years when they overlap with hatchery pink salmon, suffer poor marine growth and lowered reproductive potential.

Migratory Birds

In 1999 the ASC initiated a cooperative survey and research program with the U.S. Fish and Wildlife Service, Region 7 (Alaska), to examine the distribution, abundance, and life histories of sea ducks and other marine birds in the nearshore waters of the Beaufort Sea. This work was designed in response to information needs identified by the Minerals Management Service, Alaska Outer Continental Shelf Region. Presented here are the results from four field seasons of a multifaceted research program designed to assess the breeding ecology of Pacific common eiders and the molting ecology of long-tailed ducks along the Beaufort Sea coast of Alaska. The study area was divided into an Industrial Area adjacent to current oilfield development to the west of Prudhoe Bay and an undeveloped Control Area around Flaxman Island.

Long-tailed ducks congregate in the lagoon system of the Beaufort Sea for a post-breeding molt period from mid-July through mid-September. During this time the lagoons host 10,000–30,000 flightless long-tailed ducks. The combination of their large numbers, limited mobility, and nutritional demands, along with a declining population trend, had led to concern for this species. In 1999 and 2000 the ASC collected ducks through the molt period for a study of body condition, molt timing, and flight parameters. The dynamics of body composition during the molt act to minimize the flightless period for long-tailed ducks. These ducks meet their nutritional demands by foraging during the molt period, but there is no indication

that they are resource limited. Body condition was not affected by experimental boat disturbances or proximity to industrial development. During 2000–2002 the ASC studied aspects of movement, site fidelity, habitat use, and foraging ecology using radiotelemetry. In general, long-tailed ducks forage in the lagoons by day and roost along the barrier islands at night. Movement patterns of long-tailed ducks among years and areas were highly variable, with some individuals showing a great deal of mobility. There were no apparent effects of disturbance (including underwater seismic gunning) on movement, habitat use, or foraging; rather, weather (especially wind) appears to be the primary influence on these behaviors.

To examine the role of disease and contaminants on long-tailed ducks, the ASC analyzed blood and cloacal samples taken from live ducks and tissue samples from carcasses. Blood levels of lead were low, and there were no major differences in concentrations of trace elements between the Industrial and Control Areas. The ASC identified an adenovirus outbreak as the cause of poor body condition and mortality of long-tailed ducks in the Control Area in 2000. The data suggest that molting long-tailed ducks are more influenced by natural phenomena such as wind and disease than by human disturbance.

There is concern for the common eider of the Beaufort Sea because of recent dramatic population declines. Along the Arctic coast of Alaska, the greatest concentration of breeding common eiders is in the central Beaufort Sea, where they nest almost exclusively on barrier islands. The ASC used aerial surveys and ground-based nest monitoring to assess the breeding ecology of common eiders in the study areas. Both aerial surveys and ground-based nest searches showed a continued decline in nesting effort since 1999. This decline parallels increasingly late break-up of the sea ice between the mainland and the barrier islands, and it may be in part due to eiders forgoing nesting because of poor conditions on the breeding grounds. All of the measures of productivity (nesting effort, clutch size, hatch success, and fledging success) were low and substantially below those of Pacific common eiders nesting on the Yukon–Kuskokwim Delta in western Alaska. Predation by Arctic foxes and glaucous gulls was the greatest contributor to nest failure of common eiders. Of 52 broods followed in 2000 and 2001, none were known to survive until fledging. A reovirus, similar to one responsible for a major die-off of common eiders in Finland, was isolated from two duckling carcasses collected in 2000. Disease and predation may be responsible for poor duckling survival. Concentrations of lead and mercury in blood and eggs were lower than on the Yukon–Kuskokwim Delta. The data do not show an effect of industrial development on common eiders, with the possible exception of an increased risk of predation for eiders breeding near the oilfields. With the breeding success that the ASC documented since 2000, this population will not persist on its own. There are three possible scenarios for this population: the population may be declining rapidly, the population is maintained by recruitment from other populations, or the population is maintained by infrequent years of high recruitment. Regardless, there is cause for significant concern about the long-term viability of this population.

The ASC is engaged in research on other aspects of the life history of sea ducks in Alaska. Little is known about the migration and winter ecology of most sea ducks, which is considered a priority information need by the Sea Duck Joint Venture of the North American Waterfowl Management Plan. New and smaller satellite transmitters that can be surgically implanted in the abdominal cavities of sea ducks has permitted significant advances in understanding links between breeding areas and staging and winter habitats.

The ASC used satellite telemetry to study the migration routes and wintering areas of two allopatric breeding populations of Pacific common eiders in Alaska: the Yukon–Kuskokwim Delta and the western Beaufort Sea coast. Only 6% (2 of 36) of females wintered within the wintering area of the other breeding population. Both breeding populations wintered in the closest available ice-free habitat, perhaps to minimize migratory distance. Beaufort Sea breeding birds wintered primarily in the Chukchi Sea near the Chukotka Peninsula, Russia, and St. Lawrence Island, Alaska. Those birds that were marked in nesting areas on the Yukon–Kuskokwim Delta wintered in marine habitats off the Yukon and Kuskokwim Rivers and in Bristol Bay, Alaska. Two Beaufort Sea females wintered in areas used by Yukon–Kuskokwim Delta females, implying potential gene flow among breeding areas. The ASC concluded that these two populations are largely geographically isolated throughout the annual cycle, and the environmental factors influencing survival and reproduction likely differ between these groups of birds. Thus, regardless of the potential gene flow among breeding populations, birds from these two

breeding areas should be managed as separate populations.

Spectacled eiders were listed as threatened in 1993 under authority of the Endangered Species Act. The ASC has studied the life history of spectacled eiders in Russia, on the Yukon–Kuskokwim Delta in western Alaska, and on the North Slope of Alaska in an effort to identify factors that may be limiting their recovery. However, too little information, especially away from their breeding grounds, existed to determine the causes of the significant population decline on the Yukon–Kuskokwim Delta. The ASC described characteristics of the wintering area used by spectacled eiders in the Bering Sea, Alaska, and evaluated these characteristics in relation to long-term population trends. Remoteness, limited daylight, and extreme weather conditions precluded direct observations, so they derived the location of the wintering area from satellite telemetry, ice conditions from remotely sensed data, weather conditions from archived data sets, and benthic communities from the literature. Based on analyses of two indices spanning 1957–2002 and 1988–2002, they identified no single environmental parameter that explained the precipitous decline in nesting populations in western Alaska. In general, the number of days with extreme sea ice in winter, extreme winds, and winds in spring explained the greatest variability in annual indices. These analyses support the conclusion that annual population estimates on the breeding grounds can be negatively impacted by extended periods of dense sea-ice concentration and weather during the previous winter. Examination of population indices did not support the hypothesis that changes in benthic communities on the wintering grounds have contributed to the decline or inhibited the recovery of the spectacled eider breeding population in western Alaska.

The ASC and the National Park Service (NPS) recently agreed to collaborate on a multi-year project to inventory montane-nesting birds in National Parks of northwest Alaska. The NPS administers five large land units in northwest Alaska: Cape Krusenstern National Monument, Noatak National Preserve, Bering Land Bridge National Preserve, Gates of the Arctic National Park and Preserve, and Kobuk Valley National Park. Together they comprise the Arctic Network of Parks and cover almost 81,000 square kilometers (20.4 million acres), or about 5% of Alaska's land area. These parks host between 150 and 200 species of birds, but adequate documentation is lacking for 20–40% of these. The poorest documented avifauna occurs in montane habitats, especially in the larger parks. Recent regional and national shorebird conservation planning efforts have identified certain shorebird species and habitats as being of high conservation concern, primarily because of documented or perceived population declines and/or restricted distributions. In Alaska, 14 such species have been identified. Six of them nest in montane regions, including Pacific golden plovers, wandering tattlers, whimbrels, bristle-thighed curlews, bar-tailed godwits, and surfbirds. Despite the obvious importance of the Arctic Network Parks to regional, national, and international populations of montane-nesting birds, particularly shorebirds, information on species distribution and abundance is limited or nonexistent for most geographic areas of the parks. The goal of this project is to document the occurrence of 90% of the species of montane-breeding birds likely to occur in the Arctic Network of Parks. The ASC has employed a repeatable, scientifically valid sampling design suited to expansive areas with limited access to address three principal objectives:

- Collect and summarize all existing information on the distribution and abundance of all avian species occurring on upland habitats;
- Obtain geographic data layers needed to characterize elevation, slope, habitat, and measures of seasonal green-up; and
- Determine species-specific associations between distribution, abundance, and habitat characteristics, particularly for species of shorebirds and passerines occurring on upland areas during the breeding season.

Results from the 2001 and 2002 field seasons revealed a total of 100 species of birds on sampled plots, including 53 in Cape Krusenstern, 54 in Kobuk Valley, and 87 in Noatak. Overall, there were 23 species of shorebirds; 13 species of potential predators of shorebird adults, eggs, or young, including 8 raptors, 3 jaegers, and 2 corvids; 35 species of passerines; 22 species of waterfowl; 2 species of gulls; 2 species of ptarmigan; 1 species of grouse; 1 species of tern; and 1 species of crane. On average the ASC detected 30.4 species on Cape Krusenstern plots, 25.0 species on Kobuk Valley plots, and 26.0 species on Noatak plots during and between surveys.

Observers were able to directly associate a bird with a vegetation class for 27% of the detections of shorebirds and their potential predators. Among these, 52% of bird detections were associated with mesic graminoid herbaceous vegetation (MGH) and 13% with *Dryas* dwarf shrub (DDS)

vegetation. The remaining birds were associated with 20 other vegetation classes or combinations of classes. Habitat associations also varied by species. For example, whimbrels were almost always associated with MGH (76%), whereas American golden plovers were usually found among various classes, including MGH (38%), DDS (26%), and dry forb herbaceous vegetation (12%).

The ASC classified the behavior of 79% of 1,423 detections of shorebirds and potential shorebird predators. Based on this subsample, the behavior of most shorebirds was characterized as courtship or breeding display (47%); standing, preening, or sleeping (26%); or flying or walking (14%). For potential predators, most detections were of individuals flying or walking (68%), or standing, preening, or sleeping (24%). They were likewise able to determine the behavior for a high proportion of passerines (90% of 2,916 detections) because behavior can be inferred from vocalizations. Most passerines were performing courtship or breeding displays (81%), or flying or walking (14%). Very few passerines were seen feeding or engaged in maintenance or agonistic behaviors. Waterfowl were typically seen as pairs or groups on water bodies (24%) or flying (45%) over plots. Most detections of gulls (64%) were of birds flying low along creeks or rivers, and most detections of ptarmigans (54%) were of males standing on prominent shrubs or rock outcroppings.

Additional data analyses are in progress. The ASC will use logistic regression to estimate the probability of detecting a species at any location in the study area. To do so, they will construct a resource selection probability function by comparing characteristics of the sample points that are used or unused by each species. The presence or absence of the species will be the dependent variable, and habitat and topographic characteristics around the point will be used as explanatory variables. For those variables for which information is available on a park-wide GIS, resource selection probability functions will be developed by comparing points used by each species with a randomly selected sample of points available in the study area. Habitat composition at the points is currently being summarized.

Marine Mammals

The Department of the Interior has trust responsibility for managing three species of marine mammals: polar bear, Pacific walrus, and sea otter. Polar bears and Pacific walruses are apical carnivores in Arctic regions. The USGS is responsible for conducting research to satisfy U.S. Fish and Wildlife Service information needs for these two species. The U.S. shares both species with Russia, and polar bears are also shared with Canada. The international nature of the populations requires the U.S. to coordinate research programs with both Russia and Canada. The focus of current research relates to international actions necessary to conserve shared populations. Both species are subject to legal harvests by Alaska Natives, and research seeks to develop methods for defining and monitoring populations to establish sustainable population goals. Resource development in the Arctic habitats and their potential impacts on populations of polar bears and Pacific walruses are also topics of research interest.

*Walruses.*The USGS Pacific walrus research program focuses primarily on studies related to the estimation of walrus abundance, animal diving behavior and patterns of migration, and population genetics.

Pacific walruses occur throughout the Chukchi and Bering Seas and are important to Native subsistence in Alaska and Russia, where thousands of animals are harvested each year. Reliable abundance estimates for walrus are currently unavailable. Estimates of the potential biological removal (PBR) for all marine mammal species are required under the 1994 amendment to the U.S. Marine Mammal Protection Act. PBR estimates require an estimate of population size with estimable precision. The status of the walrus population is poorly known, but there are indications that the population declined from its most recent peak in abundance in the 1980s. Estimates of walrus population trends are critical for effective management. The purpose of the USGS studies is to evaluate trends in the walrus population by establishing new surveys, evaluating past data collected from monitoring programs in U.S. and Russia, and investigating potential genetic structuring in the walrus population.

To estimate the total population abundance from an aerial survey, the number of animals enumerated on ice and land haulouts must be divided by the proportion of the population hauled out, and thus available for sighting, at the time of the survey. Because walruses are distributed over vast areas of sea ice, an estimate of the proportion of time hauled out is best obtained using satellite telemetry data. The USGS is investigating methods to remotely affix satellite transmitters to walruses in order to estimate an availability correction

factor that can be used by the U.S. Fish and Wildlife Service in future aerial surveys. This method of affixing transmitters would alleviate the need for animal captures, which have been problematic. If funding permits, 40–60 transmitters will be deployed across a range of age and sex classes throughout the Bering Sea. The success of this year's efforts will dictate whether the development of these methods will continue into 2005.

Relatively few studies have investigated the population structure of the Pacific walrus. No genetic studies of the Pacific walrus have utilized microsatellite DNA, which is now commonly used in population genetic investigations. Comprehensive genetic studies using microsatellite and mitochondrial DNA might reveal distinct subpopulations within the Pacific walrus and aid in identifying the migration patterns of animal groups. Subpopulations may be uniquely adapted to given areas and may respond to harvest or habitat alterations in different ways, so they may warrant special management considerations. In addition, an increased understanding of walrus distributions and movement patterns will help in planning and interpreting future population studies, such as aerial surveys. The USGS is using microsatellite and sequence information from the hypervariable portion of the control region of the walrus mitochondrial DNA to investigate potential population structuring within the geographic range of the Pacific walrus. Tissue samples are derived from past research cruises, subsistence hunts, and live animal biopsies using crossbows. Preliminary results are expected to be completed by 2005.

Measures of heavy metal concentrations along the axis of growth in hard tissues such as teeth can provide a history of environmental or dietary exposure of animals to metals such as mercury, lead, copper, zinc, strontium, and calcium. Furthermore, if isotopic and metal profiles are known for geographic regions of the animal's environment, measures of these profiles can provide information on the animal's residency within geographic areas.

The USGS is collaborating with the Geological Survey of Canada to use measures of heavy metals from walrus teeth to determine walrus group affiliation and the distribution of segregated segments of the population. The study requires coordination with U.S. Fish and Wildlife Service, University of Alaska Fairbanks, and Alaskan and Russian hunters. Lab analyses have been completed on over 250 teeth, and results will be published in 2005.

*Polar Bears.*USGS polar bear studies have focused for nearly two decades on ways to manage human activities so as to eliminate or reduce the possible impacts of those activities on polar bears and their habitat. As a result, we now have information on populations to more effectively manage the harvest of polar bears. We also have developed knowledge that can dramatically reduce the impacts that may occur as a result of hydrocarbon exploration and development in the Arctic. Whereas these proximate effects of human activity can be managed, understanding and managing the ultimate effects of the dramatic decline in the habitat upon which polar bears depend may present much more challenging problems. The USGS polar bear project will be focusing on those issues surrounding large-scale climate change for the next several years.

Radio-collared polar bears have been shown to travel from the Canadian Beaufort Sea into the eastern Chukchi Sea of Alaska. Recognition that these animals are shared by Canada and Alaska prompted the development of the Polar Bear Management Agreement for the Southern Beaufort Sea. This agreement between the Inupiat hunters of Alaska and the Inuvialuit hunters of Canada was ratified by both parties in 1988. The text of the agreement included provisions to protect bears in dens and females with cubs, and it mandated that the overall harvests from the southern Beaufort Sea (SBS) polar bear population would be split between the two jurisdictions. It also dictated that the quota for each jurisdiction would be set according to the best available scientific information and would be reviewed annually.

A principal assumption of the agreement is that hunters from villages between Cape Bathurst, NWT, and Wainwright, Alaska, are harvesting polar bears from the same SBS population. The assumption that there is one group of bears in the SBS was based on analysis of radiotelemetry data collected between 1981 and 1988. Ensuing analyses of those data indicated that the concept of one homogeneous group is probably not accurate.

The studies first reported in 1999 have been re-examined. This re-assessment benefits from improved methodologies, new radio tracking data from the eastern and southern portions of the Beaufort Sea collected through June of 2003, and all available data from the Chukchi Sea. Previous research concluded there were three populations of polar bears in the study area. This conclusion was drawn from a variety of scientific data collected over a period exceeding 30 years, as well as local knowledge. Quantifiable evidence of three populations discrete enough to be managed separately,

however, has been lacking. The recent analysis corroborates the earlier suggestion that three groups of bears occur in this area.

Most human activities of concern for polar bear conservation, notably hunting and oil and gas exploration and development, occur in the very near shore zone. This is the area in which our predictive abilities are strongest. Also, it is a simple matter to convert our relative probabilities of encountering a bear from each population to absolute probabilities of encountering any polar bear. Hence, managers could advise recreationists of the likelihood of bumping into a polar bear when they are out on the land, and they can address questions such as which areas proposed for industrial developments will minimize the risks of incidental bear encounters. They also can now calculate the numbers of bears that might be exposed to oil in the event of a spill. This is the sort of information that makes risk assessments for environmental impact statements meaningful.

Another focus of these new findings will be their application to population estimates for polar bears in the Beaufort Sea. Previous capture–recapture efforts illustrated how recognition of different populations with different capture probabilities could impact population size estimates. Knowing not only that capture probabilities differ, but what the different probabilities are, is currently being built into ongoing population modeling for polar bears in the Beaufort Sea.

Polar bears in the southern Beaufort Sea are currently managed as a single population. An accurate assessment of the status of this population is needed to maintain sustainable levels of harvest by Native peoples, to understand the impact of hydrocarbon development along Alaska's North Slope, and to monitor the effects of long-term environmental change on the Arctic ecosystem. Unfortunately, despite over 30 years of capture–recapture data, conventional capture–recapture models have produced unreliable estimates of the size of the SBS population. The problematic structural features in the historic data set are sporadic capture–recapture effort and, more generally, small sample size. These issues, which are a direct result of the financial and logistical challenges of operating in the Arctic, make it difficult to take advantage of recent advances in capture–recapture theory (for example, the robust design).

In recent years the USGS has taken major steps to address the difficulties associated with estimating SBS polar bear abundance and has improved our understanding of the size and trend of this population. Spring 2004 will mark the fourth year of five years of a new capture–recapture effort in the SBS. These five years (2001–2005) of more consistent, uniform capture–recapture data should allow an expanded analysis that includes more state-of-the-art capture–recapture models (e.g. the multi-state model) and will also mitigate bias and precision problems associated with modeling the historic (1967–2000) data.

Spring 2003 capture–recapture operations were based out of Prudhoe Bay, Kaktovik, and Barrow, Alaska. The goal in using multiple logistical bases was to distribute the capture effort as evenly as possible throughout the SBS, thereby obtaining a representative sample of the polar bears utilizing this area. USGS scientists attempted to identify and/or capture every polar bear they observed regardless of age, sex, reproductive status, or previous capture history. They encountered 118 individual polar bears during the spring 2003 capture–recapture season, 104 of which were captured. Of the captured individuals, 89 were located by standard searching techniques (not by radiotelemetry). Only 21 of these bears had been captured and marked in a previous year, giving a recapture rate of about 24%. The remaining 15 captured individuals were located by radiotelemetry.

One of this year's goals was to develop a new capture–recapture model that can handle some of the difficulties specific to the SBS data set and would also be useful in other capture–recapture studies. In response to these issues a new model was developed by extending an existing model, and the model's behavior is being investigated under a wide variety of conditions. Manuscripts describing the model's performance in computer simulations and on real-world data sets are in preparation.

The USGS polar bear research program will initiate a new study in 2004 examining issues related to global climate change. Abundant evidence suggests that climate patterns are changing. The effects of this change may be greatest in the Arctic. Because of their reliance on the sea ice for all aspects of their survival, polar bears are especially vulnerable. How those changes will affect polar bears in the Beaufort Sea is not understood. The new research program is a five-year study of the effects of a changing sea ice environment on polar bear population parameters. It will examine how sea ice quality and condition have changed and will change for the period 1985–2008, and it will establish how polar bears adapt to those changes

spatially and will test whether there is evidence that spatial responses, mediated by climate change, alter polar bear condition, productivity, and survival of young.

Studies of polar bear post-denning behavior have been conducted in areas with high den concentrations, including Russia's Herald Island and Norway's Kongsøya Island. In contrast, the low density of maternal dens in Alaska usually precludes such an opportunity. During the winter of 2001-02 and 2002-03, however, several polar bear dens occurred relatively near the Prudhoe Bay oilfield. This allowed one of the first opportunities to observe the post-emergence behavior of family groups at den sites in Alaska.

The activity budgets of undisturbed animals provide a basic understanding of their behavior patterns as well as a benchmark against which human impacts can be evaluated. Polar bears are especially susceptible to disturbance during the denning period. Cubs are unable to leave dens for at least two months after birth, and even after the bears emerge, a disturbance may cause den abandonment before the cubs are developed enough to endure the rigors of life on the ice.

During the winter of 2001-02 and 2002-03, polar bear maternal dens were located near the Prudhoe Bay oilfield by conventional aerial radio tracking or by forward-looking infrared (FLIR) mounted on aircraft. In late winter, observation blinds were established at den sites. Den emergence dates were determined by fixed-wing aircraft or ground-based observations. The mean emergence date was earlier and the mean length of stay at the den site shorter than den observation studies in other parts of the Arctic. Weather factors were similar to those reported in other studies during the emergence period.

Bear response to human activity near den sites ranged from slight to significant, underscoring a need for further research investigation. Determining what comprises disturbance events as well as measuring individual variation in bear responses to disturbance can provide managers with information to mitigate potential stressors.

Contaminants and Ecology

The banking of environmental specimens under cryogenic conditions for future retrospective analysis is an important part of wildlife health and environmental monitoring programs. The goal of the Alaska Marine Mammal Tissue Archival Project (AMMTAP) is to collect tissue samples from marine mammals for archival in the National Biomonitoring Specimen Bank (NBSB) at the National Institute of Standards and Technology (NIST).

Along with the continuation of sample banking, a new emphasis of collaborative research between AMMTAP cooperators is polar bear–ice seal ecology. This Arctic focus appropriately addresses U.S. Department of the Interior strategic goals for research and management of trust resources. Further, it brings attention to rural concerns related to subsistence resources as well as larger-scale international environmental concerns being addressed by the Arctic Monitoring and Assessment Program.

In 2003 the USGS initiated a collaborative effort with the North Slope Borough Department of Wildlife, the Alaska Nanuuq Commission, and the University of Alaska Fairbanks titled "Influence of Diet on Biomagnification of Organochlorine Pollutants in Polar Bears." Varying concentrations of organochlorine contamination have been found in the tissues of polar bears throughout their range. Many of these organic pollutants are biomagnified with each trophic transfer in the food web.

Polar bears are one of the top carnivores in the Arctic marine ecosystem, with ringed seals likely representing the majority of their annual diet. However, polar bears also feed on bearded seals, beluga whales, and walruses, as well as scavenge on the carcasses of bowhead whales landed by Native subsistence hunters. Stable isotopes are an important tool in identifying trophic relationships within an ecosystem. By using two isotopes and mass balance equations it is possible to estimate what proportions of three isotopically distinct prey items may make up the diet of the predator. To estimate prey composition the USGS used ^{15}N and ^{13}C values from packed blood cells collected from 43 free-ranging polar bears along Alaska's Beaufort Sea coast in the spring of 2003. The results suggest that these polar bears may not be feeding on a single prey species; prey from a lower trophic level, such as scavenged bowhead whale carcasses, may make up as much as 33% of the diet of an average South Beaufort Sea polar bear. Isotope data on Beaufort Sea walrus are lacking.

Comparisons of the isotope signature of these bears to existing data from Canadian subpopulations reveal significantly lower ^{15}N values than those reported for bears sampled in Resolute Bay and Lancaster Sound. This may be because bowhead whale carcasses are more available to polar bears in the southern Beaufort Sea or because of the varying types of tissue analyzed.

Climate and Sea Ice

Arctic sea ice is not only critical habitat for polar bears, walruses, and several species of seals; it is also a significant component of the global climate system. The Arctic Ocean's ice cover governs heat exchange between the ocean and the atmosphere, and changes in sea ice affect large feedback mechanisms that can amplify climate change and variability. The USGS Alaska Science Center recently concluded a study with the Russia Academy of Sciences, Moscow, that investigated spatial and temporal changes in duration of the summer melt season over Arctic sea ice during 1979–2001. Because liquid and frozen water possess different emissivity signatures, passive microwave satellite images were used to document the onset dates of spring melt and autumn freeze. Details of the study are presented in the January 2004 issue of the *Journal of Climate*.

On average, melt began in the peripheral seas during late May and early June, then advanced rapidly over the Arctic Ocean, reaching the pole near the end of the third week of June. Freeze onset at the northernmost latitudes began, on average, during the fourth week of August, reaching the East Siberian and Laptev Seas in mid-September and the Chukchi, Barents, and Kara Seas in late September. In the Arctic Ocean, melt duration varied from a 75-day minimum season in 1987 to a 103-day maximum in 1989. On average, annual ice (ice that does not survive the summer melt season) began to melt 10.6 days earlier and freeze 18.4 days later than perennial (multiyear) ice. Melt duration in annual ice averaged 30.6 days longer than perennial ice and was nearly constant over the 23-year record.

Average annual melt and freeze onset dates, and melt season duration, were significantly correlated with the Arctic Oscillation (AO). The AO index is a commonly used parameter for characterizing alternating high- and low-pressure anomalies over the Arctic. Under high-index AO conditions, sea level pressures over the central Arctic Ocean are substantially lower and the vorticity of the gradient wind fields are more cyclonic. Following high-index AO winters (January–March), spring melt tends to be earlier and autumn freeze later, leading to longer melt seasons. Northward expansions of earlier melt and later freeze during the high-index AO period were most apparent in the northern East Siberian and Chukchi Seas, where the mean annual melt duration was 2–3 weeks longer after the AO shifted to a more positive phase in 1989, compared to prior years.

During high-index AO winters, atmospheric low-pressure systems in the eastern Arctic establish wind-forcing patterns that contribute to earlier sea ice melt by advecting warm southerly air into the East Siberian and northern Chukchi Seas. The low-pressure systems also force cyclonic sea ice motion anomalies that reduce ice transport into the eastern Arctic and increase divergence within, promoting the formation of thin ice and open leads. A greater abundance of open water, leads, and thin ice enhances heat flux from water, decreases surface albedo, and amplifies the summer melt through positive feedbacks. Hence, both dynamic and thermodynamic processes associated with winter AO conditions can imprint signatures that persist later into the year through their influences on spring melt and summer feedbacks.

Invasive Species

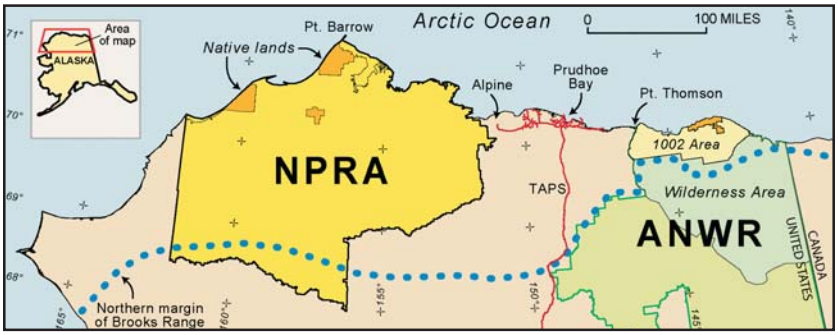
Alaska's National Parks have few invasive species compared to National Parks in other states, but the rate of exotic plant invasion and spread is increasing rapidly in developed areas of Alaska. In response, the Alaska Science Center is cooperating with the National Park Service (NPS) to conduct the first comprehensive study in Alaskan NPS units for early detection and rapid eradication of invaders. They have determined location, population size, and general site conditions of exotic plants, entered data in a statewide database (http://agdc.usgs.gov/akepic), and coordinated with NPS personnel to rapidly eradicate or control the spread of invasive plants. Starting in 2000 they

White sweet clover, a nonnative species that has invaded hundreds of acres of the gravel bars of the Nenana River in interior Alaska. This infestation could spread down the Nenana River, then down the Tanana River, and on down the Yukon River. The infestation was discovered in 2003, and quick-response interagency control efforts are underway. Sweet clover is considered a severe threat to riparian wildlands throughout Alaska.

have worked in Denali National Park and Preserve, Gates of the Arctic National Park and Preserve, Kenai Fjords National Park and Preserve, Sitka National Historical Park, Wrangell–St. Elias National Park and Preserve, and Yukon–Charley Rivers National Preserve and will expand to additional parks in 2004. The results vary among parks. In Gates of the Arctic, a remote park with few visitors and no road access, they documented near-pristine baseline conditions; the only non-native plant they found was one patch of common dandelion. In contrast, in Denali, the park with the most visitors, easy road access, and ongoing construction disturbance, non-native plants were widespread in human-disturbed areas. In 2003 they discovered, in conjunction with USDA staff, that dense stands of sweet clover had invaded undisturbed riparian areas downstream of Denali. This is the first exotic plant to invade wildlands in Interior Alaska, and this population can spread downstream all the way down the Yukon River. They consider sweet clover a serious threat to Alaskan parks, as it has the potential to invade riparian areas in every park. They are organizing an interagency team to develop a rapid response to the sweet clover invasion.

In 2002 they began two invasive plant research projects in Denali. The first project addressed the question of whether planting native legumes and/or fertilization had a long-term effect on the invasion of exotic plants. They studied cut-and-fill road construction disturbances that included areas without assisted revegetation and areas revegetated in 1991 by seeding with native legumes and grasses and adding slow-release fertilizer. Measurements on sample plots included density and cover of exotic plants, cover of native plants, and soil nitrogen, phosphorus, and potassium levels. They found no relationship between revegetation methods, soil nutrient levels, and the density and cover of exotic plants. Microclimate, however, was an important factor, with exotic plants concentrated in the warmest sites. Based on these results, revegetation with a native legume/grass mix is continuing on new construction areas. The results also show that climate warming will expand the range of invasive plants in Denali.

The surveys in Alaskan National Park units showed that exotic plant invasion was concentrated in a few small areas, primarily the road entrances. A second project tested methods for intensive early detection and rapid eradication at an invasion "hot spot," the entrance area to Denali. Repeated surveys throughout the growing season increased the number of exotic plants detected. They detected and, in coordination with NPS, eradicated four new invaders.



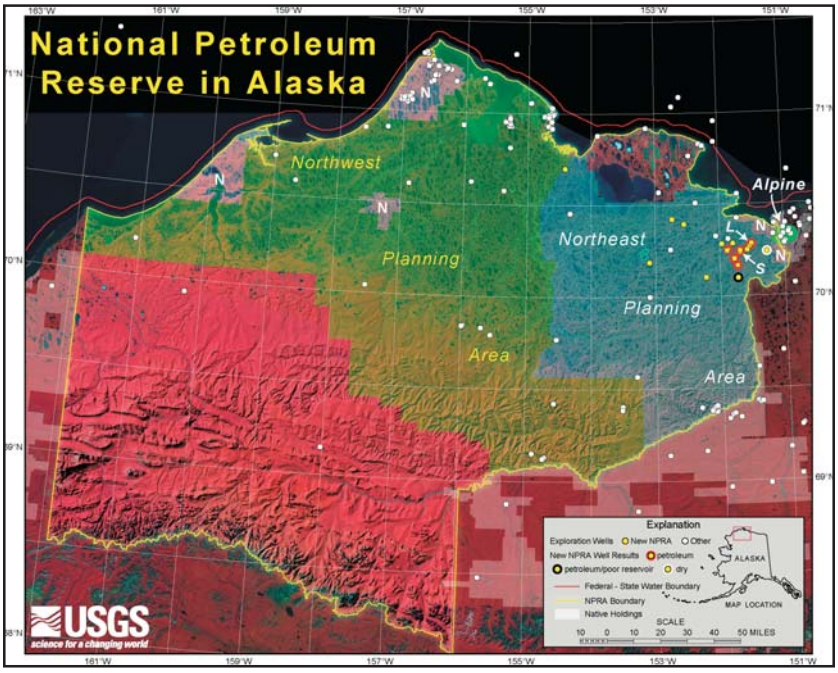
Locations and relative sizes of the National Petroleum Reserve–Alaska (NPRA) and the Arctic National Wildlife Refuge (ANWR). ANWR's 1002 Area was evaluated for petroleum potential by the USGS in 1998. The Trans-Alaska Pipeline System (TAPS) and "feeder" pipelines extending east and west of Prudhoe Bay show the extent of the existing petroleum infrastructure. Locations of the Alpine and Prudhoe Bay oil fields and the Point Thomson gas and oil accumulation are also shown.

Geology Discipline: Petroleum Resource Potential of the National Petroleum Reserve in Alaska and Recent Exploration Activities

"Whereas there are large seepages of petroleum along the Arctic Coast of Alaska and conditions favorable to the occurrence of valuable petroleum fields on the Arctic Coast...." President Warren G. Harding used those words in 1923 to describe the apparent petroleum potential of a tract of land on the western North Slope of Alaska, as he issued a one-page executive order establishing the 23-million-acre (36,000 square miles) Naval Petroleum Reserve No. 4.

During the following six decades, the U.S. Government conducted two petroleum exploration programs in the reserve, one in the wake of World War II and the second in the wake of the 1970s oil embargo. These programs found only a handful of oil and gas fields, none of them large enough to be commercial. Management of the reserve was transferred to the Department of the Interior, and the name was changed to the National Petroleum Reserve–Alaska (NPRA) in 1976. Four lease sales were held in the 1980s, but only two exploration wells were drilled by industry within the NPRA boundary—one on a Federal lease and another on Native land—and neither resulted in the development of petroleum resources.

Following a 10-year hiatus in exploration activity, NPRA again became a focus of interest



National Petroleum Reserve–Alaska (NPRA; boundary shown by yellow line), with locations of wells and the Alpine oil field. Native lands within the NPRA boundary also are labeled with "N." Northeast and northwest planning areas are shown in blue and green, respectively. Exploration wells drilled in NPRA during the 2000–2004 winter drilling seasons are shown by yellow symbols ("new NPRA" in legend). Wells proposed for development are labeled as follows: L = Lookout wells; S = Spark wells. The map base is a false-color composite Landsat image.

with the 1996 announcement of the discovery of the Alpine oilfield, located just outside NPRA. A Federal lease sale was held in part of the northeast planning area of NPRA in 1999, and a number of exploration wells in that lease sale area were completed by industry during the 2000, 2001, and 2002 winter drilling seasons. Another Federal lease sale was held in the northeast planning area in 2002, and additional exploration wells were drilled during the 2003 and 2004 winter drilling seasons.

Several of the wells drilled following the 1999 lease sale were announced in 2001 to have encountered oil and gas. The operator of those wells proposed in 2003 to develop the discovered oil accumulations as satellites to the Alpine oilfield, and that proposal is under evaluation by the Department of the Interior and other Federal and Alaska state agencies. The Department of the Interior during 2003 also initiated procedures to make available for leasing part of the northwest planning area and to expand the portion of the northeast planning area available for leasing.

In light of the recent and proposed exploration activity, it is timely to review recent estimates of oil and natural gas volumes that may occur beneath NPRA. The USGS in 2002 released an assessment of undiscovered oil and gas resources in NPRA. The results of this study provide a context for understanding recent exploration activity in NPRA and for anticipating activity that may occur in coming years.

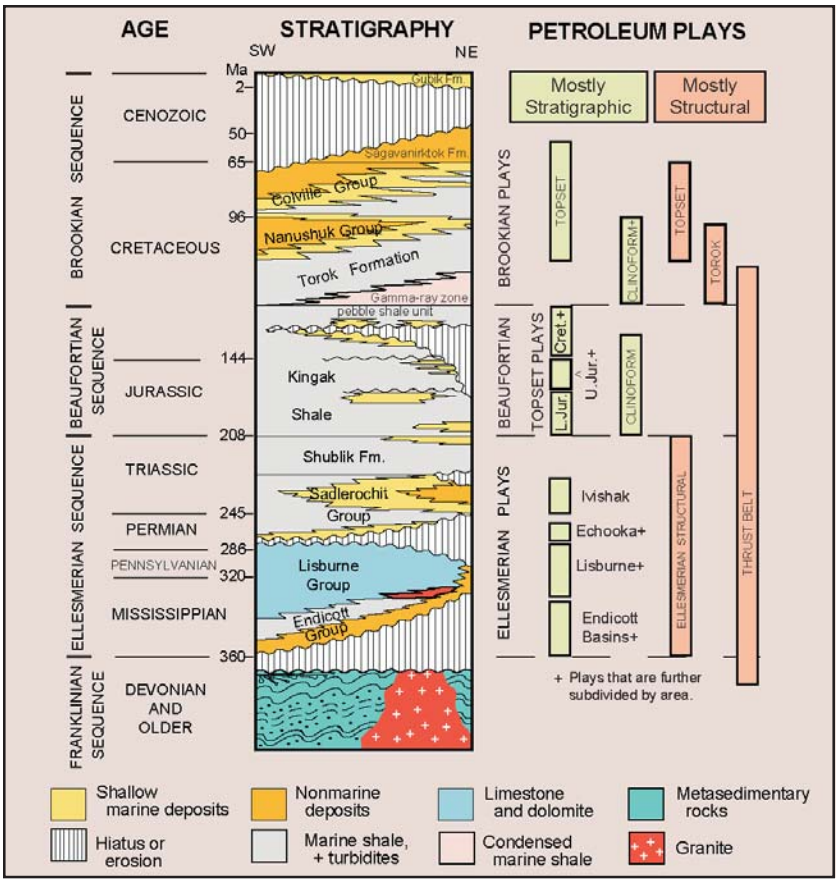
2002 USGS Assessment

The NPRA assessment involved nearly four years of study by a team of USGS scientists. Research was coordinated with colleagues in other Federal agencies, Alaska state agencies, and several universities. New field studies were conducted, new well and sample data were analyzed, some new geophysical data were acquired, and public technical workshops examining core samples were held. Data and interpretations from previous U.S. Government exploration programs were incorporated. About one-third of the 14,000 line-miles of two-dimensional seismic data collected by the the U.S. Government between 1974 and 1981 were reprocessed and reinterpreted. Special attention was focused on understanding the more recent oil discoveries immediately east of NPRA and the potential for those productive geologic trends to extend westward beneath NPRA. All available information was integrated and used as basic input to the 2002 petroleum resource assessment. Significantly, none of the data from newer, three-dimensional seismic surveys or new wells drilled in NPRA since the 1999 lease sale were available for this study, as all those data were proprietary during the assessment.

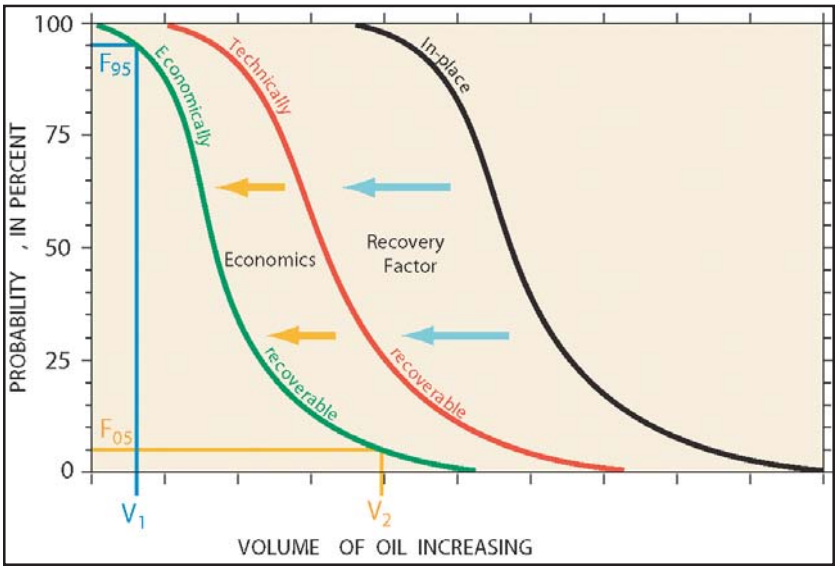
In keeping with the USGS responsibility for assessing the petroleum potential of all onshore and state water areas of the U.S., the total area considered in this assessment was extended offshore to the boundary between State and Federal jurisdiction. Thus, in addition to Federal lands of NPRA, this assessment includes resources beneath State waters offshore from NPRA and beneath Native lands within the NPRA boundary. The total assessment area consists of 24.2 million acres, of which 22.5 million acres are Federal and 1.7 million acres are non-Federal (State and Native).

The methodology used in this assessment is essentially identical to that used in the earlier USGS assessments of NPRA (1978–1980) and the Arctic National Wildlife Refuge (1987 and 1998). Twenty-four petroleum plays were defined as the initial step of the assessment. A play is a volume of rock that contains similar geological parameters (such as petroleum charge, reservoir, and trap) that determine petroleum potential. The term "petroleum" is used to include crude oil, natural gas, and natural gas liquids.

For each play, distributions of the number and size of potential petroleum accumulations were estimated on the basis of a probabilistic range of values for certain geological attributes, such as reservoir thickness and porosity. These



Ages, names, and rock types present in NPRA. The colored bars on the right show the stratigraphic position of the 24 petroleum plays evaluated in the 2002 assessment. Note that the bars with a "+" symbol indicate multiple plays in different areas. Plays indicated by bold outlines include those with the greatest oil and/or gas potential.



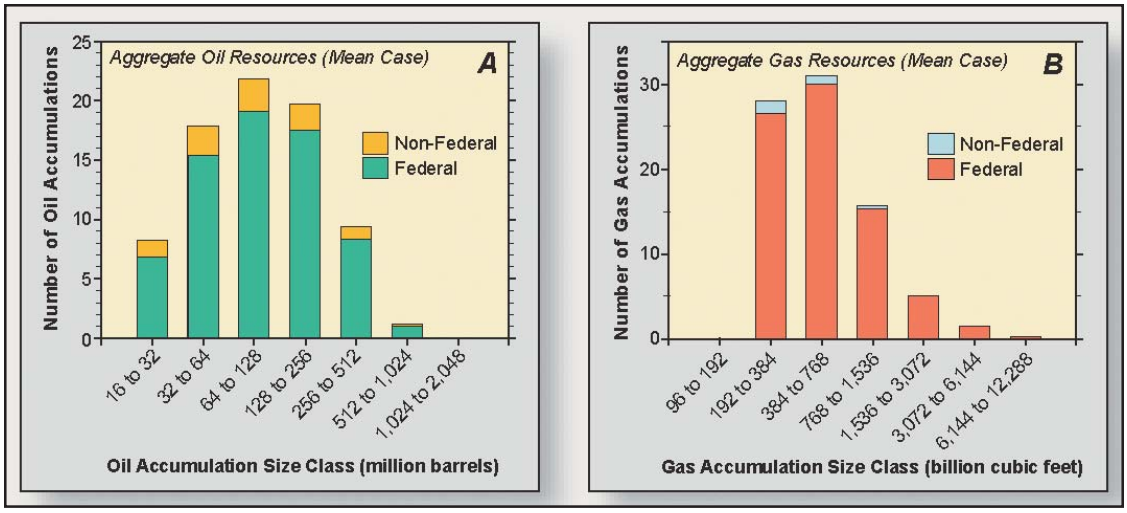
Petroleum volumes and probabilities. The curves represent categories of oil assessment. How one reads this graph is illustrated by the blue and orange lines projected to the curve for economically recoverable oil—in this example, there is a 95% chance (probability F_{95}) of at least volume V_1 of economically recoverable oil, and there is a 5% chance (probability F_{05}) of at least volume V_2 of economically recoverable oil.

distributions were restricted to potential accumulations larger than 50 million barrels of oil-equivalent (MMBOE) "in place," so that the assessment would not be influenced by smaller accumulations that are generally noneconomic on the North Slope.

The resulting distributions were subjected to a geologic risking procedure designed to weigh the likelihood that petroleum charge, reservoir, and trap conditions were sufficient to generate a 50-MMBOE in-place accumulation. In turn, a probabilistic estimate of in-place petroleum resources was calculated on the basis of the risked distributions of size and number of potential petroleum accumulations in each play. A recovery factor appropriate to each play was applied to the estimates of in-place petroleum resources to calculate technically recoverable petroleum resources. Typically only 30–50% of in-place oil resources are recoverable with existing technology. Estimates for each play were aggregated to calculate total technically recoverable petroleum resources for the entire assessment area, the Federal area, and the non-Federal areas.

This assessment methodology yields results that include probabilistic expressions of uncertainty. To stress the importance of this uncertainty, results reported here include 95% and 5% probabilities, in addition to mean values. The 95% probability level means that there is a 19 in 20 chance that the amount of petroleum present will be at least as large as the amount shown; the 5% probability level means that there is a 1 in 20 chance that the amount of petroleum present will be at least as large as the amount shown. Volumes of petroleum associated with the 95% and 5% probabilities are considered reasonable estimates of minimum and maximum volumes that may be present, and the mean is the average or expected value.

Commercial viability of undiscovered oil resources was estimated by considering costs associated with finding, developing, producing, and transporting to market (the west coast of the lower 48 states) the technically recoverable oil resources estimated to be present. The cost functions are calculated in constant 2001 dollars and are based on the expectation that production will repay all operating costs, including taxes and transport to market, and all investment expenditures and will provide an after-tax rate of return of at least 12% on the investment. The economic analysis simulates exploration by assuming that larger accumulations will be discovered early and that these accumulations may be developed



Expected (mean) numbers of oil and nonassociated gas accumulations estimated to exist in various size categories of technically recoverable resources according to the 2002 USGS assessment of NPRA. Each histogram bar is divided into Federal and non-Federal portions. The left sides of the histograms appear truncated because the methodology assesses only accumulations larger than 50 million barrels of oil-equivalent (MMBOE) in place (typically only 30–50% of in-place oil resources and 60–70% of in-place gas resources are technically recoverable). A. *Expected (mean) numbers of oil accumulations, read as follows: It is estimated that the assessment area contains approximately ten accumulations containing between 256 and 512 million barrels of technically recoverable oil; eight of those accumulations are under Federal jurisdiction and two are non-Federal.* B. *Expected (mean) numbers of nonassociated gas accumulations, read as follows: It is estimated that the assessment area contains approximately fifteen accumulations containing between 768 and 1,536 billion cubic feet of technically recoverable gas; fourteen of those accumulations are under Federal jurisdiction and one is non-Federal.*

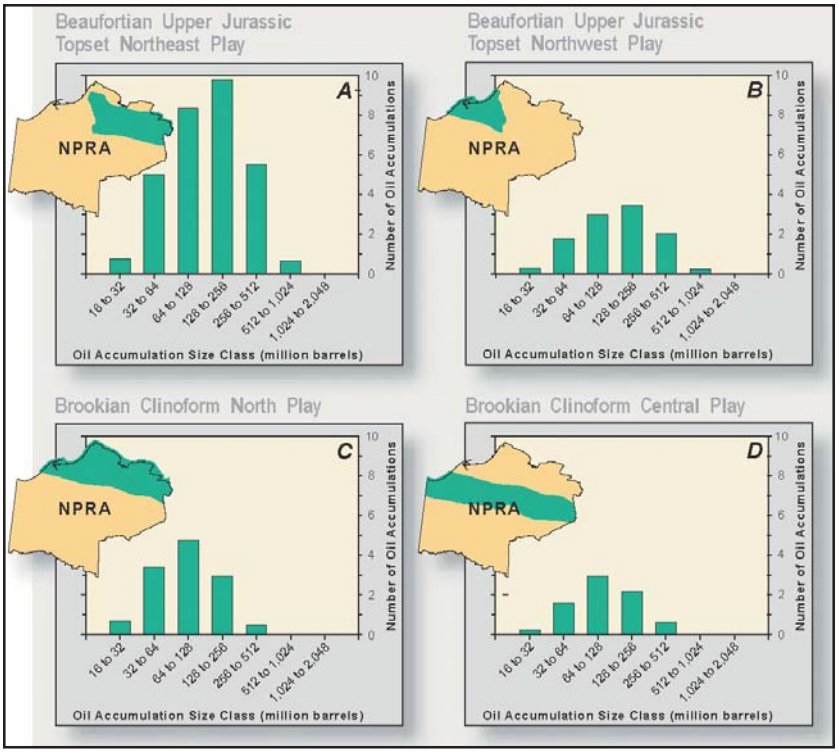
depending on their size and location. Any accumulation large enough to be developed at a specific location will support the costs of constructing processing facilities and extending infrastructure into the area. Smaller accumulations then may become economically viable if they can be developed as satellites to the larger fields. Results of the economic analysis are presented in terms of oil volume as a function of market price.

No analysis of the commercial viability of undiscovered gas resources has been made by the USGS. Such analysis is deferred until plans for a natural gas transportation system are more firmly developed.

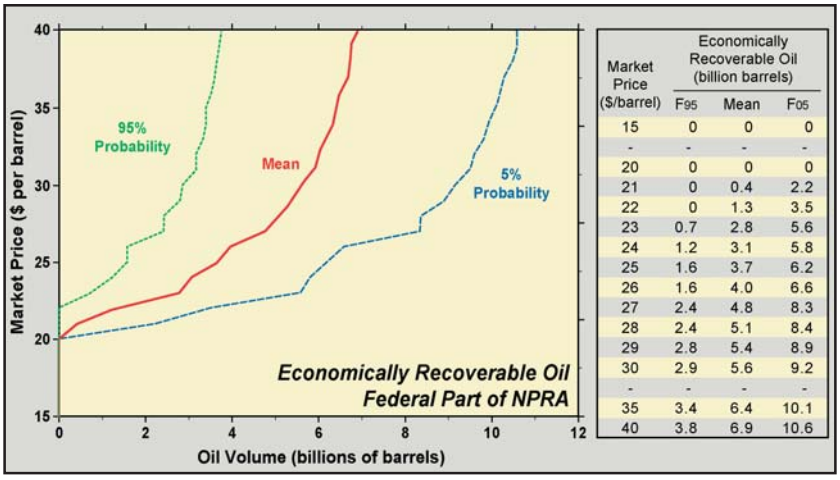
Assessment Results

Oil. The total quantity of undiscovered, technically recoverable oil within the entire assessment area is estimated to be between 6.7 and 15.0 billion barrels (BBO) (95% and 5% probability range), with a mean value of 10.6 BBO. The quantity of undiscovered, technically recoverable oil beneath Federal lands in NPRA (excluding State and Native areas) is estimated to be between 5.9 and 13.2 BBO (95% and 5% probability range), with a mean value of 9.3 BBO.

Most oil accumulations are expected to be of moderate size, on the order of 30–250 million barrels (MMBO) each, and large accumulations like Prudhoe Bay (ultimate recovery approximately 13 BBO) are not expected to occur. This conclusion is consistent with the fact that numerous exploration wells previously drilled in NPRA and in adjacent State and Federal waters tested prospects that were geologically similar to Prudhoe Bay, without success. Significantly NPRA is expected to contain many accumulations in the size range commonly developed on the Alaska North Slope in recent years. Some of these recently developed accumulations have been developed as "stand-alone" fields, which include processing facilities to prepare the oil for transport through the TAPS, whereas others have been developed as "satellite" fields, which do not have processing facilities and must use existing processing facilities of a nearby field. The determination of whether a newly discovered accumulation will be developed as a stand-alone or satellite field, or not developed at all, depends largely on the size of the accumulation and the distance from existing infrastructure. For comparison, announced estimates of ultimate recoveries from recently discovered fields near NPRA include 429 MMBO for Alpine, 70 MMBO for Tarn (20 miles southeast of Alpine), 50 MMBO



Maps of petroleum plays with histograms showing the expected (mean) numbers of undiscovered petroleum accumulations estimated to exist in various size categories of technically recoverable oil resources in the four plays estimated to hold the greatest oil potential in NPRA. About 80% of the technically recoverable oil resources, on the basis of the mean estimate, are thought to occur in northern NPRA within these four plays, which are westward continuations of the geologic trends that host Alpine and nearby oil pools just east of NPRA.



Market Price ($/barrel)	Economically Recoverable Oil (billion barrels)		
	F_{95}	Mean	F_{05}
15	0	0	0
-	-	-	-
20	0	0	0
21	0	0.4	2.2
22	0	1.3	3.5
23	0.7	2.8	5.6
24	1.2	3.1	5.8
25	1.6	3.7	6.2
26	1.6	4.0	6.6
27	2.4	4.8	8.3
28	2.4	5.1	8.4
29	2.8	5.4	8.9
30	2.9	5.6	9.2
-	-	-	-
35	3.4	6.4	10.1
40	3.8	6.9	10.6

USGS estimate of economically recoverable oil that may occur beneath the Federal part of NPRA. Left: *Relationship of market price to the volume of oil estimated to be profitably recoverable. The three curves are based on estimates of technically recoverable oil volumes at the mean (expected) value and at the 95% (F_{95}) and 5% (F_{05}) probabilities. Included are the costs of finding, developing, producing, and transporting oil to market (west coast of the lower-48 states) based on a 12% after-tax return on investment, all calculated in constant 2001 dollars. The chart is read as follows: At a market price of $25 per barrel, there is a 95% probability of at least 1.6 billion barrels of economically recoverable oil and a 5% probability of at least 6.2 billion barrels, and the mean or expected value is at least 3.7 billion barrels of economically recoverable oil.* Right: *Economically recoverable oil resources estimated to occur in the Federal parts of the NPRA at various market prices. Values for the 95% (F_{95}) and 5% (F_{05}) probabilities as well as the mean (expected) values are shown. The NPRA results are calculated in constant 2001 dollars.*

for Meltwater (25 miles southeast of Alpine), 50 MMBO for Fiord (just north of Alpine), and 40 MMBO for Nanuq (just south of Alpine).

Quantities of technically recoverable oil are not expected to be uniformly distributed throughout NPRA. This is illustrated by accumulation-size histograms and maps for the four plays estimated to hold the greatest oil potential in NPRA. Based on the mean estimate, about 80% of the technically recoverable oil resources are likely to occur in northern NPRA within plays that are westward continuations of the geologic trends that host Alpine, Fiord, Tarn, Meltwater, and Nanuq oil pools, just east of NPRA.

The economic analysis of undiscovered resources is particularly important in an area as large as NPRA, because some of the oil resources may be far from existing infrastructure. Over a range of market prices between $25 and $35 per barrel, between 3.7 and 6.4 billion barrels of oil are estimated to be economically recoverable from the Federal part of the study area on the basis of the mean estimate of technically recoverable oil volumes.

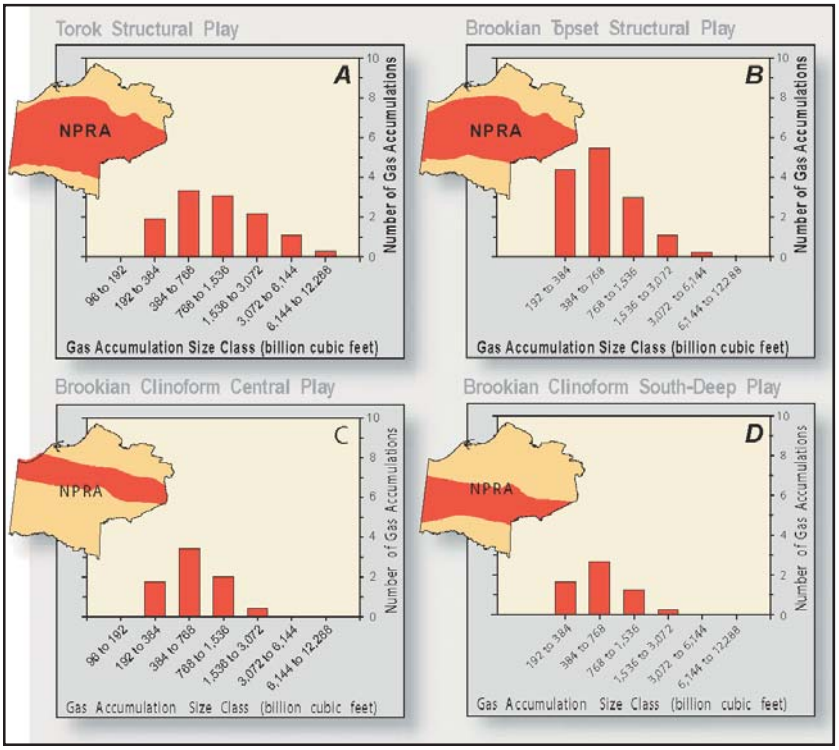
Gas. Significant volumes of natural gas also are estimated to occur in the NPRA. Although North Slope gas is currently noncommercial for lack of a transportation system, it is of growing interest because of recent discussions and proposals of gas pipeline construction. The total quantity of undiscovered, technically recoverable, nonassociated gas within the entire assessment area is estimated to be between 40.4 and 85.3 trillion cubic feet (TCF) (95% and 5% probability range), with a mean value of 61.4 TCF. The quantity of undiscovered, technically recoverable nonassociated gas beneath Federal lands in NPRA (excluding State and Native areas) is estimated to be between 39.1 and 83.2 TCF (95% and 5% probability range), with a mean value of 59.7 TCF.

Most gas accumulations are expected to range between about 200 and 1,500 billion cubic feet (BCF) each. For comparison, the gas cap at the

Prudhoe Bay oilfield contains more than 23,000 BCF, the Point Thomson gas and oil accumulation may contain more than 6,000 BCF, and a recently announced discovery in the Mackenzie River delta of Canada (about 150 miles east of the U.S.–Canada border) is estimated to contain 200–300 BCF recoverable reserves. Quantities of technically recoverable gas are most abundant in central and southern NPRA.

Recent Exploration and Development Activity in NPRA

A total of 18 exploration wells were drilled in NPRA during the 2000 through 2004 winter drilling seasons. Data from six of these wells have been released by the State of Alaska; data from the other wells are not yet available because of confidentiality restrictions. Although little information has been released by the companies that have drilled the exploration wells in NPRA, announcements by two companies indicate that at least seven wells have encountered oil or gas and condensate in amounts that may be commercial. One additional well drilled during the 2002 winter season encountered hydrocarbons in a rock unit characterized by poor reservoir quality. Significantly, all eight of these wells in which hydrocarbons have been encountered targeted the rock unit that is the main reservoir in Alpine field. Another well, announced in 2001 to be a dry hole, targeted a different rock unit. No information has been released on the remaining nine wells.



Maps of petroleum plays with histograms showing the expected (mean) numbers of undiscovered petroleum accumulations estimated to exist in various size categories of technically recoverable gas resources in the four plays estimated to hold the greatest gas potential in NPRA. About 60% of the technically recoverable gas resources, on the basis of the mean estimate, are thought to occur in central and southern NPRA within these four plays.

ConocoPhillips Alaska, Inc., which operates the Alpine field and has drilled most of the exploration wells in NPRA since the 1999 lease sale, has submitted to the Bureau of Land Management a proposal to develop NPRA discoveries as Alpine satellites. The proposed plan specifies the development of three production pads in NPRA. Two of the pads are located near the Spark and Lookout well sites, apparently indicating that those discoveries are large enough to be developed as satellite fields. The third pad (Alpine West), located in the easternmost part of NPRA, appears to be an extension of the Alpine field proper.

The limited information available from the wells drilled in NPRA during the 2000 through 2004 drilling seasons indicates that the main exploration target is the western extension of the Alpine play. The USGS 2002 assessment of undiscovered petroleum resources divided this play into two parts: the Beaufortian Upper Jurassic topset northeast play and the Beaufortian Upper Jurassic topset northwest play. These two plays were assessed to have the greatest potential for undiscovered oil across NPRA, and together these two plays extend across the entire width of both the northeast planning area and the northwest planning area. This correlation suggests that exploration during the next several years is likely to continue westward across northern NPRA.

Several other plays also have the potential to become exploration objectives in NPRA. However, these plays are estimated to contain a lower total volume of oil, and the oil is inferred to occur in smaller accumulations than the Alpine-type plays. These plays are likely to become secondary exploration objectives if additional discoveries in the Alpine-type plays sustain continued exploration across NPRA.

Summary

Anticipating the need for updated scientific information to support policy decisions, the USGS in 2002 completed a new assessment of undiscovered petroleum resources in NPRA. This new assessment concluded that the volume of technically recoverable, undiscovered oil beneath Federal

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lands in NPRA ranges between 5.9 and 13.2 billion barrels (95% and 5% probabilities), with a mean (expected) value of 9.3 billion barrels. Over a range of market prices between $25 and $35 per barrel, between 3.7 and 6.4 billion barrels of oil are estimated to be economically recoverable, on the basis of the mean estimate of technically recoverable oil volumes.

Most of the oil is estimated to occur in the northern third of NPRA, to be distributed among several plays, and to occur in accumulations of moderate size. It is unlikely that a Prudhoe Bay-size accumulation occurs in NPRA. The plays estimated to contain the greatest potential for undiscovered oil accumulations are westward extensions of the Alpine play, which hosts the 429-million-barrel Alpine field on the eastern border of NPRA. Information released from exploration drilling in NPRA during the 2000 through 2004 winter drilling seasons confirms that the Alpine play is the main objective of industry activity.

Estimates of technically recoverable, undiscovered, nonassociated natural gas resources for the same area range between 39.1 and 83.2 trillion cubic feet (95% and 5% probabilities), with a mean (expected) value of 59.7 trillion cubic feet. The economic viability of these natural gas resources will depend on the availability of a pipeline to transport the gas to market.

The results of the NPRA assessment should be viewed in the context of the larger North Slope oil and gas picture, which includes spare capacity in the oil pipeline, multiple proposals for a gas pipeline, and changing makeup of the group of companies exploring for oil and gas. An important factor affecting the future of existing North Slope oil fields and all future oilfield development is the continued operation of the Trans-Alaska Pipeline System (TAPS). Currently TAPS transports about 1 million barrels of oil per day (bpd), about half of peak production of 2 million bpd achieved in 1988. A basic, but unanswered question is the minimum throughput rate required for efficient, cost-effective operation. Multiple proposals for a natural gas pipeline are being considered to tap more than 30 trillion cubic feet of gas known to occur in the Prudhoe Bay and nearby accumulations. An important consideration is the amount of gas available beyond what is currently known. A gas pipeline would likely renew and expand exploration efforts in the foothills province. With the failure to find additional multi-billion-barrel oilfields, most of the larger, “major” oil companies have reduced or abandoned North Slope exploration. At the same time, smaller, “independent” companies have expanded their exploration activities. This shift in activity is a common pattern observed in petroleum-producing basins as they mature.

Department of Defense

The Department of Defense conducts military operations and maintains military facilities in the Arctic. As a consequence the DOD conducts a broad-based research program that extends from the ocean floor to the magnetosphere.

The DOD Arctic research program seeks to enhance our understanding of basic and applied phenomena that directly affect military activities and operations. Some specific focus areas for these research studies include but are not necessarily limited to:

- The interaction of the Arctic environment with military systems, facilities, other infrastructures, personnel, and operations;
- Energy exchange and ocean–atmosphere interaction dynamics;
- The structure and physics of the middle and upper atmosphere, and the impact of energy exchange processes on global circulation of the atmosphere; and
- The impact of extreme cold on biophysical phenomena and human biology, and methods to optimize human performance in these extreme environments.

The DOD Arctic Research Program is conducted by the military services. Each service is responsible for the conduct of its own, coordinated research program to meet service-specific and joint research and technology objectives. An overview of some of the primary activities and major accomplishments for each service is provided in the following paragraphs.

Army

Biomedical Research

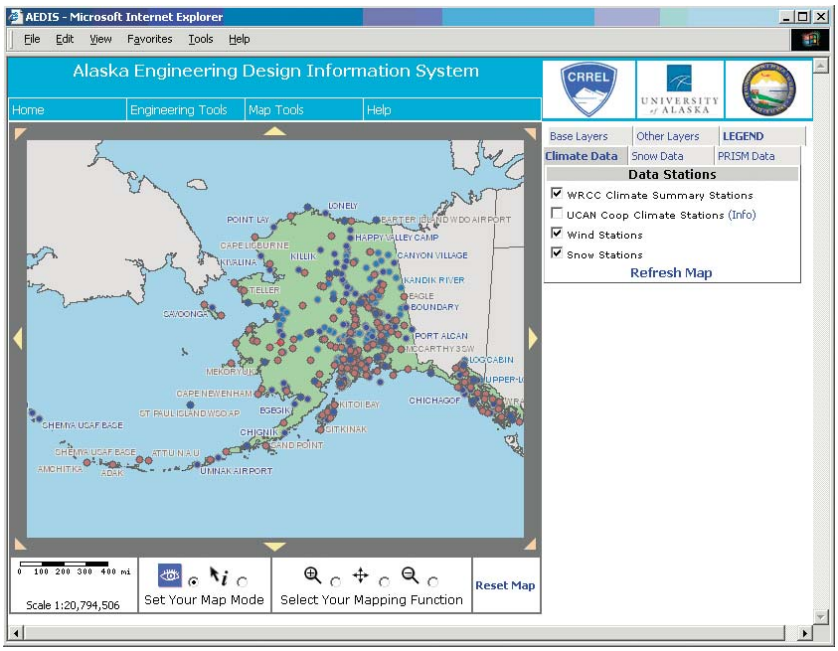
The U.S. Army Research Institute of Environmental Medicine (USARIEM), located in Natick, Massachusetts, conducts basic and applied biological and biophysical research to elucidate novel approaches for sustaining health and optimizing performance of humans exposed to cold environments. USARIEM research findings provide the biomedical basis for Army doctrine to minimize adverse effects of cold on individual military personnel, crews, and troop populations deployed in cold climates, including Arctic regions.

	Funding (thousands)	
	FY 02	FY 03
Arctic Engineering	2,750	1,246
Permafrost/Frozen Ground	430	500
Snow and Ice Hydrology	1,485	1,877
High Latitudes Program	3,030	3,050
Lower Atmosphere	100	269
High-Freq Active Auroral Program	10,700	7,600
Medical and Human Engineering	898	700
Total	19,393	15,242

USARIEM employs multidisciplinary teams of scientists using human, animal, tissue, cellular, and mathematical models to delineate pathophysiological mechanisms of cold injury, identify biomedical risk factors influencing susceptibility to cold injury, and provide physiologic data for developing and validating mathematical models for predicting human cold tolerance. Additionally, USARIEM formulates and validates exposure guidelines and safety limits to prevent cold injury during military training, develop strategies to safely extend cold tolerance and work capabilities in cold climates, and provide biomedical support for cold stress Health Hazard Assessment and MANPRINT efforts of Army materiel/clothing developers. USARIEM research capabilities include state-of-the-art technology for collecting human thermoregulatory data in the laboratory, and nonintrusive, ambulatory, real-time monitoring of warfighter physiological status during military operations in cold conditions.

Medical and Human Engineering

USARIEM maintains an active research program in the area of human physiological responses to cold. A current emphasis concerns the extent to which factors expected to be encountered by warfighters in an Objective Force scenario affect the ability to sustain thermoregulation, physical performance, and immune function in cold environments. Studies demonstrated that multiple days of exertional fatigue impairs vasoconstrictor responses



Screen image of the Alaska Engineering Design Information System.

to cold and increases a soldier's susceptibility to hypothermia. These studies also showed that immune function is not degraded by the combination of exertional fatigue and cold, wet environments. The combination of physical fatigue, sleep deprivation, and caloric restriction, as encountered on a sustained operation, increases the risk of hypothermia.

Studies also showed that moderate altitude exposure (6,000 feet) impairs the shivering and vasoconstrictor response to cold. Epidemiological studies performed by USARIEM showed that women and African–Americans have an increased risk of cold injury. Studies demonstrated that dehydration does not increase the risk of peripheral cold injury. Studies were also completed to evaluate the use of a cold-weather index for use in the Warfighter Physiological Status Monitor program. Biophysical modeling studies were also conducted to examine heat exchange in extremities. Planned research on responses of humans to cold exposure include the effect of exercise intensity, water depth, and water temperature on the risk of hypothermia as well as the role of low body temperatures on cognitive and physical performance.

Arctic Engineering

The U.S. Army has peacetime responsibility for developing, operating, and maintaining military and civil facilities in Arctic regions, ranging from military test and evaluation facilities to commercial energy transportation systems. During armed conflict the Army must be prepared to deploy forces, sustain forces and equipment, and conduct a wide variety of operations in hostile Arctic environments.

One effort being pursued to meet this need seeks to develop new engineering analysis tools to support both peacetime and wartime civil engineering tasks. In cooperation with the University of Alaska, the U.S. Army Cold Regions Research and Engineering Laboratory (USACRREL) is developing a web-accessible Alaska Engineering Design Information System (AEDIS), which is an analysis toolkit for engineers. It presents a broad array of geospatial terrestrial, oceanic, and atmospheric environmental data based on a geographic information system (GIS). In its current state of development, AEDIS contains permafrost distribution, soil distribution, towns and roads, digital elevation and aspect, and other environmental and geographic data. The web site includes climate summaries for over 200 sites in Alaska that include snow depth, load information, and recurrence intervals. Automated toolbox algorithms are available for calculating mean freezing, thawing, and heating indices. Other calculators are available for the length of daylight and a variety of climate statistics. Mean monthly maps of precipitation and temperature for Alaska are included.

Planned improvements to AEDIS include adding more geospatial environmental data and expanding the engineering tools to enable engineers to estimate soil bearing capacity; climate trends; depths of freezing and thawing; statistics for wind, precipitation, and snow load; and other engineering parameters derived from calculations requiring geographical and climate data.

While the data incorporated into AEDIS are specific to Alaska, the enhanced engineering analysis tools available through this system can be applied to problems of Arctic engineering in other locations.

A second effort on Arctic engineering tool development is the application of advanced discrete element modeling methodologies. These developments now allow an ice model to be combined with an unsteady flow model for simulating ice conditions in natural channels. Because the ice model also provides a means for simulating ice jams and ice interaction with structures, it can provide estimates of ice forces on river structures in a reasonable time and at low cost.

With these tools USACRREL created powerful three-dimensional river ice models to simulate the effects of ice interaction with the piers of a proposed bridge on the Buckland River in Buckland,

Alaska. In this project for the Alaska Department of Transportation, USACRREL investigated ice forces on three designs for the proposed bridge piers and the effect of the piers on passing ice. While the results of this particular study are specific to Alaska, the analytic tools employed can be applied to any similar ice-choked waterway.

Environmental Remediation in Permafrost and Frozen Ground

The challenging conditions and problems in the Arctic require an increased understanding of fundamental soil phenomena such as freeze–thaw cycles, phase changes, and biological adaptations. These conditions make the already complicated problem of environmental remediation even more difficult. USACRREL has demonstrated that phytoremediation can be used to treat petroleum-contaminated soils in Arctic conditions in situations and locations where other options are severely limited. Phytoremediation capitalizes on the interaction between natural plants and indigenous microbial communities. Secretions from the plant's root system stimulate the microbes to more rapidly degrade contaminants in the soil. Because this innovative technique requires minimal equipment and energy, it is particularly well suited for locations that lack significant infrastructure.

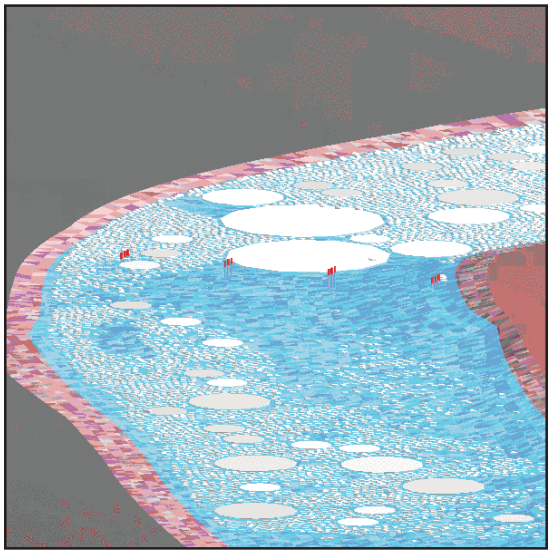
Snow and Ice Hydrology

The snow distribution throughout Alaska is heterogeneous, primarily because of drifting that redistributes the fallen snow. Shrubs trap snow, thereby increasing the snow depth and creating warmer conditions in the underlying soil. Such snow accumulations benefit the shrubs by potentially enhancing their growth. USACRREL, in efforts funded by the NSF Arctic System Science Program and the NASA Land Surface Hydrology Program, has been investigating the patterns of snow distribution using end-of-winter aerial- and ground-based measurements in conjunction with a physics-based computer model for blowing snow (SnowTran-3D). Snow–shrub interactions may have important potential for climate feedback. They may also play a vital role in the transition of tundra regions to scrublands; such transitions would have significant climatic and hydrologic ramifications. Recent results also suggest that shrubs and snow interact in an important way to affect the snow albedo.

In an associated effort, USACRREL has examined the relationship between the SeaWinds satellite scatterometer data and spring snow cover dynamics to monitor freeze/thaw processes in high-latitude boreal and Arctic landscapes. Seasonal freeze–thaw transitions represent the closest analog in nature to a biospheric and hydrologic on/off switch. Surface-level meteorological conditions, ecological trace gas dynamics, and hydrologic activity all respond profoundly to freeze/thaw transitions. Advanced Very High Resolution Radiometer (AVHRR) satellite data were employed to create a series of maps showing the percentage of snow-covered area between Anchorage and the north coast. These maps served as ground truth for evaluating evidence in the scatterometer data for the disappearance of spring snow, a proxy for thaw.

Concurrently, employing a one-dimensional mass and energy balance model called SNTHERM, USACRREL calculated surface energy exchange and associated snow cover dynamics for a portion of the boreal forest of Saskatchewan, Canada. The SNTHERM predictions across the modeling region provided regional-scale, multi-temporal maps of snowpack properties to compare with the scatterometer data. Accurately monitoring and modeling snow conditions and forest energy budgets over large areas will assist in predicting long-term changes to the boreal forest.

Also, under funding provided by the NSF Arctic Natural Sciences Program, USACRREL is collaborating with Dartmouth College faculty and students on a study of the mechanisms of deformation of pure and debris-laden ice. The project seeks to enhance understanding of the physical mechanisms that underlie the flow of large ice sheets (glaciers) and how such sheets of ice might respond to rapidly changing temperatures. The



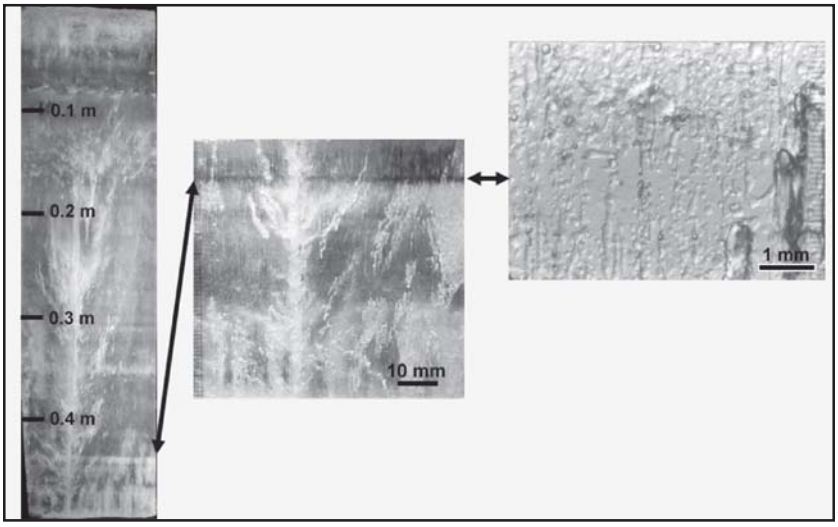
A computer-generated scene showing a simulated ice cover on the Buckland River near Buckland, Alaska, interacting with four proposed bridge pylons (in red).

program involves laboratory experiments and the application of a constitutive model for ice developed at USACRREL.

High Latitudes Program

In a recently completed three-year study sponsored by the NSF Arctic Natural Sciences Program, USACRREL and the Geophysical Institute, University of Alaska Fairbanks, examined the microstructural features and brine drainage networks in first-year sea ice. Extensive field work in the Alaskan Arctic supplied new knowledge about the physical properties of first-year sea ice. Monitoring sites in the Chukchi Sea and on Elson Lagoon, near Barrow, Alaska, provided continuous records of the ice growth and thermal regime and opportunities to conduct detailed studies of the microstructure and brine inclusion structure of sea ice on scales ranging from individual inclusions to the full thickness of the ice sheet. Image-processing techniques were employed on a comprehensive set of microstructure photos to quantify the inclusions in three dimensions and to study the horizontal banding features that are frequently observed in sea ice and that seem to be related to under-ice currents.

Recent evidence indicates that the sea ice cover of the Arctic Ocean has been thinning and decreasing in extent. Currently the only reliable method of assessing ice thickness throughout the Arctic Ocean is to analyze ice draft profiles collected by transiting submarines. Under a project sponsored by the NSF, USACRREL has archived and made publicly available formerly classified sonar profiles of ice draft collected by U.S. Navy submarines under the Arctic ice cap between 1976 and 1994. Data from fifteen such cruises between 1986 and 1994 are now available from the National Snow and Ice Data Center. Analysis of these ice draft data revealed rapid thinning in the western Arctic in the late 1980s. That thinning has been attributed to a major shift in the atmospheric circulation in the Arctic and the resultant weakening of the Beaufort Gyre, the large, clockwise ocean circulation system in the western Arctic.



Sequence of vertical sections of sea ice obtained from the Chukchi Sea in December 1999. The increasing magnification focuses on a type of narrow, very-low-porosity band often observed in sea ice.

USACRREL has modeled Arctic sea ice and climate on spatial scales from centimeters to thousands of kilometers and on temporal scales from microseconds to a century. For example, USACRREL performed a year-long simulation of the mass balance during the SHEBA year, driving the Community Climate System Model (CCSM), a sea ice thermodynamics model, with meteorological and oceanic data gathered in and around the SHEBA ice camp. SHEBA was the 1997–1998 experiment to study the Surface Heat Budget of the Arctic Ocean. USACRREL also has used global climate simulations of the 20th and 21st centuries with the Parallel Climate Model (PCM) from the National Center for Atmospheric Research (NCAR) to show that trends in present-day greenhouse gases produce a decrease of 1 million square kilometers in the simulated area of Arctic sea ice, a decrease similar to that seen in satellite data.

In other sea ice modeling work, USACRREL is developing a high-resolution Lagrangian model of the ice pack on the Arctic Ocean for NASA. In this model the ice pack is composed of discrete parcels that converge to form pressure ridges and separate to form leads. Though high resolution, the current model is capable of covering the entire ocean. Simulations begin with a continuous, frozen ice pack that covers the basin; wind drag then causes the pack to move. Stress builds up in the model ice, it breaks, and fracture lines propagate through the pack. The result is an aggregate plate structure that determines paths for subsequent deformation. Because the modeled ice pack displays linear kinematic features like those seen in satellite imagery of the Arctic Ocean, the conclusion is that large-scale wind stress, not regional topography, creates Arctic leads and ridges.

Lower Atmosphere

During the third and final phase of SHEBA in 2003, USACRREL maintained a 20-m meteorological tower in the main SHEBA camp and four instrumented remote meteorological sites at distances of 0.5–10 km. The main tower and three of the remote sites operated continuously for almost 11 months, yielding long time series of the turbulent and radi-

Ice physicists making mass balance measurements near Barrow, Alaska, June 2001.

ative components of the surface heat budget over diverse ice types.

In addition, from 2000 through 2002, USACRREL and other institutions examined the seasonal evolution of albedo and the snow and ice mass balance in the coastal region near Barrow, Alaska. This complex region of tundra, lake ice, and sea ice is an excellent location to examine interactions among the terrestrial, ocean, ice, and atmosphere environments. The field program included tundra, lake, lagoon, and sea ice study sites. Automated stations monitored conditions throughout the winter, when the snow and ice are spatially uniform and temporal variations are relatively modest. Intensive field work was also performed each year from late May through the end of June during the critical melt season when spatial variations are large and interactions among the ice, ocean, and atmosphere are greatly amplified.

The atmospheric boundary layer during SHEBA was often stably stratified and frequently near quasi-equilibrium, a condition seldom seen in the more ephemeral stable boundary layers at lower latitudes. This data set, collected in almost laboratory-like conditions, is yielding new insights into the turbulent structure of the atmospheric boundary layer during stable stratification. For example, two new turbulence regimes in very stable stratification have been defined. In one, the atmosphere is still intermittently turbulent. In the second, an even more stably stratified case, the turbulence has been damped out by the stratification. In both regimes, though, the effects of Ekman turning are obvious even within 20 m of the surface. Although these results were obtained over sea ice, they are relevant also to terrestrial surfaces at lower latitudes, where stable stratification occurs almost every night.

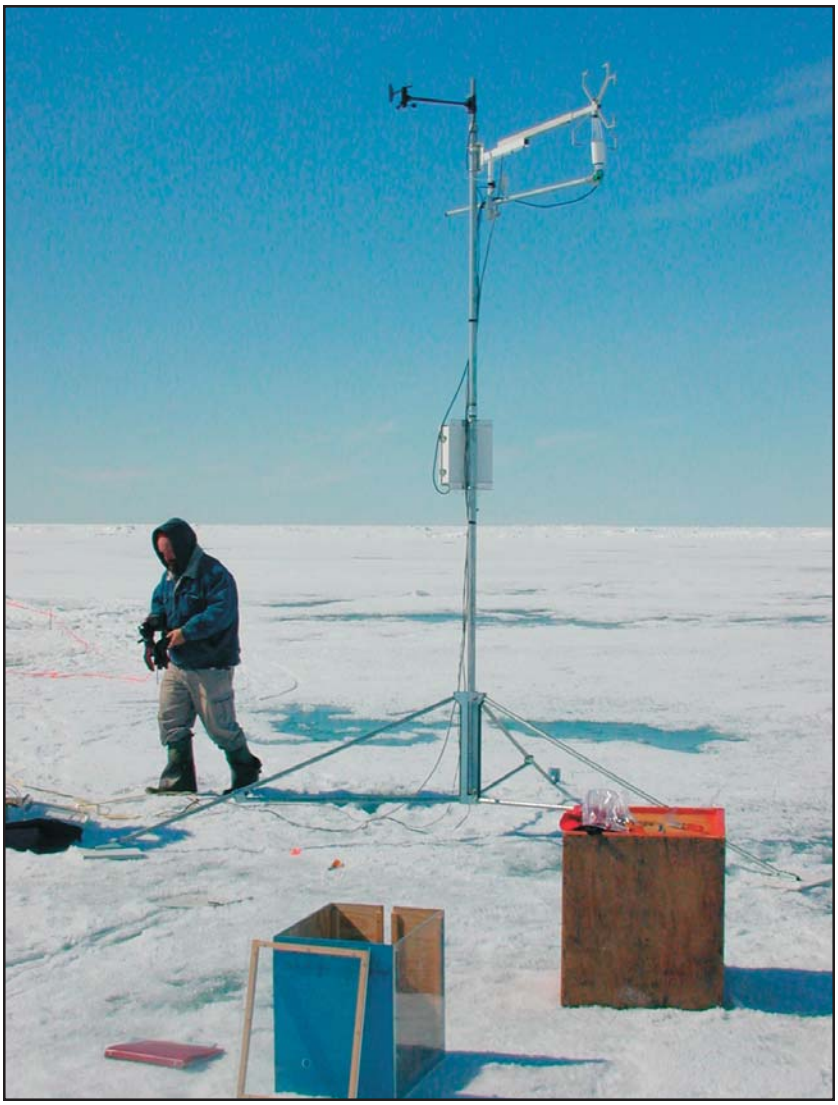
The areally averaged albedo decreased and the spatial variability increased at all sites as the melt season progressed. Comparing results from this study with data collected in the central Arctic during SHEBA showed that albedos of fast ice in the coastal regime evolve significantly faster than albedos in the central pack. In particular, the evolution of the albedo of the lagoon ice was sensitive to the amount of sediment entrained in the ice during freeze-up.

The observed rates of sea ice surface melting were typically at least twice as high as rates observed in the pack ice during SHEBA. This difference indicates the possible role, in the coastal regime, of advective heat transfer from the tundra to the nearby sea ice. The accelerated melting in the coastal Arctic that has been observed in recent years could, therefore, amplify a warming signal as it propagates from the land over the coastal ocean.

The role of the Arctic Ocean in the regional budget of CO_2 is largely unknown but is often presumed to be unimportant under the assumption that sea ice impedes gaseous exchange between the atmosphere and the ocean. To address this uncertainty, in the summer of 2002 USACRREL collaborated with scientists from the International Arctic Research Center (IARC), Fairbanks, to make the first direct (eddy-correlation) measurements of the turbulent flux of carbon dioxide over sea ice.

These direct measurements were complemented with more traditional geochemical sampling that involved placing large and small chambers on the sea ice and monitoring the CO_2 in the headspace in the chambers as a function of time. The measurements were all on the fast ice near Barrow. During these June measurements the ice had begun to melt, and melt ponds eventually formed. It was found that, in general, the surface was taking up atmospheric CO_2. The melt ponds seemed to be especially active; as ponds deepened, the partial pressure of CO_2 in them decreased, presumably as a consequence of photosynthesis. The sea ice, however, was also a sink for CO_2. Not only was photosynthesis active in the ice, but also the warming ice became more permeable to gases and permitted coupling between the atmospheric and oceanic CO_2 reservoirs. The USACRREL/IARC team has concluded that the ice-covered Arctic Ocean could be an important missing link for balancing the global CO_2 budget.

Understanding the dispersion, persistence, fate, and environmental impact of airborne pollutants in Arctic conditions is increasingly important. USACRREL has worked with the Army Directorate of Public Works and the Alaska Department of Environmental Conservation to develop low-cost monitoring techniques for characterizing the



Eddy-correlation measurements of the carbon dioxide flux and other turbulence quantities on the fast ice near Barrow, Alaska, June 2002.

dispersion and deposition of petroleum-aerosol-based fogs used for military training. Such aerial plumes behave differently in winter and summer; both predicting their deposition area and monitoring the process have environmental and homeland defense applications.

Navy

The Navy conducts several research programs for the purpose of understanding the Arctic environment and its interaction with Navy materiel, personnel, and operations. As part of these efforts, the Navy provides platforms and support to other agencies to conduct research in collaboration with or on a "non-interference" basis with the Navy. In recent years (although not in the past two years), the Office of Naval Research (ONR) has conducted the Submarine Arctic Science (SCICEX) Program. Short, 2- to 10-day periods of data collection were incorporated into portions of submarine cruises. Navy personnel assisted the research crews with data collection. During the spring of 2003, the Navy operated an ice camp in the Beaufort Sea in support of operational testing. During this period the camp also was made available for unclassified research. ONR handled the selection of experiments for the unclassified camp research and funded the additional camp logistics costs.

Air Force

The Air Force conducts research in upper atmospheric and ionospheric physics. These efforts are primarily performed by the Air Force Research Laboratory (AFRL) Space Vehicles Directorate, Battlespace Environment Division, and by the Air Force Office of Scientific Research (AFSOR). The goal of the research is to understand the basic physical and chemical processes and dynamics of the polar ionosphere, with the main objectives to specify, predict, and mitigate disruptions to DOD communications, navigation, and surveillance systems. To actively pursue and maintain a well-rounded program, the research includes experimental measurements to determine specific physical processes and first-principles numerical modeling efforts, with a strong connection to ongoing theoretical research.

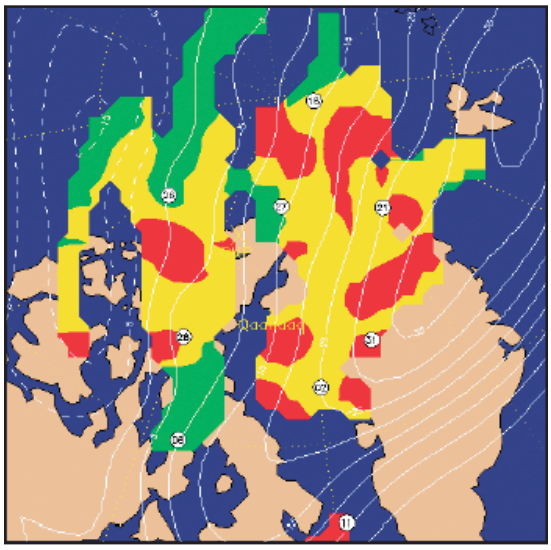
High-Latitude Scintillation Studies

Research expanded in the past two years to characterize and quantify the occurrence and impact of ionosphere scintillation, using a variety of optical and radio frequency sensing techniques. The observations spanned a variety of frequencies and propagation geometries, making use of signals from both low-earth-orbit satellites and higher-altitude (quasi-stationary) satellites, including the global positioning system (GPS) constellation. Observational campaigns in northern Greenland and Svalbard were conducted in coordination with incoherent scatter measurements from radars in Kangerlussuaq, Greenland, and Longyearbyen, Svalbard, to observe the formation of scintillation-producing regions near the dayside cusp of the auroral zone and their subsequent evolution and drift across the high-latitude region.

These ionospheric disturbances can lead to rapid fluctuation or scintillation of satellite signals at or near the earth's surface. This phenomenon is most intense at night within 20 degrees of the earth's magnetic equator, which occupies more than

one-third of the globe's surface. Affecting radio signals, scintillation seriously disrupts navigation and communication satellites signals. The Scintillation Network Decision Aid (SCINDA) was developed to advise operational users in real time when and where scintillation is likely to occur.

These ionosphere disturbances can lead to rapid fluctuation or scintillation of satellite signals at or near the earth's surface. This phenomenon is prevalent throughout the high-latitude regions, especially during winter. Scintillation of radio signals can severely disrupt navigation and communications relying on satellite links. Based on the results of these measurements, the Air Force has developed a prototype high-latitude scintillation specification tool, SCINDA-P, to advise operational users in real time when and where scintillation is likely to be encountered. The model, which follows the concept of SCINDA developed for equatorial regions, uses measurements from ground-based receivers and ionosphere radars to determine where scintillation-related difficulties or system outages can be expected in the polar regions. Ground-based receivers monitor signals from GPS satellites, measure the amount of scintillation at the GPS frequency directly or estimate it at other frequencies based on the strength of the observed ionosphere irregularities, and then combine that information with real-time measurements or models of the high-latitude convection pattern, which indicates where the observed disturbances will be traveling. The result is a map, updated every five minutes, showing the expected degree of system effects in a tri-color red–yellow–green scheme. By combining scintillation measurements with information on the movement of the ionosphere, the map helps users understand how scintillation structures develop and enables operators to determine practical strategies for maintaining system performance.



Scintillation Network Decision Aid for the Polar Regions.

High-Frequency Active Auroral Research Program

Under the High-Frequency Active Auroral Research Program (HAARP), jointly managed by the Air Force Research Laboratory and the Office of Naval Research, a major facility is being developed in Gakona, Alaska, for conducting ionosphere/radio science research. The facility includes a high-power, high-frequency (HF) transmitting system and a suite of radio and optical diagnostic instruments. The present HF transmitting system includes a phased-array antenna, consisting of 48 elements, with crossed-dipole antennas, driven individually by 10-kW transmitters, resulting in a maximum radiated power of 960 kW. In November 2002, a Memorandum of Agreement was signed by the Air Force, the Navy, and the Defense Advanced Research Projects Agency, to complete the planned HAARP Gakona facility with the addition of 132 antennas and associated transmitters to form a 12 × 15 phased array with a radiated power of 3600 kW. The facility is scheduled for completion in 2006.

HAARP is located on a DOD site near Gakona, Alaska, about 180 miles northeast of Anchorage. Research is conducted primarily via four- to five-month-long campaigns each year, with emphasis on studies relating to the generation of Extremely Low Frequency/Very Low Frequency (ELF/VLF) waves in space via modulation of auroral currents with the 960-kW HF transmitter; the production of geomagnetic-field-aligned irregularities and their effects on radio wave scattering; and the generation of optical emissions in space.

A variety of experiments have been conducted in conjunction with space platforms, including the CLUSTER, IMAGE, and WIND satellites, primarily to investigate the degree and manner in which ELF/VLF and HF radio waves propagate from the ground or ionosphere into deep space. Recent CLUSTER observations demonstrate that ELF/VLF signals generated in the ionosphere, by modulating HAARP's HF transmissions, can be routinely received in deep space. These results have led to the initiation of research programs to study the interactions of ELF/VLF radio waves with charged particle populations in the earth's radiation belts and their subsequent effects, including guided (ducted) propagation and wave amplification in the magnetosphere.

National Aeronautics and Space Administration

As part of its mission to understand and protect the home planet, the Earth Science Enterprise at NASA supports various research programs in the Arctic that emphasize space-based and airborne remote sensing studies to characterize, understand, and predict changes in the Arctic and to examine their interactions with the rest of the Earth System.

Arctic Warming

Recent satellite thermal-infrared data have provided surface temperatures from 1981 to 2001, revealing large warming anomalies in the 1990s, compared to the decade before, along with a regional variability in the trends. These compare favorably with coincident in-situ measurements. Average temperature trends were generally positive, with sea ice warming by about a third of a degree Celsius per decade, Eurasia warming by about half a degree Celsius, and northern North America warming by nearly a degree Celsius. The trend is slightly negative but insignificant in Greenland (–0.09±0.25ºC per decade), with the negatives mainly at high elevations. The trends are also predominantly positive in spring, summer, and autumn, causing the lengthening of the melt season by 10–17 days per decade, while they are generally negative in winter. The longer-term in-situ surface temperature data show that the 20-year trend is eight times larger than the 100-year trend, suggesting a rapid acceleration in the warming that may be associated with the recent change in phase of the Arctic Oscillation, which has been linked to increasing greenhouse gases in the atmosphere.

	Funding (thousands)	
	FY 02	FY 03
Polar Ice Interactions	4,000	4,700
Terrestrial Ecology	510	710
Solid Earth Sciences	4,200	4,200
Hydrological Sciences	370	420
Modeling	250	250
Arctic Ozone	6,500	7,000
Clouds and Radiation	500	580
Suborbital Sciences	2,500	2,500
Physical Oceanography	200	570
Biological Oceanography	150	150
Satellite Algorithms/Data Analysis	6,000	6,000
Data Systems	11,000	9,500
Total	36,180	36,580

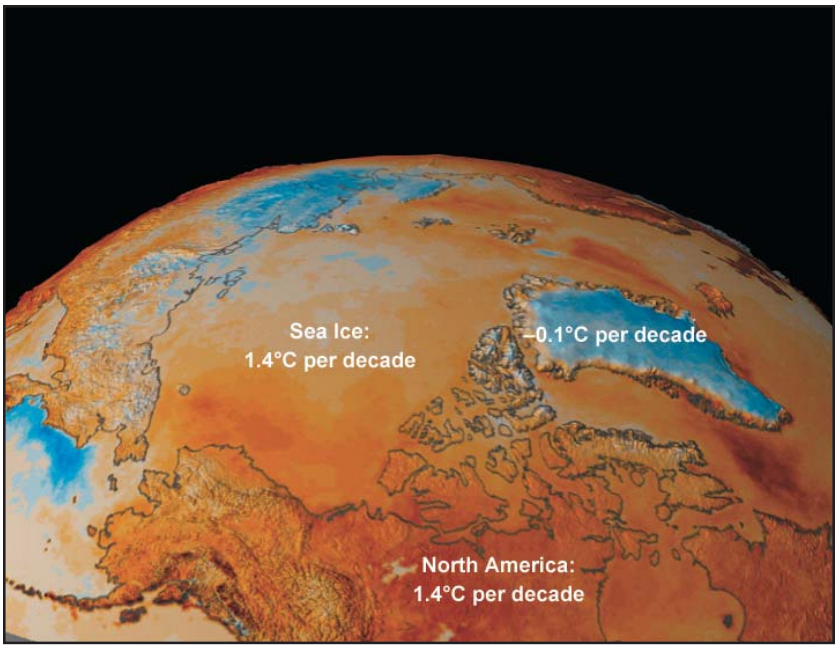
Sea Ice

Observing and Understanding Changes

For many decades, explorers have sought a Northwest and Northeast Passage with a view of finding a sea route that would greatly shorten the link between East and West. These efforts have so far generally failed; some had horrific ends, mainly because of the dominant presence of the perennial sea ice cover, which consists mainly of multiyear ice, the average thickness of which is about 3 m. These thick, multiyear ice floes are the major components of the Arctic sea ice cover as we know it today. These floes survive the summer melt mainly because of a strongly stratified Arctic Ocean that is in part responsible for the scarcity of convection in the region. Historically the Northern Hemisphere winter sea ice cover consists of almost an even contribution of seasonal and perennial ice cover, with the former found primarily in the peripheral seas. A drastic change in this balance in favor of the former would mean an entirely different Arctic climate system and environment.

Analysis of satellite data from 1978 to 2002 showed a decrease in perennial Arctic sea ice cover of nearly 10% per decade, which is consistent with the observed Arctic warming and the lengthening of the melt season. A sustained decline at this rate would mean the disappearance of the multiyear ice cover during this century, which has been predicted by some climate models, along with potentially drastic changes in the Arctic climate system. The pressing question is whether these losses will slow down, reverse, or accelerate, which is a focus of ongoing activities.

A longer 30-year satellite record of sea ice extents, derived mostly from satellite microwave radiometer observations, reveals that the Arctic sea ice extent decreased by $0.30\pm0.03 \times 10^6$ km^2 per decade from 1972 through 2002, but by $0.36\pm0.05 \times$



Arctic temperature trends derived from 20 years of satellite data.

10^6 km^2 per decade from 1979 through 2002, indicating an acceleration of 20% in the rate of decrease. In contrast, the Antarctic sea ice extent decreased dramatically over the period 1973–1977, then gradually increased. Over the full 30-year period, the Antarctic ice extent decreased by $0.15 \pm 0.08 \times 10^6$ km^2 per decade. The trend reversal is attributed to a large positive anomaly in Antarctic sea ice extent in the early 1970s, an anomaly that apparently began in the late 1960s, as observed in early visible and infrared satellite images.

A new tool, the RADARSAT Geophysical Processor System (RGPS), produces high-resolution estimates of sea ice motion and deformation from time-sequential synthetic aperture radar (SAR) imagery acquired by RADARSAT. This data set provides observations over a spatial scale ranging from kilometers to thousands of kilometers (the Arctic Basin). More than four years (from November 1996 on) of RADARSAT acquisitions have been processed into geophysical fields of small-scale ice displacements. Although these records are not as long as their passive microwave counterparts, they allow a detailed look at deformation and motion processes of sea ice on large spatial scales.

A recent investigation, using a specially acquired RADARSAT data set, examined the properties of sub-daily ice motion of the sea ice cover. A persistent level of oscillatory sea ice motion and deformation was superimposed on the large-scale wind-driven field in May 2002 (spring) and February 2003 (mid-winter) in the high Arctic over a region centered at approximately 85°N, 135°W. At this latitude the RADARSAT wide-swath SAR coverage provides four or five sequential observations every day, for ice motion retrieval, with a sampling interval at the orbital period of approximately 101 minutes. The observed motions and deformation characteristics offer remarkable new insights into sea ice processes, as short-period ice motion was previously believed to be inhibited by the strength of the ice pack in the high Arctic during winter. New ice production due to the recurrent openings and closings at these temporal scales, if ubiquitous, could be significant within the winter pack. A simple simulation of this process shows that it can account for an equivalent of 10 cm of ice thickness over six months of winter, approximately 20% of the basal ice growth of thick ice in the central Arctic (of approximately 0.5 m).

Linking Observations to Models

NASA is continuing to contribute to climate research by encouraging international cooperation and the synergistic use of models and satellite observations. A collaborative study involving the NASA Goddard Institute of Space Studies and the UK's Hadley Centre is using the complementary strengths of two global circulation models to compare key drivers of Arctic climate under control and anthropogenic warming scenarios. Under pre-industrial atmospheric conditions in HadCM3, the spatial pattern of sea ice variability appears to be determined by the atmospheric heat flux (77% of the variance in ice concentration) and variability in the northward transport of heat in the North Atlantic Ocean (42%), the latter with a lag of a year to the heat flux at 70°N, and together accounting for 82% of the variance. Under a global warming scenario, the atmospheric heat flux becomes increasingly important, explaining 95% of the Arctic sea ice variance under $4xCO_2$ conditions. Runs with the new NASA GISS Model E are being used to establish whether incorporation of the full stratosphere and more sophisticated sea ice thermodynamics confirms this situation and provides detail on changes in key atmospheric processes in a climate change scenario, as well as to provide the framework for comparisons with 30 years of satellite observations of the Arctic.

Satellite Calibration and Validation

On May 4, 2002, the Advanced Microwave Scanning Radiometer (AMSR-E) developed by the National Space Development Agency (NASDA) of Japan was successfully launched on NASA's EOS

Aqua spacecraft. This new state-of-the-art satellite radiometer provides a wider range of frequencies and twice the spatial resolution than is currently available with the Defense Meteorological Satellite Program Special Sensor Microwave/Imager. The standard AMSR-E sea ice products include sea ice concentrations at spatial resolutions of 12.5 and 25.0 km, snow depth on sea ice at a spatial resolution of 12.5 km, and sea ice temperature at a spatial resolution of 25 km. The scientific usefulness of these products depends on their level of accuracy, which will be determined through the implementation of a sea ice product validation program consisting of three elements: satellite data comparisons, coordinated satellite/aircraft/surface comparisons, and a modeling and sensitivity analysis.

The NASA Wallops P-3B aircraft at Fairbanks International Airport. The P-3, equipped with high-resolution sensors, obtained validation data as part of the EOS Aqua AMSR-E Arctic sea ice validation campaign. The same platform has been used regularly to survey changes in Arctic land ice elevations.

The main objective of the AMSR-E sea ice validation program is to establish statistical relationships between the sea ice parameters derived from the new AMSR-E sea ice algorithms and those same parameters derived from other data sets obtained from satellite, aircraft, and surface-based measurements covering as many different sea ice conditions as possible for the purpose of providing a comprehensive measure of accuracy for each product. Other objectives are to understand the limitations of each of the AMSR-E sea ice algorithms, including the reasons for their particular level of performance under different conditions, and to suggest improvements to each of the algorithms based on the results of the validation studies.

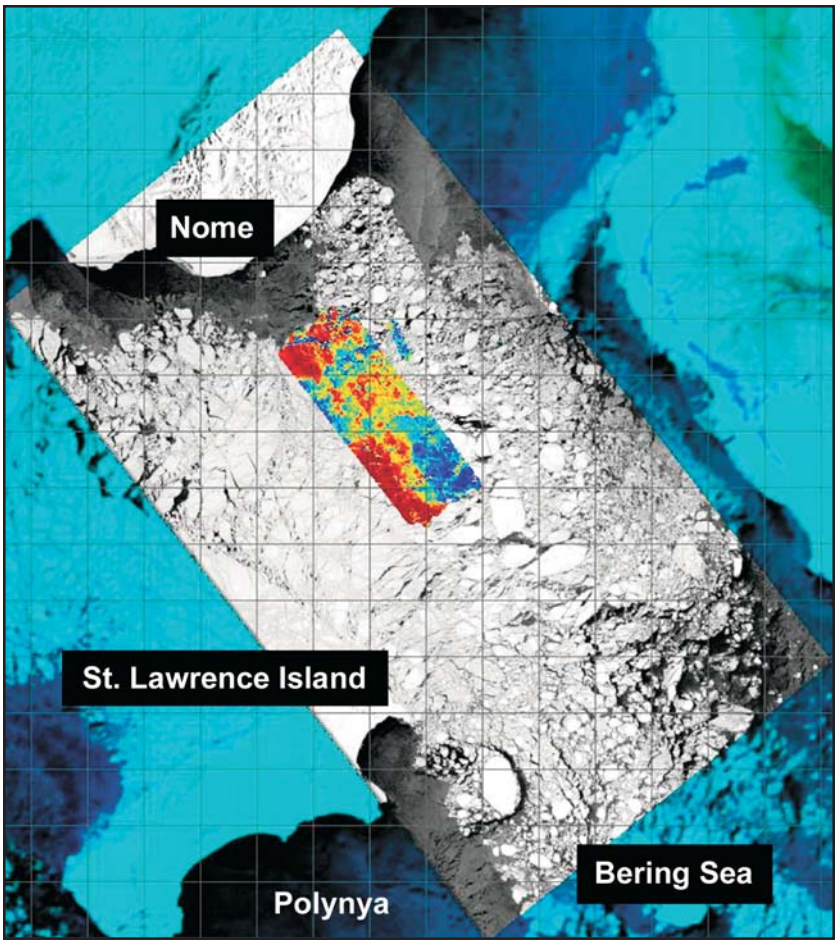
Arctic2003, the first of two coordinated Arctic satellite/aircraft/surface campaigns, was completed in March 2003. Seven flights were made with the NASA Wallops P-3B aircraft, covering portions of the Bering, Beaufort, and Chukchi Seas. Two of the seven aircraft flights were coordinated with scientists making surface measurements of snow and ice properties, including sea ice temperature and snow depth on sea ice at a study area near Barrow, Alaska, and at a Navy ice camp located in the Beaufort Sea. Two additional flights were dedicated to making heat and moisture flux measurements over the St. Lawrence Island polynya to support ongoing air–sea–ice process studies of Arctic coastal polynyas. The remaining flights covered portions of the Bering Sea ice edge, the Chukchi Sea, and Norton Sound.

The Arctic2003 aircraft flights also supported ongoing air–sea–ice process studies of Arctic coastal polynyas. The prime objective of the polynya flights is to assess the accuracy to which the AMSR-E sea ice concentration algorithms can map the size of coastal polynyas and to measure the degree of low ice concentration bias, if any, resulting from the presence of thin ice. A second objective is to directly measure surface heat and moisture fluxes over coastal polynyas to evaluate the parameterizations currently used in bulk formulation models and to measure the falloff of these fluxes downwind as the sea ice concentration and ice thickness increase.

Land Ice

The Greenland Ice Sheet

The primary focus of NASA's Arctic land ice research has been on assessing and understanding the mass balance of the Greenland ice sheet. Repeat surveys by airborne laser altimetry in the 1990s have revealed significant thinning of outlet glaciers draining the interior of the Greenland ice sheet, with thinning rates up to several meters per year. Of particular interest have been recent changes in the Jakobhshavn ice stream, Greenland's main drainage system and most active outlet glacier, with an annual discharge of about 30 km^3 of ice. It is one of the few recently surveyed glaciers to thicken between 1993 and 1998, despite locally warm summers. Repeated airborne laser altimeter surveys along a 120-km profile in the glacier basin show slow, sporadic thickening between 1991 and 1997, suggesting a small positive mass balance. However, since 1997 there has been sustained thinning of several meters per



PSR-A multicolor mosaic of a portion of the Bering Sea, from a NASA P-3 flight using the NOAA ETL PSR-A, overlain on a Landsat 7 ETM+ image (black and white), both for 15 March 2003. The Landsat image is centered on a NOAA-17 AVHRR image (blue). A 25-km AMSR-E grid is also shown for comparison. Polynyas are visible south of Nome, Alaska, and St. Lawrence Island.

year within 20 km of the ice front, with lower rates of thinning farther inland. Here, weather station data from the coast and the ice sheet were used to estimate the effects on surface elevation of interannual variability in snowfall and surface melt rates to infer the temporal and spatial patterns of dynamic thinning. These show the glacier to have been close to balance before 1997, followed by a sudden transition to rapid thinning, initially confined to lower reaches of the glacier (below about 500-m elevation), but progressively spreading inland. Between 1999 and 2001, thinning predominated over the entire surveyed region up to 2000-m elevation. If this continues, the glacier calving front, and probably its grounding line, will retreat substantially in the near future.

Observations between 1997 and 2001, showing a 30% velocity increase and up to 60 m of thinning of downstream parts of Jakobshavn Isbrae immediately following calving of about 4 km of its 15-km floating ice tongue, suggest that acceleration may have been initiated by the calving and that the force perturbation associated with such weakening is swiftly transmitted far up-glacier. Initially the observed changes are consistent with the comparatively small perturbation associated with the calving. Thereafter, it was probably sustained by thinning of the remaining ice tongue at rates of about 80 m per year. Otherwise, the force perturbation would soon have been balanced by reduction in the hydrostatic driving force for longitudinal creep as the glacier thinned, with velocities dropping to their former values. The calculated force perturbation increases to a maximum about 10 km inland of the grounding line, consistent with decreasing weight forces as the glacier thins over bedrock that slopes uphill seawards. Farther inland, it progressively decreases, probably because marginal drag increased as the glacier accelerated. Both here and on the floating tongue, marginal ice appears to have been softened by the influence of locally intense shear on ice temperature and/or fabric. More recent observations show continued acceleration and thinning, and most of the remaining ice tongue calved away in April 2003. Thus, thinning is likely to continue.

To fully appreciate the significance of these recent changes in Jakobshavn and other outlet glaciers, the magnitude of retreat and surface lowering must be placed within the broader context of retreat since the Last Glacial Maximum and, more significantly, retreat following the temporary glacier advance during the Little Ice Age (LIA). The instrumental record of glacier observations in Greenland dates back to aerial photography conducted by the Danes in the 1930s and 1940s. Glacier histories extending farther back in time must be based on geological information retrieved from formerly glaciated regions. In particular, the LIA maximum stand is marked by trimlines, a sharp boundary between unvegetated rocks recently deglaciated and vegetated surfaces at higher elevations.

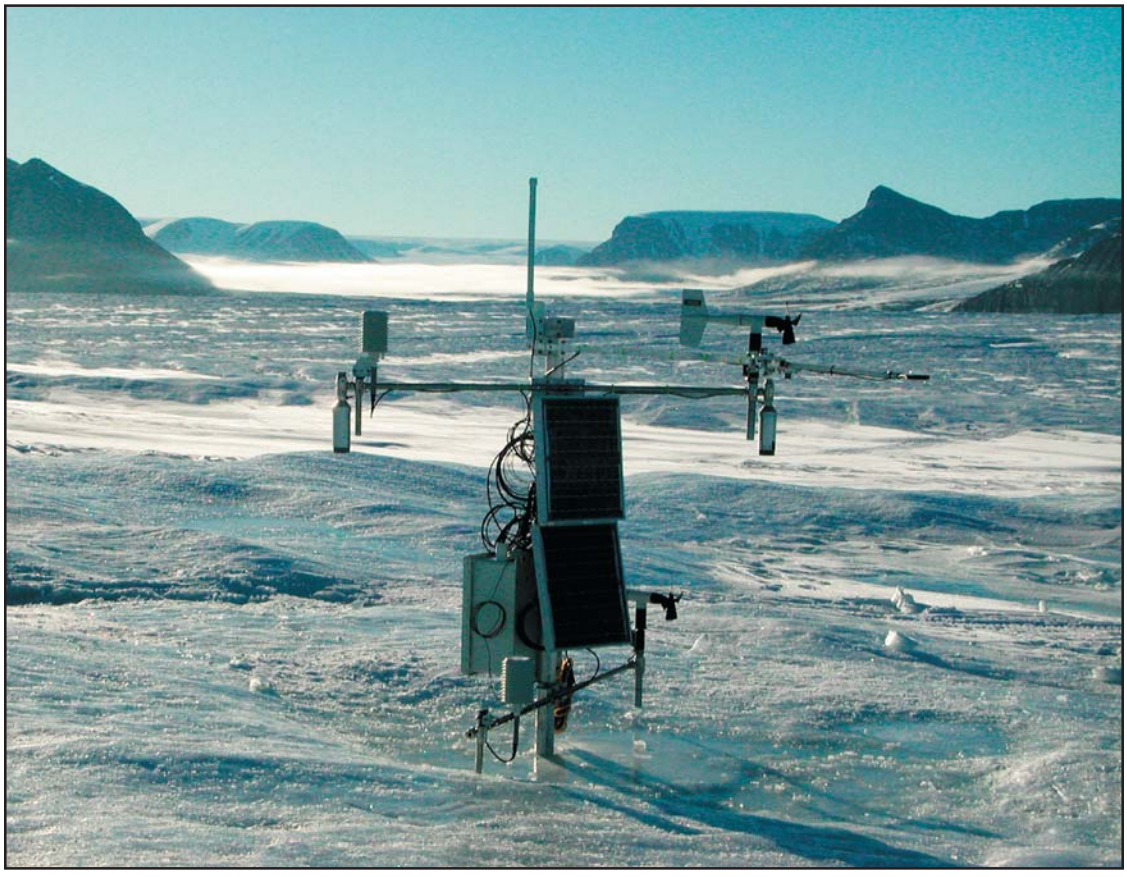
To evaluate whether multispectral satellite images can be used to map trimlines and to distinguish different surface types, a Landsat ETM+ image of Jakobshavn Isbræ and vicinity was aquired. Applying supervised classification, thirteen surface types were identified, ranging from bare ice, debris-covered ice, and open water, to different types of vegetative cover. Each surface type is characterized by its spectral reflectance curve. To support the interpretation of the various surface classes, field measurements were conducted during July 2003 at three camps near the ice margin. Spectra of typical landcovers (mosses, lichen, sand and gravel, freshly deposited sediments,

etc.) were measured in the spectral range from 350 to 2500 nm, thus including the six Landsat spectral bands. Spectra measured in the field were compared to spectra of the thirteen classified surfaces to validate our interpretation of these classes.

While in the field, moraine mapping was conducted with the intent to evaluate whether geomorphological landforms can be identified on satellite images. Unexpectedly, at the camp on the northern margin of the ice fjord, inspection of the surface below the trimline revealed a succession of lateral moraines consisting of boulders, gravel, and sand. These moraines were most likely formed at times when the ice margin was stationary or slowly changing, so each moraine signifies a period since the LIA during which the general trend of glacier thinning was interrupted. Accurately mapping these moraines involved extending a profile line from the trimline to the margin of the fjord ice for geomorphological mapping, and surveying it using a global positioning system and optical leveling to obtain accurate elevations. Also, along this profile, sizes of various lichen species were measured in an attempt to establish a dating curve. To assign ages to lichens of given size, a calibration curve was derived by measuring lichen sizes on surfaces of known exposure date in the town of Ilulisat. Further analysis of these data is in the process, but preliminary interpretation suggests that thinning of Jakobshavn Isbræ since the LIA occurred intermittently. Interestingly, periods of thinning do not correlate in a simple way with retreat of the calving terminus.

To enable the interpretation of changes observed by remote sensing measurements, NASA established the Greenland Climate Network (GC-Net), a network of 18 automatic weather stations (AWSs) and five smart stakes (less sophisticated AWSs with measurements at one level only) distributed over the entire Greenland ice sheet. Four stations are located along the crest of the ice sheet (at elevations ranging from 2,500 to 3,200 m) in a north–south direction, ten stations are located close to the 2,000-m contour line (1,830–2,500 m), and four stations are positioned in the ablation region (560–1,150 m).

The GC-Net was established in the spring of 1995 with the intention of monitoring climatological and glaciological parameters at various locations on the ice sheet for at least 10 years. The first AWS was installed at the Swiss Camp, followed by four AWSs in 1995, four in 1996, five in



Automatic weather station at Petermann Glacier (part of a joint project with the National Science Foundation described in the NSF section).

1997, four in 1999, one in 2002, and two in 2003. Some were temporary, and 18 remain functioning on a quasi-permanent basis. The objectives for the Greenland weather station network are to measure daily, annual, and interannual variability in accumulation rate, surface climatology, and surface energy balance at selected locations on the ice sheet and to measure near-surface snow density at the AWS locations for the assessment of snow densification, accumulation, and metamorphosis.

Currently 630 parameters are transmitted every hour, and until a site is revisited, transmitted data are used. All the AWS sites are revisited within 2–3 years depending on logistics and accumulation. Statistical procedures are applied to the GC-Net data in effort to improve data quality. These include rejecting impossible values and using a gradient threshold comparing the measurement with the next sequential hourly value. A moving sample interval scans the time series to identify and reject data beyond a variance threshold for a given sample size. In some cases a spectrum of window sizes is employed to reject outliers caused by occasional data scrambling by transmission errors. In general, the data that are rejected by these filters represent a minor fraction of the data volume. Once a station is revisited, continuous data are retrieved to replace the transmitted data.

An annual mean latitudinal temperature gradient of –0.78ºC per 1º of latitude was derived from the AWS data for the western slope of the ice sheet, while –0.82ºC per 1º of latitude was derived for the eastern slope. The mean annual lapse rate along the surface slope is 0.71ºC per 100 m, with monthly mean lapse rates varying between 0.4ºC per 100 m in summer and 1.0ºC per 100 m in winter. The annual range of monthly mean temperatures is between 23.5ºC and 30.3ºC for the western slope of the ice sheet, with increasing ranges from south to north and with increase in elevation. The annual mean air temperature was found to be 2ºC higher for the central part of Greenland for 1995–1999, compared to the standard decade 1951–1960.

In addition to providing climatological and glaciological observations from the field, further applications of the GC-Net data include the study of the ice sheet melt extent, which has been increasing over the last 2.5 decades; estimates of the ice sheet sublimation rate; reconstruction of long-term air temperature time series; assessment of surface climate; and the interpretation of satellite-derived melt features of the ice sheet. Potential applications for the use of the GC-Net data are comparison of in-situ and satellite-derived surface parameters; operational weather forecasts; validation of climate models; and logistic support for ice camps and Thule AFB.

Canadian Ice Caps

Analysis of data from airborne laser surveys has shown that, much like the Greenland ice sheet, the Canadian ice caps appear to be losing mass in their ablating margins, while at their higher elevation accumulation zones they are either thickening slightly or remaining fairly constant. For most of the ice caps in the Queen Elizabeth Islands, this thinning can be explained by warm temperature anomalies during the late 1990s survey period. However, in the south, on Baffin Island, large thinning rates, on the order of a meter a year, do not seem to be related to any short-term temperature anomaly but rather are more likely a result of ongoing mass loss associated with deglaciation since the mini-ice age several centuries ago.

Alaskan Glaciers

Recent surveys of Alaskan glaciers has shown significant wastage, estimated to be about 30% of the total glacier contribution to sea level rise.

As a complement to this work, digital elevation models (DEMs) of Bagley Ice Valley and Malaspina Glacier produced by 1) Intermap Technologies, Inc. (ITI) from airborne interferometric synthetic aperture radar (InSAR) data acquired 4–13 September 2000, 2) the German Aerospace Center (DRL) from spaceborne InSAR data acquired by the Shuttle Radar Topography Mission (SRTM) 11–22 February 2000, and 3) the U.S. Geological Survey (USGS) from aerial photographs acquired in 1972-73, were differenced to estimate glacier surface elevation changes from 1972 to 2000. Spatially non-uniform thickening, 10 ± 7 m on average, is observed on Bagley Ice Valley (an accumulation area), while non-uniform thinning, 47 ± 5 m on average, is observed on the glaciers of the Malaspina complex (mostly an ablation area). Even larger thinning is observed on the retreating tidewater Tyndall Glacier. These changes have resulted from increased temperature and precipitation associated with climate warming and rapid tidewater retreat.

Work on Alaskan glaciers supported by NASA during 2003 included acquisition of small-aircraft laser altimeter data on selected glaciers and icefields of the St. Elias Mountains in south-central Alaska and Yukon. Profile data were acquired on seven glaciers that had not been measured

Fjord near the Barnes Ice Cap on Baffin Island.

previously, and repeat profile data were acquired on five glaciers that had been measured previously. The latter included the largest glacier systems in continental North America; that is, Bagley Ice Valley–Bering Glacier and the Seward–Malaspina Glacier systems, which have areas, including all tributaries, of about 5,200 and 5,000 km^2, respectively. Repeat profile data were also acquired, and the position of the terminus was measured on Hubbard Glacier, which has been advancing and threatening to block the entrance to Russell Fjord. Ice dams caused by the advance of Hubbard Glacier have temporarily blocked this fjord entrance twice, in 1986 and 2002. If an ice dam forms that is strong enough to "hold," the economy of the nearby community of Yakutat may be threatened by redirection of the drainage of the fresh water that now discharges into the Gulf of Alaska via the fjord mouth. An additional study of Alaskan glaciers has included detailed investigations into the mechanisms that control surging behavior.

Arctic Climate Modeling

The goal of some of the more recent modeling efforts at NASA's Goddard Institute for Space Studies (GISS) was to investigate and develop more realistic sea ice/upper ocean models as part of the GISS GCM, with the ultimate purpose of improving the climate change forecast in the polar regions. Investigations focused on the model sensitivity to cavitating fluid and viscous–plastic dynamics; the oceanic mixing characteristics; and the viscosity diffusion models.

The primary improvement came from including the resistance to shear stress in the viscous–plastic dynamics: comparison to satellite data indicates much more realistic sea ice concentrations, thickness, and export through the Fram Strait. Reduced oceanic isopycnal mixing leads to reduced and thinner ice throughout the Arctic, while the viscosity diffusion produces expanded and thicker sea ice in the Arctic, both due primarily to their effect on North Atlantic Deep Water (NADW) production and associated heat transport. On the basis of these runs, composite experiments with the best combination of parameterizations were generated, which, besides affecting the sea ice, had influences of up to 4°C on atmospheric temperatures in the Arctic. Climate change experiments are underway to assess the polar region response with this new model.

Polar stratospheric clouds, as seen from the NASA DC-8 over southern Sweden on January 14, 2003.

Atmospheric Chemistry

The SAGE III Ozone Loss and Validation Experiment (SOLVE II) was a measurement campaign designed to examine the processes controlling ozone levels at mid- to high latitudes and acquire correlative data needed for the validation of the Stratospheric Aerosol and Gas Experiment (SAGE) III satellite measurements. SAGE-III is a NASA instrument aboard a Russian Meteor-3 satellite platform. SAGE-III is primarily used to measure high-latitude ozone loss.

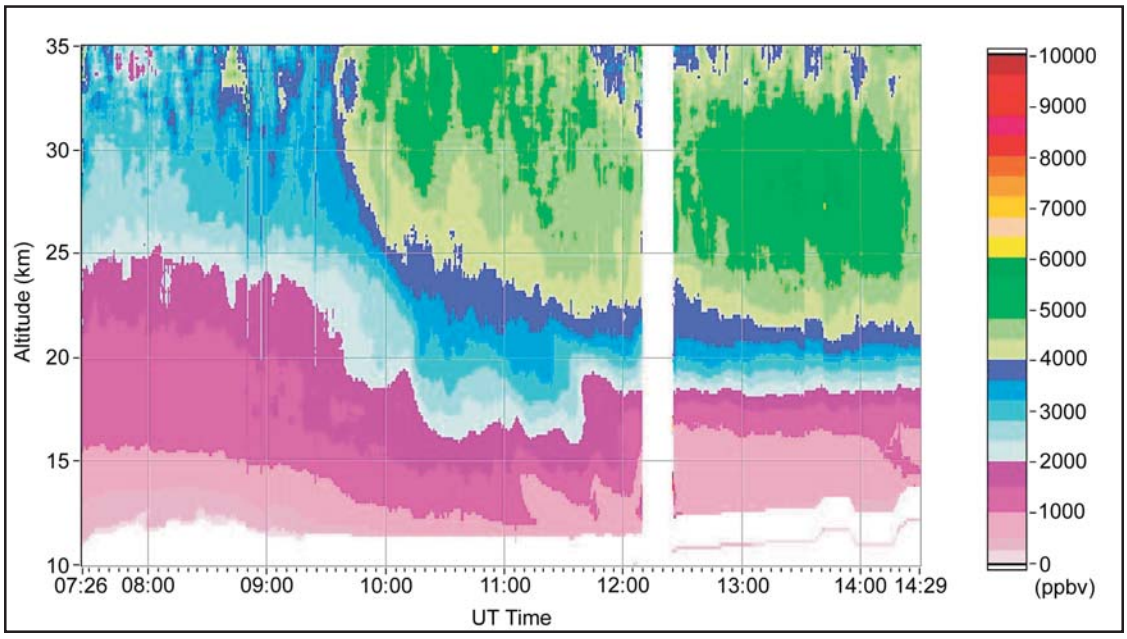
The SOLVE II mission was primarily conducted during January 2003. Measurements were made in the Arctic high-latitude region during winter using the NASA DC-8 aircraft, as well as two heavy-lift balloon flights, a number of smaller balloon packages, and ground-based instruments. The NASA DC-8 arrived in Kiruna, Sweden, slightly north of the Arctic Circle, on January 9, 2003. A total of 11 science flights were conducted in Kiruna, and the DC-8 returned to NASA Dryden on February 6, 2003.

Ozone loss in the polar stratosphere is directly caused by catalytic chlorine and bromine reactions. The high levels of reactive chlorine occur because of reactions of reservoir chlorine species on the surfaces of polar stratospheric clouds (PSCs). PSCs were observed by the NASA DC-8 lidar systems on the flights of January 9, 12, and 14 and February 4, 2003 at altitudes between 65,000 and 80,000 feet.

During the winter of 2002–2003, the polar vortex was cold and had moved southward toward Europe, exposing the air to sunlight. Normally ozone values in the core of the vortex near 20 km would be approximately 3 parts per million. However, because of the high levels of reactive chlorine, ozone steadily decreased over the course of the month. During early February, though, these values are near 1,500 ppbv, showing the very large ozone losses inside the polar vortex.

These initial results are only qualitative and will require further processing and quantitative analysis. These SOLVE II results will be directly used to quantify ozone loss in the vortex. The ozone values and ozone loss will then be compared to the SAGE III ozone values to validate our global observations of ozone.

Ozone values observed on the flight from Kiruna, Sweden, to California on February 6, 2003. The x-axis of the figure shows the time, while the y-axis shows altitude. The polar vortex was situated over Kiruna (left side of the figure), such that the low ozone values at 20 km on the left are inside the polar vortex. Typically values of ozone inside the vortex in January would be near values of 3000 ppbv (the aqua color).



Department of Commerce

National Oceanic and Atmospheric Administration

NOAA performs research in the high-latitude regions of the planet in connection with its environmental assessment, monitoring, and prediction responsibilities. Research programs focus on scientific questions that address the Arctic environment and its relation to the global environment.

Office of Oceanic and Atmospheric Research

Arctic Research Office

The Arctic Research Office was formed in FY 2000 to administer the Arctic Research Initiative and to build a NOAA program focused on Arctic science issues of national importance. For this purpose, the "Arctic" is defined loosely as the northern hemisphere land area underlain by permanent or discontinuous permafrost, and ocean areas subject to permanent or annual sea ice cover. Consideration of watersheds and airsheds that flow to the Arctic can extend the geographic boundaries significantly, as can consideration of the impacts of Arctic processes on hemispheric weather and climate. In FY 2003, newly appropriated funds became available to initiate a NOAA contribution to the interagency Study of Environmental Arctic Change (SEARCH).

Under the overall guidance of the NOAA Strategic Plan, the ARO has formulated more specific goals that relate to its specific mission:

- Characterize poorly known high-latitude marine habitats and understand and model factors controlling the populations of key marine species in the Arctic and sub-Arctic;
- Monitor ecosystem indicators of climate change;
- Understand ecosystem impacts of critical contaminants and human uses in the Arctic; and
- Understand the causes and impacts of atmospheric, oceanic, and climate variability and change in the Arctic.

Several projects are planned over the next few years to address these goals and contribute to the SEARCH Science Plan. These projects are:

- Retrospective Analysis of Ocean Climate and Populations of Key Living Marine Resources;
- Collaborative, international program of Arctic exploration;
- Bering Sea Ecosystem Study;
- Atmospheric and Cryospheric Change in the Arctic;
- Arctic/Sub-Arctic Ocean Fluxes;
- Arctic System Reanalysis;
- Arctic Climate Impact Assessment;
- Environmental Sources, Fate, and Impact of Mercury and Persistent Organic Pollutants in the Arctic;
- Assessment of Environmental and Economic Impacts of Oil and Gas in the Arctic; and
- Development of updated AMAP Strategic Plan.

To date NOAA has funded the following SEARCH programs.

Retrospective Analysis of Arctic Clouds and Radiation from Surface and Satellite Measurements. Recent studies have shown that Northern Hemisphere sea ice extent and thickness have been decreasing, while land surface air tempera-

	Funding (thousands)	
	FY 02	FY 03
Atmos Trace Constituents	800	300
Fisheries Assess/Manage	18,900	18,900
Marine Mammal Assessment	12,675	6,675
Ocean Assessment	15	10
Stratospheric Ozone	250	200
Data Management	357	331
Remote Sensing	388	273
Aircraft/Vessels	2,053	550
Weather Research	0	25
Western Arctic/Bering Sea Ecosys	7,507	2,050
Barrow Observatory	1,350	650
Ocean Exploration	808	250
Tsunami Warning/Env. Obs	250	250
Arctic Research Initiative	1,650	2,000
Ocean Observations/Arctic Fluxes	360	360
Arctic Climate Research (SEARCH)	0	2,000
CIFAR	0	350
Total	47,363	35,174

ture has increased markedly over the last 30 years. Arctic climate change has also been noted in the horizontal flux of precipitable water snowfall and in vegetation. While these studies indicate that the Arctic has been warming, it is not clear how other aspects of the climate system have forced the change. In particular, how do changes in surface and cloud properties interact and affect the surface radiation budget; that is, what is the cloud–radiation feedback?

Answers to these questions will only come through an analysis of multi-decadal data sets. Surface-based meteorological and radiation data have been collected at various locations across the Arctic for many years, with some observations dating back to the 1920s. However, surface stations are sparse, and many are scaling back operations. Satellite meteorological data sets that now span two decades provide a pan-Arctic perspective. While the measurement principles are very different, both types of observations offer the potential to detect and monitor climate change. For example, long-term measurements from meteorological stations have shown that the surface temperature of the Arctic land areas has been increasing over the past few decades. These trends have been verified by satellite data for the past 20 years, and trends in satellite-derived cloud amount and the cloud radiative effect have recently been reported. Similar trends found at surface stations corroborate the satellite findings.

Nevertheless, there is still much that can be learned from the historical surface and satellite data sets. Cloud and radiation fields need to be examined in more detail, other geophysical parameters should be examined, similarities and differences in surface and satellite-derived measurements need to be assessed, and regional trends must be explained. Furthermore, the interactions between parameters, such as the ice/snow albedo and cloud radiation feedbacks, are poorly understood. The objective of this element is to evaluate the degree to which historical and ongoing measurements can be used to answer SEARCH science questions and to aid in evaluating optimum locations for an expansion of the Arctic observing network. The task is to perform a retrospective analysis of coincident surface measurements and satellite-derived quantities, comparing one to the other and assessing the spatial and temporal variability in each parameter.

Atmospheric Observatory Site Selection Building National and International Linkages. This element contains three main objectives critical to the success of SEARCH. First, information on existing environmental monitoring in the Arctic will be compiled, and selected data sets will be analyzed for their usefulness in providing information on trend detection. The analysis is expected to yield information about the locations, time scales, and variables most likely to allow climate trends in the Arctic to be detected. Second, the combined information about current and optimal monitoring will help suggest strategic locations for atmospheric observing stations. The ability to build off or utilize existing measurements programs and infrastructure will be considered in developing recommendations for possible locations. Third, coordination and linkages will be developed between national and international polar programs and observing networks. This coordination will assist in maximizing the SEARCH measurement program goals.

Atmospheric Observatory. At present, the only continuous measurements of Arctic surface radiation, clouds, aerosols, and chemistry sufficient for detailed evaluation of interactive climate change processes in the lower atmosphere (0–15 km) are made in Barrow, Alaska. The Barrow facilities include the National Weather Service (with records from the 1920s), the NOAA/CMDL Baseline Observatory (in operation since 1972), and the DOE ARM North Slope of Alaska (NSA) site (in operation since 1998). It is the intention of the Atmospheric Observatory Element of the NOAA/SEARCH program to mirror the Barrow atmospheric measurements, first in northeastern Canada and at some later date in central Siberia.

The Canadian and Siberian regions have been selected based on the principal hypothesis of the SEARCH program that Arctic climate change is related to the Arctic Oscillation (AO). There have been observations of large-scale co-variability between a number of climatic variables (surface temperature, hydrological balances, cloud cover, winds) with the primary modes of the Arctic Oscillation. Analyses suggest that one of the most significant AO-related trends over the last 50 years is warming in eastern Siberia and cooling in the northeastern Canada–western Greenland region. The Barrow site appears to be in a region of lower variability with respect to the AO, so additional measurements in the regions where AO-related variability is expected to be the most pronounced are desirable. A coordinated set of intensive atmospheric measurements in Alaska, northeastern Canada, and Siberia will not only provide important observational records on regional variations

within the Arctic but will also provide key data sets for validating satellite measurements and improving model parameterizations.

Correction of Systematic Errors in TOVS Radiances. The TIROS Operational Vertical Sounder (TOVS) instrument has flown on NOAA polar-orbiting satellites since 1979 and has collected one of the longest and most complete satellite data records in existence. It was originally designed to serve the weather forecasting community by providing temperature and moisture profiles in regions of the earth that have few conventional meteorological stations. The TOVS data can also be used to retrieve cloud properties (coverage, cloud-top height, optical depth, and phase) and surface properties (skin temperature, surface type, and drag coefficient). While this instrument was intended for operational applications, many researchers have demonstrated its tremendous potential for studying a wide range of climate applications as well, particularly in regions with poor coverage of conventional measurements, such as the Arctic Ocean and adjacent seas.

A problem arises in using TOVS data for climate applications, however, as the radiances were not adequately calibrated for long-term accuracy. Consequently, substantial systematic errors from various sources greatly reduce the potential value of TOVS observations for monitoring and understanding climate change. The proposed work will attempt to identify, quantify, and mitigate these errors, with the ultimate goal of producing a 20-year (or more) record of TOVS radiances and retrieved products that are as error-free as practicable, given available resources. Many of the known errors should be regionally and seasonally independent, but some may be peculiar to or exacerbated by Arctic conditions. Thus, while the efforts will be global, the focus will be primarily Arctic. The expected product of this investigation will be a data set of tremendous value for geophysical retrievals with sufficient accuracy to identify changes since 1979, as well as for direct assimilation by numerical atmospheric models.

Observations for SEARCH: Data Integration for Arctic Reanalysis and Change Detection. Unaami, the changes in the Arctic that are the subject of the SEARCH program, became apparent to researchers in the context of long-term and pan-Arctic observations. In November 2001 the SEARCH Workshop on Large-Scale Atmosphere/Cryosphere Observations reached two related conclusions:

- There is no cohesion among various Arctic disciplines and data types to form a complete observation set of Arctic change; and
- Present data are vastly underutilized in understanding Arctic change.

The proposed work will address these conclusions by assessing what data are relevant to SEARCH reanalysis and change detection activities, collecting these data from a wide variety of sources, and facilitating the SEARCH research community's access to the data. The work will be carried out in cooperation with Jim Overland, PMEL, as a contribution to the NOAA SEARCH Arctic Change Detection and Reanalysis efforts.

There are many existing observational data sets that may be useful to SEARCH but that are underutilized for reasons that may include:

- They cover only a limited length in time or spatial extent;
- They have unknown accuracy and limited or no information about observing methods;
- They are not an ongoing record;
- They are inaccessible or costly to acquire; or
- The research community is unaware that they exist.

In addition to observational data sets, there are data streams that are underutilized. For example, only about 10% of the Russian national station network data are internationally exchanged over the GTS system and included in quality-controlled data sets available from U.S. national data centers.

These underutilized data sources are not optimal because of the effort required to use them, but at the same time they can be vitally important to reanalysis and change detection efforts. For example, the planned Arctic reanalysis will assimilate precipitation data in order to improve how the model treats moisture. Yet precipitation measurements are especially problematic in the Arctic, there are a number of data sets with differing characteristics, and a data stream for ongoing measurements has not been identified. Permafrost extent, borehole temperature, and active layer depth are sensitive indicators of climate change and therefore good candidates for climate indices. These observations reside in a number of institutions around the world, and here the challenge will be to obtain and combine data sets into useful Arctic-wide products.

Arctic Change Detection. A major task outlined in the SEARCH Science Plan is to determine how current and retrospective observations can be best used and enhanced to understand and anticipate the course of the ongoing changes in the Arctic. This project will address the highest prior-

ity identified in the SEARCH Implementation Plan, specifically, to understand the key characteristics of the multivariate change in the Arctic in space, time, and persistence.

There is a need for high knowledge return on existing and future data and for the capability to supply this information to nonspecialists and interdisciplinary researchers. This is a challenging task. It seeks to include operational weather and climate data rather than relying on a focused experimental design such as SHEBA. It is multidisciplinary, and its goal is knowledge extraction, a task beyond the development of data archives, or even data accessibility. The development of an Arctic Change Detection protocol is a necessary SEARCH startup activity.

While many SEARCH activities seek to documenting Arctic climate processes, this project will assume a larger role of providing the global change and broader communities with a clear understanding of the complex changes that are occurring in the Arctic. Communicating climate change information is a difficult process. NOAA's new role as a leader of the U.S. Climate Program makes this function all the more necessary, as NOAA has an explicit responsibility for communicating scientifically validated Arctic status and change information.

There is some recent help in this process. The field of data mining has now been extended to knowledge discovery, which recognizes the important step of consolidating information into knowledge and communicating the results. Certain guidelines for communicating climate change detection and ecological indicators to decision makers and the public are being articulated. Of particular importance is the issue of uncertainty. Methods for the rational use of environmental indices is also developing rapidly.

A broad review of recent changes in the Arctic has been accomplished. Of importance now is to reduce this information to a set of several key indicators of Arctic change and to relate the magnitude, location, and causes of current changes (the previous 30 years) to extremes in earlier historical and proxy records.

Initiation of an Arctic Reanalysis Activity in SEARCH. At the SEARCH Workshop on Large-Scale Atmosphere/Cryosphere Interactions (in Seattle, WA, in November 2001), the presentations and discussions provided several reasons why a compelling case could be made for an Arctic reanalysis. First, the reanalysis would produce long time series of temporally and dynamically consistent fields (subject to changes in observing system input) of Arctic upper-air and surface winds, humidities, and temperatures for studies of circulation variability, for budget studies, and for the driving of sea ice and ocean models. Second, the atmospheric component of the reanalysis would provide fields for which direct observations are sparse or problematic (such as precipitation, evapotranspiration, radiation, and clouds) at higher spatial and temporal resolution, and with greater reliability, than from existing reanalyses. Third, the system-oriented approach required for a reanalysis would provide a community focus, involving at least the Arctic terrestrial, sea ice, and atmospheric communities. Fourth, the reanalysis would leverage upon, and provide a synthesis of, Arctic field programs (SHEBA, LAII/ATLAS, ARM), capitalizing on prior investments by bringing field results to bear on the parameterizations used in large-scale models. Finally, the groundwork for an Arctic regional reanalysis can now be performed by capitalizing upon ongoing efforts such as ERA-40 and NCEP's North American Regional Reanalysis (NARR), as well as recently compiled Polar Pathfinder products from satellites. The coincidence of this groundwork and the spin-up of SEARCH provides a unique window of opportunity for an Arctic reanalysis. However, in addressing the viability of an Arctic system reanalysis, the recent workshop report notes that preliminary activities need to be undertaken now if SEARCH is to capitalize on this window of opportunity. For example, the reprocessing of the TOVS radiances will likely require several years. In addition, the momentum provided by ERA-40 and NCEP's NARR can be harnessed for SEARCH only if the Arctic output from these efforts is evaluated by the Arctic community, allowing for the implementation of parameterizations tailored to Arctic conditions. The enhancement of ERA-40's Arctic performance resulted from several years of such evaluation (and associated enhancements) of ERA-15 by a core of Arctic investigators.

Monitoring Ice Thickness in the Western Arctic Ocean. Recent studies indicate that the sea ice cover is undergoing significant climate-induced changes, affecting both its extent and thickness. For instance, satellite-derived estimates of maximum ice extent suggest a net reduction between 1978 and 1996, at an average rate of –3% per decade. A recent report indicates an even more rapid reduction in the perennial sea ice cover: –9% per decade. Data on the ice thickness, derived from submarine-based upward-looking

sonar, also suggest a net thinning of the sea ice cover since 1958. NOAA is continuing to monitor these changes to improve the fundamental understanding of the role of the sea ice cover in the global climate system and to take advantage of the sensitivity of the sea ice cover as an early indicator of the magnitude and impact of climate change.

The extent of the sea ice cover is effectively monitored from satellite platforms using passive microwave imagery. Monitoring changes in the ice thickness is more problematic. As with ice extent, the ideal platform for monitoring ice thickness is a satellite because it provides a full-basin perspective. However, to date, no technique has been adequately developed to obtain satellite-based measurements of ice thickness. Until satellite imagery can be used to monitor ice thickness, we must rely on measurements made from submarines, aircraft, seafloor moorings, and drifting buoys. As determined at the recent SEARCH Workshop on Large-Scale Atmospheric/Cryospheric Observations, this is most effectively done through a coordinated effort to establish a large-scale sea ice observing system. It is also necessary to disseminate the data collected from the various components of this system to the scientific community in a timely and consistent fashion. Once available, the data can be used to gain insight on the relationship between the characteristics of the sea ice cover and climatic forcing. Specific emphasis should be placed on efforts to work in tandem with those developing satellite-based assets designed to measure ice thickness. Data from the ice-based observing system can play a central role in assuring an optimal approach for obtaining accurate satellite-based measurements. Together, these platforms can provide an effective means of assessing the state of the sea ice cover over the entire Arctic basin.

The primary objective of this proposal and the related proposal "Monitoring the Eurasian Basin of the Arctic Ocean" is to establish and maintain a large-scale sea ice thickness observing system. The establishment of two distinct elements recognizes the different logistical challenges in the western and eastern sectors of the Arctic region. This proposal focuses specifically on measurements within the western sector of the Arctic. This sector of the Arctic is currently more accessible and therefore makes it feasible to conduct a program involving instrumentation that must be maintained after deployment. Within the western sector of the Arctic, this proposal seeks to initiate an array of moored upward-looking sonar (ULS) and drifting buoys. In the eastern sector of the Arctic, the focus of the proposal "Monitoring the Eurasian Basin of the Arctic Ocean," the instrumentation would be limited to the drifting buoys, which only need support during the deployment phase. Recently, it has been revealed that the Russians plan to establish a permanent, manned ice camp within the eastern sector of the Arctic, which will be available to the scientific community at large as an operational platform. If this resource becomes a reality, it may be possible to extend the deployment range of the moored ULS.

Instrumentation within the large-scale observing network will be located to complement existing measurement sites and activities and to take advantage of historical data records. Specifically, it will augment the data currently being collected at the North Pole Environmental Observatory (NPEO, http://psc.apl.washington.edu/northpole/), by the International Arctic Buoy Program (IABP, http://iabp.apl.washington.edu/), and from SCICEX cruises. Specific site locations will be determined using models of ice motion, which incorporate recorded observations. Data from the observation sites will be combined with data from other sources to produce annual reports on the state of the sea ice cover, including both its extent and thickness. A contextual setting for current data will be established by summarizing earlier western Arctic observations of sea ice mass balance over an annual cycle, beginning in 1957. The availability of data in the Russian literature, which is likely to cover the eastern Arctic, will also be investigated.

Monitoring the Eurasian Basin of the Arctic Ocean. NOAA has funded a network of automatic data buoys to monitor synoptic-scale fields of sea level pressure, surface air temperature, and ice motion throughout the Arctic Ocean as recommended by the U.S. National Academy of Sciences in 1974. Based on the Academy's recommendation, the Arctic Ocean Buoy Program was established by the Polar Science Center (PSC), Applied Physics Laboratory (APL), University of Washington, in 1978 to support the Global Weather Experiment. Operations began in early 1979, and the program continued through 1990 under funding from various agencies. In 1991 the International Arctic Buoy Program (IABP) succeeded the Arctic Ocean Buoy Program, but the basic objective remains—to maintain a network of drifting buoys on the Arctic Ocean to provide meteorological and oceanographic data for real-time operational requirements and research purposes, including support to the World Climate Research Programme

and the World Weather Watch Programme.

Dramatic changes in Arctic climate have been noted during the past two decades. Observations from the IABP have played a significant role in the detection of this change over the Arctic Ocean. For example, IABP data have shown that sea level pressure has decreased, surface air temperature has increased, and the circulation of sea ice and the ocean have changed so as to flow less clockwise. In addition to studies of Arctic climate and climate change, observations from the IABP are also used for validating satellites, for forcing, for validation and assimilation into numerical climate models, and for forecasting weather and ice conditions.

The continued success of the IABP, and our ability to monitor many aspects of Arctic climate change, depend on maintaining and further developing the buoy network. The buoys drift with the sea ice and have finite life spans, so a tremendous amount of resources are required to purchase and deploy buoys to maintain the buoy network. In the past the IABP was able to seed the buoy network in the Beaufort Sea, and the large, clockwise gyre circulation would carry the buoys out to cover the Arctic Ocean. However, given the changes in circulation, the Beaufort Gyre has shrunk, and maintaining the buoy network in the Eurasian Arctic has been more difficult. For example, the latest map of buoys on the Arctic Ocean shows that only 6 of the 26 buoys in the network are monitoring the Eurasian Basin.

Monitoring the Eurasian Basin is important, as this is the center of many of the changes in Arctic climate. For example, the decrease in sea level pressure, the warming in surface air temperature, and the thinning of Arctic sea ice are most significant in this area. One could ask, did the increase in surface air temperature act to thin sea ice, or did the thinner sea ice allow more heat to flux from the ocean to warm the atmosphere? It has been hypothesized that the dynamic thinning of sea ice driven by the changes in atmospheric circulation causes the increasing trends in surface air temperature. Enhanced buoys will be placed in the Eurasian Basin of the Arctic Ocean in 2004 to monitor the thickness of sea ice. Establishing a record of climate-induced changes in the thickness of the sea ice cover is essential to understanding the role of the sea ice cover in the global climate system and to using the sea ice cover as an early indicator of climate change in the polar regions. As explained in the recent report on the SEARCH Workshop on Large-Scale Atmosphere/Cryosphere Observations, buoys within the IABP network can play an important role in monitoring changes in ice thickness by enhancing their measurement system.

Oceanic Observations of Climate Change in the Arctic–Subpolar Zone. This is a new, multiyear project to observe water masses and fluxes of water, salt, heat, ice, and tracers between the Arctic Ocean and the sub-Arctic seas. The goal is to provide understanding of the changing state of the Arctic and anticipate its future. The logistic issues are severe and require innovative observational platforms as proposed here. The project will utilize sea-gliders and ice-hardened moorings to provide the physical data. A retrospective analysis of existing tracer data will provide context for the new data.

Ecosystem Change in the Northern Bering Sea. This project investigates the hypothesis that recent anomalous spring and summer productivity on the Northern Bering Sea shelf relates to decadal-scale atmospheric/sea ice/oceanographic processes, reflecting regime-induced climate changes in the western Arctic. Recent work shows that there are hot spots of biological productivity southwest of Saint Lawrence Island and that this productivity has been decreasing over the past decade. The Bering Sea is shifting to an earlier spring transition, based on ice melt and changes in atmospheric circulation patterns. Since changes in the north Pacific Ocean show little long-term trend while the trend in Arctic Oscillation appears to be a clearly increasing climate signal, the northern Bering Sea is an important location to monitor for ecosystem changes. The recent studies demonstrate the timeliness for increased focus on the ecosystem of the northern Bering Sea. Such a program would include the following tasks:

- A retrospective analysis of all northern Bering Sea data to put future changes into context and to provide an objective measure for change detection;
- Establishment of a northwest Bering Sea biophysical oceanographic mooring to document ongoing changes, similar to the successful multiyear FOCI mooring, M2, on the southeast Bering Sea shelf; and
- Process studies of the northern biological hot spots, primarily funded by non-NOAA sources.

Ice Dynamics and Oceanography

NOAA supports a program to carry out observations and modeling of the freshwater dynamics connecting the Arctic and Atlantic Oceans. Concentrated activity occurs where the Arctic and

Atlantic meet and interact. Increasing amounts of fresh water have been pouring out of the Arctic and, in combination with intensified winds, have altered the circulation of the Atlantic. Improved observations of water masses and fluxes of water, salt, ice, and tracers between the Arctic and the Atlantic will help us understand this changing state and anticipate its future. An investigator at the University of Washington is studying observational and modeling methods relevant to the intense flows linking the Arctic and Atlantic Oceans. He is examining the feasibility of an affordable but adequate long-term measurement program in the Canadian Archipelago and Davis Strait, the Labrador Sea, and the Labrador continental shelf.

NOAA is continuing to study the variability of thermohaline circulation and freshwater storage in the Arctic Ocean. The Arctic Ocean and its marginal seas are key areas for understanding the Arctic climate system and its change through time. Changes in the freshwater balance would influence the extent of sea ice cover; changes in surface albedo, energy balance, temperature, and the salinity of water masses; and biological processes in the Arctic.

Ocean and Coastal Ecosystems and Living Resources

NOAA has undertaken several programs focusing on ocean ecosystems, including analyses in the Bering Sea region to study climate variability and its impacts on ecosystems and a study of the trophic pathways on the Chukchi–Beaufort shelf. Microalgae grow on the undersurface of sea ice as well as within the sea ice matrix and are a well-known feature of Arctic ecosystems. They contribute a poorly known proportion of the total primary production in Arctic seas, and recent studies suggest that ice algal primary productivity has been greatly underestimated. Ice algae are important to microbial food webs and the dissolved and particulate carbon and nitrogen pools of the Arctic Ocean. Novel techniques are being used to quantitatively trace carbon fixed by ice algae and water column phytoplankton through pelagic and benthic food webs using conservative fatty acid signatures. The results of this work will help us understand trophic dependencies and carbon budgets in Arctic food webs and predict the effects of environmental change caused by global warming and further reductions in sea ice.

NOAA's Arctic Research Office has supported projects to examine possible connections between Arctic climate and oceanic change and the declining Steller's sea lion population. The areas of interest include the impacts of climate change on the Bering Sea ecosystem over the past 500 years, retrospective studies of climate impacts on Alaskan Steller's sea lions, the nature of North Pacific regime shifts and their impacts on Steller's sea lions, ocean climate variability as a potential influence on Steller's sea lion populations, north Pacific climate variability and Steller's sea lion ecology, interannual variability of biophysical linkages between the basin and shelf in the Bering Sea, and climate-driven bottom-up processes and killer whale abundance as factors in Steller's sea lion population trends in the Aleutian Islands. The National Marine Mammal Laboratory's Alaska Regional Office and Protected Resources Management Division are responsible for research on the management of 22 species of marine mammals that commonly occur in Alaska, including the Steller's sea lion.

NOAA's Resource Assessment and Conservation Engineering Division and Resource Ecology and Fisheries Management Division are promoting a full-scale program to provide information on the run characteristics of Yukon River Chinook salmon. Over 1,100 fish will be radio-tagged near the river mouth and tracked to upriver spawning areas to provide information on stock composition and timing, nation of origin, migration patterns, and the location of previously undocumented spawning areas.

NOAA's Pacific Marine Environmental Laboratory (PMEL) conducts fisheries oceanography and ecosystem studies in the Bering Sea and the western Gulf of Alaska. Fisheries–Oceanography Coordinated Investigations (FOCI) is a cooperative program among PMEL, NMFS's Alaska Fisheries Science Center, NOS's Coastal Ocean Program, and the University of Alaska. FOCI's goals are to increase understanding of the Alaskan marine ecosystem, to document the role of walleye pollock in the ecosystem, to determine factors that affect pollock survival, and to develop and test annual indices of pre-recruit pollock abundance. FOCI is also investigating decadal variability and climate change of the North Pacific and western Arctic, particularly in light of the declining Steller's sea lion population.

Underwater Research

In 2002 NOAA funded the development of an ROV, the *Global Explorer*, to investigate under-ice life, the water column, and the seafloor of the

deep Canada Basin and the Northwind Ridge. This program, called Arctic 2002, was a collaboration between NOAA's Ocean Exploration Office and Arctic Research Office, the Canadian Department of Fisheries and Oceans, JAMSTEC, and institutes in China. The objectives were to take censuses of marine life in unexplored regions of the Arctic. Baseline transects are needed to be able to quantify changes in the ecosystems over space and time.

As a follow-up to this mission, NOAA's Ocean Exploration Office and the Arctic Research Office supported a multibeam mapping expedition to the Chukchi Cap and the Northwind Ridge on the USCGC *Healy* during the summer of 2003. During this expedition, scientists from NOAA, the University of New Hampshire, and other partners discovered and mapped a new complex underwater seamount (larger than Mount Rainier) lying at the northernmost end of the Chukchi Plateau. The scientists mapped 1,530 nautical miles of the 2,500-m depth contour of the continental slope north of Alaska as they accomplished the U.S.'s first Law of the Sea ocean mapping surveys in the Arctic Ocean. Before the expedition, existing charts of the Arctic seafloor showed only a small knoll where the seamount was discovered. The team also discovered water depths of more than 4,000 meters, depths not previously measured anywhere in the Amerasian Basin of the Arctic Ocean. The expedition also added important information about ice age glaciation and past climates. Randomly oriented seafloor scours, mapped at depths of 300–400 m, provide evidence of large icebergs scraping the seafloor. In addition, large pockmarks discovered on the Chukchi Plateau seafloor sediments are indicative of active venting of gas from the seafloor. The expedition also obtained oceanographic data that will improve knowledge of the water masses and circulation in the Arctic.

Climate and Weather

NOAA is supporting a program to study the recent changes in sea ice and snow cover and their impact on the Arctic Oscillation (AO). Changes are occurring in the Arctic that appear to have begun in the late 1960s and increased in the 1990s. These include tropospheric warming, reduction in ice extent, and increased variability in snow cover. Ecological impacts of these changes are already being noted. Much scientific interest has focused on the AO, which represents an Arctic-wide increase in upper atmosphere winds and decrease in sea level pressure. A paradox is that the main shifts in the AO are seen in mid-winter, while many of the surface changes are seen in spring and summer. A second issue is whether the reductions in sea ice and snow cover in the western Arctic actually have an impact on the atmosphere. The goal of this project is to determine the impact of the AO on low-level wind and temperature fields in spring in the Arctic and to evaluate the magnitude of feedback from sea ice and snow anomalies to the atmosphere in spring and summer.

Glaciology and Hydrology

NOAA has supported a program to study the hydrologic response of Siberian major rivers to climate change and variation. Arctic rivers are an important component in global ocean and climate systems, and recent studies have shown remarkable changes in hydrologic regimes of the major rivers in Siberia over the past several decades. This project, at the University of Alaska Fairbanks, is a comprehensive assessment of change and variability in Siberian river systems and their connections to surface climate and atmospheric circulation.

Climate Monitoring and Diagnostics Laboratory

The Climate Monitoring and Diagnostics Laboratory (CMDL) conducts sustained observations and research related to source and sink strengths, trends and global distributions of atmospheric constituents that are capable of forcing climate change through modification of the atmospheric radiative environment, those constituents that may cause depletion of the global ozone layer, and those that affect baseline air quality. CMDL accomplishes this mission primarily through long-term measurements of key atmospheric species at 65 sites spanning the globe, including five well-instrumented and manned Atmospheric Baseline Observatories at Barrow, Alaska; Trinidad Head, California; Mauna Loa, Hawaii; American Samoa; and South Pole.

In the Arctic, CMDL measurements include carbon dioxide, carbon monoxide, methane, nitrous oxide, surface and stratospheric ozone, halogenated compounds including chlorofluorocarbon (CFC) replacements, hydrocarbons, sulfur gases, aerosols, solar and terrestrial UV, and broadband and infrared radiation. In addition, field campaigns in key regions, utilizing an array of platforms including aircraft, balloons, ocean vessels, and towers, complement the long-term measurements. The CMDL data are used to assess climate forcing, ozone depletion, and baseline air quality; to

develop and test diagnostic and predictive models; and to keep the public, policy makers, and scientists abreast of the current state of our chemical and radiative atmosphere.

CMDL Arctic Baseline Atmospheric Observatory Operations. CMDL has operated the Atmospheric Baseline Observatory at Barrow, Alaska, (BRW) for 30 years. In addition to the 24 core atmospheric baseline measurement projects, BRW supports 20 cooperative research projects, with the majority coming from universities or agencies in Alaska. As part of the Barrow Arctic Science Consortium (BASC) facilities upgrade, CMDL is in the design phase of a new observatory building at the present BRW site. Construction is set to begin in late 2004.

At Summit, Greenland, a National Science Foundation research site, CMDL initiated year-round carbon-cycle air flask sampling and in-situ surface ozone and black carbon measurements in the spring of 2003. CMDL collects weekly pairs of discrete samples from a 65-site global network that includes Arctic or near-Arctic sites at Barrow, Cold Bay, and Shemya, Alaska; Ocean Station "M"; Heimaey, Iceland; Alert, Canada; Pallas, Finland; and Ny Alesund, Spitzbergen, in addition to the sampling at Summit, Greenland. Vertical profiles of a large suite of trace gases are obtained over Poker Flats, Alaska, on a biweekly basis, with an aircraft flying profiles to 8,000 m above sea level.

Boreal Forest Fire Impact on Global Tropospheric Chemistry. Continued studies by CMDL and the University on Maryland on the transport and atmospheric effects of effluents from the 1998 and 2000–2003 fires in Siberia show that the effects of these fires are sensitive to their timing and location. While the 2003 boreal fires burned a greater area than any previous year on record, the hemispheric increase in CO was much smaller than that observed during 1998. The early-season fires of 2003 may have produced large amounts of CO, but seasonally high levels of photochemically derived OH efficiently removed the CO from the troposphere. In contrast, the late-season fires in 1998 occurred when OH production was decreasing towards its seasonal minimum, leaving less OH to react with the fire-produced CO. Several laboratories are using CMDL data in global chemical-transport models to better understand the factors that link forest fires with their broader impact on the global atmosphere.

Measurements of Ozone-Depleting and Climate-Forcing Gases in the Arctic Troposphere and Stratosphere. From January 2002 through February 2003, CMDL scientists participated in the NASA SAGE III Ozone Loss and Validation Experiment (SOLVE-II), a high-altitude airborne research campaign with deployments out of NASA Dryden Flight Research Center at Edwards Air Force Base, California, and Kiruna, Sweden. During SOLVE-II the CMDL PAN (peroxyacetylnitrate) and Trace Hydrohalocompounds Experiment (PANTHER) instrument, along with 13 other instruments onboard the NASA DC-8 platform, sampled air from the midlatitudes across the Arctic vortex edge and into the vortex core region. In January the northern vortex broke into two lobes and then rejoined, thereby trapping midlatitude air inside the vortex. The subsequent mixing of this air, coupled with the production of numerous polar stratospheric clouds (PSCs), allowed the mission scientists to conduct a suite of unique measurements leading to a highly successful mission. A major goal of calibration and validation comparisons between the aircraft instrumentation and remote NASA SAGE III satellite measurements was achieved.

Observations of Stratospheric Water Vapor During SOLVE II. During the winter of 2002–2003, balloon profile measurements were carried out in Sweden, Finland, and Norway using the CMDL cryogenic, chilled-mirror hygrometer to measure water vapor in the stratosphere up to altitudes of approximately 25 km. During this campaign, significant dehydration was not noted in the profiles, unlike several previous campaigns in which there was some dehydration of the stratosphere in the Arctic vortex. This lack of dehydration in the Arctic stratosphere is in contrast to the Antarctic, where extensive polar stratospheric cloud formation and subsequent dehydration takes place on a large scale.

Surface Ozone Observations in the Arctic. Sites operated by CMDL make surface ozone observations in three distinct regimes within the Arctic. Barrow represents an Arctic Ocean environment with seasonal ice cover. Summit, Greenland, is a high-altitude site on the permanent ice cap, while Westman Islands, Iceland, is representative of a high-latitude site on the permanently ice-free North Atlantic. At Barrow in the spring, there are numerous episodes of ozone depletion that may persist for several days and often completely remove ozone from the lower atmospheric boundary layer. At Summit and Westman Islands, on the other hand, events of this type are not seen. This demonstrates that both the ocean environment and sea ice formation are critical ingredi-

ents in the ozone-depletion process. Halogen compounds (primarily those containing bromine) processed on the Arctic ice pack, in the presence of increasing spring sunlight, are the primary catalysts for ozone loss in what appears to be a natural process.

Study of Environmental Arctic Change. Beginning in FY 2003, CMDL became involved in two elements of SEARCH funded through the Arctic Research Office: Retrospective Analysis of Arctic Clouds and Radiation from Surface and Satellite Measurements, and Expansion of the Arctic Network of Climate Monitoring Observatories. The following summarizes the CMDL involvement in SEARCH.

Trends in Sea Ice Extent and Snow Cover in the Western Arctic. The spring snowmelt date has been monitored at BRW for many years. Since 1940 the spring melt at BRW has advanced by about 10 days (±4.8 days). Most of the advance occurred after 1976, when a major regime shift occurred.

Incursions and Impact of Asian Dust Over Northern Alaska. Using an assimilation of data collected at BRW, the direct effects of atmospheric aerosols on the surface radiation budget in the Arctic are being monitored. In the past the focus has been on Arctic Haze, which is air pollution transported from Eurasia to BRW each spring. Spectral aerosol optical depth measurements are used to differentiate dust from haze; dust contains much larger particles and is often of higher optical depth. Because polar atmospheres are generally very clean, even small increases in aerosol concentrations can perturb the radiometric structure of the atmosphere and thus the surface energy balance.

During the spring of 2002, massive dust storms in the Gobi Desert region of Mongolia lofted dust into the atmosphere, where it was transported eastward in a broad plume that reached and crossed the continental U.S. Some of this dust was also blown over northern Alaska, passing over BRW. CMDL measurements show that when Asian dust is present in the Arctic atmosphere, the surface tends to cool but to a lesser extent than at lower latitudes that are free of snow. Even though these Arctic dust events are episodic and occur mainly in late winter through spring, their effect is not insignificant when they are present. Should the Arctic atmosphere become more turbid in the future, projections of enhanced warming in the the Arctic due to greenhouse gases could be episodically negated because of this negative feedback induced by dust and aerosols. On the other hand, should the dust contain high concentrations of carbonaceous particles that directly absorb sunlight, additional atmospheric heating could occur. More data and model simulations will be required before we fully understand the climatic impacts of these polar aerosols.

Enhancing the Network of Arctic Climate Monitoring Observatories. While SEARCH is addressing several complex issues related to climate change in the northern high latitudes, improving Arctic observational records is fundamental to the entire program. In collaboration with the NOAA Environmental Technology Laboratory (ETL), CMDL is taking a lead in efforts to expand or enhance the sparse network of observing stations now in existence. The combined facilities at BRW and the adjacent Atmospheric Radiation Measurement (ARM) Program site represent the state of the art in climate monitoring, especially for studies of cloud and aerosol effects on the surface radiation balance. One goal of SEARCH is to establish BRW-like observatories at other strategic Arctic locations to better characterize the Arctic climate system and to produce long-term data records that will help us understand the processes and feedbacks that drive the Arctic climate system. A component of this activity is to enhance atmospheric and radiation monitoring in the Canadian Arctic at Alert and Eureka at sites operated by the Meteorological Services Canada and possibly at two Siberian sites in conjunction with the Russian Academy of Sciences and Roshydromet.

Trace Gas Emissions Measured along the Trans-Siberian Railway. To study the trace gas emissions of a large sector of both Europe and Asia, a consortium of Russian, German, and U.S. scientists have instrumented a Russian railway car with a wide range of atmospheric measurement instrumentation, coupled the observatory carriage to regularly scheduled passenger trains, and conducted 17,000-km traverses from Moscow to Khabarovsk and back. These 13-day Trans-Siberian Observations Into the Chemistry of the Atmosphere (TROICA) missions have been conducted seven times since 1995. In the summer of 2001, CMDL Boulder scientists were the project leads on the program, as they were in early 2004 on a mid-winter journey during which temperatures as low as –40°C were encountered. This railway platform is ideal for atmospheric measurements because the railway is electrified between Moscow and Khabarovsk, minimizing the potential contamination of measurements by the train itself.

During the 2001 summer expedition (TROICA-7), emissions of six man-made, ozone-depleting substances were measured for the first time ever in Siberia. TROICA-8 occurred in the winter, when the emissions of biologically produced gases (such as carbon dioxide) and biomass burning gases from forest fires (such as carbon monoxide) are at a minimum.

Russia ended production of the chlorofluorocarbons (CFCs, used as refrigerants), chlorinated solvents (methyl chloroform, CH_3CCl_3, and carbon tetrachloride, CCl_4), and halons (used as fire extinguishing agents) at the end of 2000 as a result of the Montreal Protocol, but emissions persist from banks of these chemicals (in existing refrigerators, air conditioners, etc.). One goal of this program is to measure the reduction of the ozone-depleting substances between 2001 and 2004. Measurements on board the carriage include oxides of nitrogen (NOx), ozone, aerosols, radon-222, CO, CH_4, CO_2, and meteorological parameters, including vertical temperature profiles.

Measurements on the TROICA missions are supported by NOAA (Arctic Research, CMDL, OAR) programs, NASA (Atmospheric Chemistry Modeling and Analysis; Radiation Sciences; and Upper Atmospheric Research) programs, the Max Planck Institute for Chemistry in Mainz, Germany, and the Russian Railway Institute.

Cooperative Institute for Arctic Research at the University of Alaska Fairbanks

Arctic Climate Impact Assessment. The Arctic Climate Impact Assessment (ACIA) is an activity of the Arctic Council to assess the impacts of climate and UV radiation changes in the Arctic. An ACIA Secretariat, supported by the U.S. through NSF and NOAA, is located at the University of Alaska Fairbanks and is responsible for the conduct of the assessment. In 2002–2003 the 200 international authors of the assessment wrote several successively improved versions of the assessment in 17 chapters, and after internal review an extensive external review of the assessment by about 200 international experts took place. Final revisions are now occurring, responding to and taking the numerous reviewer comments into account. The length of the final document is expected to be about 1,500 printed pages and deals with impacts on the environment, on economic sectors, and on people's lives. A summary "Overview" report of about 80–100 pages has also been produced for a more general readership. The four-year ACIA project will conclude with a final scientific conference in Reykjavik, Iceland, on 9–12 November 2004, at which time the ACIA documents will be released.

Russian–American Long-Term Census of the Arctic. In 2003, NOAA and the Russian Academy of Sciences signed a Memorandum of Understanding for World Ocean and Polar Regions Studies. Also in 2003 both Russia and the U.S. requested proposals from investigators for participation in the first joint U.S.–Russia research cruise to the Bering and Chukchi Seas, including sampling and instrument deployment in both U.S. and Russian territorial waters. This is the first activity under the Russian–American Long-term Census of the Arctic (RUSALCA), a joint project of NOAA and the Russian Academy of Science. The cruise objectives are to support the U.S. interagency Study of Environmental Arctic Change (SEARCH) program (http://psc.apl.washington.edu/search/) and the NOAA Ocean Exploration Program (http://www.oceanexplorer.noaa.gov/). These seas and the life within are thought to be particularly sensitive to global climate change because they are centers where steep thermohaline and nutrient gradients in the ocean coincide with steep thermal gradients in the atmosphere. The Bering Strait acts as the only Pacific gateway into and out of the Arctic Ocean and as such is critical for the flux of heat between the Arctic and the rest of the world. Monitoring the flux of fresh and salt water and establishing benchmark information about the distribution and migration patterns of the life in these seas are also critical before the emplacement of a climate monitoring network in this region.

In November 2003 a workshop on the RUSALCA expedition mission was held in Moscow to define the main research topics and regions. In February 2004, after panelists met in Russia and the U.S., nine programs were funded. The primary study area will be the northern Bering Sea (north of 60°N) and the Chukchi Sea (Wrangel Island to Point Barrow and north toward the Chukchi Plateau to the extent that ice conditions permit). The cruise is expected to occur in the summer of 2004 on a Russian ice-strengthened (not icebreaking) research ship (the *Khromov*). The ship will depart from Vladivostok and make two or three port stops in Alaska before returning to Russia. The cruise length will be about 45 days, with intensive activities in the primary study area during the middle 20 days or so. Underway activities can be carried out during the entire 45 days.

Participants will include individuals from the following organizations: the University of Alaska

Fairbanks, the Smithsonian Institution, the University of Tennessee, the University of Texas, the University of Washington, the Woods Hole Oceanographic Institution, NOAA Fisheries, NOAA's Arctic Research Office, NOAA's Ocean Exploration Office, the U.S. Fish and Wildlife Service, the U.S. Army Cold Regions Research and Engineering Laboratory, the Shirshov Institution of Oceanology (Moscow), VNIIOkeangeologia (St. Petersburg), the Zoological Institute (St. Petersburg), the Institute of Microbiology (Moscow), the Arctic and Antarctic Research Institute (St. Petersburg), the Pacific Oceanographical Institute (Vladivostok), Roshydromet (Vladivostok), the Russian Federation Navy, and ECOSEA (group alliance). Funding is provided by NOAA and the Russian Academy of Sciences

NOAA's Undersea Research Program

NOAA's Undersea Research Program (NURP) has the responsibility to establish programs for the assessment, protection, development, and utilization of U.S. underwater resources. In meeting this responsibility, NURP has established six regional centers for support of in-situ research and technological development. The West Coast and Polar Regions Undersea Research Center serves the Arctic and Antarctic regions, as well as the entire west coast of the U.S. In FY 2002 the center supported development of next-generation equipment for studying the activities of marine mammals.

Although there have been significant advances in miniaturized video technology and virtual-reality data assessment, their use in the study of large marine animals has lagged considerably behind the applications for ROVs and other submersible platforms. There is great potential for using marine mammals as "biological autonomous underwater vehicles" to study their behavior and the ocean environment.

The first generation of video/data recorders designed to be mounted on marine mammals was developed under a 1998 NURP grant. It has been deployed on Weddell seals during NSF-sponsored research at McMurdo Sound, Antarctica. The use of this equipment has provided new insights into the behavior of both the seals themselves (while under water) and the behavior of their prey—several species of pelagic fishes. Both the seals and the fish are difficult to study by any other method because of the logistics of observing their activity under the Antarctic ice. The scientific results have been reported in several journals, including *Science* and *Marine Biology*.

In 2002 the West Coast and Polar Regions Undersea Research Center supported development of a next-generation version of this equipment. Modifications include digital video recording to a mini-hard drive, the use of on-the-fly MPEG video compression, incorporation of GPS for geolocation at the surface, extended data recording for up to 14 days, and a 50% reduction in size. The system records pressure, swim speed, compass bearing, ambient temperature, dissolved oxygen, ambient light, and tilt, pitch, and roll. The digital video/audio uses near-infrared LEDs and a low-light-sensitive, black and white camera. The equipment is powered by rechargable lithium batteries connected to solar panels. One factor that limited the use of the first-generation equipment to Weddell seals was the size and weight of the package. A 50% reduction in size now permits the new equipment to be used on smaller marine mammals. Tests have been conducted with Stellar's sea lions at the Alaska SeaLife Center in Seward, Alaska. This technology will yield new insight into the activities and habitat of these Arctic marine mammals at sea.

Alaska Fisheries Science Center

National Marine Mammal Laboratory

The National Marine Mammal Laboratory, Alaska Regional Office, and the Protected Resources Management Division are responsible for research on and management of 22 species of marine mammals that commonly occur in Alaska, including five endangered cetacean species (bowhead, fin, humpback, North Pacific right, and sperm whales), one pinniped species (Steller's sea lion) that is threatened in one portion of its range and endangered in another, and two depleted species (Cook Inlet beluga whale and northern fur seal). Field research by the NMML staff on marine mammals off central and northern Alaska focused on two pinniped and six cetacean species during 2002 and 2003: Steller's sea lions, harbor seals, Cook Inlet beluga whales, killer whales, and large cetaceans (fin, blue, humpback, and North Pacific right whales) in the Bering Sea.

Steller's Sea Lions. NOAA/Fisheries is the lead agency responsible for the management and recovery of the endangered western and threatened eastern populations of Steller's sea lions. The western population has declined by more than 80% in the last two decades, but it may have stabilized over much of its range during the last

two years. Conversely the eastern population appears to be recovering from severely reduced levels in the early part of this century and has exhibited consistent growth over the past three decades. Factors hypothesized for the dramatic decline in the western population include reduced prey availability leading to nutritional stress, poor juvenile survival, and decreased reproduction; disease; pollution; predation by killer whales; incidental mortality in groundfish fisheries; and legal and illegal shooting. The Steller's sea lion research program at NMML conducts scientific research on each of the potential factors that could have contributed to the decline of the western population. The core research program includes vessel and aerial surveys to quantify abundance, molecular and genetic studies to elucidate stock structure, assessment of predator–prey dynamics and foraging distributions to determine foraging ecology, and individual identification and tracking to provide the foundation of mortality and life history studies.

Alaska Harbor Seals. In recent decades, Alaska harbor seals have declined dramatically in some regions, while their numbers have increased in other regions. The primary objectives of NMML's research on this species are to obtain data on the abundance of the species throughout Alaska and to collect information on haulout patterns that can be used to better interpret abundance information. In 2002 and 2003 the NMML produced peer-reviewed papers describing the abundance of harbor seals in the Gulf of Alaska and the stability of harbor seal haulout patterns. In addition, research was undertaken to determine the response of harbor seals to cruise ships and the genetic relatedness of harbor seals via molecular genetic techniques. Obtaining information on Alaska harbor seals is critical, as they are an important component of the Alaska Native subsistence harvest. A comanagement agreement, signed by the Alaska Native Harbor Seal Commission and NMFS, has charged the Harbor Seal Comanagement Committee to prepare an annual action plan for this culturally important species.

Cook Inlet Beluga Whales. Research on the Cook Inlet beluga whale stock has been conducted annually since 1993. This stock was designated as depleted under the Marine Mammal Protection Act in 2000. Scientists from NMML, in cooperation with the Alaska Beluga Whale Committee, the Cook Inlet Marine Mammal Council, the Alaska Native Marine Mammal Native Hunters Committee, the Alaska Department of Fish and Game, and NMFS's Alaska Regional Office, have estimated the abundance of this relatively small and isolated population each year since 1994. Analyses of sighting data from aerial surveys indicated that the abundance of Cook Inlet beluga whales has declined by nearly 50% between 1994 and 1998. Distribution and abundance estimates from annual aerial surveys in 2002 and 2003 indicated that the population was stable but low in number. In 2002, research efforts were directed toward catching whales and outfitting them with radio and satellite tags to determine seasonal movement patterns and correction factors for aerial surveys. A Cook Inlet beluga habitat model is in development based on satellite tracking data and fatty acids analyses of blubber samples used to determine diet and contaminant burdens.

Killer Whale Surveys: Kenai Fjords to the Central Aleutians. To investigate the potential role of killer whales in the decline of the western population of Steller's sea lions, a vessel-based survey for killer whales extending from the Kenai Fjords to the central Aleutian Islands was initiated in 2001. The DART (Distribution and Abundance of Residents and Transients) surveys are designed to estimate the abundance of killer whales by ecotype. Three killer whale ecotypes have been identified in Alaskan waters thus far: the piscivorous (or resident) ecotype; the mammal-eating (transient) ecotype; and the offshore ecotype, which apparently preys mostly on fish. Biopsy samples are taken whenever possible to provide data for molecular genetic, prey isotopic and fatty acid, and contaminant analyses. When conditions permit, photographs and biopsies of sperm, fin, humpback, and Baird's beaked whales were also taken. These data augment sighting and biopsy sampling conducted in collaboration with the AFSC/RACE groundfish surveys.

Large Cetaceans in the Southeast Bering Sea and Northern Gulf of Alaska. NMML researchers were able to determine the abundance and distribution of large cetaceans (primarily fin and humpback whales) in the southeast Bering Sea and Gulf of Alaska because of new collaborations and the application of new technologies. A line-transect survey was conducted in 2002 in association with an AFSC/RACE groundfish stock assessment survey. These data provide a synoptic sample of large whale distribution and relative abundance in the southeast Bering Sea and northern Gulf of Alaska and are being used to update marine mammal stock assessment reports. In addition, cooperative research with Scripps Institute of Oceanography and NOAA's Pacific Marine Environmental

Laboratory (PMEL) has focused on using passive acoustic recorders to record calls from large whales in the southeast Bering Sea and northern Gulf of Alaska. These passive recorders remotely document the occurrence of calling North Pacific right whales and other baleen whale species during seasons in which conducting fieldwork is impractical due to short days or inclement weather. Information collected using passive acoustics will provide important insights into the seasonal distributions of large cetaceans and the relationships between large cetaceans and their environment.

Resource Assessment and Conservation Engineering Division and Resource Ecology and Fisheries Management Divisions

Marine Fisheries Assessment. The Alaska Fisheries Science Center (AFSC) of NMFS continued its long-standing commitment to assessment studies of U.S. living marine resources in the Bering Sea, Aleutian Islands, and Gulf of Alaska during 2002 and 2003. This effort included fishery-independent resource surveys, collection of data from commercial fisheries through fisheries observers, collection of recreational and commercial harvest statistics, and basic population biology and ecological research. The scientific information generated by these activities supports Federal fishery conservation and management responsibilities in the 200-mile U.S. Exclusive Economic Zone.

During 2002 and 2003, living marine resource populations in western U.S. Arctic waters were sampled at sea aboard NOAA ships, chartered fishing vessels, and cooperating foreign research vessels. Significant area-extensive survey efforts were conducted in the eastern Bering Sea, the Aleutian Islands, and the Gulf of Alaska. The principal survey methods included bottom trawls for demersal fish and crabs; hydroacoustic and midwater trawls for semipelagic fish; and special-purpose nets for eggs, larvae, and juvenile fish and shellfish. Trawl and acoustic surveys were used to estimate biomass and define community structure, and biological collections were taken to examine variability in growth, mortality, and stock recruitment.

Recruitment indices and processes that generate variations in abundance are being studied to improve prediction through the Fisheries–Oceanography Coordinated Investigations (FOCI) program. FOCI is a cooperative program between the AFSC and PMEL. To increase the accuracy and precision of these assessments, AFSC scientists conduct biological research to define recruitment processes, develop computer models to simulate interactions and dynamics of population change, and conduct or collaborate in extramural studies to improve sampling methods and survey designs.

Pacific Salmon: Bering Sea and Western Alaska. Pacific salmon runs to rivers emptying in the Bering Sea have been inconsistent and at times very weak. Low returns of chinook and chum salmon to the Yukon River, Kuskokwim River, and Norton Sound area (called the AYK region) of Alaska prompted the State of Alaska to restrict commercial and subsistence fisheries during 2000 and declare the region a disaster area. The weak AYK salmon returns follow several years of low sockeye salmon returns to Bristol Bay, which was declared a disaster region during 1998 by both the State of Alaska and the U.S. Department of Commerce. The cause of these disastrous returns is not fully understood but may be related to changes in the marine environment. To provide critical information on the marine ecology of Pacific salmon, scientists from the AFSC's Ocean Carrying Capacity (OCC) program conduct fall (August–October) surveys on juvenile salmon in the eastern Bering Sea shelf. The surveys are extensive, covering eastern Bering Sea shelf waters from the Alaska Peninsula to Kotzebue Sound. The research is conducted as part of a larger Bering Sea salmon ecology study conducted by the North Pacific Anadromous Fish Commission's Bering–Aleutian Salmon International Survey (BASIS) program. The goal of the OCC/BASIS salmon research is to understand the mechanisms underlying the effects of environment on the distribution, migration, and growth of juvenile salmon on the eastern Bering Sea shelf. The primary objectives of the survey are 1) to determine the extent of offshore migrations of juvenile salmon from rivers draining into the eastern Bering Sea; 2) to describe the physical environment of the epipelagic waters along the eastern and northeastern Bering Sea shelf occupied by juvenile salmon; and 3) to collect biological information of other ecologically important species.

Pacific salmon return to spawning areas in the Yukon River basin is of particular concern, as they support important commercial and subsistence fisheries in both the U.S. and Canada. These returns have been the focus of numerous harvest allocation disputes between the two countries, and returns have declined severely in recent years. A drainage-wide radio-tagging study was initiated in 2000 by the AFSC's Stock Identification and Assessment Program and the Alaska

Department of Fish and Game to provide information on the run characteristics of Yukon River chinook salmon. Returning adults were tagged in the lower river and tracked as they moved upriver to spawning areas. Work in 2000–2001 developed baseline information on the behavior and movement patterns. Large-scale, basin-wide tagging studies in 2002 and 2003 provided information on the stock composition and timing of U.S. and Canadian returns, movement patterns, and the location of undocumented spawning areas. These data have also been used to evaluate information from other assessment programs within the basin and to refine genetic stock identification baselines. An additional year of the basin-wide tagging study is planned for data collected during the late 1990s. Analyses include that of a remnant population of the endangered North Pacific right whale on the southeastern Bering Sea shelf. NWFSC scientists contributed input to the Science Steering Committee of NSF's Ocean–Atmosphere–Ice Interactions program. The importance of sea ice as critical habitat for polar marine mammals and birds is also being studied in collaborative efforts by NOAA scientists and other U.S. and Canadian researchers.

A paper detailing the analyses of 77 killer whale biopsy blubber samples for selected organochlorine compounds and lipid content has been published. The paper reported that concentrations of chlorinated biphenyls and DDT were relatively high compared to other marine mammal species that occur in Alaska. Furthermore, biological factors such as age, sex, reproductive status, and birth order were found to be important influences in the accumulation of organochlorine compounds in killer whales. A manuscript describing lipid and organochlorine contaminant profiles in gray whales was also published.

National Environmental Satellite, Data, and Information Service

National Ice Center

The National Ice Center (NIC) is a cooperative, interagency organization responsible for providing Arctic, Antarctic, and Great Lakes ice information to U.S. and allied armed forces, U.S. government agencies, and various segments of private industry. Manpower and fiscal resources for the NIC are provided by the U.S. Navy, NOAA/NESDIS, and the U.S. Coast Guard. The Office of Research and Applications (ORA) is the NESDIS research organization that, among other things, supports the NIC. Real-time global, regional, and tactical-scale ice guidance products are generated in support of mission planning, safety of navigation, and climate research. Routine products include satellite-derived sea ice analyses of current ice conditions and forecasts depicting future changes to the sea ice pack. Ice analyses are distributed in JPEG format and as geographic information system (GIS)-compatible files via the NIC web page (http://www.natice.noaa.gov). Metadata that detail the data sources integrated into routine ice analysis products are available on the NIC web page. As part of the Environmental Working Group, NIC released the High-Resolution Arctic Sea Ice Climatology in 2000, which encompassed historical data from 1972 to 1994. Work is nearing completion on extending the archive through 2003.

During 2002–2003 the NIC Science and Applied Technology Department expanded to include a new visiting scientist, a post-doctoral fellow, and increased support staff. The main goals of the department include:

- Improving the efficiency of data processing and analysis through the development of automated data fusion techniques;
- Automating the analysis and classification of data;
- Improving operational ice forecasting models;
- Optimizing Special Sensor Microwave/Imager (SSM/I) algorithms for operational sea ice analysis; and
- Developing new ice products by applying new techniques and incorporating data from new sensors.

The NIC science team evaluated the existing suite of sea ice concentration algorithms for the SSM/I and modified the operational sea ice algorithm. A passive microwave algorithm was developed using a principal components combination of SSM/I brightness temperatures and NIC-provided local ice conditions from visible and infrared data to provide improved global sea ice concentrations. Another accomplishment was the implementation of an algorithm to track ice motion using 85-GHz SSM/I. SSM/I and ice model products are available in near-real-time on the NIC experimental products web page (http://science.natice.noaa.gov). They have also recently completed the development of a new scatterometer ice edge algorithm.

The ORA is exploring the application of Cryosat altimetry data for estimating sea ice draft. Launch is expected in 2005. Other groups within ORA are exploring the application of cloud-tracked

winds and TIROS Operational Vertical Sounder (TOVS) data for improved Arctic wind products. Currently ORA cloud-tracked winds are being assimilated into the European Centre for Medium Range Weather Forecasts (ECMWF) forecast models. ORA is also continuing the Alaska synthetic aperture radar (SAR) demonstration (AKDEMO), which provides experimental high-resolution (1-km) SAR-derived winds and vessel positions for open water areas in the Bering Sea and other Arctic seas (http://www.orbit.nesdis.noaa.gov/sod/mecb/sar). Recent studies show that these winds are accurate to better than 2 m/s. The experimental wind product is useful for understanding gap winds, barrier jets, and wind shadowing by islands such as the Aleutians. Such knowledge can be beneficial to the safety of coastal transporation. AKDEMO SAR imagery and vessel positions are being evaluated in Alaska in an effort to provide improved guidance to fishing vessels operating near the ice edge. In addition, SAR imagery is being evaluated for use in monitoring river ice breakup in the larger Alaskan rivers such as the Yukon and Koskokwim.

NIC manages the U.S. Interagency Arctic Buoy Program (USIABP), which provides an important source of surface meteorological data and ice drift information in the Arctic. Since its inception in 1991, the mission of the USIABP has been to establish and maintain a network of 40 evenly spaced meteorological buoys on the drifting Arctic ice pack. NIC achieves this goal through coordinated deployments and international cooperation by participants in the International Arctic Buoy Program (IABP). During 2002–2003, nearly 95% of all Arctic drifting meteorological buoys reported data in real time over the Global Telecommunications System. Real-time buoy data are used to initialize operational weather and ice forecast models. All buoy data are quality controlled within six months of receipt and then assembled into a historical (1979–2003) database, which is archived by the Polar Science Center of the University of Washington (http://iabp.apl.washington.edu) and the National Snow and Ice Data Center (NSIDC). These data have been useful in initializing global circulation models and in climate change research. Buoy data are also used to generate a three-hour spatially and temporally interpolated data set of surface pressure and temperature.

National Snow and Ice Data Center

The National Snow and Ice Data Center and World Data Center for Glaciology, Boulder, (http://nsidc.org) was chartered by NOAA/NESDIS in 1982 to provide a focus for cryospheric data management activities. NSIDC is operated under an agreement between NOAA and the University of Colorado's Cooperative Institute for Research in Environmental Sciences and is affiliated with the NESDIS National Geophysical Data Center (NGDC), Boulder. NSIDC is home to the NSF-funded Arctic System Sciences Data Center and Antarctic Glaciological Data Center. The Frozen Ground Data Center (FGDC) at NSIDC is supported by the International Arctic Research Center, University of Alaska Fairbanks. Over 80% of NSIDC's funding comes from NASA for operating a Distributed Active Archive Center for Earth System Enterprise data sets. These include Geoscience Laser Altimetry System (GLAS), Advanced Microwave Scanning Radiometer–Earth Observing System (AMSR-E), and Moderate Resolution Imaging Spectroradiometer (MODIS) products, as well as "heritage" data sets such as the nearly 30-year record of sea ice concentration from satellite passive microwave data.

More than 113 new data sets were made available through NSIDC's online catalog in 2002 and 2003. These included detailed maps of permafrost and soils from Russia and China, published in cooperation with the International Permafrost Association. Available in a variety of formats, including GIS-compatible files, these products contribute to a unified international depiction of frozen ground important for monitoring and hydrological studies.

Frozen soils and snow were the focus of the NASA/NOAA Cold Land Processes Field Experiment (CLPx), which took place in Colorado in 2002 and 2003. NSIDC data managers went into the field to work directly with researchers studying cold land processes over a wide range of conditions and spatial scales. NSIDC AMSR and MODIS snow cover products are being used with CLPx data to address the question of how uncertainties in remote sensing observations constrain data assimilation and prediction.

While new satellite sensors offer improvements in accuracy and resolution, NSIDC continues to archive and publish historical data records that provide the long view needed to assess climate change. Because glacier extent fluctuates in response to climate changes, historical glacier photos can be used to determine changes in glacier terminus location and to estimate changes in mass balance. The Glacier Photograph Collection database now provides over 1000 images of

glaciers on-line. Photographs, dating from 1883, were scanned through a joint National Geophysical Data Center/NSIDC project funded by NOAA's Climate Database Modernization Project.

In-house scientific expertise helps NSIDC improve the quality of research data sets and respond quickly to inquiries on snow and ice topics from the general public. The record minimum Arctic ice extent in September 2002 drew widespread media attention and was monitored at NSIDC using the Sea Ice Index (http://nsidc.org/data/seaice_index/), an easy-to-use source of information on sea ice trends and anomalies. Ice extent in September 2003 was similarly low, about 14% below the long-term (1978–2000) mean, and is the most recent evidence of a downward trend in Arctic sea ice in the three decades since passive microwave monitoring began. In a paper published in *Geophysical Research Letters*, NSIDC researchers attributed the record 2002 extent to an unusually warm summer over much of the Arctic Ocean, combined with stormy conditions that helped break up the ice.

On an international level, NSIDC is involved in setting directions for Climate and Cryosphere (CliC), a World Climate Research Programme core project established to coordinate research on the role of the cryosphere in the global climate system. NSIDC Director Roger Barry is seeking to establish a U.S. CliC committee in partnership with NOAA, NASA, and NSF.

National Oceanographic Data Center

NODC and the co-located World Data Center for Oceanography (WDC Oceanography) in Silver Spring, Maryland, continues to have an active data exchange program and engages in collaborative joint projects with many Arctic countries, academic institutions, other Federal agencies, and international organizations. In March 2002, NODC/Ocean Climate Laboratory (OCL) released the *World Ocean Database 2001* (*WOD01*), which contains 479,562 profiles in the Arctic region (60°–90°N) representing data of physical, chemical, and biological variables dating back to 1827. These profiles reflect data obtained from bottle, low-resolution CTD, and plankton instruments (Ocean Station Data); high-resolution conductivity–temperature–depth instruments (CTD); mechanical bathythermographs (MBT); expendable bathythermographs (XBT); surface-only instruments (bucket, thermosalinograph) (SUR); subsurface drifting floats (PFL); and surface drifting buoys with thermister chains (DRB). These last three instrument types were new additions to *WOD01* for the Arctic and did not exist in the 1998 version. Data continue to be added to the database on a daily basis, and there are now 485,088 profiles in the Arctic seas and oceans. The exchange of data is facilitated under the auspices of the Intergovernmental Oceanographic Commission (IOC) Global Oceanographic Data Archaeology and Rescue (GODAR) project and the World Ocean Database (WOD) project. These efforts are supported by NOAA's Office of Global Programs (OGP) and NOAA's Environmental Science, Data, and Information Management (ESDIM) program.

Data exchange and collaborative activities have been particularly fruitful with the Russian Federation for many years. In FY 2002, *Zooplankton of the Arctic Seas 2002* was released on CD-ROM. This product was prepared jointly by the NODC/OCL-WDC Oceanography, Silver Spring, Maryland, and the Zoological Institute, Russian Academy of Sciences. It includes physical and biological data for the Arctic and sub-Arctic regions, extending from the Barents Sea to the northwest Pacific. Samples were taken during 25 scientific cruises between 1903 and 1956.

In FY 2003, a three-year ESDIM grant was awarded to OCL to further its collaboration with Russian colleagues to develop an oceanographic database of the Arctic seas (Barents, Kara, Laptev, White, East Siberian, and Chukchi) for use in studying the Arctic climatic system. Two products have been prepared thus far, both of which are available online. The product *History of the Arctic Exploration 2003: Cruise Reports, Data*, released in October 2003, was prepared jointly with the P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences. It represents data collected from 1870 to 1940 at 3,936 stations from 62 cruises in the eastern Arctic seas as well as the Arctic Ocean. The second product, *36-Year Time Series (1936–1998) of Zooplankton, Temperature, and Salinity in the White Sea*, released in November 2003, was prepared jointly with the White Sea Biological Station (WSBS) of the Zoological Institute. This product presents an analysis of zooplankton data from the WSBS for the period 1963–1998 (2,436 plankton samples), as well as temperature and salinity observations at different depths for the period 1961–1999 (938 stations). In addition to being available online, this product is also available in manuscript form along with a CD-ROM of all the data. Another product is in progress and is expected to be released sometime in the spring or summer of 2004. This product, *Climatic Atlas of*

Further information about and access to the World Ocean Database and the products associated with the International Ocean and Atlas Information Series can be found at http://www.nodc.noaa.gov/OC5/indprod.html. The point of contact for the Ocean Climate Laboratory, the World Data Center for Oceanography, and the World Ocean Database is Sydney Levitus, U.S. Department of Commerce, National Oceanic and Atmospheric Administration/Ocean Climate Laboratory, 1315 East-West Highway (E/OC5), Silver Spring, MD 20910; 301-713-3290, ext. 194. For the Arctic databases, the points of contact are Renee Tatusko or Igor Smolyar, U.S. Department of Commerce, NOAA/OCL, 1315 East-West Highway (E/OC5), Silver Spring, MD 20910; 301-713-3295, ext. 206.

the Arctic Seas 2003: Part 1, Database of the Barents, Kara, Laptev, and White Seas, is being prepared jointly with the Murmansk Marine Biological Institute (MMBI), Russian Academy of Sciences. This atlas is expected to contain data from about 400,000 oceanographic stations from 1810 to 2002. There will be more than 20,000 plankton samples, including 260 collected during cruises of nuclear icebreakers in regions previously inaccessible for studies during the winter. The atlas will also include data from about 100 benthos samples collected along the Kola Meridian between 1921 and 1922 and in 1977. All of these data are or will be incorporated into the World Ocean Database and made available online.

The NOAA Central Library, located in Silver Spring, Maryland, is the largest oceanic and atmospheric sciences library in the Western Hemisphere and has extensive holdings related to Arctic exploration and Arctic science. The library's on-line catalog has over 1,800 entries related to Arctic activities and another 1,000 entries related to the oceanography and fisheries of Arctic marginal seas. The library's on-site collection is supplemented by 1,200 historical documents that can be found through the library's traditional card catalog. Through NOAA Library services, access can be gained to literally the full range of publications that are dedicated specifically to Arctic issues and science or have information relevant to Arctic issues. The library has also imaged thousands of pages of Arctic climate data for regions of Alaska, Canada, Norway, and Russia that are available on-line through the NOAA Library Climate Imaging Project. The library assists data rescue and recovery efforts of Arctic researchers, and its collections and services are particularly relevant to those studying climate issues and living resource issues. As an adjunct to textural material, the library also manages the NOAA Photo Library, which has over 600 on-line public domain images related to Arctic themes.

Further information about and access to the NOAA Library can be found at http://www.lib.noaa.gov/. The point of contact for the NOAA Library is Janice Beattie, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NOAA Central Library, 1315 East–West Highway (E/OC4), Second Floor, Silver Spring, MD 20910; 301-713-2607, ext. 139.

National Climatic Data Center

NCDC updates and maintains a 120-year-long mean monthly temperature time series zonally averaged over the Arctic. This work is done in collaboration with the Russian State Hydrological Institute. Long-term daily precipitation time series for the former Soviet Union have been rescued and homogenized. These data are available from NCDC and are being used in Arctic studies, including the Arctic Climate Impact Assessment. This work was done by NCDC in collaboration with the Russian Research Institute for Hydrometeorological Information and the Institute for Global Climate and Ecology.

National Ocean Service

From 1996 to 2002 the Coastal Ocean Program within the National Ocean Service supported the Southeast Bering Sea Carrying Capacity (SEBSCC) program, with a total of $5.5 million. The goals of SEBSCC were to increase understanding of the southeastern Bering Sea ecosystem, to document the role of juvenile walleye pollock and factors that affect their survival, and to develop and test annual indices of pre-recruit (age-1) pollock abundance. Four central scientific issues focused the research efforts: 1) How does climate variability influence the Bering Sea ecosystem? 2) What limits population growth on the Bering Sea shelf? 3) How do oceanographic conditions on the shelf influence biological distributions? and 4) What influences primary and secondary production regimes? These questions were addressed through collaborative research by NOAA scientists at the Pacific Marine Environmental Lab and the Alaska Fisheries Science Center and academic researchers at the University of Alaska, the University of California, and the University of Washington. The research effort included moored observations, process field cruises, modeling, retrospective studies, and syntheses.

In 2002, synthesis of SEBSCC results were published in two special journal issues with wide distribution to the oceanographic community. A special issue of *Progress in Oceanography* (vol. 55, no. 1–2, 2002) entitled "Variability in the Bering Sea Ecosystem" published 16 papers resulting from a session discussing the Bering Sea from 1991 to 2001 at the 10th annual meeting of the North Pacific Marine Science organization. A special issue of *Deep Sea Research II* (vol. 49, no. 26, 2002) on the ecology of the southeastern Bering Sea presented results of SEBSCC and an NSF-sponsored Inner Front program. Both of these programs were at work in the Bering Sea between 1995 and 2000. This was a time of great variability in the Bering Sea. An extremely warm year occurred in 1997, coincident with the first recorded observation of coccolithophore blooms on the Bering Sea shelf. Jellyfish increased in abundance, whereas salmon, shearwaters, northern fur seals, and Steller's sea lions declined. The collection of 21 papers in this volume present the current understanding of relationships between atmospheric forcing,

ocean circulation, phytoplankton growth, zooplankton dynamics, pollock abundances, and seabird diets. A new hypothesis about controlling factors on Bering Sea production and energy transfer was put forward by SEBSCC investigators.

Office of Marine and Aviation Operations

NOAA ship *Miller Freeman* conducted approximately 100 and 40 operating days in the Bering Sea during FY 2002 and FY 2003, respectively.

In FY 2002 the *Freeman* participated in a number of cruises that focused on echo integration-trawl (EIT) surveys of walleye pollock in the eastern Bering Sea near Bogoslof Island. The vessel succeeded in recovering and deploying various moorings that collect oceanographic and fisheries-related data for the Fisheries–Oceanography Coordinated Investigations (FOCI) program. The ship also accomplished a cruise that examined the community structure and transport of fish larvae and plankton on the continental shelf, slope, and deep water areas of the southeastern Bering Sea and Unimak Pass.

In FY 2003 the *Miller Freeman* continued to recover and deploy moorings in support of the FOCI program, as well as taking biological and physical ocean property samples at and near the mooring locations. Ongoing EIT surveys near Bogoslof Island and ichthyoplankton studies in the southeastern Bering Sea near Unimak Pass were also accomplished.

Department of Agriculture

The Department of Agriculture supports and conducts research to improve the understanding, use, and management of natural resources at high latitudes. Research is directed toward solving problems in agriculture, forestry, and the environment and improving technology for enhancing the economic well-being and quality of life for Alaskans.

Agricultural Research Service

The research activities of the Agricultural Research Service (ARS) are focused on 22 multidisciplinary and cross-cutting National Program Areas of high priority designed to develop a knowledge base to promote timely responses to technical agricultural problems of broad scope and national interest. Programs in the Arctic or adjacent northern regions are limited in scope. They are, however, providing critical information necessary to solve issues in such diverse areas as preservation of plant germplasm, integrated pest management for grasshoppers, and biodiversity of pathogens and parasites in northern ruminants. This research addresses the sustainability of renewable natural resources in the Arctic and has implications for managing plants and animals elsewhere.

Plant Germplasm Research

The primary mission of the National Arctic Plan Germplasm Resources Unit (NAPGRU) is the acquisition, propagation, storage, and distribution of plant germplasm for all presently existing agricultural crops and nonagricultural species in Arctic, sub-Arctic, and alpine regions of the world. NAPGRU also serves as a grow-out site for both seed and clonal samples for some of the cooler-season accessions from other plant germplasm repositories. The mission also includes research of diseases affecting the germplasm increases and/or preservation of Arctic crop and native species.

To date, there has been no systematic effort on the part of any U.S. agency to preserve high-latitude or high-elevation plant germplasm. There is no way of knowing what possible medical, commercial, or other research benefits are to be gained from the preservation and study of some of these unique and environmentally isolated plant species.

	Funding (thousands)	
	FY 02	FY 03
Forest Service–Global Change	729	653
Natural Res Cons Svc–Soil Survey	560	360
Ag Res Service–Global Change	2,000	2,000
Total	3,289	3,013

In addition, there are accessions that are high latitude or altitude in nature that are difficult to grow at low-latitude sites where the summer days are much shorter and warmer than in Palmer, Alaska. The long days during the growing season on the Palmer site may also reduce the time necessary for seed production of accessions from other National Plant Germplasm System sites (for example, cauliflower produces seed in the first year instead of the expected second year for a biennial). Plant diseases, both indigenous and introduced, in Alaska are poorly understood; comprehensive plant disease surveys in crop, exotic, and native plant species are negligible, especially for plant viruses. Viral diseases can have a significant impact on the short-season crops as well as the growth of native species.

Arctic germplasm preservation will be improved by the ability to detect and understand the biology of viruses in native plant species living in natural environments. The study of diseased twisted-stalk in Denali State Park and near Skwentna revealed two different viruses, which were partially characterized from the plants with either single or multiple infections from each site. The significance of this study is the added biological knowledge of plant pathogens in native plants and, in this specific case, the unexpected high number of infected plants in two isolated natural habitats.

Little is known about pathogens and the management of wetland plants in the Arctic. Barley yellow dwarf virus was identified for the first time in the Palmer area using molecular tools. Germplasm

increase plots were established to regenerate depleted or endangered seed supplies with local wetland accessions and those transferred from the state of Washington, Switzerland, and the Chinese Himalayas; this is the first time an Arctic germplasm repository has been established for Arctic, sub-Arctic, alpine, and sub-alpine plant taxa in the U.S. This will have considerable impact on restoration and site rehabilitation efforts in the future.

Grasshopper Pests

Grasshoppers are economically important pests in rangeland and crop agro-ecosystems throughout western North America, including parts of Alaska. Efforts to develop a local agricultural industry in the Delta Junction area of Alaska based on hay, grain, and livestock are hampered by periodic outbreaks of grasshoppers. The mix of state and private lands, as well as environmentally sensitive and agricultural areas, restricts the options for controlling grasshoppers. The ability to predict outbreaks and the development of new cultural and biological tactics will be a major step toward resolving grasshopper problems in Alaska. Additionally, much of the information generated in Alaska will also be directly relevant to grasshopper population management in other areas of North America. During years of high grasshopper densities, severe losses may be inflicted on barley crops; in 1990, crop losses were estimated at 50%. There are many hurdles to be overcome by the fledgling row-crop industry in Delta Junction, such as access to markets, cultivar selection, and weed control, in addition to the normal challenges of farming, such as vagaries of weather and low market prices. At this stage of development, farming operations may not be as resilient as in more established farming areas. Therefore, it is important to the success of the Delta agriculture project that farmers have the tools to avoid preventable losses.

Predicting grasshopper outbreaks requires a thorough understanding of the parameters affecting grasshopper growth and reproduction. At the Subarctic Agricultural Research Unit on the campus of the University of Alaska Fairbanks, growth and respiration rates of eggs, nymphs, and adults were measured at several temperature regimes. These data were used to refine phenological models of pest species of grasshoppers. This information from high-latitude populations will lead to more robust models of grasshopper development, which will be used to predict outbreaks and will be included in an individual-based model of grasshopper populations used for research purposes.

Very little information is available regarding the effect of grasshopper damage on cultivated crops, and no information is available on the interactions between insect damage and other biotic and abiotic factors in small-grain crops. Field experiments were conducted to evaluate the effect of grasshopper feeding and weed competition on barley and oats. This information is essential for the development of economic thresholds for management of grasshoppers in cultivated crops. Currently, there is no reliable means of sampling grasshoppers with dense crop canopies, making it difficult to study the invasion of crops by grasshoppers. Further field tests of windowpane/pan traps were conducted to examine the efficiency of the traps in relation to grasshopper population density, species composition, and vegetation type. A spatially extensive survey of grasshopper populations in the Delta Junction area was repeated to assess the influence of habitat attributes on the distribution of grasshopper populations.

Parasites of Wild Ruminants

Parasitic worms of large food animals cause production losses to farmers and ultimately result in higher prices to consumers. The economic impact of parasites is significant, leading to additional production costs of 2 billion dollars annually. Slower weight gain, death of young animals, higher feed costs, costs of drugs to remove parasites, and contamination of pastures all contribute to substantial losses for producers. Scientific research aimed at reducing the diverse impacts of parasitic worms is hampered by difficulties in identifying and classifying economically important helminths, especially the forms of the parasites that are found in the environment or in the waste products of the host. Parasites found in wild ruminants in Arctic regions are important in our understanding of parasite host ranges, their impacts on wild animals, co-evolution with their hosts, and potential reservoirs in wild populations.

ARS research provides basic information on structural and molecular characteristics, particularly documentation of variation, useful for assessing parasite biodiversity. Accurate determination of the species causing the losses and construction of classifications to predict the appropriate control measures for new, emerging, or invasive pathogens depends on a comparative approach integrating morphological and molecular data. Such baseline information is used by scientists to understand patterns of parasite biodiversity and distribution requisite for documenting invasive

and emergent pathogens, to determine the importance of reservoir hosts such as wildlife, to develop specific diagnostic tools, and to evaluate biological or chemical control agents.

With the curation of the U.S. National Parasite Collection, one of the largest specimen-based research collections in the world, ARS also provides a resource for reference specimens and information to support parasitology and animal health nationwide and globally. Predictive classifications of related parasites provide information useful for recognizing and controlling imported, invasive, or emerging pathogens that threaten farm animals or contaminate our food or water. Accurate systematics is the foundation for understanding the distribution and impact of parasites, emerging and invasive pathogens, local versus introduced species, and the interface between agricultural and natural ecosystems.

Biodiversity knowledge in Arctic and northern systems serves both theoretical and real-world issues. Current research programs serve as models for research, such as that under the Beringian Coevolution Project (BSP), to reveal evolutionary, biogeographic, and ecological structure and the history of biotas. It is apparent that these systems can serve as important historical analogs for understanding contemporary global change. Additionally, we can apply parasite biodiversity data in the context of real-world issues such as those considered under the Research Group for Arctic Parasitology (RGAP), including animal health, emerging pathogens, impacts to keystone species such as caribou, and potential impacts of global change driven by both climatological or anthropogenic forces. The cross cuts between basic knowledge and the application of biodiversity information indicate the degree to which the BCP and RGAP are complementary programs with a strong interface. They serve as model systems for programs in biodiversity assessment. Taxonomy and systematics integrating comparative morphology, molecular systematics, and phylogeographic approaches are requisite. We need robust theoretical frameworks for studies of cospeciation, historical biogeography, and historical ecology. Contemporary surveys and inventories continue to serve as the basis for demonstrating distribution and host association and how these are linked through relationships to landscape ecology, pathogen distribution, and disease. Ecosystem approaches that shift the focus from a single host species to a broader context are clearly necessary to identify the role of parasites and pathogens at the community level. Synoptic baselines to monitor change or stability in terrestrial systems in the Arctic are important contributions from these studies. The BCP and RGAP are works in progress and serve to show our continued need for the most basic of information about the distribution and host associations of parasites and pathogens.

Forest Service

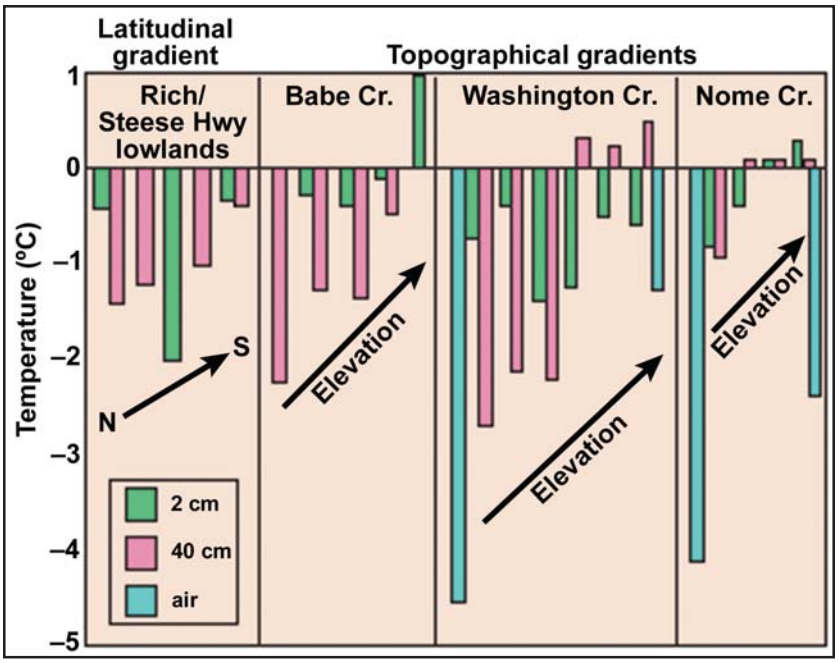
The USDA Forest Service's Pacific Northwest Research Station (PNW) is responsible for boreal forest research in Alaska through the Boreal Ecology Cooperative Research Unit (BECRU) located on the campus at the University of Alaska Fairbanks. The research activity of BECRU is, in part, a commitment to the NSF-sponsored Long-Term Ecological Research (LTER) conducted at the Bonanza Creek Experimental Forest (BCEF). The BCEF-LTER seeks to understand the Alaskan boreal forest as an integrated regional system in which climate, disturbance regime, and ecological processes are interactive components, with the objective to document the controls over these interactions and their ecological consequences. Research focuses on four major disturbance types—fire, flooding, forest harvest, and beetle outbreaks—and is organized around three major themes:

- Forest dynamics;
- The changing boreal carbon cycle; and
- Landscape controls over a changing disturbance regime.

These themes operate at different scales and have key societal relevance but require improved understanding of the basic scientific processes.

Forest dynamics research focuses on the interactions between population/community processes, disturbance regime, and ecosystem dynamics. Study of the changing boreal carbon cycle focuses on ecosystem processes. These changes hinge on interactions with the hydrologic cycle and other element cycles. Carbon balance depends on spatial and temporal variation in climate and disturbance regime and on population and community processes associated with succession. Landscape controls over changing disturbance regime focus on landscape and regional processes such as disturbance spread. These landscape processes are a logical consequence of changes in population, community, and ecosystem processes occurring at the stand scale.

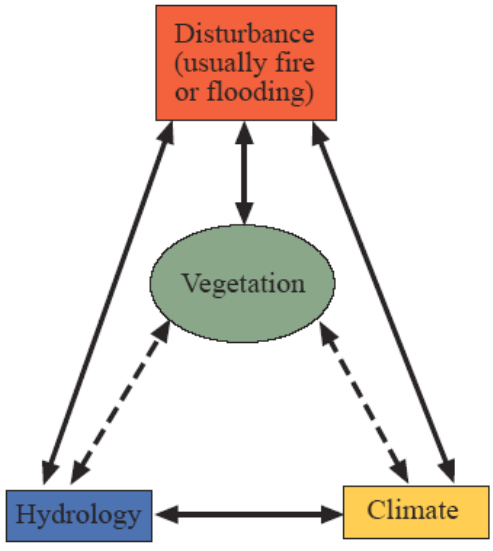
In 2003, scientists at the Boreal Ecology Cooperative Research Unit, USDA Forest Service in



Air and soil temperatures from 20 black spruce sites. These data will aid in relating temperature gradients to the structure and function of black spruce communities.

Fairbanks, Alaska, created a Landsat classification of spruce stands in Interior Alaska based on a combination of soil conditions and vegetation. In this classification, sites were grouped into the categories wet/cold, dry/warm, and intermediate. This classification, although in its early phases, has helped in examining the complex role of disturbance, particularly fire, in black spruce communities.

In collaboration with scientists from the Bonanza Creek LTER, these data were analyzed and presented at the recent Long-Term Ecological Research Symposium. Data presented included soil and air temperatures along climatic gradients within a subsample of black spruce communities and stand age data for 75 black spruce sites. These results are aiding scientists in understanding the potential differences in ecosystem drivers between the different black spruce communities. In particular, these findings are important in the context of the carbon cycle in black spruce forests and the key roles of vegetation, permafrost, and the fire cycle.



Conceptual model of the role of fire in changing the vegetation, hydrology, and climate of black spruce communities.

PNW is continuing to develop a conceptual model of the role of fire in black spruce communities. This model is unique in that it addresses the interactions between vegetation, permafrost, and abiotic factors, not as processes, but as relationships. The principal idea is that fire "weakens" these relationships, and by understanding how, we can predict landscape patterns in black spruce communities in the interior of Alaska.

Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) cooperates with and provides assistance to private, Alaska Native, state, and Federal landowners. NRCS field office personnel and other cooperating agencies in Alaska work together to provide technical resource planning and application assistance to landowners, users, and planners. Coordinated resource management plans, allotment management plans, or interim plans are developed. Engineering assistance is provided to individual landowners and managers and to Alaska Native villages, both to assist in sound resource management and to assist in overcoming natural threats including flooding and accelerated coastal and stream erosion. Soil data are collected, with maps and interpretations prepared for private, Alaska Native, and government lands in Alaska. The NRCS provides assistance to all landowners with USDA Farm Bill programs. NRCS also cooperates with the University of Alaska Fairbanks and the Pacific Northwest Forest Research Station with research on permafrost soils and wetland soils.

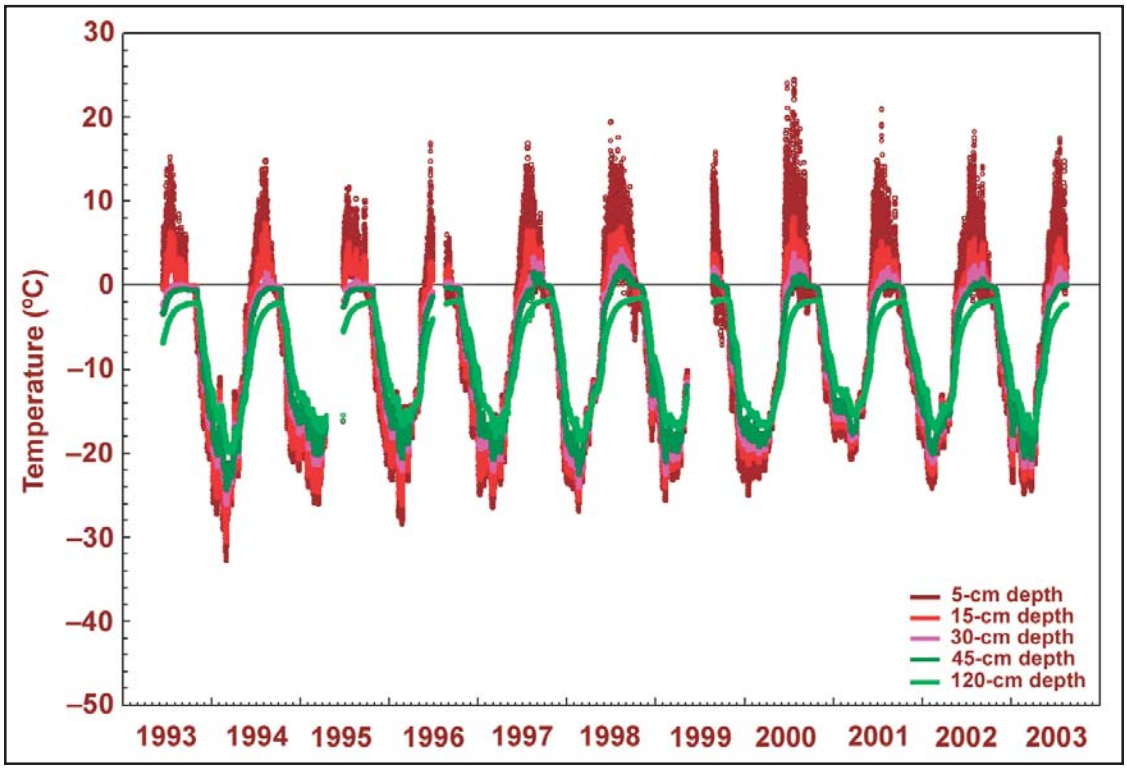
The research activities of the NRCS are done in cooperation with several universities (the University of Alaska Fairbanks, the University of Wisconsin, the University of Delaware, and the University of Cincinnati). The major joint project is monitoring soil temperature and moisture, along with several above-ground parameters, to study changes to the active layer and other possible

changes that may be taking place as the level of atmospheric greenhouse gases increases, creating possible global warming. Sites have been established along the Dalton Highway in the area of Barrow and other locations in Alaska. Similar sites have been established in the Himalayas and in Antarctica. At each of the sites the soils are sampled and completely characterized (chemical, mineralogical, and physical properties are measured). The soil moisture data are being reviewed to see if there is any warming and if the thickness of the active layer is changing. Early data suggest that the active layer thickness is increasing, which may suggest warming. Longer-term monitoring will be needed to see if this trend continues.

Soil climate monitoring stations were maintained and/or upgraded throughout the state. Sites are now established on the North Slope, in western Alaska, and along the populated road/rail corridor extending from Fairbanks to Homer. The data collected at all soil climate monitoring sites in Alaska are also being incorporated into USDA's overall national study on global climate change. Wetland soil study sites have also been established in southeast Alaska. Data from these sites will be used to help develop an Alaska-specific field manual for wetlands covered by the Clean Water Act. Several of the sites are now connected to a USDA telemetry network so that the analyzed data are readily available to the public via the World Wide Web.

Research also continued in cooperation with the NSF-funded university group to look at carbon storage near Barrow, Alaska. The major part of the NRCS activity is to develop better ways to determine the thickness of frozen peat layers. Much of the peat is in the permafrost zone, and if there is global climate change and an increase in the thickness of the active layer, more of the carbon may be thawed. This carbon may then be oxidized by microbes, resulting in more carbon dioxide or methane emissions. The problem with determining the thickness of the peat is the difficulty of sampling the frozen material. Cores are taken when the active layer is frozen so that coring equipment can be moved about the tundra. Ground-penetrating radar is used to develop patterns that show the depth and thickness of the peat and other soil layers so that large areas can be surveyed. Fieldwork is difficult when using ground-penetrating radar equipment in the harsh environment, and field calibration is a challenge.

Scientists sampling soil along the Dalton Highway for characterization.



Soil temperature records for Barrow, Alaska, for a 10-year period.

The techniques are being refined so that this can be done on the North Slope.

Approximately one million additional acres of land in Alaska were covered by new soil surveys in the last year. The projects are in both permafrost and non-permafrost areas. Current projects include private and Alaska Native lands in the Yukon–Kuskokwim River basins, the western Kenai Peninsula, and interior Alaska. Fieldwork was completed on public lands at Denali National Park and Fort Greely Army installation, with preliminary products available in 2004. The soil surveys often represent the only comprehensive baseline resource data in some of the more remote areas of Alaska. Requests for surveys are increasing and are driven by resource development, as well as health and safety issues, especially on Alaska Native lands and in villages. Issues related to climate change, including the impacts of forest pest infestations, warming permafrost, and coastal storms, are also driving the increased requests for survey data. Soil temperature and moisture studies, comprehensive laboratory analyses, and vegetation surveys are being conducted as part of the soil surveys. Survey products are being released to the public as GIS datasets and through the World Wide Web.

Data collection using ground-penetrating radar. The plastic bag is to exclude the bright ambient light and allow the operator to see the readout.

Department of Energy

The Department of Energy has responsibility for providing for the long-term energy security of the United States. DOE's Arctic and sub-Arctic activities support the DOE mission through studies of energy production, relevant atmospheric/environmental measurements and modeling, and radioactivity.

The Arctic and sub-Arctic activities of the Department of Energy (DOE) include support for projects in three diverse areas:

- Energy production and power generation;
- Atmospheric/environmental measurements and modeling related to climate change; and
- Measurement, modeling, and mitigation of radioactivity.

Assessment of the recoverability and production of methane hydrates and related free-gas accumulations is an important part of these activities. DOE researchers also collaborate with other Federal and state agencies in the development of energy sources that provide affordable and reliable electric power for rural Alaskan villages. There are compelling scientific reasons to study climatic change at high latitudes, as well as elsewhere. Through its Atmospheric Radiation Measurement (ARM) Program, DOE investigates cloud and radiative processes at the North Slope of Alaska/Adjacent Arctic Ocean site (NSA/AAO), near Barrow. The resulting data are used to refine atmospheric models critical to the understanding of potential climate change. The DOE continues to have an interest in understanding radiological issues in the Arctic in general and Alaska in particular. Examples include projects that measure and model the transport of anthropogenic and natural radionuclides in the atmosphere, soil, and aquatic systems. The following is a list of projects and programs that are wholly or partly focused on the Arctic.

	Funding (thousands)	
	FY 02	FY 03
Amchitka Island Project	1,340	400
Arctic Energy Office	3,000	5,500
Arctic Methane Hydrates	3,250	3,720
Atmospheric Radiation Measurement Program	3,200	3,200
Geothermal Activities in Alaska	0	100
Global Meas of Radionuclides and JCCEM/Arctic Transport Studies	160	150
Nat Institute for Global Env Change	100	200
Neighborhood Environmental Watch	40	40
Wind/Renewable Activities in the Arctic	1,240	1,500
Total	12,330	14,810

Amchitka Island Project

Amchitka Island is located about 1,340 miles southwest of Anchorage, near the western end of the Aleutian Islands. The U.S. Atomic Energy Commission, the predecessor to DOE, conducted three underground nuclear tests on the island in the late 1960s and early 1970s. The first test was part of a program to differentiate between an earthquake and a nuclear detonation. The following two tests were part of the weapons effects program.

In 2002 the DOE's National Nuclear Security Administration's (NNSA) Nevada Site Office prepared and submitted a Closure Report to the Alaska Department of Environmental Conservation for the surface remediation work completed in 2001, which consisted of placing engineered covers on numerous drilling mud pits on the island. The report included a risk assessment for material existing on the surface from past spills.

In 2003 the DOE completed computer modeling of the subsurface environment for evaluating groundwater flow and associated contaminant transport from each underground test area. In addition, the potential for release of radionuclides into the marine environment from each test location was evaluated, and an associated human health risk assessment report was released.

Arctic Energy Office

The Arctic Energy Office (AEO) was established by PL 106-398 to support research that is appropriate for regions "where permafrost is

present or located nearby." Specifically the office is to sponsor research in two broad categories:

- Fossil energy, by promoting research, development, and deployment of enhanced oil recovery, drilling technologies, transportation systems, gas hydrates, conventional and unconventional gas, etc., and
- Remote power, by promoting research, development, and deployment of small hydroelectric facilities, wind, geothermal, fuel cells, and other alternative energy technologies.

To ensure that the most urgent research needs are being addressed, the AEO collaborates with state and Federal agencies, the energy industry (oil, natural gas, coal, and power generation), the environmental community, and the general public. The majority of AEO-funded projects are selected by two industry panels, one for each category listed above, and are coordinated through the University of Alaska Fairbanks under a five-year cooperative agreement that began in FY 2001.

Access to Federal and state lands is a critical factor for future exploration and development of oil and gas in Alaska. Ice roads are the preferred method for providing access to drilling sites on the North Slope. Water to build these roads is pumped from tundra ponds, which has resulted in controversy because there is little precipitation on the North Slope and little water flow except during the snowmelt in the spring. One project sponsored by the AEO examines the amount of water that can be safely pumped from tundra ponds and lakes. Similarly an AEO-sponsored research project being conducted by the Alaska Department of Natural Resources' Northern Region Land Section is investigating the potential for a new standard for tundra travel that will allow exploration activity, including seismic and exploration drilling activity, to be permissible for an increased period of time. The objective is to increase the exploration window to at least 130 days per season. In recent years the number of days in which the North Slope is "open" for exploration has been just over 100. Finally the office is collaborationg with the North Slope oil producers to identify novel gas treatment options that, if proven, could lead to significant reductions in the capital and operating costs associated with delivering North Slope natural gas to the lower-48 states.

In addition to addressing oil and gas research needs, the Arctic Energy Office sponsors research aimed at providing reliable and affordable power to remote villages. There are over 200 small Alaskan villages not serviced by an electric distribution grid system. While many villages are clustered along rivers or the coastline, they have very little infrastructure and no connection to the road system. Those located on rivers may be served by barges during the summer. Most are served by air transport year-round. The lack of transportation options complicates the economics of power generation. Most of these villages have diesel generators and small distribution systems. The cost of power in these villages runs from $0.20 up to as much as $0.80 per kilowatt-hour. The cost is heavily subsidized by the state government, but that subsidy is due to be reduced and phased out.

Many of the remote sites have potential for improving the efficiency of their diesel generators and for developing non-diesel energy resources. Villages located on or near the major rivers may benefit from run-of-the-river hydropower systems. Coastal locations have consistent and strong winds and strong tides that could be harnessed. Some locations have the potential for shallow natural gas, coal bed methane, or gas hydrates. Still others have identified coal beds in the region, but most of these are not defined or developed.

Following is a partial list of AEO-sponsored projects:

- Tundra travel model for the North Slope of Alaska;
- Physical, biological, and chemical implications of mid-winter pumping of tundra ponds (http://www.uaf.edu/water/projects/NorthSlope/lake_recharge/index.html);
- Injection of carbon dioxide for recovery of methane from gas hydrates;

Why Focus on Alaska?

- Alaska contains 22% of the total U.S. oil reserves (7.1 billion barrels) and 19% of the total U.S. natural gas reserves (36 trillion cubic feet—tcf).
- Alaska produces 19% of the total U.S. oil production (0.963 million barrels per day).

With regard to undiscovered resources:

- The USGS mean estimate for the National Petroleum Reserve–Alaska (NPRA) is 10.6 billion barrels of oil. The NPRA is partially open for exploration, and some discoveries have been announced.
- The USGS mean estimate for the Arctic National Wildlife Refuge (ANWR) is 10.4 billion barrels.
- The USGS and MMS estimates for undiscovered technically recoverable oil for onshore and offshore Alaska total almost 100 billion barrels of oil and natural gas liquids.
- The USGS estimate for technically recoverable natural gas for the entire North Slope region is 61.4 tcf.

Tracked vehicle of the type used for many years for tundra access in winter. Vehicles with very wide tires called rollagons are also used for this purpose.

- Rural Alaska coalbed methane: application of new technologies to explore and produce energy;
- South central Alaska natural gas supply study;
- Low-rank coal grinding performance vs. boiler performance;
- Characterization and alteration of wettability states of Alaskan reservoirs to improve oil recovery efficiency;
- Transportation issues in the delivery of gas-to-liquids products from Alaska North Slope to market;
- Solid oxide fuel cell system for remote power generation;
- Diesel-fueled solid oxide fuel cell system for remote power generation;
- Village power systems performance monitoring;
- Effects of village power quality on fuel consumption and operating expenses;
- Galena electric power situation options analysis; and
- Development of tilt-up, guyed, tower, and foundation system for wind turbines.

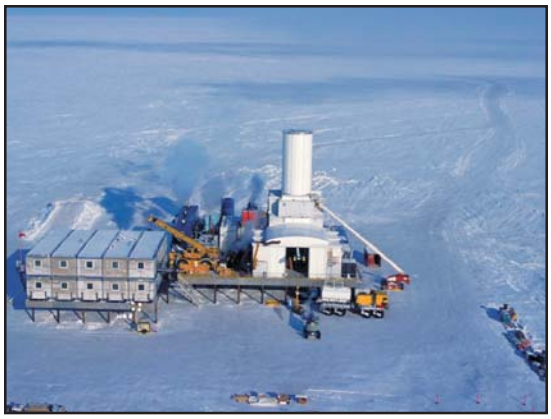
Arctic Methane Hydrates

The DOE is involved in several projects aimed at evaluating the methane hydrate resource on the North Slope of Alaska and in the Canadian Arctic. The primary objective of the effort is to characterize, quantify, and determine the resource potential of the gas hydrate and associated free gas in the region. The U.S. Geological Survey (USGS) estimates that roughly 45 tcf of methane is stored in the form of hydrate beneath the North Slope permafrost.

The USGS and DOE are working with industry partners to sample wells of opportunity and run well logs through the permafrost to the base of the gas hydrate stability zone. Wells have been sampled and logged in the Tarn and Milne Point units with Phillips (now ConocoPhillips) and BP Exploration–Alaska. Mud log and temperature data were correlated with gas sample analyses to identify the gas-hydrate-bearing formations at these locations. Observations from these wells provide data points for improving future hydrate resource estimates for the North Slope. Additional well sampling is anticipated in the NPRA, farther west.

BP is in the second year of a project to evaluate the hydrate potential of the Milne Point unit. The University of Alaska Fairbanks is developing a detailed reservoir model of the depositional environment and reservoir parameters from well logs. The reservoir model will be integrated with the geological structure model being developed from the shallow, 3,500-foot-depth, three-dimensional seismic data by the University of Arizona to identify fault control and seismic attributes related to permafrost, gas hydrate, and free gas distribution across the Milne Point study area. Results to date indicate there is a complex geometry of fault blocks that controls sediment and the distribution of gas in the shallow section. Discussions will be initiated in the third quarter of FY 2004 to develop the Phase 2 well plan.

Maurer Technology is in the second and final year of a project with Anadarko Petroleum Corporation to evaluate and test technologies for drilling, coring, seismic imaging, and sampling the hydrate stability zone in the area between the



Aerial view of Anadarko's Arctic Platform, set up and fully operational at Hot Ice #1.

Kuparuk River and Tarn units on the North Slope of Alaska. On February 7, 2004, the Hot Ice #1 well reached its total depth of 2,300 feet, approximately 300 feet below the hydrate stability zone. Although significant gas shows did occur in the hydrate stability zone, no confirmed hydrate was encountered. The project team is currently conducting a thorough post-drilling analysis of the core, log, and vertical seismic profile data to understand the drilling results. The project demonstrated a number of innovative technologies, including Anadarko's Arctic Drilling Platform, a mobile core analysis laboratory, and a new application of a continuous coring rig.

DOE was also involved in the Mallik Program, an international consortium that drilled a hydrate research well on Richard's Island, in the Mackenzie Delta, Northwest Territories, Canada, in the winter of 2001–2002. The other partners included the Geological Survey of Canada, Japan National Oil Company, Geoforschungs Zentrum Potsdam, USGS, India Ministry of Petroleum and Natural Gas, BP-ChevronTexaco-Burlington Joint Venture Group, and the International Scientific Drilling vProgram. In addition to numerous geological and geophysical analyses to map the concentration and extent of the hydrate, the program partners ran two production tests that both produced gas from hydrates.

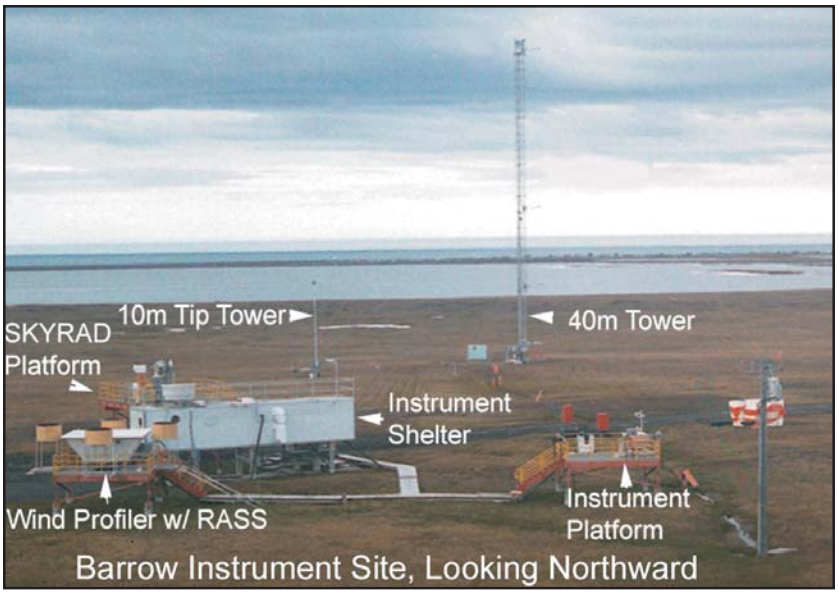
Atmospheric Radiation Measurement Program

The ARM Program, DOE's principal climate change research effort, seeks to resolve scientific uncertainties about global climate change with a specific focus on improving the performance of general circulation models (GCMs) used for climate research and prediction. The ARM program focuses on one critical feature of the GCMs: the transport of solar and thermal radiation (sunlight and radiant heat) through the earth's atmosphere to and from the earth's surface. Within this area the greatest uncertainties are associated with clouds: their formation, quantitative description, behavior, and optical characteristics as influenced by atmospheric and underlying surface conditions.

ARM created a number of long-term, highly instrumented climate research sites in carefully selected locations around the world. The site locations were selected primarily on the basis of what needs to be learned about clouds and radiation to improve the models, but secondarily on the basis of cost and logistics. Three Cloud and Radiation Testbed (CART) sites now exist, each with facilities at more than one location. The first site, in the southern Great Plains of the U.S. north of Oklahoma City, began operations during 1992. The Tropical Western Pacific (TWP) site began phased operations in 1996. The third CART site, the North Slope of Alaska and Adjacent Arctic Ocean (NSA/AAO), was dedicated in July 1997. The Barrow facility ramped up operations over the following year. Subsequently an outlying facility was established at Atqasuk, 100 km inland from Barrow. Routine data acquisition at the NSA/ AAO site offshore began in October 1997 as part of the Surface Heat Budget of the Arctic (SHEBA) experiment primarily sponsored by the National Science Foundation and the Office of Naval Research (ONR). SHEBA involved a research ice camp deployed around an icebreaker frozen in and drifting with the Arctic ice pack for a year. ARM provided radiometric and cloud characterization data using its instrumentation deployed aboard the icebreaker. SHEBA concluded in October 1998.

The CART sites originally had a planned life of ten years. The rationale for their long duration is that virtually all process-focused meteorological and climatological efforts to date have been based on short-term field efforts (a few weeks to a few months). During these brief periods the quantity of data that can be acquired is inadequate to provide the statistical accuracy and precision required. With all of its potential economic and other societal impacts, global climate change is nevertheless the result of small radiative effects—a difference of a few watts per square meter in the energy balance out of an average energy flow of several hundred. To improve our ability to predict climate change, the physical effects that must be measured and accurately modeled are small. This requires statistics drawn from large numbers of measured situations, not just a few.

Other agencies have been monitoring climate for decades. Why aren't these efforts adequate for ARM purposes? Monitoring efforts focus on measuring a few important climate-related parameters, not the full range of parameters needed for the process studies that will improve the GCMs. The ARM program fills the critical gap between field campaigns and other agency measurements. For the NSA/AAO CART site, the central facility is adjacent to NOAA's high-latitude climate monitoring facility near Barrow. The only National Weather Service station on the North Slope of Alaska is also located at Barrow, further enriching the data



Low-level aerial view of the ARM Climate Research Facility (ACRF) Barrow site. See http://www.arm.gov for a description of the instrumentation.

environment. ARM has taken advantage of existing facilities and has greatly augmented the instrumentation to provide the data needed for climate process research.

A generic, fully developed CART site includes facilities spread over a large area. The central facility at Barrow has the largest concentration of instrumentation. It relies heavily on upward-looking remote sensors (radars, lidars, and radiometers of several kinds) to determine the characteristics of the clouds, winds, and atmosphere as a whole above the site on a continuous basis. The inland facility at Atqasuk has a subset of the instrumentation deployed at Barrow. A temporary facility at Oliktok Point to the east of Barrow is planned for field campaigns that use instrumented tethered balloons, which cannot be accommodated at Barrow because of FAA constraints. In addition to ground-based instrumentation for characterizing the atmosphere and the earth's surface, it is necessary to depend heavily on data from polar-orbiting satellites and to make occasional instrumented aircraft flights to measure conditions aloft.

The NSA/AAO site provides data about cloud and radiative processes at high latitudes and, by extension, about cold and dry regions of the atmosphere in general. These data will be used to refine models and parameterizations for high-latitude regions and for the upper atmosphere. More specifically the issues of principal interest as they apply to cold regions are as follows:

- Atmospheric radiative transfer;
- Ice and mixed-phase cloud formation, evolution, and dissipation;
- Behavior of surface radiative characteristics;
- Direct and indirect aerosol radiative effects; and
- Development and testing of satellite remote sensing algorithms.

For more information, visit the ARM NSA/AAO web page at http://www.arm.gov/sites/nsa.stm.

Since the ARM/CART sites were first established, they have hosted many projects and researchers from other DOE programs and from other agency programs that find the data-rich environment of the CART sites convenient and cost effective for conducting their own related research. Consequently in June 2003 the three ARM/CART sites taken together were declared to be a DOE National User Facility known as the ARM Climate Research Facility (ACRF). ACRF is not limited to a predetermined life. It is planned that ACRF will continue as long as it is needed. What has now become ACRF NSA/AAO conducted the following Intensive Operating Periods (IOPs) in recent years (IOPs are the mechanism through which additional site activities are authorized):

- FIRE (First ISCCP [International Satellite Cloud Climatology Program] Regional Experiment, in collaboration with NASA, 1998);
- Single Column Model (in collaboration with Aerosonde Inc. and the Australian Bureau of Meteorology, 1999);
- MM Wave Arctic Winter Radiometric Measurements (in collaboration with NOAA and NASA, 1999);
- Second International Pyrgeometer and Absolute Sky Scanning Radiometer Comparison (in collaboration with the World Radiation Center, 2000);
- Russian Ice Station Comparison (in collaboration with the International Arctic Research Center, since 2001);
- Digicora Radiosonde Installation and Testing (an internal ARM program, 2002);
- Radiosonde Intercomparison (in collaboration with the National Weather Service, since 2002);
- ADEOS (Advanced Earth Observing System) Validation (in collaboration with the Japanese Space Agency, 2003);
- Aerosonde Robotic Aircraft Development (in collaboration with the National Science Foundation, with more than a half dozen deployments since 2000);
- AIRS (Atmospheric Infrared Sounder) satellite remote sensor validation (in collaboration with NASA, with annual several-month intercomparisons since 2002); and

- Boundary Layer Cloud Experiment (an internal ARM program, 2003).

In addition, another five IOPs are either ongoing or planned at the NSA/AAO.

Geothermal Energy Activities in Alaska

The Geothermal Technologies Program has initiated a Geopowering the West program in Alaska. Activities are underway to develop a Geothermal Working Group there. DOE funded the Alaska Division of Energy to support this effort and to sponsor a mission for approximately 15 Alaskans to travel to Nevada, tour producing geothermal sites, and talk to developers, regulators, and others about geothermal development. This is a kick-off activity.

Global Measurements of Radionuclides in the Atmosphere and Precipitation

The objectives of this program are to characterize, quantify, and model the environmental pathways of natural and anthropogenic radionuclides deposited on the earth's surface and to evaluate their environmental and human health impacts on regional and global scales. A component of this program is the operation of a high-quality global radioactivity sampling network by what had been DOE's Environmental Measurements Laboratory (now part of the Department of Homeland Security), which includes stations in the Arctic and sub-Arctic (Alaska, Canada, Greenland, and Norway). Through the global network, DOE continues to be poised to react quickly to any new introduction of atmospheric radioactivity.

U.S.–Russia Contaminant–Transport Studies

The nuclear waste storage facilities in Russia, where plutonium was produced in large quantities during the Cold War, now pose threats to the environment. Nuclear wastes were often stored in shallow soils and surface water impoundments at these facilities. One of these sites is at the Mayak Production Facility, Ozersk, in the Chelyabinsk region of the southern Urals, Russia, where from 1949 to 1951, medium- and high-level radioactive waste was discharged directly into the Techa River system, which flows via the Ob River into the Kara Sea. When this discharging ceased in 1951, the medium- and high-level waste from Mayak was then discharged into Lake Karachay, inside the complex. This area in Russia, which lies near the edge of the West Siberian Plain and Basin, is now one of the most severely contaminated environments in the world. Furthermore, it is possible that the surface water and groundwater in that region are hydraulically connected to an extensive system of rivers, lakes, and swamps that might discharge to the western Siberian oil and gas fields and eventually to the Arctic Ocean.

DOE's Office of Environmental Management International Collaboration Projects, through Florida State University's Institute for International Cooperative Environmental Research, sponsored subsurface contaminant transport studies at the Mayak, Krasnoyarsk, and Tomsk sites in Russia. This work was performed under the auspices of the former Joint Coordinating Committee for Environmental Restoration and Waste Management (JCCEM) between the Office of Environmental Management (DOE-EM) and the Ministry of Atomic Energy (MINATOM) for the Russian Federation. The main types of investigations conducted in 2002–2003 and their results are reported below.

Investigations at the Mayak site included hydrogeological, geochemical, geophysical, and radiometric characterization, as well as three-dimensional modeling of the migration of the groundwater plume containing radionuclides (^{90}Sr, ^{137}Cs, ^{238}U, and ^{239}Pu) and a nitrate. These investigations also included the evaluation of sorption effects on contaminant transport. Based on the results of geological and hydrological field investigations at Mayak, an extensive computer model of the Mayak site was developed that included the surrounding land areas, the surface water bodies, and the geological formations underlying the site. This numerical model has been adapted to the Hanford site. Although the geologic and hydrologic conditions at the Hanford site are somewhat different, the application of this model at Hanford will be used in the development of a comprehensive plan for addressing the potential environmental threats to the Columbia River Basin region. The development of a transient modeling scheme will permit improved characterization of the horizontal and vertical migration of radioactive plumes at the Mayak and Hanford sites.

Russian scientists have developed a local three-dimensional hydrodynamic and contaminant transport model for radioactive contamination in Lake Karachay groundwater. Using inverse modeling, these scientists determined the migration

The point of contact for the Amchitka Island, Alaska, Project is Monica Sanchez, U.S. Department of Energy, Environmental Restoration Division, Nevada Operations Office, Las Vegas, NV; 702-295-0160.

The point of contact for the Arctic Energy Office is Brent Sheets, National Energy Technology Laboratory, P.O. Box 750172, 539 Duckering Building/ UAF Campus, Fairbanks, AK 99775-0172, 907-452-2559; brent.sheets@netl.doe.gov.

The point of contact for DOE's Methane Hydrate Program is Brad Tomer, U.S. Department of Energy, National Energy Technology Laboratory, Morgantown, WV 26507; 304 285-4692.

The point of contact for the ARM program is Dr. Wanda R. Ferrell, Atmospheric Radiation Measurement Program Manager, Climate Change Research Division, SC-74, U.S. Department of Energy, 1000 Independence Ave., SW, Washington, DC 20585; 301-903-0043, wanda.ferrell@science.doe.gov.

The point of contact for the NIGEC program is Dr. Jeff Amthor, NIGEC Program Manager, Climate Change Research Division, SC-74, U.S. Department of Energy, 1000 Independence Ave., SW, Washington, DC 20585; 301-903-2507, jeff.amthor@science.doe.gov.

The point of contact for the Geothermal Program is Roy Mink, Office of Energy Efficiency and Renewable Energy (EE-14), U.S. Department of Energy, Washington, DC 20585; 202-586-5340; Roy.Mink@ee.doe.gov.

parameters for ^{90}Sr and ^{137}Cs in groundwater. The study of the historical evolution of contamination in water-bearing rocks (the solid phase of the Lake Karachay plume) included an evaluation of groundwater contamination by radionuclides leaching from the solid phase. The results of extensive modeling studies allowed the scientists to better understand the field-scale migration of radionuclides in ground water from a former surface nuclear waste repository at Lake Karachay towards the Mishelyak River.

Based on geologic, hydrogeologic, and hydrologic characterization data, these Russian scientists developed a transient, three-dimensional regional hydrodynamic model, containing the deep-well injection areas and the recharge and discharge areas for subsurface water at the Siberian Chemical Combine near Tomsk. The study also included an evaluation of the effectiveness of monitoring and remediating deep ground water near deep injection wells.

U.S. researchers involved in the program are from the Pacific Northwest National Laboratory, the Savannah River Laboratory, the Environmental Measurements Laboratory, and the Lawrence Berkeley National Laboratory. Russian scientists are from Hydrospetzgeologiya, the Mayak Production Association, the Siberian Chemical Combine, the Institute of Industrial Technologies, and the Institute of Physics and Power Engineering.

The results of these projects can be used to support the remediation programs at Hanford, Savannah River, Rocky Flats, and other DOE sites and to calibrate and validate conceptual and numerical models developed by DOE scientists.

National Institute for Global Environmental Change

Through the DOE National Institute for Global Environmental Change, headquartered at the Davis campus of the University of California, university scientists can apply for research support to study ecological effects of climatic change in Alaska (and other states). In FY 2003, two university projects were funded in Alaska. One, conducted by Columbia University, is examining the response of Pacific Northwest and Alaskan forests to recent multiple environmental changes, including climatic changes. The question to be answered is whether environmental changes, which have been relatively large and rapid in sub-Arctic regions, is having a discernable effect on the growth and health of forest trees. The second, conducted by the University of Oregon and the University of Alaska, is examining potential effects of warming on plant parasites in the understory of boreal forests. Any changes in plant parasites caused by global warming could have effects, negative as well as positive, on basic plant growth and the goods and services supplied to humans by Alaskan forests.

Neighborhood Environmental Watch Network: NEWNET

NEWNET is a network of environmental monitoring stations and data storage and data processing systems, with public access to the data through the Internet. This allows interested members of the public to have constant access to the stations so they can observe the results at any time.

NEWNET was started in 1993 with stations in Nevada, California, Utah, and New Mexico. It is based on concepts developed by DOE for the Community Monitoring Program at the Nevada Test Site Nuclear Testing Facility. These concepts date back to the Three Mile Island Nuclear Power Reactor accident in the late 1970s. Five stations are located in Alaska: in Barrow, Fairbanks, Kotzebue, Nome, and Seward. A station manager from each community is trained in station maintenance and has access to researchers and support organizations that can provide technical assistance if needed. Station managers serve as liaisons to their communities and can help citizens understand measurements.

Stations can vary in configuration. Most NEWNET stations have sensors for monitoring wind speed and direction, ambient air temperature, barometric pressure, relative humidity, and ionizing gamma radiation. Some stations have tipping bucket rain gauges, and others have additional radiation sensors. Other types of sensors are being investigated for air quality measurements.

The Alaska stations are being set up in collaboration with the Alaska Department of Environmental Conservation (ADEC) and the University of Alaska Fairbanks. The project is funded by DOE. This effort will strengthen collaborations between Los Alamos National Laboratory (LANL), ADEC, and DOE in studying the environment in Alaska. It will promote an understanding of radiological issues in Alaska and provide continuous monitoring of radiation levels. More information on NEWNET, including readings from NEWNET stations, can be found on the web at http:/newnet.lanl.gov/.

For the Global Measurements of Radionuclides in the Atmosphere and Precipitation projects, the points of contact are Matthew Monetti and Fabien Raccah, U.S. Department of Homeland Security, Environmental Measurements Laboratory (EML), Environmental Sciences Division, 201 Varick Street, NY, NY 10014; 212-620-3525 and 212-620-3379. The point of contact for the Joint Coordinating Committee for Environmental Management: Contaminant Transport Studies Project is Kurt Gerdes, DOE, Office of Environmental Management, International Programs Manager, 301-903-7289, Kurt.Gerdes@em.doe.gov. The point of contact for the NEWNET Program is Mike McNaughton, M.S. J978, Los Alamos National Laboratory, Los Alamos, NM 87545; 505-667-6130. The points of contact for the Department of Energy Wind Activities in Alaska are Dennis Lin, Office of Wind and Hydropower Technologies (EE-2B), Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington, DC 20585; 202-586-7285; and Thomas Sacco, Office of Weatherization and Intergovernmental programs (EE-2K), Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington, DC 20585; 202-586-0759.

Wind and Renewable Activities in the Arctic

The Department of Energy has been supporting wind power projects in Alaska for several years through various local and state organizations. These projects are aimed at providing lower-cost energy alternatives to rural Alaskan communities. These include projects through the DOE's Tribal Energy and Wind Programs. In addition, other renewable energy studies are underway. National Wind Technology Center personnel provide expert technical support to these projects by supplying anemometers, evaluating the wind resources, conducting wind workshops, and sponsoring local representatives to attend technical workshops. A list of the ongoing relevant Arctic/sub-Arctic projects is given below.

Kotzebue Electric Association

The objectives of this project for the Kotzebue Electric Association (KEA) are:

- To test and verify wind generation technology applications in wind/diesel hybrid systems and to provide system performance/cost data;
- To maximize the reduction in consumption of diesel fuel by KEA through the use of wind power generation;
- To develop a cold-weather wind turbine test site that will be available to DOE and the U.S. wind industry to develop advanced turbine designs;
- To provide educational outreach activities for the general public in Alaska and for operators who will be trained to operate the hybrid wind/diesel power plants; and
- To provide a basis for the evaluation of wind power system applications in the numerous diesel power plants serving remote, non-grid-connected Alaska villages.

City of Unalaska

The City of Unalaska is utilizing the DOE funds to evaluate future wind power installations and other combinations of wind plus diesel, biogas, hydro, or other cogeneration fuel sources. The city is conducting studies to determine wind resources; evaluate and characterize sites; gather data on physical installation of turbines; and develop a better understanding of other design considerations. This project is part of a larger effort by the city to obtain additional energy sources and to reduce dependencies on fossil fuels. Projections for the electrical demands of the city demonstrate that Unalaska will be unable to meet its energy demand in approximately five years.

TDX Corporation (St. Paul Island)

TDX is using its DOE grant funds to proceed with detailed engineering analysis and to purchase and install measurement equipment needed to evaluate the expansion of the TDX-owned wind/diesel cogeneration power station on Saint Paul Island, Alaska. In addition, TDX will begin acquisition of specific plant equipment in preparation for expansion, including expansion of the existing hot water loop, cooling system modifications, and acquisition of a second wind turbine gear box. This expansion will enable TDX to become Alaska's largest wind–diesel power plant. The goal of this study is to develop a master plan for interconnection with the City of St. Paul diesel generation plant and to provide electricity for the entire island.

Yukon–Kuskokwim Health Corporation

The Yukon–Kuskokwim Health Corporation (YKHC) is conducting a feasibility study for installation of small-scale wind turbines to serve YKHC facilities. Energy cost savings resulting from this project will allow the YKHC to direct more money toward its core mission of providing quality health care to the Alaska Native communities in the Yukon–Kuskokwim Delta region.

Native Village of Venetie

The Native Village of Venetie Tribal Government is conducting a feasibility study for powering an entire village during the season of the midnight sun using renewable solar energy. The system will allow the diesel generators to be turned off for most of the summer, yielding great economic, environmental, and social benefits. The system would operate year round. While there would be no solar energy input during the long night of December and January when the sun does not rise above the horizon, the system's energy storage component would continue to provide benefits by saving fuel by allowing more steady generator operation and by providing back-up power during generator outages.

Department of Health and Human Services

The Department of Health and Human Services supports and conducts Arctic health research through the National Institutes of Health and the Centers for Disease Control and Prevention.

National Institutes of Health

The National Institutes of Health is an agency of the Department of Health and Human Services. Comprising 27 institutes and centers, the NIH is headquartered in Bethesda, Maryland, and has satellite facilities elsewhere in Maryland and in North Carolina, Montana, and Arizona. The NIH's mission is to uncover new knowledge that will lead to better health for everyone. NIH supports research on Arctic-related health issues through grants and contracts to non-Federal scientists and through the projects carried out by scientists in NIH laboratories and clinics.

	Funding (thousands)	
	FY 02	FY 03
National Institutes of Health	21,292	32,776
Health Resources Services Admin.	500	0
Centers for Dis. Control/Prevent.	4,400	4,400
Total	26,192	37,176

National Institute on Aging

The NIA funded a major new initiative in FY 2001 under the U.S. Arctic Research Plan. The NIA and the Icelandic Heart Association are collaborating on the Age, Gene/Environment Susceptibility (AGES) Study: "The Reykjavik Healthy Aging Study for the New Millennium." This study was initiated by the NIA to examine genetic susceptibility and gene–environment interaction as these contribute to phenotypes common in old age. The clinical examination center at the Icelandic Heart Association near Reykjavik opened on September 1, 2002. Over the following four years, 8,000 participants from the earlier Reykjavik Study (1967–1996) will be examined in the clinic, with another 1500 examined in a home examination. The study has four major focus areas: neurocognitive conditions, cardiovascular health, musculoskeletal conditions, and body composition and metabolic disease. An examination of 9,500 surviving members of the Reykjavik Study will define phenotypes for candidate gene studies and will also be used as end-points of the cardiovascular risk factors. By September 2003 approximately 2,000 men and women had been examined in the clinic. Since the inception of the project, the National Eye Institute, the National Institute for Deafness and Communication Disorders, and the National Heart, Lung, and Blood Institute have joined the collaboration.

The NIA continues to fund the Resource Center for Minority Aging Research, titled the Native Elder Research Center (NERC), supported by a $2.5 million, five-year grant from the National Institute on Aging and the National Institute for Nursing Research, located within the Division of American Indian and Alaska Native Programs of the Department of Psychiatry, School of Medicine, University of Colorado Health Sciences Center in Denver. The center coordinates a research career development program targeted at American Indian (AI) and Alaska Native (AN) investigators, focusing on aging, health, and culture. Denise Dillard, a new Native investigator in the center, works for the Southcentral Foundation, an Alaska Native 503C nonprofit extension of the Cook Inlet Region, Inc., which is examining the relationships among depression, health status/functioning, service use, and medication patterns. The center augments partnerships with AI/AN communities to ensure access to systems of care in aging research.

Engaging the University of Alaska in aging research and enhancing research capabilities consistent with the goals of the Alaska Geriatric Education Center (AKGEC) were the main goals of a September 2003 Regional Meeting on Aging Research. NIA staff conducted workshops in Anchorage and Fairbanks, Alaska. Developed with input from the NIA Work Group on Minority Aging and the Task Force on Minority Aging Research, a subcommittee of the National

Advisory Council on Aging, the Regional Meeting format provides a framework for engaging underrepresented groups and populations in strategic activities designed to strengthen research on diseases and conditions of aging and optimize the NIA's research portfolio.

National Institute on Alcohol Abuse and Alcoholism

Alcoholism is one of the most important public health problems among Alaska Natives in the Arctic region. While Alaska Natives comprise about 20% of the population, approximately 50% of individuals admitted for alcohol treatment in the region are Alaska Natives. The NIAAA goal is to identify the causes and consequences of alcohol consumption and to develop and validate effective treatment and prevention strategies for adverse health and behavioral consequences of drinking. The institute supported two projects in the Arctic region in FY 2002–03, one to test the efficacy of pharmacological adjuncts in current alcoholism treatment of Alaska Natives, the other to test a theoretical model of pathways that facilitate recovery from alcohol abuse.

National Institute of Allergy and Infectious Disease

The NIAID conducts and supports scientific research on infectious and immunologic diseases. The institute's basic and applied research promotes the development of vaccines, diagnostic tests, and drug therapies to prevent and control these diseases.

Haemophilus influenzae type b

Before the introduction of a vaccine against *Haemophilus influenzae* type b (Hib) in the late 1980s, an estimated 16,000–25,000 children in the U.S. annually showed signs of invasive bacterial infection by Hib. Today, with use of a conjugate vaccine developed with support from NIAID, Hib infection has been reduced by 99% in the U.S. Interestingly there is evidence that the Hib vaccine decreases the rate of carriage of Hib among vaccinated children, therefore decreasing the chance that unvaccinated children will be exposed. In FY 2002 and FY 2003, NIAID continued its support of a three-year pilot intervention trial in three Alaska Native villages with high numbers of asymptomatic carriers of Hib. The goal is to determine if Hib conjugate vaccine can be given to persons of all ages to eliminate or reduce Hib colonization. The researchers hope to determine what treatment most effectively eliminates the Hib reservoir from a village. Several treatment regimes are being compared, including the comparison of treatment with the Hib conjugate vaccine with and without the antibiotic rifampin to that of treatment with rifampin alone (the standard treatment). Preliminary results indicate that mass vaccination with Hib conjugate vaccine is possible and may decrease the burden of Hib colonization and overall disease in communities where Hib disease is persistent.

Hepatitis C

Hepatitis C (HCV) is a blood-borne, liver-targeting viral infection and is an important cause of morbidity and mortality in this country. Approximately 80% of the people infected with HCV will develop chronic hepatitis, and all are at higher risk for cirrhosis and a type of liver cancer, hepatocellular carcinoma. NIAID continued to support studies of the relationships between hepatitis C virus replication, evolution, and disease progression in Alaska Natives. To date, over 900 HCV-positive patients have been enrolled in the study. Blood and liver specimens are being collected to examine levels of and variation in HCV virus and to compare these with disease progression. This well-defined Alaskan Native population may lead to many key answers regarding the natural history of hepatitis C.

Histocompatibility and Immune Recognition

In FY 2002 and FY 2003, NIAID, in conjunction with several other NIH institutes and centers and the Juvenile Diabetes Research Foundation International, continued its support of the International Histocompatibility Working Group, a network of more than 200 laboratories in over 70 countries that collect and share data on genes of the human leukocyte antigen (HLA) complex. Researchers analyzed HLA genes in Alaskan Yup' ik Eskimos to determine the different types of histocompatibility genes and their frequency in that population.

Organ Donation

NIAID continued its support of an education outreach program at the University of Washington Hope Heart Institute aimed at increasing organ donation and transplantation among Alaska Natives. The Hope Heart Institute developed an educational video on organ donation and transplantation that was culturally sensitive and specific to Alaska Natives.

National Cancer Institute

The Role of EBV in the Etiology of Nasopharyngeal Carcinoma

The University of North Carolina, Chapel Hill is determining the role of the Epstein–Barr virus (EBV) in the etiology of nasopharyngeal carcinoma (NPC), an epithelial malignancy that develops with high incidence in southern China, in northern Africa, and among Eskimos. The viral genes that are expressed in NPC include the latent membrane proteins LMP1 and 2 and a new family of mRNAs, transcribed through the BamHI A fragment. Glutathionein transferase fusion proteins will be synthesized to produce monospecific antisera to identify the proteins in transfected cell lines and in NPC tumor tissues. The proteins will be tested for interactions with cellular proteins and for transactivation of the LMP1 promoter.

Reports from the Alaska Native Tumor Registry

The Alaska Native Tumor Registry (ANTR) was initiated in 1974 in collaboration with NCI and the Centers for Disease Control and Prevention. Procedures and policies were those of the NCI Surveillance, Epidemiology and End Results (SEER) Program. The registry became a member of the SEER Program in 1999 as a supplemental registry, increasing SEER's coverage of minority populations. ANTR has completed two recent reports, "Cancer in Alaska Natives 1969–1998, 30 Year Report" and "Alaska Native Cancer Update, 1987–1999," distributed statewide to medical providers, tribal health board members, and key tribal personnel. In addition, ANTR has worked with the New Mexico Tumor Registry to complete a comparison of cancer rates between Alaska Natives and southwest American Indians.

New Studies Undertaken by Northwest Portland Tribal Registry

Over the last ten years, health care delivery for northwest American Indians and Alaska Natives (AI/AN) has evolved from a centralized system maintained by the Indian Health Service (IHS) to a diverse and complex environment. The Northwest Tribal Registry Project was developed in January 1999 by the Northwest Tribal Epidemiology Center, located at the Northwest Portland Area Indian Health Board (NPAIHB) in Portland, Oregon. The existing disease registry has linked with state data to ascertain the incidence and prevalence of diseases such as cancer among northwest AI/AN. A critical difference with previous studies is the longitudinal focus.

Patterns of Cancer Care Among Native Americans

Limited information is available about contemporary cancer care among Native American populations. Data have been combined from several sources, including SEER and the Indian Health Service (IHS), augmented by abstracting data from medical records in a sample of cancer patients. The first project focused on the linkage of SEER and IHS data files to evaluate the completeness and quality of data elements. A current effort involves gathering data on patterns of care for American Indians and Alaska Natives living in South Dakota. In 2003, three personnel were trained in cancer registration for South Dakota tribes, attending the "Principles of Oncology" course at NCI.

Native Cancer Information Resource Center and Learning Exchange

C.I.R.C.L.E. has been in operation as a national clearinghouse for cancer education materials specific to American Indian and Alaska Native communities since 1998. The center has become the educational arm for the American Indian/Alaska Native Leadership Initiative on Cancer, funded as a cooperative agreement. The center has the most up-to-date bibliography in the nation on cancer affecting American Indians and Alaska Natives.

Conference Support for American Indians and Alaska Natives

In 2003, NCI assisted C.I.R.C.L.E. in funding

- The Second Annual Northern Plains Regional Indian Cancer Conference, hosted by the Shakopee Mdewakanton Sioux Community in Prior Lake, Minnesota;
- The annual meeting of the Native WEB (Women Enjoying the Benefit); and
- The semi-annual meeting of the Network for Cancer Control Research among American Indian and Alaska Native Populations, in Rochester, Minnesota.

National Institute on Drug Abuse

NIDA supports over 85% of the world's research on behavioral, psychological, biological, medical, and sociological aspects of drug abuse and addiction. Since 1994, NIDA has been funding a series of grants to the University of Alaska Anchorage (UAA) dealing with the spread of substance abuse, related mental health problems, and HIV/AIDS and other infectious diseases (such as

STDs, hepatitis B and C, and tuberculosis). Out of this has come a large, five-year project with the University of New Mexico (UNM), the first systematic study of rural health care for stigmatized illnesses. Researchers are defining the unique health issues in rural and frontier populations, including the ethics of health care (such as the ability to maintain confidentiality in small communities); psychosocial issues of rural life; the effects of stigma in small, scattered populations; and the unique barriers to care. NIDA supports drug-abuse-related health issues in Alaska Native women, such as unsafe sexual practices and how they affect the transmission of diseases such as AIDS and hepatitis B and C. NIDA-funded researchers at UAA have been developing a model to predict and identify subgroups of women and their risk behaviors relative to the use of drugs and condoms.

The NIDA-supported extramural research initiatives at the UAA have also benefited from UAA's Telemedicine Project, which helps transmit important clinical and disease and drug use prevention information across Alaska in a series of "research at a distance" projects. These projects use desktop video teleconferencing and narrowband technology.

NIDA is also involved in Arctic research efforts in Russia, which has one of the fastest growing AIDS epidemics in the world; drug abuse is the primary transmission mode. The immune deficiencies caused by the HIV viruses have led to an explosion of opportunistic infections and drug-resistant tuberculosis. NIDA will continue to play a leadership role in conducting related research and research training on treating and preventing these diseases with the Russian scientists and other NIH institutes that are funding projects in the region. NIDA has participated since 1992 in the annual International Conference on AIDS, Cancer, and Related Problems, sponsored by the Russian Ministry of Science, the Russian Biomedical Center, St. Petersburg State University, and the NIH Fogarty International Center. In January 2003, NIDA was involved in a special meeting at St. Petersburg State University to establish the first school of public health in the former Soviet Union.

National Institute of Dental and Craniofacial Research

The NIDCR provides support to the Northwest/Alaska Center to Reduce Oral Health Disparities, located at the University of Washington in Seattle, for research projects that will impact on children in the Yukon–Kuskokwim Delta of southwestern Alaska. Objectives include the prevention and control of dental caries. Alaska Native children are disproportionately affected by early childhood caries, compared to all U.S. children. The cultural practice of pre-mastication of solid food for infant feeding amplifies the transmission of oral secretions from adult to child. The prevention of early *S. mutans* acquisition and subsequent caries in infants and toddlers requires efforts starting at birth. A community-based, randomized clinical trial will determine if the serial use of chlorhexidine and xylitol in mothers will reduce the vertical transmission of cariogenic bacteria between Alaska Native mothers and infants. This novel preventative intervention could have an impact on the prevalence of caries. Also, through the University of Washington Northwest/Alaska Center, NIDCR supports development of a web-based tool (EthnoDent) that focuses on reducing cultural barriers between providers and multicultural patients (including Native American/Alaska Natives) in the area of children's oral health.

National Institute of Environmental Health Sciences

The NIEHS is funding studies investigating the perinatal effects of peri- and postnatal exposure to endocrine disruptors, including several organochlorine pollutants and methylmercury in the Faroe Islands. Stored maternal serum from week 34 of pregnancy and neonatal serum will be used to evaluate the endocrine status. Data on growth and development from annual examinations up to age 5.5 years are available and will be supplemented by examinations at ages 7 and 9 years, when advanced testing will be applied to assess sexually dimorphic behaviors, domain-related neurobehavioral function, serum hormone concentrations, and developmental markers of early puberty development. The study assessing the effects of methylmercury showed mild deficits associated with prenatal exposures that were previously thought to be safe.

The effects of environmental contaminants and infant development are being investigated at Nunavik, Canada. The traditional diet of the Inuit from Nunavik includes ringed seal and beluga whale meat and blubber and other marine food. Since these species may contain high concentrations of environmental contaminants, the Inuit Cohort Study was initiated to investigate pre-

and postnatal developmental outcomes resulting from exposure to these substances. Inuit women reported eating large amounts of fish, beluga, and seal meat and fat during their pregnancies. Fish and seal meat consumption was associated with increased mercury exposure as measured in hair samples. Traditional food intake during pregnancy was unrelated to PCB body burden because it is more of a function of lifetime consumption and exposure. Many women increased their consumption of these foods because of pregnancy-related changes in food preferences and their belief that these foods were beneficial for the women and their fetuses. Studies will determine whether the children experience any learning disabilities associated with the diets of their mothers during pregnancy.

The Environmental Justice and Health for Saint Lawrence Island project is intended to serve as a model of the most effective way to exchange information among remote or isolated Alaska Native maritime communities, healthcare providers, and scientists concerning environmental justice and health. The primary objective is to establish self-sufficiency in Alaska Native communities, within existing healthcare systems, to minimize exposure to environmental contaminants. An advisory committee, a research team, healthcare providers, and members of the affected community will collaborate to set up communication among the collaborating groups, create a sampling program to test for environmental contaminants, establish a community health assessment program, and use the emerging data to implement an environmental justice and health training program. Elevated levels of PCBs were reported in soil, air, berries, greens, water from the Suqi River, and sediment samples at the Saint Lawrence Island Northeast Cape military site. All of the people tested had elevated levels of PCBs.

The Geographic Modeling of Traffic and Asthma Rates study is examining the factors associated with the incidence of asthma in young school children in Anchorage, Alaska. The purpose of the study is to evaluate individual risk factors and environmental proximity to traffic with the incidence of asthma in kindergarten and first-grade children in 12 neighborhood schools. The use of asthma medication among elementary schoolchildren was associated with particulate pollution in a locale where PM10 consisted primarily of coarse-fraction material derived from road sanding and re-entrained volcanic ash. All models showed positive and significant coefficients for PM10 during periods when asthma medication was administered to the schoolchildren.

The Dietary Benefits and Risks in Alaskan Villages project addresses dietary questions raised by Native people living in Atka, St. Paul, and other Aleut villages dependent on traditional foods collected from the Bering Sea and islands where they live. The project aims are to:

- Develop, utilize, and evaluate a model that requires greater community responsibility, involvement, guidance, and participation with researchers and government;
- Document the diets of two Alaskan villages, including the types, quantities, and methods of preparation, for the purpose of guiding contaminant research;
- Collect preliminary data on nutritional value, as well as levels of persistent organics, radionuclides, and heavy metals in subsistence foods for tracking of contaminant trends;
- Provide a balanced assessment of both the risks associated with environmental contaminants and the nutritional, cultural, and physical benefits of a traditional diet; and
- Develop, utilize, and evaluate a model for combining a variety of village-specific data streams including diet, epidemiological effects, and contaminant levels.

Accomplishments in the first two years of this project include a dietary survey in the community of St. Paul, creation of Village Advisory Groups in St. Paul and Atka, two films (*Alaska Native Diet: Introduction to Dietary Benefits* and *Risks in Alaskan Villages and Alaska Native Diet: The Importance of a Traditional Diet*), the beginnings of a risk assessment model process, and many community educational outreach activities. The next phase of this project is to sample selected traditional foods from both St. Paul and Atka. The Village Advisory Group in St. Paul has met several times recently and has decided to sample halibut for nutrients and contaminants. Atka is in the process of identifying and choosing the laboratories that will do the analysis for contaminants and nutrients.

National Institute of General Medical Sciences

The NIGMS, through a partnership with the Indian Health Service, is supporting several projects by the Alaska Native Tribal Health Consortium through a four-year grant. One applied study investigates the degree of concordance of

diagnoses of the effects of myringotomy via telemedicine versus live diagnosis. This study is important because of the challenges of delivering care to rural Alaska. Another study examines the prevalence of disabilities. For rural, subsistence, or working class families, disabilities can have profound effects. Two projects deal with nutrition. One is on the Alaska Native diet and an assessment of the nutrition of subsistence foods. Another is a study of maternal nutrition during pregnancy among Alaska Natives. Three studies, funded in part by co-funding from NIAID, examine infectious diseases. Chronic hepatitis B is examined to determine prevalence and serotype, which may aid in understanding modes of communication of the disease. The rates of re-infection with *Helicobacter pylori* after treatment is being examined, since infection rates are as high among Alaska Natives as anywhere in the developing world. Pneumococcal disease prevention is another high priority because of the alarming incidence of otitis media in Native populations.

National Institute of Mental Health

Mental and behavioral health in rural and frontier Alaska is tied to the emotional, physical, spiritual, family, social, and cultural well-being and health of individual Alaska Natives, their families, and the communities where they live. Among the leading causes of death for Alaska Natives are suicide, accidental injury, alcohol-related deaths, and homicide.

The behavioral health-related issues of alcohol, drug and inhalant abuse/addiction, depression, tobacco usage, violence, accidental and intentional injury, and lifestyle contribute to all of these leading causes of death. Unfortunately, very little mental health and behavioral research is being conducted in Alaska.

American Indian and Alaska Native Mental Health Research

NIMH continues to support the National Center for American Indian and Alaska Native Mental Health Research, at the University of Colorado Health Sciences Center, which provides an important resource for the American Indian and Alaska Native communities. Its mission is to promote the health and well-being of American Indians and Alaska Natives by pursuing research, training, continuing education, technical assistance, and information dissemination within a biopsychosocial framework that recognizes the unique cultural contexts of this population. One of the research projects is focused on understanding the dissemination of mental health practices and policies in American Indian and Alaska Native communities, and it began with a rural mental health program. Extensive work was completed on developing an appropriate data collection instrument containing a set of specific and detailed questions. The detailed instrument was tested with a focus group of people familiar with the state of human services in small, rural Alaska communities, as well as respected academics familiar with conducting ethnographic research in Native communities. Three documents were eventually created: a very general set of introductory questions, in both adult and adolescent versions, designed to make respondents familiar with the direction of the interview, a main tool consisting of 21 broad questions that allow the respondents to describe the dissemination process in their own words within the framework of the three theories, and a detailed set of questions that will be used by the researchers to aid in their analysis of the information from interviews. Data collection will begin using telephone interviews.

Health Survey of Two-Spirited Native Americans

This study at the University of Washington's Department of Psychology focuses on Native American gay, lesbian, bisexual, and transgender individuals (referred to as two-spirits), a drastically understudied and underserved group at risk for multiple health and mental health problems. There are no national, quantitative, representative studies of this population on any topic. Investigators will conduct structured survey interviews with 400 individuals to test a theoretical model of stress and coping in this population. The investigators plan to:

- Establish preliminary prevalence rates of trauma and health outcomes (HIV sexual risk behaviors, alcohol and other drug use, and mental health indicators);
- Test the direct associations between trauma and health outcomes;
- Determine how cultural and spiritual coping factors moderate the effect of trauma on health outcomes; and
- Examine the mediating role of substance use on the trauma–HIV sexual risk behavior and trauma–mental health relationships.

The last approach is to conduct a qualitative study involving 12 focus groups and 60 key informant interviews to identify emergent themes

regarding stressors and coping strategies specific to two spirits. This study is one of the first examining stress-coping processes among two-spirit populations and is the only AI/AN two-spirit HIV risk and mental health study in the country.

Alaskan Basic Neuroscience Program

The NIMH, along with the National Institute of Neurological Diseases and Stroke (NINDS) and the National Center for Research Resources, continues to co-fund the Alaskan Basic Neuroscience Program at the University of Alaska Fairbanks. This program is part of the Specialized Neuroscience Research Program (SNRP) at Minority Institutions initiative of NINDS. The purpose of the SNRP initiative is to establish and enhance competitive research programs in basic neuroscience at minority institutions. The research projects examine themes of interest to Alaskan peoples, including circadian rhythms, hibernation mechanisms, and neural development and repair. The program conducts outreach activities to Alaskan Natives with the goal of increasing diversity in the university's undergraduate and graduate programs, especially in the area of neuroscience and behavior.

Technical Assistance to University of Alaska Researchers

To gain firsthand knowledge of the challenges faculty members face in conducting biomedical research in Alaska research institutions, a team of government mental health scientists and researchers met with research staff from the University of Alaska at Anchorage and Fairbanks in 2002. This outreach effort resulted in UAF submitting a grant proposal to MARC (Minority Access to Research Careers), a grant program of the National Institute of General Medical Sciences, one of the NIH institutes. Technical assistance is also being provided as needed to various investigators developing research programs in mental health research, including a group of researchers developing a proposal to study psychiatric co-morbidity among Alaskans.

Centers for Disease Control and Prevention

Arctic research programs of the Centers for Disease Control and Prevention (CDC) are focused on improving public health in Arctic communities. Programs are conducted by the National Center for Infectious Disease (NCID), the National Center for Environmental Health (NCEH), the National Institutes of Occupational Safety and Health (NIOSH), and the Agency for Toxic Substances and Disease Registry (ATSDR). These programs represent an excellent example of interagency cooperation and collaboration with the State of Alaska Division of Public Health, the Alaska Native Medical Center, the Alaska Native Tribal Health Consortium, the Indian Health Service (IHS), the Alaska Area Native Health Service (AANHS), local and regional Native health corporations, universities, and other state and local agencies and organizations.

National Center for Infectious Diseases

The Arctic Investigations Program (AIP), located in Anchorage, Alaska, is one of three U.S. field stations operated by the National Center for Infectious Diseases or the Centers for Disease Control and Prevention. The mission of AIP is prevention of infectious diseases among residents of the Arctic and sub-Arctic, focusing on diseases of high incidence and concern among the indigenous populations of these regions, as well as recently emerging and re-emerging disease problems, especially via partnerships with other organizations.

Emerging Infectious Diseases

Infectious diseases are a continuing menace to all peoples of the globe, regardless of age, gender, lifestyle, ethnic background, and socioeconomic status. They cause suffering and death, curb sustainable economic development, and impose an enormous financial burden on all societies. Arctic populations have long endured the debilitating effects of both endemic and epidemic infectious diseases, the effects of which have impacted both social and economic development in circumpolar regions of the globe. Global surveillance is a critical component of prevention and control of infectious diseases.

International Circumpolar Surveillance Initiative

The International Circumpolar Surveillance (ICS) project, established in 1999, aims to create an infectious disease surveillance network of hospital and public health laboratories and authorities throughout the Arctic states. ICS was approved as an Arctic Council Sustainable Development Working Group project at the ministerial meeting

in Barrow, Alaska, in October 2000. ICS allows for the sharing of uniform laboratory and epidemiological data on infectious diseases and assists in the formulation of control strategies.

From 1999 to 2002, isolates of *Streptococcus pneumoniae* recovered from patients with invasive disease were collected in Alaska, northern Canada, Greenland, Iceland, Norway, and Finland and were sent to one of three reference labs for testing. A total of 5,283 cases of invasive pneumococcal disease were reported from Alaska (449), northern Canada (165), Greenland (26), Iceland (142), Norway (2643), and Finland (1858). Rates of invasive pneumococcal disease in aboriginals in Alaska and northern Canada were 43 and 45 cases per 100,000 persons, respectively. Rates among children less than two years old and persons two years of age or older were 39–154 and 11–25 cases per 100,000 persons, respectively. Invasive pneumococcal disease can be prevented through the use of vaccines. Continued surveillance is needed to determine the impact of vaccination programs in circumpolar countries. Surveillance of invasive diseases caused by *Haemophilus influenza*, *Neissera meningitidis*, and Groups A and B streptococcus was undertaken by ICS in Alaska and northern Canada (2000–2003) and Greenland (2002–2003). Initial findings indicate that aboriginals in Alaska and northern Canada have higher rates of invasive bacterial diseases caused by *Haemophilus influenza*, *Neissera meningitidis*, and Groups A and B streptococcus than the non-aboriginal population. In spite of vaccine programs for children, cases of invasive disease caused by *Haemophilus influenzae* type b continue to occur among children under two years of age in Alaska.

The prevention and control of certain high-priority emerging infectious disease issues have been targeted by CDC, including:

- Antimicrobial resistance;
- Food and waterborne diseases;
- Vector-borne and zoonotic diseases;
- Diseases transmitted through blood transfusions or blood products;
- Chronic disease caused by infectious agents;
- Vaccine development and use;
- People with impaired host defenses;
- Diseases of pregnant women and newborns; and
- Diseases of travelers, immigrants, and refugees.

The AIP focuses its prevention research activities on antimicrobial resistance among pathogens of concern, the prevention of food-borne diseases, the control of chronic diseases caused by infectious diseases, and the prevention of infectious disease through vaccine use.

Antimicrobial Resistance

In recent years, antimicrobial resistance has emerged in a number of pathogens causing disease among residents of the U.S. Arctic, thus limiting treatment options for those seeking medical care. Problem pathogens include *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Helicobacter pylori*, and *Staphylococcus aureus.*

Methicillin-resistant *Staphylococcus aureus* (MRSA) infections have been a common problem in hospitals in the U.S. for more than two decades. In the past five years in the U.S., MRSA soft tissue infections have become a problem among persons without known exposure to health care settings in certain populations. In Alaska, outbreaks of furuncles (boils) associated with *Staphylococcus aureus* have long been a problem, especially in rural villages. In 1996 the first documented outbreak of MRSA furunculosis in Alaska was reported in one rural village. An investigation showed that the risk of infection was higher among those who used a home sauna. In 2000 a marked increase in boils associated with MRSA infection was reported from a regional hospital in rural Alaska. An investigation revealed that 80% of all *S. aureus* infections were due to MRSA and that 77% of MRSA infections were community acquired (that is, among persons without significant health care exposure in the prior year). The response to this outbreak included revising treatment guidelines for the use of antibiotics and developing guidelines for proper cleaning of home saunas.

High rates of *Helicobacter pylori* infection have been documented in Alaska Natives. *Helicobacter pylori* causes stomach ulcers and gastritis in about 10% of persons infected and has been associated with iron-deficiency anemia and gastric cancer. A retrospective seroprevalence study performed in 1999 demonstrated that among Alaska Native 0–4 years of age and Alaska Native adults less than 20 years of age, 32% and 86% had antibody *Helicobacter pylori*, respectively. A study performed in 1996 confirmed that 60–98% of Alaska Natives tested using the C^{13} urea breath test had active infections. Seropositivity was age dependent. Treatment commonly includes a 14-day course with a proton pump inhibitor plus two antibiotics.

An early study had found that two years following successful treatment of infection with *Helicobacter pylori*, 55% of Alaska Native patients

were re-infected. Further studies have shown that 30% of *Helicobacter pylori* isolates cultured from gastric biopsies from Alaska Native patients seeking medical care were resistant to clarthomycin, and 66% were resistant to metronidazole, two antibiotics commonly used to treat *Helicobacter pylori* infection. Ongoing studies on *Helicobacter pylori* infection are focusing on three groups: urban Alaska Natives, rural Alaska Natives, and urban non-Natives following successful treatment of infection. An evaluation of laboratory methods used to diagnose *Helicobacter pylori* infection is also being undertaken.

Food-borne and Waterborne Diseases

Alaska has the highest rates of food-borne botulism in the U.S. Nearly 30% of all U.S. cases since 1973 occurred in Alaska, and almost all of these cases were among Alaska Natives. The majority of these cases have been associated with consumption of fermented foods prepared from fish or marine mammals. A high index of suspicion by health care providers, early diagnosis, and rapid antitoxin treatment has markedly reduced the fatality rates of food-borne botulism from 31% during 1950–1959 to no deaths among 80 cases since 1994 in Alaska. In 1998 a collaborative effort between the Bristol Bay Area Health Corporation and the CDC's Arctic Investigations Program designed a community-based botulism prevention strategy that included the production of an educational video and a web site titled "A Helping Hand: Keeping your Family Safe from Botulism" (http://www.phppo.cdc.gov/phtn/botulism/default/default.asp).

Food-borne botulism is not unique to the U.S. Arctic. High rates of botulism have been noted among the Canadian Inuit population as well. Observers in other countries have pointed to the increased use of plastic bags and buckets to ferment foods as a possible cause for the increased rates of botulism since the 1960s. This is plausible; *Clostridium botulinum* is an anaerobic bacterium and would be expected to thrive in the oxygen-poor environment of sealed plastic bags or buckets. Experiments performed by CDC in 1999 showed that *Clostridium botulinum* toxin production was greatest when fish head fermentations were carried out in sealed plastic buckets, compared to traditional methods such as placing fish heads into a grass-lined hole in the ground. Thus, more traditional fermentation practices, although not risk free, may be safer for persons who choose to consume traditional fermented foods.

Chronic Diseases caused by Infectious Agents

Hypochromic microcytic anemia has long been found to be common among Alaskan Natives despite a diet rich in bioavailable iron. In the 1990s it was found that fecal blood loss may be a major contributing factor to iron deficiency anemia in Alaska Natives and that hemorrhagic gastritis was associated with *Helicobacter pylori* infection. A large population-based serosurvey has shown that the seroprevalence of *Helicobacter pylori* in Alaska Natives is 75%. The rate increased with age. By 14 years of age 78% of children were found to have evidence of infection. Iron deficiency was found in 20% of males and 36% of females. A significant association between iron deficiency and seropositivity for *Helicobacter pylori* was found in those persons less that 20 years of age. Iron deficiency anemia remains common among Alaska Native preschool children. In one village surveyed in 1999, 38% of the 123 children between one and five years of age were iron deficient, and 17% were anemic. Serologic evidence of *Helicobacter pylori* infection was found in 41% of these children, and there was a strong statistical association between *Helicobacter pylori* seropositivity and both anemia and iron deficiency. In 2002 the State of Alaska Division of Public Health, together with the CDC's Arctic Investigations Program, initiated a randomized controlled trial of antibiotic therapy for *Helicobacter pylori* infection to treat iron deficiency among children in rural Alaska. Eradication of *Helicobacter pylori* infection using antibiotics should result in a greater resolution of iron deficiency in children than iron therapy alone.

Alaska Native children experience very high rates of lower respiratory tract infections (LRTI). The most common cause of LRTI hospitalization in infancy is respiratory syncytial virus (RSV). In 1993–1996, Alaska Native children from the Yukon–Kuskokwim Delta region experienced an RSV hospitalization rate (156 per 1,000 infants) five times higher than the U.S rates. Severe RSV infection in infancy can result in higher rates of recurrent wheezing in childhood. Between 1999 and 2002 the Arctic Investigations Program, together with the Yukon–Kuskokwim Health Corporation, evaluated RSV-hospitalized children and their non-hospitalized control subjects approximately five years after hospitalization. Children who were hospitalized with RSV infection had higher rates of wheezing, LRTIs, and asthma diagnoses during the first four years of life. The association decreased with age and was no longer significant by five years of age. However, hospitalization for

RSV infection was associated with increased respiratory symptoms, including chronic productive cough at five years of age.

Vaccine Use and Development

Rates of invasive pneumococcal infection (bacteremia and meningitis caused by *Streptococcus pneumoniae*) for Alaska Natives are the highest in the U.S. and are approximately five times higher than for non-Natives living in Alaska. The disease is most common in the very young and the elderly (73 cases per 100,000 Natives at least 55 years old). Fatalities from pneumococcal infection are highest in the elderly (greater than 15%). Once fully susceptible to antibiotics, *Streptococcus pneumoniae* has acquired resistance to commonly used antibiotics. In Alaska 13% of isolates recovered from patients with invasive disease in 2000 were found to be fully resistant to penicillin. A 23-valent pneumococcal polysaccharide vaccine has been licensed for use in adults in the U.S. since 1983. The overall effectiveness against invasive pneumococcal disease among immuno-competent persons of at least 65 years of age is 75%; however, the efficacy may decrease with increasing age. A new 7-valent pneumococcal conjugate vaccine was licensed in 2000 for preventing pneumococcal disease in infants and young children. In 2000, rates of invasive pneumococcal disease in Alaskan children less than two years of age was 36 cases per 100,000. In 2002, following vaccine introduction, rates of invasive pneumococcal disease in Alaskan children less than two years old fell to 13 cases per 100,000. In addition the percentage of pneumococcal isolates fully resistant to penicillin fell from 13% in 2000 to 2.6% in 2002, demonstrating the potential of this vaccine to reduce infections caused by pneumococci that are resistant to antibiotics.

Haemophilus influenzae type b was the most common cause of bacterial meningitis in preschool-age children prior to the development and widespread use of protein conjugate vaccines. Routine immunization of all Alaska Native infants with a *Haemophilus influenzae* type b conjugate vaccine began in 1991 and reduced the incidence of invasive *Haemophilus influenzae* type b infection more than ten-fold by 1993. The effectiveness of these vaccines are largely due to the induction of a circulating antibody and the interruption of oropharyngeal carriage, leading to the protection of susceptible children through herd immunity. Despite the success of *Haemophilus influenzae* type b conjugate vaccines in preventing disease in the rest of the country, cases continue to occur among fully and partially vaccinated Alaska Native children at a rate of 15 cases per 100,000 (1996–1997), ten times the rates found in children in other parts of the U.S. However, by 2002, rates in Alaska Native children had declined to 6 cases per 100,000.

National Center for Environmental Health

The National Center for Environmental Health's Division of Environmental Hazards and Health Effects will continue a study of human exposure to environmental pollutants in the Arctic. Maternal and umbilical cord blood samples from Alaska Natives are being evaluated for persistent organic pollutants, nonpersistent pesticides, and trace metals, as well as for various nutritional markers. This study is underway in Barrow and Bethel and in communities in the Aleutian and Pribilof Islands. Additional sites will be added as the study progresses.

A study of environmental contaminants as cofactors in breast cancer in Alaska Natives is nearing completion. Two hundred study subjects were enrolled, and analysis of their biological samples has begun. A unique aspect of this study is the analysis of serum collected from the women over time and stored in the CDC/AIP serum bank. By analyzing stored serum collected many years ago, researchers will be able to model exposure to organochlorines over time.

A protocol for assessing arsenic exposure and associated health effects in rural Alaska communities is in development. The study will evaluate current and long-term human exposure to inorganic arsenic among Alaskans by measuring arsenite and arsenate in urine and in hair or toenails. The health conditions of study participants will also be assessed. This study will be conducted in collaboration with ANHB and the State of Alaska's Division of Public Health.

National Institute for Occupational Safety and Health

Occupational Injury Prevention

NIOSH identified Alaska as having the highest risk of traumatic occupational fatalities compared to all states in the U.S. To address the unique hazards and work environments facing employees and employers in Alaska, NIOSH established a field station in Anchorage in 1991.

The Alaska Field Station (AFS) of NIOSH implemented a comprehensive surveillance system for occupational injuries, the Alaska Occupational Injury Surveillance System (AOISS). AOISS obtains risk factor information and permits quantitative epidemiologic analyses for sound public health and prevention. The database contains more than 800 fatality records, as well as for over 4,000 nonfatal injury records via the Alaska Trauma Registry (ATR).

NIOSH has collaborated with the Alaska Department of Health and Human Services, the Alaska Department of Labor, the U.S. Coast Guard, the National Transportation Safety Board, the Federal Aviation Administration, the U.S. Occupational Safety and Health Administration, industry and labor organizations, communications media, health care providers, universities and community colleges, and other public and private individuals and organizations. Since establishing the field station, Alaska has experienced a significant decline in all work-related deaths, including deaths in the high-risk industries of commercial fishing and air transportation. The trends in occupational fatalities for the periods 1990–1992 compared to 2000–2002 illustrate the following:

- Overall, the number of work-related deaths in Alaska declined 40%, from an average of 83 fatalities per year to 50 fatalities per year. The total of 34 deaths in 2002 was the lowest work-related mortality in Alaska since data have been collected.
- Occupational injury deaths in the commercial fishing industry declined by 59%, from 34 to 14 per year.
- Occupational deaths from aviation-related crashes showed a 39% decline, from 23 to 14 per year.

Trauma registries are a unique source of injury data, including information on demographics, geography, disability, medical cost, payment sources, cause of injury, discharge diagnosis, and injury severity. The ATR has proven to be a useful information source for monitoring non-fatal work-related injuries in Alaska. All 23 hospitals in Alaska report to the ATR, making it a population-based data source from which injury rates can be calculated. Analyses of the trend data and identification of hazardous processes have led to injury prevention strategies specifically targeted to high-risk areas. The objectives of this work include using information from the ATR to:

- Reduce the morbidity resulting from work-related injuries in Alaska by providing data for developing appropriate prevention strategies;
- Facilitate state, Federal, and international work-related injury comparisons;
- Improve awareness of nonfatal work-related injury as a significant health problem;
- Assist in evaluating work-related injury prevention strategies; and
- Facilitate research for the prevention of nonfatal work-related injuries.

An aviation accident investigator at a remote crash scene in Alaska.

Aviation Initiative

In FY 2000, Congress funded a Federal initiative to reduce aviation-related injuries and fatalities: the Alaska Aviation Safety Initiative. The initiative, begun in October 1999, is led by NIOSH with three other Federal agencies: the Federal Aviation Administration (FAA), the National Transportation Safety Board (NTSB), and the National Weather Service (NWS). The purpose is to reduce the number of aircraft crashes and deaths, to promote aviation safety in Alaska, and to evaluate safety interventions. The initiative's methods and objectives are to:

- Gather and analyze injury and fatality data to identify risk factors;
- Bring together aviation industry working groups to characterize the problems;
- Develop aviation safety information for pilots, companies, and the flying public;
- Evaluate the effectiveness of and changes in flight safety interventions; and

Commercial aviation crashes are one of the leading causes of death to workers in Alaska.

Reduced visibility is a frequent hazard in Alaska's flight environment.

- Evaluate progress and suggest additional improvements.

NIOSH contracted with the University of Alaska Anchorage's Institute of Social and Economic Research (ISER) to design and administer two statewide aviation safety surveys during 2001–2002, one of air carrier managers and one of active commercial pilots. Both surveys addressed pilot and company demographics, pilot flight hours (total hours, aircraft type, and instrument hours), Alaska flying experience, attitudes about safety, flying practices, and other salient risk factors. The purpose was to collect information on pilot and company practices and attitudes in order to design policy options that would reduce aviation fatalities. Return rates for the operator and pilot surveys were approximately 81% and 75%, respectively.

Although occupational aviation fatalities continue to be a problem, with Alaska commercial pilots having the highest occupational fatality rate during 1990–1999 (410 per 100,000, compared to 150 per 100,000 for loggers and 125 per 100,000 for fishermen), there has been a downward trend in occupational aircraft crashes and fatalities over the 12-year period of 1991–2002. Between 1990–1992 and 2000–2002, deaths from aviation-related crashes showed a 39% decline, from 23 to 14 per year. This secular trend is also supported using broader intervals. Thus, progress is being made toward the overall goal of reducing occupational aircraft crash fatalities in Alaska by at least 50% by the end of 2009 (comparing 1990–1999 to 2000–2009).

The busy fishing port in Sitka, Alaska.

Commercial Fishing

The commercial fishing industry is a major contributor to the high numbers of fatal and hospitalized nonfatal injuries in Alaska. Data from AOISS show 285 work-related fatalities in the Alaskan commercial fishing industry from 1990 through 2002. Commercial fishing deaths in 2000–2002 decreased 59% from 1990–1992. Many of the fatalities were vessel-related, caused by either a vessel capsizing or sinking (36%). Interventions to date, including the implementation of the Commercial Fishing Industry Vessel Safety Act, have been successful in reducing fatalities due to vessel-related events. Nonfatal injury data have shown that of the 648 hospitalized nonfatal injuries, 32% were machinery-related. Many of the machinery injuries occurred in the Bering Sea crab fishery while working around crab pots and crab pot launchers.

Several interventions have been identified to modify the equipment and environment to improve deck safety, including machine guarding, machinery placement, and increased visibility. From this first phase, a deck safety publication and demon-

Commercial fishermen haul crabs from the northern waters off Alaska.

stration deck model have been produced. The second phase is underway, with evaluation of the purse seining, long-lining, troll, gillnet, small crab, and dive fisheries.

International and Circumpolar Collaboration, Conferences, and Workshops

Through its Alaska Field Station, NIOSH has continued its international research in partnership with commercial fishing research scientists and injury prevention program workers; the Circumpolar Health networks; and the World Health Organization's International Safe Communities Program. AFS co-sponsored the Second International Fishing Safety and Health Workshop (IFISH II) in Sitka, Alaska, in September 2003. The conference was attended by 135 participants from 16 countries, including Sri Lanka, Pakistan, India, Australia, Chile, Indonesia, Sweden, Norway, Canada, and New Zealand.

The AFS also participated in the Twelfth International Congress on Circumpolar Health, in Nuuk, Greenland, in September 2003. In addition to co-chairing the Injury and Occupational Safety and Health Working Groups, AFS staff presented three scientific papers, one on hypothermia and cold-water drowning, one on the prevention of worker deaths in Alaska, and one on deaths of scientific fieldworkers in Alaska.

Commercial fishermen in Alaska work in one of the most hazardous environments in North America.

Agency for Toxic Substances and Disease Registry

The Agency for Toxic Substances and Disease Registry's Alaska Traditional Diet Project (ATDP) is a pilot project to assist consumers of Alaskan traditional foods in making informed dietary decisions to prevent potential adverse health outcomes from environmental contamination. The project, managed by the Alaska Native Health Board, is a collaborative endeavor with the State of Alaska, other Federal agencies, Native villages and corporations, and Native organizations.

The ATDP has identified and characterized regional traditional diets, including beneficial nutrient information. Using a comprehensive and comparable dietary survey, data are available for 13 villages representing several regions in Alaska. The ATDP is now conducting sampling and analysis for contaminants in traditional foods at two villages (a subset of the 13 survey participants). This project will assist in the development of a response to environmental contaminant issues in Alaska.

Substance Abuse and Mental Health Services Administration

Inhalant Abuse Program

The Tundra Swan Inhalant Program, funded by SAMHSA's Center for Substance Abuse Treatment (CSAT), is the only residential inhalant abuse treatment program in the nation. Statewide

outreach from its office in Anchorage enhances accessibility to the entire state, while the Tundra Swan Center provides residential treatment in Bethel. The statewide program trains providers regarding aftercare programs for youth returning to their home communities following residential inhalant treatment. The project has established close links with the Canadian substance abuse treatment system and its inhalant abuse experts.

Cooperative Agreements for the Comprehensive Community Mental Health Services for Children and Their Families Program

Under this program, SAMHSA's Center for Mental Health Services (CMHS) provides grants for state and tribal governments to develop systems of care for children with serious emotional disturbance, along with their families. Current grantees for these six-year grants are the Yukon–Kuskokwim Delta and the Fairbanks Native Association. Over 80 isolated villages are represented. The National Institute of Mental Health (NIMH) participates in an advisory committee for the cross-site evaluation of the grant program.

Circles of Care Program

Supported by CMHS, this program provides grants for tribes and urban Indian communities to plan, design, and assess culturally specific mental health service system models for American Indian and Alaska Native children and their families. Among current grantees are the Tlingit and Haida Tribes of southeast Alaska. Each of the three-year grants (approximately $350,000 per year) includes a cross-site evaluation provided through an Inter-Agency Agreement (IAA) with NIMH. An IAA with the Indian Health Service (IHS) provides for on-site technical assistance.

Targeted Capacity Expansion Program

A CSAT Targeted Capacity Expansion grant to the Norton Sound Health Corporation ($749,083) serves Alaska Native young adults and adolescents with co-occurring SA/MH disorders. This project is enhancing treatment capacity by making resources available to treat young adults and adolescents (ages 12–24) dually diagnosed as mental or emotionally ill and substance impaired in 15 remote villages of the Bering Straits region.

Alaska Fetal Alcohol Syndrome/ Alcohol-Related Birth Defects Program

Alaska has a relatively high incidence of FAS/ARBD births. The overall goal of this program, supported jointly by SAMHSA's Center for Substance Abuse Prevention (CSAP) and CSAT, is to improve the practice of identifying, preventing, and treating FAS/ARBD. It is a five-year, $5.8 million program that provides prevention activities for public school students and families and the general public. Interventions include family planning, alcohol treatment, and other services for women of childbearing age; screening and diagnosis for all children in state custody; and development of a centralized FAS/ARBD Information and Evaluation Center.

National FAS/ARBD Center for Excellence

Supported by CSAP and funded at $3.8 million a year for five years (through FY 2004), the Center for Excellence coordinates activities to ensure that advances in both science and practice are synthesized and efficiently disseminated to the field. Among the center's activities are:

- Studying adaptations of innovative clinical interventions and service delivery improvement strategies for children and adults with fetal alcohol syndrome or alcohol-related birth defects and their families;
- Identifying communities that have exemplary comprehensive systems of care for such individuals so that they can provide technical assistance to other communities attempting to set up similar systems of care;
- Providing technical assistance to communities that do not have comprehensive systems of care for such individuals and their families; and
- Developing innovative techniques for preventing alcohol use by women in childbearing years.

Health Resources and Services Administration

Telehealth is the use of telecommunications and information technologies to share health-related information, provide clinical care, deliver health profession and patient education, and support consumer health education outreach, public health, and health-care-related services at a distance. The Health Resources and Services Administration (HRSA) established the Office for the Advancement of Telehealth (OAT) to promote the use of telehealth for underserved populations. In 2001–2003 the office administered three telehealth grants in Alaska with the goal of delivering clinical services to remote areas in the state. The Eastern

Aleutian Tribes Telemedicine Program serves 12 sites encompassing 6,985 square miles of land, with a population of 2,800, spread over 8,029 square miles of Bering Sea and the Pacific Ocean. Clinical services initially focus on seven areas: dermatology; ear, nose, and throat; mental health; radiology; nutritional consultations; and obstetrics and gynecology. Recently they have added specialized services in diabetes and cardiovascular care, injury prevention, and emergency medical care. The network can also support two-way videoconferencing. Most recently they have added formal health aide training over the video and telepharmacy services. The project provides access to Internet library sites and closely coordinates with the Alaska Federal Health Care Access Network (AFHCAN).

AFHCAN is a 43-member organization with representation from Federal agencies, tribal health organizations, rural health care facilities, public health care organizations, tertiary health care centers, and the State of Alaska. The initial focus is improving access to health care services for Federal beneficiaries. The network includes 248 sites and is estimated to serve a population of 265,000, or 42% of the population. By September 2003 the program had conducted 9,494 cases, largely related to primary care; audiology; ear, nose, and throat; dermatology; and cardiology. Preliminary evaluation indicates that the AFHCAN system prevented travel 34% of the time, caused travel 8% of the time, and had no effect 59% of the time. A validation study determined if post-surgical follow-up of ear patients via store-and-forward telemedicine was as effective as an in-person exam. The simple conclusion is that store-and-forward telemedicine, with images taken by community health aides, is as good as an in-person exam for patients receiving pressure equalizing (ear) tubes.

Smithsonian Institution

The Smithsonian has been engaged in Arctic research for more than 150 years, almost from the beginning of its operation as the main national research and museum institution. Today, most of the Smithsonian Arctic activities are conducted by the Arctic Studies Center at the Smithsonian National Museum of Natural History, with its prime focus on northern cultures, communities, and environments.

Since their first ventures in northern Alaska and Canada in the mid-1800s, Smithsonian scientists have produced an outstanding array of research publications; they also amassed unique national collections of northern natural and cultural specimens. Today, individual Smithsonian scientists maintain their strong interest in many fields of northern natural sciences. The institution's current Arctic activities are being carried primarily via the Arctic Studies Center (ASC) of the Smithsonian National Museum of Natural History (NMNH). The ASC's main focus is on cultural heritage and collection studies, exhibits, and educational and public programs that are developed in partnership with local indigenous communities across the Arctic.

Established in 1988, the ASC is the only active and long-term Federal program that has a special mission in Arctic cultural research, education, and outreach. Over 15 years of its history, ASC's scientists, fellows, and associates have conducted studies throughout the entire circumpolar zone; it is also the only national research body that has international capabilities and a solid network of scholarly partners across the Arctic region.

With its stated mission in "the increase and dissemination of knowledge," the Smithsonian, and the Arctic Studies Center in particular, promotes its signature blend of research, collections development, and public programs. Today, such a blend includes several new components driven by new technologies and growing public interest in the cultures and heritage of northern people. Traveling exhibits reaching out to the most distant northern communities; internships and fellowships for local knowledge experts, artists, and cultural activists; museum and educational training programs; heritage documentation; cultural and knowledge repatriation; website development; and cooperative community research are the trademark features of the Smithsonian approach. Under a cooperative agreement with the Anchorage Museum of History and Art, the Smithsonian also operates its Alaskan regional office in Anchorage (since 1995). The ASC Alaskan office provides research, education, and training opportunities; it advances the Smithsonian vision and its strong public focus to local researchers, residents of Anchorage, and rural Alaskan communities.

	Funding (thousands)	
	FY 02	FY 03
Anthropology	400	400
Arctic Biology	50	50
Total	450	450

The level of the Smithsonian internal funding for its Arctic-focused research remains fairly steady over the last several years at an annual level of $0.4–0.5 million. That covers four staff positions at the Arctic Studies Center in Washington and Anchorage and a small operational budget. Substantial additional funds are generated each year through grants and institutional and interagency partnerships in order to support various Smithsonian northern initiatives.

Research and Collection-Based Activities

Each year Smithsonian scholars are engaged in several research, collection, and documentation projects across the Arctic region. Major initiatives by the Smithsonian staff, fellows, and associates are featured in the annual issues of the *Arctic Studies Center Newsletter* (published since 1991), with its current print run of over 1,500 copies. The

Aleutian elders work with objects from their area in the Smithsonian collection.

newsletter is a valuable source of information to northern scholars (both in the U.S. and worldwide), policy makers, northern residents, and community institutions on the wide range of Smithsonian activities. The projects described below offer a few illustrations of the breadth of the Smithsonian approach and its special focus on collaboration with other agencies and northern communities.

Alaska Collections Project

The Alaska Collections Project (ACP), now in its fourth year, is a product of a partnership of two Smithsonian museums—the National Museum of Natural History (NMNH) and the National Museum of the American Indian (NMAI)—and local Alaskan communities. The purpose of the ACP is to bring Native elders and cultural experts from several Alaskan communities on research trips to the Smithsonian museums to explore and document ethnographic collections from their respective areas. The project allows members of the Alaskan rural communities to get their first-hand knowledge of local cultural resources held in the national collections; it also offers a basic orientation in museum policies, collection management, research, and conservation. In addition, the elders are selecting objects that will be loaned for display and studies at the ASC regional office in Anchorage and used for traveling exhibits in Alaska.

The research will eventually yield a major exhibition in Anchorage, several traveling exhibits for Alaskan communities, a Smithsonian web site, publications, and detailed information to be incorporated into the Department of Anthropology's collections records. During 2001–2003, five ACP trips in a scheduled series of seven have brought to the Smithsonian local teams from Barrow, the Aleutian Islands, the Nome–St. Lawrence Island area, and the Yukon–Kuskokwim Delta region.

Looking Both Ways: Heritage and Identity of the Alutiiq People

This award-winning traveling exhibit was produced in 2001 by the Smithsonian, in collaboration with the Alutiiq Museum in Kodiak and Alaskan Native communities from the Kodiak–Cook Inlet region. The exhibit is based on the collections of Smithsonian naturalist William J. Fisher, who conducted research in southern Alaska on behalf of the Smithsonian in the 1880s. The exhibit inspired great interest in local communities; it offered to many Native Alaskans their first chance to reconnect with their cultural legacy and traditions repressed for generations.

In 2002 and 2003 the exhibit traveled from its original opening venue at the Alutiiq Museum in Kodiak to Homer, Anchorage, and Juneau. In December 2003 it arrived at the Smithsonian NMNH in Washington, where it will be on display through 2004.

Watching Ice and Weather Our Way: Environment Observation on St. Lawrence Island

There is extensive interest across the science community in the ways indigenous Arctic residents observe climate, sea ice, and weather and how this knowledge is used in their daily lives and subsistence activities. There is also growing pressure on polar researchers to incorporate data and observations from northern residents into the current models of global climate warming. To enhance such a transition, the Smithsonian, the Marine Mammal Commission, and the Yupik communities of Savoonga and Gambell on St. Lawrence Island, Alaska, undertook a joint project on ice and weather observation off St. Lawrence Island "the Yupik way" (2000–2003).

This collaborative effort to document Yupik knowledge and observation practices was named "Watching Ice and Weather Our Way." It emerged as an outcome of a special workshop, Impacts of Changes in Sea Ice and Other Environmental Parameters in the Arctic, organized by the Marine Mammal Commission in Girdwood, Alaska, in 2000. Two former workshop participants from St. Lawrence Island, Conrad Oozeva from Gambell and George Noongwook from Savoonga, agreed to organize sea ice and weather observations in their respective communities by local monitors to

be recorded in Yupik language. Several months of observations produced an unprecedented set of data, including dozens of pages of records that are full of Native terms, detailed explanations of ice patterns, references to shifts in ice and weather regimes, migrations of marine mammals, and local hunting activities. Local Yupik participants generated almost 200 pencil drawings and photographs to illustrate various local terms for ice and weather conditions. The ASC, the Savoonga Whaling Captains Association, and Marine Mammal Commission published the materials of the project as a bilingual volume, *Watching Ice and Weather Our Way/Sikumengllu Eslamengllu Esghapalleghput*, in 2004.

Labrador Community Archaeology Project

This long-term research and educational initiative has been undertaken jointly (since 1999) by the ASC; the Canadian Labrador community of Makkovik, including its local historical society, community museum, and high school; and Brown University in Providence, Rhode Island. For the past two years the project has focused on a mid-18th century Labrador Inuit village site at Adlavik Harbour. This project integrates methods of archaeological research (such as surveys and excavations), high-school curriculum development, and local heritage training in site preservation, archaeological fieldwork, and museum development. It is aimed at documenting cultural changes in early colonial Inuit communities in central Labrador, with a special emphasis on developing local knowledge, increasing potential employment opportunities in heritage preservation and tourism, and fostering pride in Labrador Inuit culture and heritage. The project is supported through funding provided by the Smithsonian, the Robert S. Peabody Museum at Phillips Academy, the International Grenfell Association, the Newfoundland and Labrador School Boards Association, and Inuit Pathways. The very generous support of the Inuit Pathways is critical, as it covers local Inuit student salaries and transportation.

Yupik skin boat sails off the whaling camp at Pugughileq, St. Lawrence Island. Alaska. This picture is one of many dozen taken by Chester Noongwook, a Yupik boat captain and a participant in the sea ice observation project.

Jesup-2: Cultures and Nations of the Greater Bering Sea Region

In October 1992 the Smithsonian inaugurated a multi-year research and publication program focused on Native cultures of the Bering Sea–North Pacific region. The program was called Jesup-2 to commemorate the centennial anniversary of the Jesup North Pacific Expedition (JNPE) of 1897–1902 and its legacy. The Jesup-2 program, now in its second decade, has created a thriving network of partnership among research and museum institutions, and individual scholars in the U.S., Canada, Russia, Japan, and other countries. Two collections of papers have been published during 2002 and 2003, as the volumes in the newly launched Smithsonian series *Contributions to Circumpolar Anthropology*; many new projects have been initiated.

In October 2002, another Jesup-2 international symposium was held in Sapporo, Japan. Titled "The Raven's Arch," it was focused primarily on the Asian side of the North Pacific. Several Japanese agencies and institutions offered their support for the meeting. The proceedings of the symposium will be published in both English and Japanese, as parallel volumes. The Raven's Arch symposium was accompanied by several public events, including public lectures, an exhibit of several dozen historical photographs from the Jesup Expedition collections, and meetings with Japanese and Ainu museum curators.

A new Jesup web site was launched in 2002 produced by the American Museum of Natural History in New York. It features all recent Jesup-2 publications and several collaborative efforts, such as the ongoing study of the Jesup Expedition Siberian collections and other records stored at the American Museum of Natural History, at the Smithsonian, and in Russia.

Gateways: Quebec Lower North Shore Survey

For the past three years (2001–2003), the ASC has been conducting archaeological studies along the Quebec Lower North Shore (LNS) under its survey and excavation effort titled "The St.

A camp of Tsaatan (Dukha) reindeer herders in the mountainous region of northern Mongolia.

Lawrence Gateways Project." The project is aimed at documenting various local prehistoric cultures starting from 8,000 years ago. It also explores the impact of colonial trade and culture contacts on local indigenous residents, when European sailors, primarily the Basques and the French, became established in the region around the year 1600. The surveys are authorized by the Quebéc Ministry of Culture and Communications and funded by the Smithsonian and private donors.

Surveys to date have produced evidence of nearly 50 new sites dating from circa 7,000 years ago to the present. These surveys offer insight into prehistoric maritime adaptations, seasonal and decadal fluctuations in marine ecosystems, resource scarcity, and settlement pattern variability along Quebec's LNS.

The project's second major accomplishment was the documentation of the 16th–17th century European stations operated primarily by the Basque whalers, seal hunters, and later fishermen. The new sites on the Quebéc LNS offer information on changing Basque economy, environmental conditions, and contacts with Native groups for fishing, trapping, and trade, which are likely to have become important concerns for Basque activities at this time. Such studies will help document the long history of European–Native relations in the St. Lawrence "gateway" region.

The "Deer Stone" Project: Smithsonian Research in Northern Mongolia

In 2001 the ASC launched a new interdisciplinary research initiative in northern Mongolia's Muron–Darkhat region. Although located far below the Arctic Circle, at the southernmost confines of the Siberian Sayan Mountains, the region features some of the most typical Arctic complexes as well as the southernmost indigenous reindeer-herding communities in Eurasia. A virtual extension of the Arctic world, northern Mongolia may have played an important role in Ice Age ecology, the peopling of the New World, and the history of ancient Beringian ecosystems.

For over three years the Smithsonian interdisciplinary team has pursued studies in archaeology, climate history, lichen ecology, and the ethnology of the local reindeer-herding Tsaatan (Dukha) people. It seeks to understand the origins of northern Mongolian cultures and their relationships with other peoples of China, Mongolia, and Siberia. Special emphasis is placed on its connections to more distant cultures, including Scythians and Eskimos. The research is being conducted by Smithsonian scholars in partnership with the University of Pittsburgh, the National Museum of Mongolian History, and the Mongolian Academy of Sciences.

In 2002 and 2003 research in the Tsaatan mountainous camps was focused on the herders' adaptations to changing conditions in their summer and winter pastures in the forest and tundra regions. Smithsonian scientists worked with Tsaatan elders, recording their knowledge of reindeer ecology and folk taxonomies for the lichen the animals feed on. Theories abound arguing that the reindeer-herding system of the Arctic tundra residents was a mere cultural offshoot of the ancient mountainous taiga pattern still practiced by the Tsaatan. Periodic rapid climate change may have played a role in herders' migrations from the Siberian mountainous areas. This is to be investigated by an analysis of several lake sediment cores, collected from the nearby alpine lakes, that document the Holocene climate history of this border area between Siberian forest and Inner Asia steppe landscapes.

Interagency Collaboration: Relationships and Partnerships

Since its creation in 1988 the ASC has represented the Smithsonian at various boards and in many Federal interagency programs and initiatives that deal with the polar region. Through the ASC, the Smithsonian keeps its permanent seat on the Interagency Arctic Research Policy Committee (IARPC), the Arctic Research Commission (ARC), the Arctic Policy Group (APG), and others. ASC staff members and associates represent the Smithsonian, and Arctic social sciences in general, at the Polar Research Board of the National Academies, the Science Advisory Committee of the NSF Office of Polar Programs, and other science policy

teams. Overall the center has a prominent role in formulating national policy in Arctic research; it takes seriously its advisorship to government and international bodies.

The Smithsonian has developed partnerships with many Federal agencies, such as NASA, NOAA, NSF, DOI (National Park Service), USDA, and others. For many decades, interagency partnership were pivotal in expanding resources and logistical support to Smithsonian scientists working in the polar regions; it also allowed the institution to advance high-quality research, public and educational programs, and management of the national collections. Recently these ties have been strengthened through new cooperative projects, research, and public initiatives.

Study of Environmental Arctic Change

The Smithsonian, and the ASC in particular, has an established record of involvement in studies of Arctic climate and environmental change. Over the last two decades, Smithsonian teams have participated in several interdisciplinary projects across the North. Smithsonian researchers have been involved with issues of today's Arctic environment, its ongoing change, and its impact on northern people. The Smithsonian is also spearheading several outreach initiatives that are focused on the general public, indigenous communities, and northern residents.

Since 2001 the Smithsonian has participated in the Study of Environmental Arctic Change (SEARCH), an interdisciplinary and interagency initiative that addresses the origins and mechanism of today's rapid shifts in Arctic environment. The evidence of change in the current Arctic climate and biota is extensive and mounting, but social scientists have been rather late, and usually junior, partners to such research, which is driven primarily by physical and environmental science. It has been a common knowledge that northern residents should be included as critical "subjects" to any interdisciplinary survey of global climate change. However, it was not until recently that scientists also realized that Arctic people are the first and usually the most dedicated observers of change in their regions. From their side, Arctic people are also eager to cooperate with scientists and to have their observations documented and transmitted to the management agencies and policy makers. This is a critical junction, a new Arctic science frontier that will guide the course of scholarly studies, outreach and educational efforts, and public support for northern research for years to come.

During its first years the SEARCH initiative (announced in 1998) was regarded mainly as an ocean–atmosphere modeling enterprise. After 2000, SEARCH gradually evolved into a much broader venture supported by the Interagency Working Group (IWG) made up of representatives of nine participating governmental agencies, such as NSF, NOAA, DOI, EPA, NASA, and the Smithsonian.

The Smithsonian contribution to SEARCH is focused primarily on promoting the initiative's human component. From the science perspective, Smithsonian scholars contribute expertise in using paleo-environmental and archaeological records to decipher former environmental and resource fluctuations across the polar regions. Such studies provide valuable time depth to current models of Arctic climate oscillations, which are based mainly on instrumental data of the last century.

At the institutional level, Smithsonian offers to SEARCH an ideal venue to present its agenda to the policy and decision makers, the media, the general public, and Arctic residents. In 2001, ASC scientists suggested that a Smithsonian-based exhibit would be the best way to introduce the SEARCH initiative to the broader public by using the existing NMNH educational and exhibit program *Forces of Change* (started in 2000). The Smithsonian *Forces of Change* exhibit initiative features the dynamics of global change and examines the connections among the physical, biological, and cultural forces that shape our world. The core of this program is a 6,000-square-foot exhibit space at the NMNH, which will be used over several years for a series of thematically and regionally focused exhibits. Each of these exhibits will feature various "faces" of ongoing global change. The first in the series, *Listening to the Prairie: Farming in Nature's Image*, was successfully launched in November 2000, in partnership with the U.S. Department of Agriculture's Sustainable Agriculture and Research Education Program. The second *Forces of Change* exhibit, *El-Niño's Powerful Reach*, was launched in 2002. More ventures are in the making, including the new exhibit on Arctic environmental change, *The Arctic: A Friend Acting Strangely*, which will be the Smithsonian contribution to SEARCH. The preparatory and production work was started in the summer of 2003, with the support from the NOAA Arctic Research Office; the opening of the exhibit at the Smithsonian's National Museum of Natural History is due in the spring of 2005. It will be followed by several public events, lectures, and outreach activities.

U.S. Research Station in Barrow, Alaska, operated during the First International Polar Year, 1881–1883.

The Smithsonian also made two other contributions to the SEARCH initiative. In 2002 a new volume, titled *The Earth Is Faster Now: Indigenous Observations of Arctic Environmental Change,* was published by the Arctic Research Consortium of the U.S. (ARCUS) in collaboration with the ASC. The volume is a collection of ten papers featuring various recent projects involved in documenting indigenous knowledge of environmental change in Alaska and the Canadian Arctic.

Another Smithsonian contribution to SEARCH was a special panel on Arctic environmental change organized at the annual meeting of the American Association for the Advancement of Sciences (AAAS) in Seattle in February 2004. The panel, titled *Unaami: A New Model for Arctic Environmental Change,* was the first concerted effort to present the spirit and some results of the SEARCH initiative to a primarily non-science audience of media people and policy planners.

International Polar Year 2007–2008

Planning is underway for a new large international program in polar research called the International Polar Year 2007–2008 (IPY). The IPY initiative of 2007–2008 will be the fourth similar effort undertaken by the international polar science community, 125 years after the first International Polar Year of 1882–1883. All previous IPY ventures provided major opportunities to enhance polar research. They promoted international cooperation among polar scientists and national research institutions; they also served as major vehicles to capture the public's imagination and to convey the crucial role that the polar areas play in the functioning of the earth as the planetary ecosystem.

In February 2003 the International Council for Science (ICSU) formed an International Polar Year Planning Group (IPY-PG), and in August 2003 the National Research Council of the U.S. National Academies created the U.S. Planning Committee on the IPY. Igor Krupnik, Smithsonian Arctic ethnologist, and Richard Glenn, from the Arctic Slope Regional Corporation in Barrow, Alaska, are serving on the U.S. committee to represent the interests of social scientists and northern indigenous residents, respectively. Both constituencies have great stakes in this major international effort. Unlike the previous IPY ventures, which were primarily (if not exclusively) focused on the geophysical and natural sciences, the IPY 2007–2008 is planned as a truly interdisciplinary program. The new vision is to incorporate polar residents and social scientists into all its activities, so that

many cultural, social, health, and environmental issues critical to polar communities and social/human scientists are featured prominently on the new IPY agenda.

In anticipating major planning and research activities for the new IPY initiative, Smithsonian scientists have already established their informal IPY planning team. The Smithsonian is sure to play an important role in the new IPY 2007–2008 effort. To explore the opportunities, the ASC is joining forces with the International Arctic Social Science Association (IASSA), the Barrow Arctic Science Consortium (BASC), and other interested agencies. The first IPY-focused panel, International Polar Year 2007–2008: Opportunities for Northern Communities and Social Science, was organized by the ASC scholars at the Fifth International Congress of Arctic Social Sciences in Fairbanks in May 2004.

Smithsonian–NPS Partnership

The National Park Service (NPS), and particularly its Alaska Regional Office in Anchorage, has been a proven partner to the Smithsonian Arctic programs. Recently the NPS, through its Ocean Alaska Science and Learning Center (OASLC) program, has provided research grants to the ASC Anchorage office for its Archaeology and Oral Traditions on the Outer Kenai Coast, Alaska effort. The project, started in 2000, is investigating the archaeology and oral history of a little-known region of southern Alaska—the spectacular, glaciated Pacific coastline of the Kenai Peninsula. The study area is within Kenai Fjords National Park. The important partners in the joint effort are the lower Cook Inlet Native villages of Nanwalek, Port Graham, and Seldovia; the Pratt Museum in Homer; and scientists from the Anchorage and Fairbanks faculties of the University of Alaska. The project has a very strong focus on education, student training, and community outreach.

Native residents of Nanwalek, Port Graham, and Seldovia are knowledgeable about the outer Kenai coast and its history. Vivid stories of traditional life and travels on the outer coast have been passed down to current generations, and interest in revisiting the area and working with scientists to study it is strong. Oral traditions, combined with traditional knowledge about subsistence resources and the outer coast environment, are invaluable for interpreting archaeological sites that range from 100 to 1,000 years old.

Another important initiative conducted jointly by the ASC and the NPS Alaskan office is the study of northern ethnographic landscapes. Under this joint project, scientists, park managers, and Native researchers from Alaska, Canada, Russia, Norway, and Iceland share results of their current research, as well as the expertise of their respective national and regional bodies in working with northern indigenous communities to protect northern landscapes and to support cultural knowledge associated with past and present use of the northern land, coastal, and sea areas. The results of the collective study are presented in the volume *Northern Ethnographic Landscapes: Perspectives from Circumpolar Nations* to be published jointly by the ASC and NPS in 2004.

Environmental Protection Agency

The U.S. Environmental Protection Agency's Arctic research program is designed to protect the health of Arctic residents and safeguard the Arctic environment.

The U.S. Environmental Protection Agency's (EPA) Arctic-related work is designed to protect the health of Arctic residents and safeguard the Arctic environment. EPA research in the Arctic is focused on the source, transport, fate, and effects of contaminants in the environment; risks and benefits of subsistence foods; global climate change; and UV-B radiation. An emerging EPA effort to develop an Arctic strategy will help the agency coordinate activities and target resources more effectively. EPA Arctic priorities are:

- Research and development;
- Regional implementation; and
- International activities.

Within this framework, EPA research continues to focus on three primary objectives:

- Improve basic knowledge about Arctic stressors and effects;
- Understand and reduce risk to Arctic residents and the Arctic environment; and
- Implement innovative technologies to solve environmental problems.

These primary objectives are being addressed through a variety of research and management efforts. The following discussion provides a brief summary of EPA-sponsored research projects, each highlighted under a particular objective, although individual projects may address more than one objective.

	Funding (thousands)	
	FY 02	FY 03
Research and Development	200	377
Regional Activities	100	100
International Activities	100	100
Total	400	577

Arctic Stressors and Effects

EPA has increased the understanding and awareness among regional, national, and international partners concerning the risks associated with contaminants in the U.S. Arctic. Activities include leading international efforts to assess heavy metals in the Arctic, investigating mercury deposition, and partnering on enhancing education about Arctic contaminants.

Arctic Monitoring and Assessment Programme Phase II Assessment: Heavy Metals

AMAP is one of five working groups operating under the direction of the Arctic Council, a high-level, eight-nation, international forum implementing the Arctic Environmental Protection Strategy. AMAP's mission is to assess environmental contamination in the Arctic. The first AMAP assessment was published in 1998. An important and comprehensive document, the assessment highlighted potential risks to the Arctic from contaminants. However, U.S. data were missing from the first assessment. As AMAP Phase II began, in 1998, the U.S. was requested to serve as the lead country for the assessment of heavy metals. In March 1999 the EPA Office of Research and Development (ORD) agreed to fulfill this role.

Initial efforts defined the scope and features of the heavy metals assessment, completed at the international workshop Heavy Metals in the Arctic held in Anchorage, Alaska, during September 1999. In 2000, EPA funded scientists to identify and assemble research results from 1996 to the present and earlier work not represented in the AMAP Phase I assessment. In June 2001, EPA sponsored another international workshop, Trends and Effects of Heavy Metals in the Arctic, in McLean, Virginia, where new research results were reported in preparation for writing the assessment. Since then, multiple drafts of the assessment have been generated and submitted to the international scientific community for review and comments.

In July 2002, a semi-final draft was submitted to the AMAP Secretariat to support the publication of the primary report to the Arctic Council Ministers and the larger international public. This document, *Arctic Pollution 2002*, provides summarizes the results, conclusions, and recommendations of all five AMAP Phase II assessments, including

human health, heavy metals, persistent organic pollutants, radioactivity, and changing transport pathways.

In October 2002, *Arctic Pollution 2002* was first distributed at the Second AMAP Symposium on Contaminants in the Arctic, held in Rovaniemi, Finland. At this meeting, EPA staff, serving on behalf of the U.S. as lead country and as chair for the international heavy metals assessment team of 23 scientists, presented the technical results of the heavy metals assessment and served on the U.S. delegation to the Arctic Council for the ministerial meeting in Inari, Finland, convened immediately after.

To finalize the scientific document, a formal external peer review was planned and executed by EPA. Ten experts, not previously engaged in the process, reviewed the document in its entirety, and two additional scientists reviewed specific chapters. Comments were incorporated into the draft and submitted to the AMAP Secretariat in July 2003 for formal editing and final publication.

Mercury and Arctic Sunrise

One of the key findings in the AMAP Phase II heavy metals report is the transformation of mercury in the Arctic at polar sunrise. EPA has been instrumental in investigating the nature and geographical extent of the phenomenon termed "Arctic sunrise," where atmospheric elemental gaseous mercury levels have been shown to drop drastically during the Arctic spring, when sunlight returns to the region. The majority of atmospheric mercury is present in elemental form, but reactive gaseous mercury has much higher wet and dry deposition rates. Thus, speciation of mercury is of particular interest in the Arctic because of the sunrise phenomenon and the greater local impact of reactive forms.

Since 2000, EPA scientists have designed and implemented a series of mercury speciation studies. Successful work first completed in Barrow, Alaska, led to implementation of partnership studies during 2002 and 2003 at the Italian South Pole Atmospheric TerraNova Science Research Base and at the Norwegian Polar Research Base at Ny Alesund. EPA scientists trained collaborators and helped design and install specialized instrumentation at all three polar monitoring sites. The primary objectives of monitoring studies conducted during polar sunrise were threefold:

- Measure and speciate the various forms of mercury in air and snow [elemental mercury (HgO), reactive gas phase mercury (HgX_2, where X is a halide), and fine-particle-bound mercury (HgP)];
- Obtain snow samples for subsequent chemical analysis; and
- Obtain air quality data and meteorological measurements.

These measurement campaigns were designed to obtain information on the factors that lead to mercury depletion events (MDEs) to better understand and model the impact of MDEs on the half-life of mercury in the atmosphere and the potential bioavailability of mercury transformation products. The instrumentation and methods developed by EPA to speciate mercury are being used by atmospheric scientists in the U.S., Canada, Norway, Italy, Germany, Denmark, and Sweden, and study results are being published in the scientific literature.

UV Monitoring

EPA, in collaboration with the National Park Service, continues to maintain a network of ground-based UV monitoring instruments at 14 national parks and 7 urban locations in the U.S. One of these PRIMENet (Park Research and Intensive Monitoring of Ecosystems Network) sites is in Denali National Park, Alaska. While below the Arctic Circle, the site offers useful data for northern regions in comparison with other areas.

U.S. Federal agencies continue to coordinate their efforts to operate a network of ground-based UV monitoring instruments in response to a U.S. Global Climate Research Program plan published in 1995. Participating agencies are EPA, USDA, NOAA, NSF, the Smithsonian Institution, NASA, and DOE.

The USGCRP FY 2000 document *Our Changing Planet* calls for the need to understand changes in UV fluxes and how these changes affect human health and the productivity of ecosystems. Through PRIMENet, data from Denali National Park and other UV monitoring sites provide a valuable basis for primary research and assessments of the consequences of climate change.

Understanding and Reducing Risk

EPA and others have broadened the risk assessment approach to effectively bring together scientific research and management strategies to enhance risk reduction. In the Arctic this specifically targets reducing risk to humans potentially exposed to contaminants in traditional foods, as well addressing the profound changes occurring

in the Arctic and Bering Sea region from the combined effects of many stressors. EPA is focusing resources and time in the Arctic to integrate ecosystem-level risk assessment with human health and cultural risk.

Benefits and Risks of a Traditional Diet

EPA ORD is working with Native, academic, state, and other Federal agencies on evaluating both the nutritional benefits and the potential health risks of contaminants in wild-caught food. Through a grant to the Aleutian/Pribilof Islands Association (APIA) from the National Institute of Environmental Health Sciences (NIEHS), scientists are working with two Native communities, St. Paul and Atka, to identify preferred food consumption, the proportion of wild and store-bought foods consumed, and the levels of contaminants in foods, as well as the values and benefits of collecting and consuming traditional foods. EPA was instrumental in assembling the research team and facilitating the research design during 2000 and 2001. During 2002 and 2003, EPA played a key role in facilitating the development of community goals, generating hypotheses, and linking assessment goals and conceptual model development to data collection activities.

Heavy Metals and Persistent Organic Pollutants in Traditional Foods

Increasing concern by Native people in Alaska about the levels of pollutants in traditional foods led EPA (Region 10, ORD) to provide funding to the Sea Otter and Sea Lion Commission, a Native-based scientific organization, to assess the levels of heavy metals and persistent organic pollutants (POPs) in seagull eggs used for subsistence. The commission used funding to train local people to collect and transport eggs and prepare specimens and to support lab analysis. Collections were completed during 2000 and 2001. The results, published in 2003, were encouraging for local communities since levels of POPs and heavy metals were low.

Implementing Technologies

Introducing and implementing innovative technologies and management opportunities has been a cornerstone within EPA. In the Arctic, EPA continues to focus on reducing contaminants reaching the Arctic through long-range transport and building capacity within the U.S. Arctic to reduce potential environmental impacts.

Reducing Atmospheric Mercury Releases from Arctic States

The Arctic Council agreed to act to reduce exposures to a number of priority pollutants in the Arctic region. To accomplish this, the Arctic Council Action Plan (ACAP) Mercury Project was initiated in 2002. The project is being led by the Denmark Environmental Protection Agency, all eight Arctic nations are participating, and four, including the U.S., are providing funding. The EPA is coordinating U.S. involvement.

The project objective is "to contribute to a reduction of mercury releases from the Arctic countries; partly by contributing to the development of a common regional framework for an action plan or strategy for the reduction of mercury emissions, and partly by evaluating and selecting one or a few specific point sources for implementation of release reduction measures. The reduction of mercury releases…should serve as a demonstration of existing possibilities, giving inspiration to other measures in the region."

Initial work in 2003 centered on developing a detailed inventory questionnaire that addressed releases, usage, and disposal and was completed by each country. In August 2003, EPA provided the U.S. response using the questionnaire. All data are publically available, and most are from U.S. inventories, for example, the latest (1999) National Emissions Inventory for air emissions and the 2001 Toxics Release Inventory for solid waste disposal and water discharges. It is expected that in late 2004, Denmark will make available a Regional Inventory Report reflecting information submitted by the various countries. About the same time, it is expected that Denmark will make available a detailed Russian Inventory Report, which was developed by a Russian Federation team of scientists with the assistance of the ACAP project. Now the ACAP project is considering candidate control demonstrations in the Russian Federation that can provide new scientific information and inspiration for all Arctic countries.

Reducing PCBs in Russia

The Russian Federation depends on PCBs and PCB-containing equipment, and it has not accepted the Protocol on Persistent Organic Pollutants (POPs) of the Convention on Long-Range Transboundary Air Pollution (LRTAP) because of its inability to phase out PCB use. To assist Russia in phasing out PCB use, EPA proposed a multilateral technology transfer and demonstration project under the auspices of the Arctic Council Action

Plan (ACAP). The objective of this multilateral cooperative pilot program is to protect the Arctic ecosystems and indigenous U.S. populations by assisting the Russian Federation in:

- Developing an inventory, or source term, for PCBs in the Russian Federation;
- Ceasing the use of PCBs;
- Developing and constructing or retrofitting facilities for the production and use of PCB alternatives;
- Providing safe disposal and destruction of PCBs and PCB-contaminated equipment and material; and
- Remediating PCB sites that have the greatest potential to impact the Arctic.

The project has been implemented in three phases. Phase I, implemented during 1997–1999, organized the effort and developed an inventory of PCBs in Russia. During Phase II, feasibility studies were conducted to identify effective collection, storage, destruction, and remediation techniques, as well as to identify alternative dielectric fluids and technologies to convert and retrofit facilities so that they produce and use PCB alternatives. Phase III, begun in mid-2002, is based on a pilot project that implemented the use of alternative dielectric fluids. The destruction of PCBs in active use in Russia has begun.

General Assistance Program Grants

EPA Region 10 continues to support capacity building for Federally recognized tribes in Washington, Oregon, Idaho, and Alaska for managing community-based environmental protection programs. The total General Assistance Program (GAP) investment, while not represented in the research budget, represents an annual investment of over $21 million for Region 10 across the four states, with approximately $17.5 million going to Alaska Tribes.

Access by Alaska Native villages to GAP funds has resulted in research to develop sustainable technologies amenable to the Arctic bush that assist in achieving local environmental goals. Funding has enabled the pursuit of low-tech alternatives for pollution prevention, specifically in the areas of waste oil recycling and the use of antifreeze washers and can crushers. Practical implementation of management alternatives based on this research has had a direct impact on the ability of Alaskan villages to protect watersheds and extend the life of rural Alaskan landfills. EPA is continuing to document emerging management strategies and technologies that are reducing local environmental pollution and improving quality of life.

Arctic Strategy Development

EPA continues to recognize the importance of rapid changes occurring in the Arctic that are significantly impacting humans and the environment. Contaminants, climate change, and resource development are contributing factors changing terrestrial and marine ecosystems and threatening the health and abundance of subsistence and commercially harvested foods.

EPA Region 10 initiated an effort in FY 2003 to develop a strategy for agency work in the Arctic. A series of meetings were held with key staff and managers within EPA who are engaged in Arctic-related work. The purpose was to gain insights about priorities and develop a better understanding of current activities, as well as the staff and offices supporting them. Conversations with Alaska tribes and Native organizations also occurred during FY 2003 and will continue in FY 2004. Input obtained from these discussions will be used to shape the emerging strategy.

A draft EPA Region 10 Arctic strategy will be released in FY 2004 for agency review. The draft will propose EPA's role in the Arctic and serve as a guide or framework for wider agency discussion on developing EPA infrastructure and interest in the Arctic consistent with the agency's mission. The strategy is likely to include key research recommendations (such as sources, transport pathways, and impacts of contaminants) and identify opportunities to mitigate risk.

Department of Transportation

The Department of Transportation's Arctic and cold weather programs cover transportation issues in the air, on land, and at sea and are conducted by the Federal Aviation Administration, the Federal Highway Administration, and the Maritime Administration.

Federal Aviation Administration

The FAA's Capstone Program is an urgent initiative to improve commercial flight safety in western Alaska. It is a joint industry and FAA Alaskan Region effort to improve aviation safety and efficiency by putting cost-effective, new-technology avionics equipment into aircraft and providing the supporting ground infrastructure.

The demonstration areas are non-radar environments where most of the air carrier operations have been limited to visual flight rules. Capstone is equipping aircraft used by commercial operators in the area with a government-furnished avionics package that uses a global positioning system (GPS). In addition to the avionics suites, Capstone is deploying equipment for weather observation, data link communications, surveillance, and flight information services.

Capstone has also increased the number of airports served by an instrument approach and now enables radar-like instrument flight rule (IFR) air traffic control services. A significant number of mid-air collisions, controlled flight into terrain, and weather-related accidents can be avoided with new technologies incorporated into the Capstone avionics package.

The University of Alaska Anchorage is conducting training for Capstone participants and is performing an in-depth safety study and assessment of the Capstone program.

For more information on Capstone, visit http://www.alaska.faa.gov/capstone or call James Call at 907-271-3771.

Phase II of Capstone will move to southeast Alaska, a more environmentally challenging area of the state. As with Phase I in the Yukon–Kuskokwim Delta, Capstone plans to equip aircraft used by commercial operators and deploy a ground system that will support a usable IFR infrastructure and improve communications.

Federal Highway Administration

The Federal Highway Administration (FHWA) coordinates a number of activities aimed at improving safety, mobility, productivity, environmental quality, and national security on the nation's highways with respect to weather threats. It includes research to advance the state of the art concerning road weather management tools, as well as documentation and promotion of the best practices.

The Road Weather Management Program has documented the best practices of maintenance managers, traffic managers, and emergency managers in response to various weather threats. In May 2003, FHWA released Version 2.0 of the *Best Practices for Road Weather Management* CD-ROM. This resource contains 30 case studies of systems in 21 states that improve roadway operations in adverse weather, a listing of over 200 publications related to road weather management, and an overview of environmental sensor technologies, as well as online resources. Each case study has six sections, including a general description of the system, system components, operational procedures, resulting transportation outcomes, implementation issues, and contact information and references.

One example of successful road weather management was when the maintenance division of the Montana's Department of Transportation (DOT) used mobile anti-icing and de-icing strategies to proactively respond to winter storms. When performance was compared to a maintenance division that used reactive treatment after storms, it was found that average labor, materials, and equipment costs for the proactive division were 37% lower. Additionally the level of service was higher on

road sections treated by the proactive division, resulting in safety and mobility improvements.

The Maintenance Decision Support System (MDSS) project is a multi-year effort to develop and field test decision support components for winter maintenance managers. The MDSS was designed by a consortium of national laboratories, based on requirements articulated by maintenance managers, to help the managers improve the level of service on roadways during winter weather and to minimize road treatment costs by optimizing the use of labor, materials, and equipment. This data management tool has advanced weather and road condition prediction capabilities, including air and pavement temperatures, precipitation start and stop times, precipitation types, and accumulation amounts. These predictions are fused with customized maintenance managers' rules of practice to generate route-specific treatment recommendations, such as strategy, timing, and material application rates.

Additional information on the MDSS project can be found at http://www.rap.ucar.edu/projects/rdwx_mdss.

From February to April 2003 the MDSS prototype was demonstrated and evaluated in three Iowa DOT maintenance garages. The main display of the demonstration prototype includes predicted weather and road conditions, a weather parameter selection menu, a map of roads and weather alerts, and forecast animation controls.

Lessons learned from the preliminary demonstration will be used to enhance the prototype prior to a second demonstration planned from December 2003 to March 2004. Version 2.0 of the MDSS software will be released in the fall of 2003. Such products support the FHWA deployment strategy, which consists of the private sector building end-to-end products based on the core MDSS functionality. These products will be procured by public agencies such as state DOTs, enabling both the private and public sectors to benefit from millions of dollars of high-risk research.

Maritime Administration

MARAD is the advocate for commercial shipbuilding in the Federal government, and it provides expertise and support services to other Federal agencies in this technical area. In 2003 the NSF signed a Memorandum of Agreement with MARAD for the conduct of a number of technical studies related to a new-generation polar research vessel. Prior to this, however, two workshops were held to determine the scientific and operational requirements for the vessel for possible operations in the first half of the 21st century in the Antarctic. Those requirements are being translated into a set of technical criteria to assess the size and characteristics of the vessel.

Department of Homeland Security

DHS supports Arctic research through the U.S. Coast Guard, which operates polar icebreakers as national polar research assets for Arctic oceanographic expeditions of both government and nongovernment researchers.

U.S. Coast Guard

	Funding (thousands)	
	FY 02	FY 03
Arctic Science/Logistics Support	59,730	37,834
Extramural Science Support	30	30
Total	59,760	37,864

Icebreakers

The Coast Guard supports Arctic research through its operation of three polar icebreakers, USCGC *Polar Sea* and USCGC *Polar Star*, which serve as high-latitude research platforms in both the Arctic and Antarctic, and the new polar icebreaker USCGC *Healy*, which started Arctic science cruises in 2001. Support of Arctic research by the U.S. Coast Guard dates back to the 1880s, when voyages on revenue cutters were made by scientists, including the renowned naturalist John Muir on the Revenue Cutter *Corwin* in 1881 and others on the Revenue Cutter *Bear* commanded by Captain Michael Healy in the 1880s and 1890s. Arctic research aboard Coast Guard icebreakers intensified in the late 1960s and early 1970s, when the prospect of increased oil and gas exploration in the Alaskan Arctic required ecological baseline surveys in the Chukchi and Beaufort Seas. The Coast Guard icebreakers *Northwind, Burton Island,* and *Glacier* supported these cruises. In the 1980s these vessels were decommissioned as the Polar-class icebreakers joined the fleet.

Polar-Class Icebreakers

The two Polar-class icebreakers were designed to carry out a range of missions in the Arctic, including escorting non-icebreaking vessels through the ice, resupplying military and research bases, and supporting scientific operations. In recent years the role of the Polar-class vessels in research has expanded as more complex projects and larger science teams placed added requirements on these ships. This led to a major upgrade of their capabilities in 1987 through the Polar Science Upgrade Project, a five-year program to enhance the scientific support capabilities of these vessels. Laboratories and living areas were expanded to allow up to 32 scientists and technicians to embark on scientific cruises. Upgraded oceanographic winches, new cargo and science gear handling systems, expanded lab spaces, new oceanographic instrumentation, and new communications and satellite data acquisition systems significantly improved the research capabilities of the Polar-class vessels.

Since 2001, severe Antarctic ice conditions have critically reduced the service life of the *Polar Sea* and *Polar Star*. The condition of *Polar Star* and *Polar Sea* will pose a challenge to the Coast Guard and stakeholders in the U.S. polar research program.

USCGC Healy

To meet the expanding needs of the future, the Coast Guard commissioned a new research platform designed primarily for Arctic science, though capable of work in the Antarctic as well. The new vessel, USCGC *Healy*, was built by Avondale Industries in New Orleans, Louisiana. *Healy* is 420 ft long, has a beam of 82 ft, and displaces 16,000 long tons. The maximum speed is 17 knots, with a range of 16,000 nautical miles at 12.5 knots. *Healy*'s primary mission is to function as a world-class high-latitude research platform. *Healy* is able to conduct scientific operations during all seasons in the Arctic, including wintering over for planned missions.

The scientific support capabilities of *Healy* substantially surpass those provided by the Polar-class icebreakers. The ship is able to accommodate

35 scientists on a routine basis and provide surge accommodations for up to 50. Over 5,000 square feet of science lab and support space is provided, including a main science lab, a wet science lab, a biological and chemical analysis lab, an electronics lab, a meteorology lab, and a photography lab. In addition *Healy* has five hydraulically operated cranes, two oceanographic winches, and a double-drum core/trawl winch. It also provides over 4,000 square feet of open deck space and 20,000 cubic feet of scientific storage space in three cargo holds. Installed bathymetric and oceanographic instrumentation includes a bottom profiling system, a Seabeam bottom mapping sonar system, an XBT data acquisition unit, and an acoustic Doppler current profiler. Lab spaces are equipped with

USCGC Healy *enters the ice for the first time, April 2000.*

a science data network providing 120 dual fiber-optic-connected Ethernet ports throughout the science spaces for real-time data transfer between data processors, workstations, and printers. In addition there is a dedicated Inmarsat-B with high-speed data transmission and e-mail capabilities for scientists.

After delivery on 9 November 1999 by Litton-Avondale Industries, *Healy* underwent a period of fitting-out availability and propulsion system repairs. The ship departed New Orleans on 26 January 2000 to conduct machinery, hull, and science suite testing. Initial warm-water trials were completed in March. Ice trials were conducted from April to June in Baffin Bay in the eastern Arctic. *Healy* performed well, with icebreaking performance exceeding design requirements of 3.0 knots through 4.5 ft of ice. The maximum thickness of unbroken level ice encountered was 5.5 ft, which *Healy* transited at a continuous speed of 2.6 knots. Ice ridges of 45 ft were broken through in three rams. *Healy* transited the Northwest Passage in July and arrived at Seattle on 9 August. The ship was commissioned on 21 August 2000.

During the first science cruises in 2001, *Healy* conducted successful cruises in the eastern Arctic Ocean, including the North Pole.

Arctic Research Cruises

The Coast Guard's major Arctic research efforts supported during the past two years were the Arctic West Cruises aboard *Polar Star* and *Healy* in 2002, and the Arctic East and West Cruises aboard *Healy* in 2003.

USCGC Polar Star *2002*

After returning from Operation Deep Freeze 2002 on 14 April and following shipyard and dockside repairs, *Polar Star* departed on July 9 for the Arctic West Summer 2002 (AWS-02) mission for the multi-year Western Arctic Shelf–Basin Interactions (SBI) project. These studies, funded by the National Science Foundation and the Office of Naval Research, were aimed at understanding the flux of carbon and water properties (nutrients, temperature, and salinity) from the surrounding continental shelf into the Arctic Ocean basins and their relation to climate dynamics. *Polar Star*'s effort was conducted in two phases.

SBI 2002 Mooring Cruise. The first 30-day phase of AWS-02 began 15 July with the science party, led by Dr. Thomas Weingartner of the University of Alaska, embarking from Dutch Harbor and then transiting to the northern edge of the Chukchi Sea to study physical oceanography. During the cruise, 13 moorings were deployed for measuring oceanographic parameters for a period of one year. Data were also collected from 80 casts using conductivity, temperature, and density (CTD) sensors and the rosette water sampler at different depths. In addition, 36 expendable probes (XCTDs) were launched. Institutions participating in Phase One included the University of Alaska Fairbanks, the Woods Hole Oceanographic Institute, the University of Washington, and the Scripps Institute of Oceanography.

SBI 2002 Chuckchi Borderlands Cruise. The Phase Two science party, led by Chief Scientist Dr. Rebecca Woodgate of the University of Washington, embarked from Barrow, Alaska, on 19 August for a five-week cruise that extended Phase One studies farther north and west into the Beaufort Sea. Water column samples were analyzed for chemical tracers, including radioisotopes and

chlorinated fluorocarbons (CFCs) to calculate the contribution to the Arctic Ocean from Arctic rivers and Pacific water masses and how these might be changing in response to climate dynamics. Gail Grimes, a high school science teacher participating in the Teachers Exploring Antarctica and the Arctic (TEA) project, was on the cruise. Her postings are online at http://psc.apl.washington.edu/HLD/CBL/Teacher/Webcode/index.html.

Phase Two ended with the collection of 126 CTD and water-sampling profiles and 40 XBTs. The mission also successfully deployed and recovered all of a series of current meter moorings along the northern edge of the Chukchi Sea. The current meter data were used to document the transport of Pacific waters and continental shelf materials into the Central Arctic Basin. The institutions participating in Phase II included the University of Alaska Fairbanks, the University of Washington, the Scripps Institute of Oceanography, the Lamont–Dougherty Earth Observatory, and Lake Stevens High School, Lake Stevens, Washington.

USCGC Healy *2002*

On 27 April *Healy* sailed for the five-month AWS 2002 mission to support two multidisciplinary projects: the Western Arctic Shelf–Basin Interactions (SBI) project and the Marine Climate and Relative Sea Level Across Central Beringia project. Each project consisted of two phases, separated in time. General summaries of each of the phases are provided below, with links to more specific information.

Western Arctic Shelf–Basin Interactions (SBI). The SBI project is a multiyear, interdisciplinary program to investigate the impact of global change on physical, biological, and geochemical processes over the Chukchi and Beaufort Sea shelf basin regions in the western Arctic Ocean. The SBI project is jointly sponsored by the National Science Foundation and the Office of Naval Research and consists of 14 ongoing research projects. More information is available at the SBI website (http://sbi.utk.edu).

During the *Healy* SBI spring 2002 cruise (5 May–14 June), led by Dr. Jackie Grebmeier of the University of Tennessee, 12 interdisciplinary research projects participated, ranging from hydrographic measurements to biological studies of various trophic levels. Thirty-nine stations were occupied in the northern Bering Sea (test station), the Chukchi Sea shelf (Herald Valley transect), the Chukchi outer shelf to Arctic Basin lines (West Hanna Shoal and East Hanna Shoal transect lines), stations near Point Barrow, and the Barrow Canyon transect.

Physical, biogeochemical, and biological measurements were made using a variety of sampling devices. Subsamples from four CTD/rosette casts were used for primary production, chlorophyll content, nutrients, particulate carbon, inorganic carbon, biomarkers, microzooplankton, and radioisotopes. Various nets were used to collect zooplankton for both population and experimental purposes. Benthic grabs and cores were used to collect benthic fauna and sediment samples for population, community structure, food web, and metabolism studies. Scientists were lowered to the ice to collect ice cores and make in-situ measurements of the ice. Shipboard marine mammal surveys from the bridge were made by the U.S. Fish and Wildlife Service. Helicopter operations were used for ice reconnaissance and for observing and photographing marine mammals.

The institutions participating included the University of Tennessee, the University of Miami, Old Dominion University, Oregon State University, the University of Alaska Fairbanks, the Lamont–Dougherty Earth Observatory, the University of Rhode Island, the Scripps Institution of Oceanography, the Bedford Institute of Oceanography, the Canadian Department of Fisheries and Oceans, the University of Texas, the University of Colorado, and the U.S. Fish and Wildlife Service.

During the *Healy* SBI summer 2002 cruise (17 July–23 August), led by Dr. Lee Cooper of the University of Tennessee, 15 interdisciplinary research projects participated, ranging from hydrographic measurements to biological studies of various tropic levels. Forty-five stations were occupied for hydrographic and biological sampling using the same systems described above for the *Healy* SBI spring 2002 cruise. Betty Carvellas, a high school teacher participating in the TEA project, was aboard. Her web site may be found at http://tea. rice.edu/ tea_carvellas frontpage.html.

The institutions participating included the University of Tennessee; the University of Miami; Old Dominion University; Oregon State University; the University of Rhode Island; the Scripps Institution of Oceanography; the Bedford Institute of Oceanography; the Canadian Department of Fisheries and Oceans; the University of Colorado; Woods Hole Oceanographic Institution; Essex High School in Essex, Vermont; Bigelow Laboratory; the University of Washington; ESRI; the University of South Carolina; Bermuda Biological

Station; the National Science Foundation; CBS News; the Associated Press; and *USA Today*.

Marine Climate and Relative Sea Level Across Central Beringia. Research for this project was led by Chief Scientist Dr. Lloyd Keigwin of Woods Hole Oceanographic Institute and colleagues Neal Driscoll of the Scripps Institution of Oceanography and Julie Brigham-Grette of the University of Massachusetts Amherst. The study, which focused on the relationship between the seafloor and the Bering Land Bridge that had connected Alaska and Russia, was the first coring program on the new icebreaker *Healy*. Additional measurements were made with hull-mounted and towed sonar arrays and with the CTD device. Further information may be found at http://www.geo.umass.edu/beringia/index.html.

During the first phase, which departed Nome on 16 June and returned on 6 July, measurements were made in three areas of the northern Bering Sea: the Navarin Pervents Canyon, the Bowers Ridge, and Briston/Bering Canyons. To assess potential coring sites, high-resolution maps of the seafloor bathymetry and sub-bottom were made with *Healy*'s multi-beam sonar and with a towed chirp sonar. At each coring station, samples of seafloor sediments were taken in the following order: a gravity core, then if conditions allowed, a multi-core, and finally a jumbo piston core (JPC). During the mission, data were obtained during 18 chirp sonar tows, 14 CDTs, 24 gravity cores, 14 multi-cores, and 9 JPCs, including one 80 ft long, a *Healy* record. The institutions involved in this phase include Woods Hole Oceanographic Institute, the Scripps Institution of Oceanography, the University of Massachusetts Amherst, Princeton University, the University of Kentucky, West Washington University, and the University of Delaware.

During the second phase, which departed Nome on 26 August and arrived in Barrow on 16 September, operations were identical except a fourth bottom sampling device, the vibracore, was added. During the mission, 3 gravity cores, 3 multi-cores, 23 JPCs, and 11 vibracores were taken. Institutions involved in this project include Woods Hole Oceanographic Institute, the Scripps Institution of Oceanography, the University of Massachusetts Amherst, Princeton University, the University of Kentucky, West Washington University, the University of Delaware, the University of Alaska Fairbanks, Old Dominion University, and the *New York Times*.

USCGC Healy *2003*

On 13 June, *Healy* sailed toward the Panama Canal for a five-month mission circumnavigating the North American continent and conducting science operations in Baffin Bay, as well as north of Alaska. Science operations on *Healy* during AEWS 2003 included the Nares Strait Expedition, Northwest Passage Transit, Chukchi Cap Mapping, and SBI Mooring Cruise.

Nares Strait Expedition. The five-year Canadian Archipelago Throughflow Study (CATS) is a contribution to the U.S. Global Change Program. Further information about the CATS project may be found at http://newark.cms.udel.edu/~cats. The summer expedition to Nares Strait between northern Greenland and Ellesmere Islands contributed to the first-ever simultaneous tracking of the major freshwater fluxes out of the Arctic Ocean. The freshwater flux from the Arctic into the North Atlantic constitutes a key process that impacts the thermohaline ocean circulation and thus global climate. In conjunction with concurrent European studies east of Greenland, the Nares Strait Expedition tested the hypothesis that the freshwater fluxes through the Canadian Archipelago are similar in size to those through the Fram Strait between Greenland and Norway.

During this interdisciplinary cruise, led by Chief Scientist Dr. Kelly Falkner of Oregon State University and co-chief scientist Dr. Humfrey Melling of the Canadian Department of Fisheries and Oceans' Institute of Ocean Sciences, the main activities were deploying the Nares Strait pressure-measuring array, conducting hydrographic surveys of northern Baffin Bay and Nares Strait, recovering bottom-dwelling clams, coring into bottom sediments of Baffin Bay and Nares Strait, and conducting ADCP surveys to produce current velocity surveys of Nares Strait. Eighteen moorings were installed during deployment of the Nares Strait array, which records the pressure field that forces the fluxes of seawater through the strait. The array will be recovered in the spring of 2005. Coast Guard divers were used in the installation of the pressure-measuring array moorings as well as the collection of bottom-dwelling clams. Data from 79 casts of the CTD/rosette package were used to produce detailed hydrographic sections in northern Baffin Bay, Smith Sound, southern Kennedy Channel, and Robeson Channel. Additional casts were made in the heretofore unsampled Peterman Glacier Fiord and the Hall Basin. Four piston cores were taken in the area off Bylot Island, and one gravity core was taken in

Hall Basin. Two high school teachers, Gerhard Behrens and Robert McCarthy, were aboard. Their web sites may be found at http://newark.cms.udel.edu/~cats/healy_2003/update/gerhardindex.html and http://newark.cms.udel.edu/~cats/healy_2003/update/bobindex.html.

The institutions included Oregon State University; the Institute of Ocean Sciences of the Canadian Department of Fisheries and Oceans; Adams Elementary School of Corvallis, Oregon; Governor Mifflin High School of Reading, Pennsylvania; the University of Delaware; the University of Hawaii; Environment Canada; the University of Victoria; the Bedford Institute of Oceanography; the University of Rhode Island; New York University; and the Canadian Ice Service, as well as a freelance journalist and a representative from the Grise Fiord Inuit village

Northwest Passage Transit. During the 19–30 August transit from Thule, Greenland, to Barrow, Alaska, *Healy* sailed the Northwest Passage by way of Prince of Wales Strait. A Ship of Opportunity (SOO) underway data collection effort was coordinated by David Forcucci, *Healy*'s Science Liaison. During the transit Chief Scientist Dale Chayes of Lamont–Dougherty Earth Observatory of Columbia University and David Monahan of the Canadian Hydrographic Office and the University of New Brunswick collected underway data including multibeam bathymetry. Collection of ADCP data and thermosalinographic data were supported by the U.S. Coast Guard. Expendable probe (XCTD) launches were coordinated by Dr. Kathy Crane of NOAA's Arctic Research Office and Dr. Eddy Carmack of the Institute of Ocean Sciences of the Canadian Department of Fisheries and Oceans. Marine mammal and seabird observations were made by Marc Weber of the U.S. Fish and Wildlife Service and Stephanie Burkhart of the U.S. Coast Guard.

Institutions involved in this effort included the Canadian Hydrographic Office, the University of New Brunswick, the Institute of Ocean Sciences of the Canadian Department of Fisheries and Oceans, the Lamont–Dougherty Earth Observatory of Columbia University, NOAA's National Marine Fishery Service, NOAA's Arctic Research Office, the National Ice Center, the Canadian Ice Service, the U.S. Navy Arctic Submarine Laboratory, Mississippi State University, Brookhaven National Laboratory, the U.S. Fish and Wildlife Service, the U.S. Coast Guard, and the University of Delaware.

Chukchi Cap Mapping Cruise. The purpose of the next phase of AEWS 2003, a ten-day cruise led by Chief Scientist Dr. Larry Mayer of the University of New Hampshire, was to map the seafloor north of Alaska for use in future EEZ claims. Under Article 76 of the U.N. Convention on the Law of the Sea, a country may claim rights to the seafloor beyond the normal EEZ limit. Key pieces of evidence to support a claim are the locations of the 2,500-meter depth contour and the foot of the continental slope. Although the U.S. has not ratified the convention, it is gathering data to support future claims. While the U.S. has made significant progress in temperate zones, this is the first Law of the Sea bottom mapping survey in the Arctic Ocean.

During the multibeam sonar survey of the continental slope north of Alaska, 1,530 nautical miles of the 2,500-meter-depth contour were mapped, and a new seamount, subsequently named Healy Seamount, was discovered. In addition, the cruise observed water depths greater than 4,000 meters, depths not previously measured in the Amerasian Basin. Before this *Healy* cruise, charts of the Arctic bottom showed only a small knoll where scientists discovered the seamount, which abruptly rises more than 3,000 meters from the ocean floor to approximately 925 meters of depth. During this cruise, it was demonstrated that an icebreaker's multibeam sonar could successfully map the seafloor while the icebreaker is breaking ice.

The cruise also added important information about ice age glaciation and past climates. Randomly oriented seafloor scours, mapped at depths of 300–400 meters, gave evidence of large icebergs scraping the seafloor. Parallel flutes, or grooves mapped at greater depths, provided clues to the motion of huge ice sheets creeping across what is today the continental shelf. A sediment core from the continental slope will be studied for insights into past periods of climate variability. Additionally, temperature and salinity data at stations spread across the survey area were collected to study water masses and circulation. Further information is available at http://www.noaanews.noaa.gov/stories2003/s2137.htm and http://www.ccom-jhc.unh.edu/healy/index.htm.

Scientists were from the University of New Hampshire, the Lamont–Dougherty Earth Observatory of Columbia University, NOAA's Arctic Research Office, NOAA's Office of Exploration, the Naval Research Laboratory, the U.S. Navy Arctic Submarine Laboratory, the University of Stockholm, the Geological Survey of Denmark and Greenland, and the Danish Hydrographic Agency.

SBI 2003 Mooring Cruise. During the period 11 September to 18 October, Chief Scientist Dr.

Rebecca Woodgate of the University of Washington led a cruise in support of the SBI project. After recovering moorings that had been on the ocean floor since the 2002 deployment by *Polar Star*, scientists transferred data from the array's sensors and then redeployed the moorings. Sonobuoys were deployed for recording sounds from whales. The cruise also conducted CTD, ADCP, and multibeam surveys; net tows; and remote determination of plankton concentration using a video plankton recorder (VPR). During the cruise there were 14 mooring recoveries and 15 mooring deployments. Extensive data were collected during 321 CTD casts, 34 VPR casts, 11 net tows, 63 XBTs, 70 sonobuoys, and 35 days of ADCP and multibeam surveys.

The institutions included the University of Alaska Fairbanks, the Woods Hole Oceanographic Institute, the University of Washington, the Scripps Institute of Oceanography, the University of Maryland, Brookhaven National Laboratory, Earth and Space Research, the University of Delaware, the Lamont–Doherty Earth Observatory, Louisiana State University, NOAA, and the University of New Hampshire.

International Ice Patrol

The Coast Guard International Ice Patrol (IIP), located in Groton, Connecticut, participated in two research programs, one an iceberg-detection study using satellite-borne radar systems and the other a cooperative research program with the Canadian Ice Service (CIS) to test the accuracy of iceberg drift models, including one recently developed by CIS. Although this research occurred south of the Arctic Circle, it has direct relevance to high-latitude navigation and is an integral part of the Coast Guard's Marine Science Program.

The iceberg-detection effort is part of the Global Monitoring for Environment and Security (GMES) program, which is co-led by the European Space Agency (ESA) and the European Commission (EC). IIP is participating as an end user in the program called Northern View: Earth Observation for Northern Monitoring, which is led by C-CORE, a research and development corporation located in St. John's, Newfoundland. Under the program, C-CORE provides IIP the location of icebergs obtained from the analysis of images by the synthetic aperture radar on two satellites, Canada's RADARSAT-1 and ESA's ENVISAT. During 2003, IIP compared the satellite observations with observations from other sources, including IIP's aerial reconnaissance. This program will continue throughout the 2004 iceberg season.

The second program is a joint IIP and CIS effort to evaluate the accuracy of the operational iceberg drift model used by the two organizations and a new model created by CIS. In 2003, IIP deployed a satellite-tracked transponder onto a fragment of an ice island and tracked its movement for 14 days. The movement of the ice island fragment was compared with model predictions. In 2004, additional ice beacons will be deployed by aircraft onto icebergs, and their observed movement will be compared to the model predictions.

Department of State

The Department of State continues to be involved in multilateral and bilateral activities related to environmental protection, sustainable development, and scientific research in the Arctic.

In the international arena, U.S. policy in the Arctic focuses on environmental protection and sustainable development. In 1991 the United States, along with Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, and Sweden, became signatories to the Arctic Environmental Protection Strategy (AEPS), a high-level forum designed to identify priorities for regional cooperation with regard to environmental protection in the Arctic. Organizations representing the Arctic indigenous communities were admitted as Permanent Participants to the AEPS.

In 1996 the eight Arctic countries signed a declaration establishing the Arctic Council and expanding its mandate to deal with issues of sustainable development. The Council now includes four environmental working groups:

- Arctic Monitoring and Assessment Program (AMAP);
- Conservation of Arctic Flora and Fauna (CAFF);
- Emergency Prevention, Preparedness, and Response (EPPR); and
- Protection of the Arctic Marine Environment (PAME).

A fifth subsidiary body, the Sustainable Development Working Group (SDWG), was established at the Arctic Council's Ministerial meeting in Iqaluit, Canada, in 1998. The Council's six Permanent Participants represent indigenous Arctic residents; four count Native communities in Alaska among their members. The Permanent Participants sit at the Arctic Council table and are a source of traditional knowledge for many council studies.

The U.S. served as the second chair of the Arctic Council in 1998–2000. The State Department's Office of Oceans Affairs, which represents the U.S. on the Council, housed the Council's secretariat during the U.S. chairmanship. During this time, the State Department improved the flow of communication among Council members and supported important initiatives on environmental protection and sustainable development. The U.S. continues to pursue these goals and remains a leader on the Council. In 2002 the U.S. assumed the chair of CAFF and in 2003 the chair of the Arctic Council Action Plan to Eliminate Pollution in the Arctic (ACAP). Finland chaired the Council in 2000–2002, and Iceland assumed the chair for 2002–2004. Russia has indicated its willingness to chair the Council for 2004–2006.

The State Department has provided financial support for many recent Council initiatives. The Department contributed to an ACAP activity to reduce dioxins and furans. The ACAP, approved at the 2000 ministerial meeting in Barrow, Alaska, outlines actions to address some of the pollution threats in the Arctic identified during the first AMAP assessments, such as PCBs, pesticides, and mercury. The State Department provided funds to support U.S. authors' contributions to the *Arctic Human Development Report*, a comprehensive and scientifically based overview and assessment of human conditions in the entire circumpolar region written for the nonspecialist. The State Department contributed to developing and implementing integrated ecosystem management strategies in the Russian Arctic, and it supported the Arctic Council's work at the New York preparatory meeting and the 2002 World Summit on Sustainable Development. The Department helped fund the participation of indigenous residents of Alaska in the Arctic Council, contributing to the Indigenous Peoples Secretariat and supporting indigenous Alaskan delegates' travel to Arctic Council meetings and an all-Alaska delegation to the Taking Wing conference on gender equality in the Arctic.

Another Arctic Council initiative backed by the U.S. is the Arctic Climate Impact Assessment (ACIA). With NOAA and NSF funding, this comprehensive effort, which has the support of all

Council members, will evaluate and synthesize knowledge on climate change, climate variability, and increased ultraviolet radiation and their consequences on the Arctic environment. The final reports are expected in November 2004.

In the area of sustainable development, the U.S. focuses on human health in the Arctic. The State Department, along with the State of Alaska, is coordinating Council members' activities in the area of telemedicine. The State Department supports the project led by the Centers for Disease Control and Prevention on emerging infectious diseases in the Arctic. The State Department also provided funding to Alaska for the ecotourism project of the Arctic Council over the last two fiscal years.

As coordinator of U.S. international policy concerning the Arctic, the Department of State welcomes input from individuals and agencies with an interest in participating in the work of the Arctic Council or contributing to the knowledge base that underlies the Council's working groups. Interested parties are encouraged to visit the Arctic Council web site at http://www.arctic-council.org. The web site lists current and future activities of the Council, as well as the names and addresses of individuals and secretariats related to specific aspects of the Council's work.

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